Port Phillip Bay Beach Nourishment Program Preliminary Assessment

Incorporating Victorian Coastal Monitoring Program (VCMP) Data

April 2023, Jak McCarroll

Energy, Environment and Climate Action

Acknowledgment

We acknowledge and respect Victorian Traditional Owners as the original custodians of Victoria's land and waters, their unique ability to care for Country and deep spiritual connection to it. We honour Elders past and present whose knowledge and wisdom has ensured the continuation of culture and traditional practices.

We are committed to genuinely partner, and meaningfully engage, with Victoria's Traditional Owners and Aboriginal communities to support the protection of Country, the maintenance of spiritual and cultural practices and their broader aspirations in the 21st century and beyond.

ISBN 978-1-76136-254-5 **(pdf/online/MS word)**

Port Phillip Bay Beach Nourishment Program Preliminary Assessment, Incorporating Victorian Coastal Monitoring Program Data

Jak McCarroll

EXECUTIVE SUMMARY

This report examines beach nourishment activities at sites within Port Phillip Bay (PPB), overseen by the DEECA Statewide Coastal Programs unit. The work is informed by beach monitoring activities at the selected sites, conducted by the Victorian Coastal Monitoring Program (VCMP). The aim of this report is to provide a first-pass assessment of beach nourishment within PPB, in order to understand nourishment dynamics, and assist in choosing future nourishment sites. Five nourishment-monitoring sites were selected for detailed assessment. At the time of writing, nourishments were completed at only two of the sites, with the remainder to be completed over coming months. A subsequent report will address nourishment performance after the current round is completed, in addition to assessing potential sites for the next round of nourishment activities. The report is structured as:

- Part 1: Introduction to sediment budget concepts and beach nourishment processes.
- Part 2: Background – Sites, data, and methods.
- Part 3: Detailed site assessments:
    - Site 1. Blairgowrie
    - Site 2. Dromana-McCrae
    - Site 3. Sandringham (and Half Moon Bay)
    - Site 4. Anderson Reserve
    - Site 5. St Leonards
- Part 4: Data synthesis and site comparison.
- Part 5: Insights for the nourishment planning process.
- Part 6: Guidelines, general issues, and recommendations.
- Part 7: Summary and Conclusions

Prior to the VCMP's commencement in 2018, no centralised effort was made to monitor Victoria beaches, either open coast or estuarine. In particular, no concerted effort had been undertaken to study the dynamics of beach nourishments within PPB. Monitoring activities conducted by the VCMP in Port Phillip Bay since 2018 are summarised in Table E1.

Table E1. VCMP survey observations in Port Phillip Bay

Survey method	Description	Total
Drone	Total PPB sites	9
	Total PPB surveys (from 2018)	109
	New PPB monitoring sites (from Dec 2020)	4
	New site surveys	23
Topographic	PPB topographic surveys (from Dec 2020)	5
Bathymetric	PPB bathymetric surveys (from Dec 2020)	5

The five nourishment monitoring sites assessed in this report and wave data across PPB are summarised in Fig. E1. For each of the 5 sites assessed, the overarching questions asked are:

1. What are the goals of nourishing this site?
2. What is the sediment budget for the site, and what are the controlling processes?
3. Is nourishment required to prevent an imminent hazard occurring?
4. How have previous nourishments performed?
5. Overall, how important is it to nourish this site, relative to other potential sites?

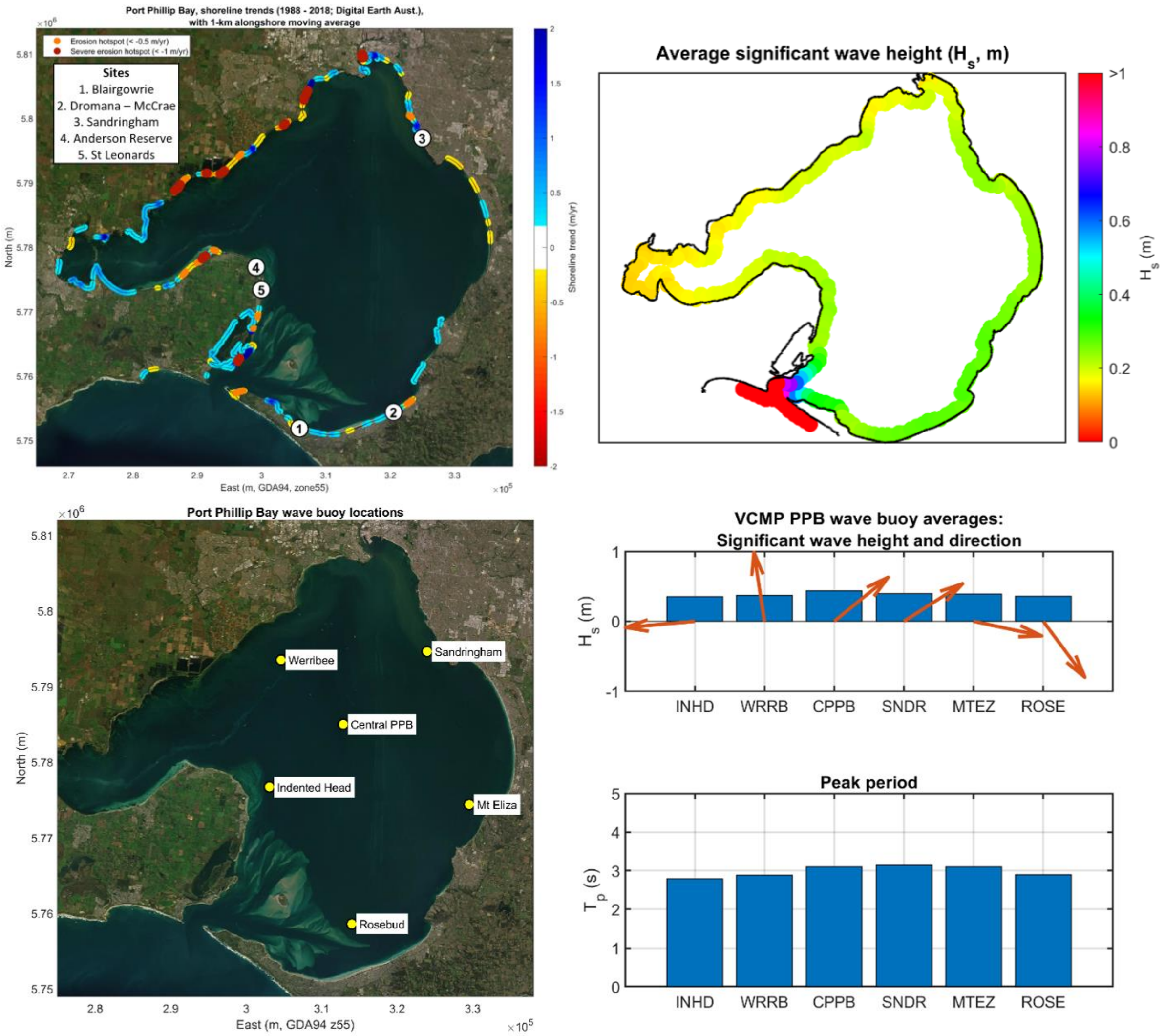


Fig. E1. (Top left) Nourishment monitoring sites and Digital Earth Australia satellite shoreline trends; (top right) modelled mean significant wave heights around PPB; (bottom left) wave buoy locations; and (bottom right) wave buoy summary statistics.

A summary interpretation of the sediment budget for each site is given in Fig. E2. Annual sediment budgets range from -1,000 to + 3,500 m^3/yr. For sites where past nourishment volumes can be estimated, beach nourishment volumes make up a minor proportion (less than 10%) of the total budget. However, past records of nourishments are poor, so some historical nourishments may have been missed.

Fig. E2. Sediment budget summaries for the five monitoring-nourishment sites assessed in this study. Pink transect lines indicate nourishment targets for the 2020-21 period. Cold to hot colours along the shoreline are change trends over the 1988 – 2018 period from satellite data (DEA).

Analysis of long-, medium- and short-term shoreline change trends across the 5 sites found that recent trends (i.e., the last 5 to 10 years) often differ from longer-term patterns of shoreline change. For example, at Blairgowrie (Fig. E3, top panel), erosion has occurred over the short-term, while the medium-term trend has been accretive.

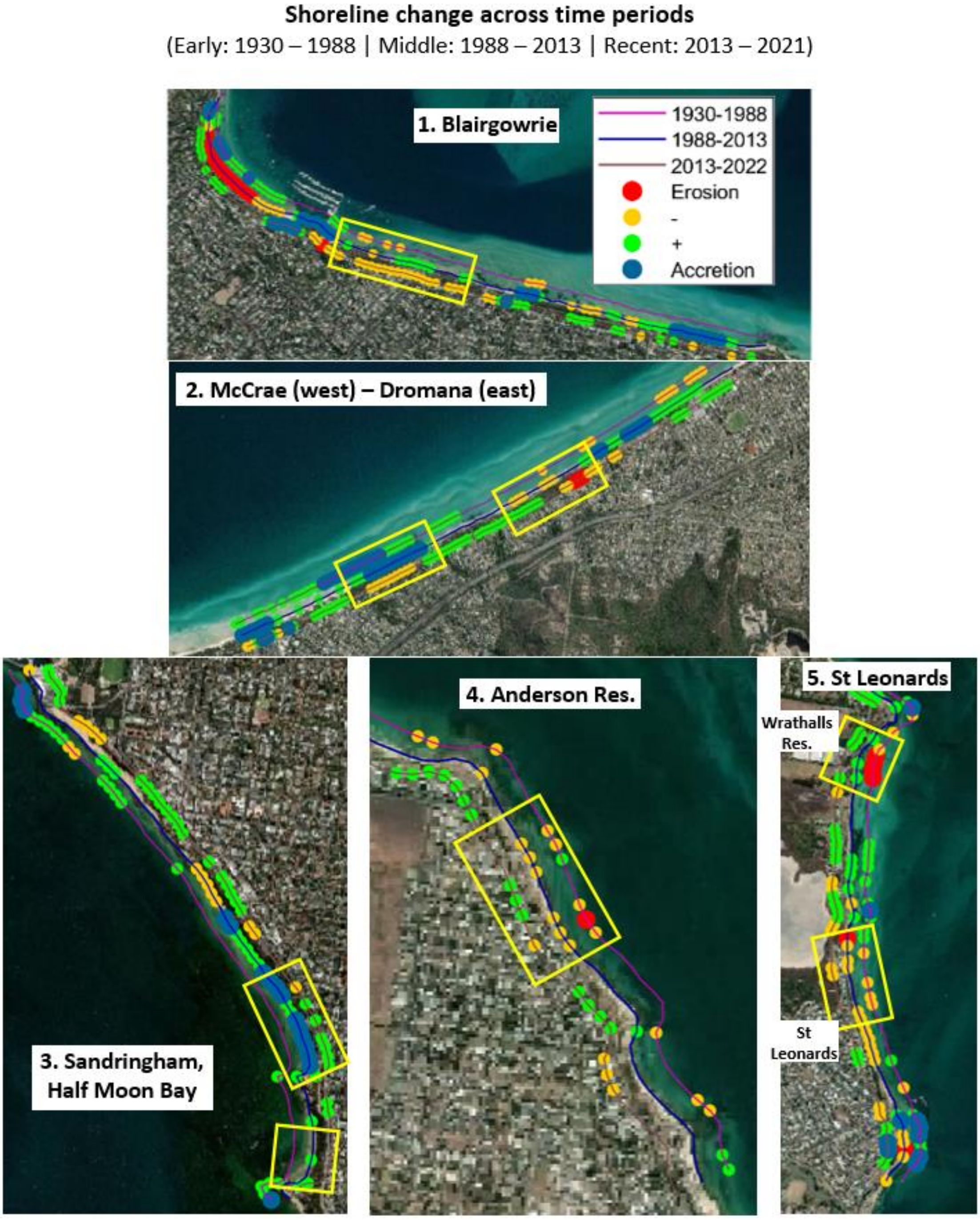


Fig. E3. Historical shoreline change across five nourishment monitoring sites, for 'early period' (1930 – 1988) , 'middle period' (1988 – 2013), and 'recent period' (2013 – 2022) periods. For the long- and medium term, the high rate of erosion/accretion (red/blue dots) are >0.5 m/yr movement; for short-term the high erosion/accretion dots are > 2 m/yr. Yellow boxes are nourishment target zones for the 2020-2021 period.

Comparative shoreline trends across the sites are summarised in Fig. E4, briefly:

- Sandringham has experienced a steady accretive trend.
- Dromana-McCrae and Blairgowrie have seen steady accretion across the full site, but both have short-term erosion around the nourishment sites. Blairgowrie in particular.
- Both Anderson Reserve and St Leonards have a long-term erosion trend, which is worse at the nourishment locations than the site as a whole. However, both sites have recently seen a neutral to slightly accretive trend.

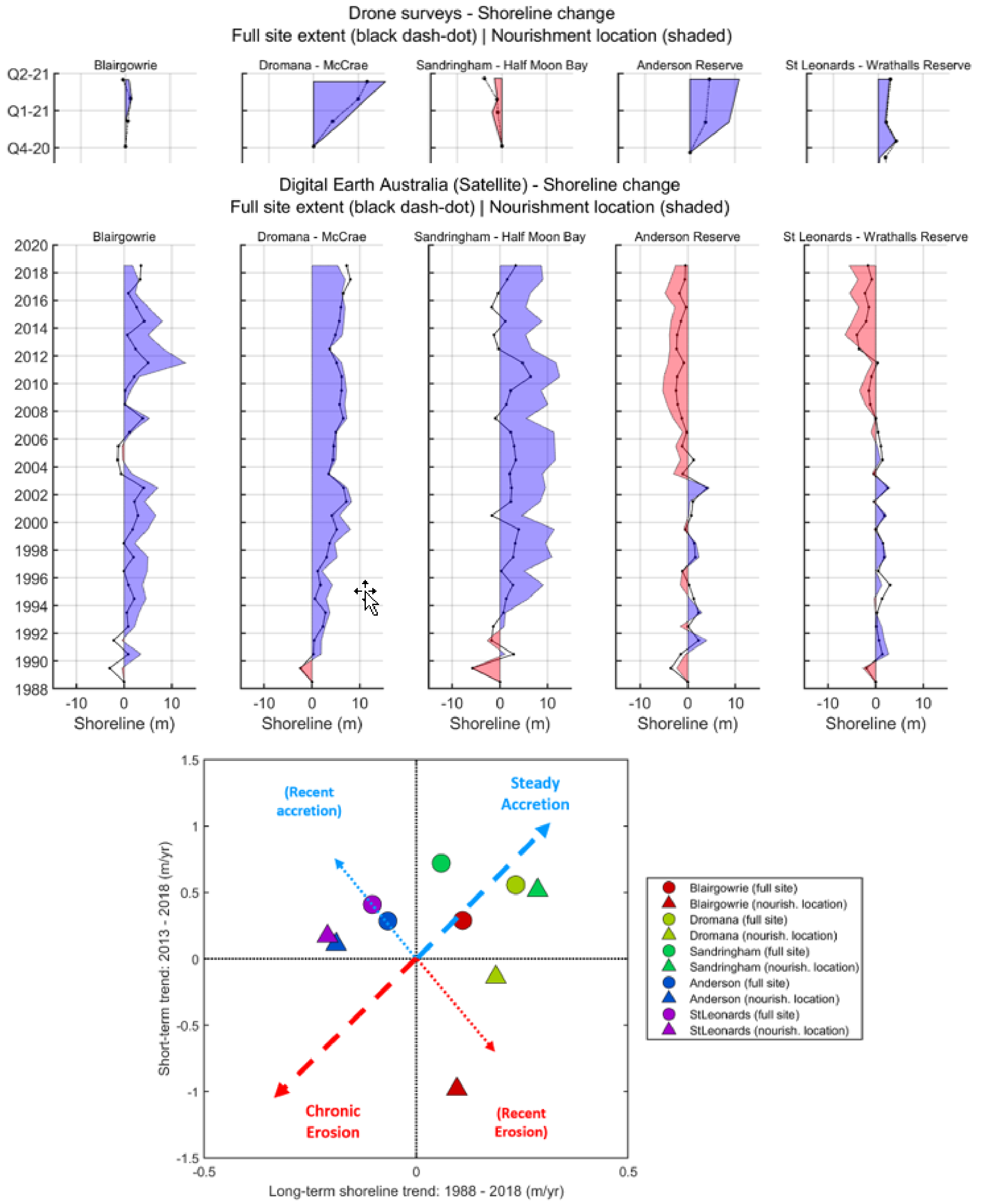


Fig. E4. (Top) Shoreline time series for drone surveys; and (middle) satellite shorelines. Shoreline averaged across the full site is shown as a black dash-dot line, nourishment location shoreline is shown as shaded red/blue. (Bottom) Comparison of short- and long-term trends, by full site and nourishment area (indicated by yellow boxes in Fig. E3).

Insights from the detailed site assessments and comparative analysis were used to propose a **7-step process for future nourishment site selection.** Elements of this process include:

- Preliminary site selection
- Site assessment: Reasons to nourish
- Nourishment goal (restore, maintain, grow)
- Coastal processes: Wave, tides, shoreline change
- Past performance of nourishments
- Expected performance of proposed nourishment
- Summary assessment, final site selection

Following this process requires an assessment of reasons to nourish a site (example in Table E2), and a summary site rating (Table E3), that can be produced after following the steps outlined above (full details in Sec. 5). The examples below require further consultative development.

Table E2. Example needs / reasons to nourish a site

		Blairgowrie	*Dromana*	*McCrae*	*Sandringham*	*Half Moon Bay*
5.1. Need/reason to nourish						
Infrastructure protection	*Public*	High	Low (?)	Mod - High	Low	Low-Mod
	Private	Med	High (?)	Low	Low	Low
Vegetation protection		High	Mod	High	Low-Mod	Low-Mod
Habitat protection		??	??	??	??	??
Beach amenity		High	Mod - High	High	Mod	Mod
Coastal structure protection		Low	Low - Mod	Low	Low	Low - Mod

Table E3. Example summary site assessment for determining nourishment suitability.

		Sites		
5.6. Summary assessment	**Scale**	***Blairgowrie***	***Dromana***	***McCrae***
Urgency	4 - Imminent hazard (<5 years) and or severe consequence (major asset loss) 3 - Short-term hazard if no action taken (<10 years) 2 - Hazard may occur in the medium term (> 10 years) 1 - Hazard may occur at over the long-term 0 - Hazard unlikely / not a reason for the nourishment	4	3	2
Importance - to DEECA goals and community	2 - High 1 - Medium 0 - Low	2	1	1
Importance - to nourishment research program	2 - High 1 - Medium 0 - Low	2	2	2
SUMMARY SCORE (Total of above 3 ratings)	**(MIN = 0 ---> MAX = 8)**	**8**	**6**	**5**

Conclusions and recommendations

The goal of this report was to provide a first-pass assessment of beach nourishments within PPB in order to understand nourishment dynamics, and assist in choosing future nourishment sites. The five selected sites cover a wide range of morphologic and wave conditions across PPB. Data are analysed from the VCMP as well as other sources, such as satellite and aerial imagery.

Conclusions and recommendations from the report include:

- Shoreline trends across the sites include some areas of short-term erosion, in particular around zones targeted for nourishment, while other sites were found to be accreting.
- Historical nourishment volumes were found to comprise only a small proportion of the sediment budget for each compartment, indicating that areas of concern are mostly localised hotspots, that can continue to be nourished with relatively small volumes, into the medium term.
- Short-term variability, including seasonal rotation, was found to be an important factor in choosing and designing nourishments at some sites (e.g., Sandringham).
- None of the sites were found to be chronically eroding.
- A draft 7-step process for site selection was proposed.
- Risk of an erosion hazard to infrastructure was ***not*** a necessary factor for determining current beach nourishment targets. Other reasons to nourish may include:
    - Maintaining or increasing beach amenity, by widening the beach.
    - Protecting vegetation, including large trees, from erosion risk.
    - Protecting aging / failing coastal protection structures, such as seawalls (this needs further examination).
- It is recommended that nourishment monitoring procedures between the Statewide Coastal Programs group and the VCMP are formalised (e.g., mandatory pre- / post-nourishment surveys).
- Modifications to the VCMP methodology may be required (e.g., more bathymetric surveys) and are currently being developed.

Selecting future sites will be the basis of an upcoming investigation. It must be emphasised that DEECA is currently in a 'testing phase' in regard to beach nourishments**, e**very site selected during this phase acts as a test case to inform future nourishments. This should influence how nourishments are planned and discussed, both within DEECA and to stakeholders:

- Nourishment longevity should not be considered in terms of 'success' or 'failure', e.g., if a site is nourished and the shoreline returns to the pre-nourishment position within a single year, this is still useful data.
- Rather, a measure of success during this phase should be: Have we effectively monitored the nourishment over its lifetime, and used this to inform future nourishments at this, or similar, sites?
- As long as DEECA does not intervene at a site in ways that actively draw a negative response from the community, then any given nourishment, if properly monitored, serves a purpose.

This report must be considered a preliminary assessment given that 2020-21 nourishment activities were still in progress at the time of writing. A follow-up report is required once this round is complete, in addition to an assessment of potential new sites for the next round in 2022 and beyond.

Contents

PART 1: INTRODUCTION, SEDIMENT BUDGET CONCEPTS AND BEACH NOURISHMENT PROCESSES

1.1 The Port Phillip Bay beach nourishment program

Port Phillip Bay (PPB), Victoria, Australia, is a large scale estuary, extending over 50 km across at the widest points from north to south and east to west. The shorelines around the entrance are partially exposed to long period, high-energy ocean swells, though most of bay is only impacted by short-period, fetch-limited, locally generated wind waves.

The shorelines around the bay vary from long sandy embayments (>20 km alongshore) at the south and east of the bay, to shorter embayments bounded by headlands (e.g., to the northeast), interspersed by rocky platforms and cliffs, with some areas of very low energy, muddy shorelines to the west of the bay.

Winds are dominantly southwesterly in summer and northwesterly in winter. The locally generated wind waves are typically <0.5 m in height with periods <5 s, though locally generated storm waves can reach up to 2 m at the north, east and south of the bay.

The coastline across many sections of PPB have seen extensive interventions, such as seawalls, revetments, groynes, marinas bounded by jetties, and shipping terminals. Interventions have been intense around the city of Melbourne at the north of the bay, in particular around the entrance to the Yarra River where shipping terminals and reclaimed areas have resulted in an entirely engineered coastline.

The Victorian Government Department of Energy, Environment and Climate Action (DEECA), and in particular the Statewide Coastal Programs group, is responsible for managing and implementing coastal interventions across PPB, including the construction and maintenance of coastal structures, such as seawalls and groynes, while also overseeing a beach nourishment program (described idiomatically in Victoria as “renourishment”).

The Victorian Coastal Monitoring Program (VCMP) was established in 2018 to monitor the open coast and estuarine beaches of Victoria, through a Citizen Science based drone survey scheme, also employing wave buoy observations and bathymetric surveys. Prior to the VCMP commencing in 2018, no centralised effort was made to monitor Victoria beaches, either open coast or estuarine. In particular, no concerted effort had been undertaken to study the dynamics of beach nourishments within PPB.

The aim of this report is to provide a first-pass assessment of beach nourishments within PPB, in order to understand nourishment dynamics, and assist in choosing future nourishment sites. Data are analysed from the VCMP as well as other sources, such as satellite and aerial imagery.

What is the purpose of a nourishment monitoring program?

An ongoing nourishment monitoring program within PPB is critical to planning and predicting the behaviour of future nourishments. Applications and benefits include:

- **Prediction by extrapolating observations:** If we have previous data on how a nourishment performed at a given site, it is a reasonable *a priori* assumption that future nourishments will behave similarly.
- **Training predictive models:** Observational data are fundamental for training morphodynamic models. Unvalidated models can be highly misleading.

- **Improved stakeholder feedback:** Quality data are needed to report to stakeholders on nourishment performance, including whether desired goals have been achieved.

1.2 Total sediment budget

This report takes a ‘sediment budget approach’ to assessing coastal dynamics. The components of a total sediment budget comprise:

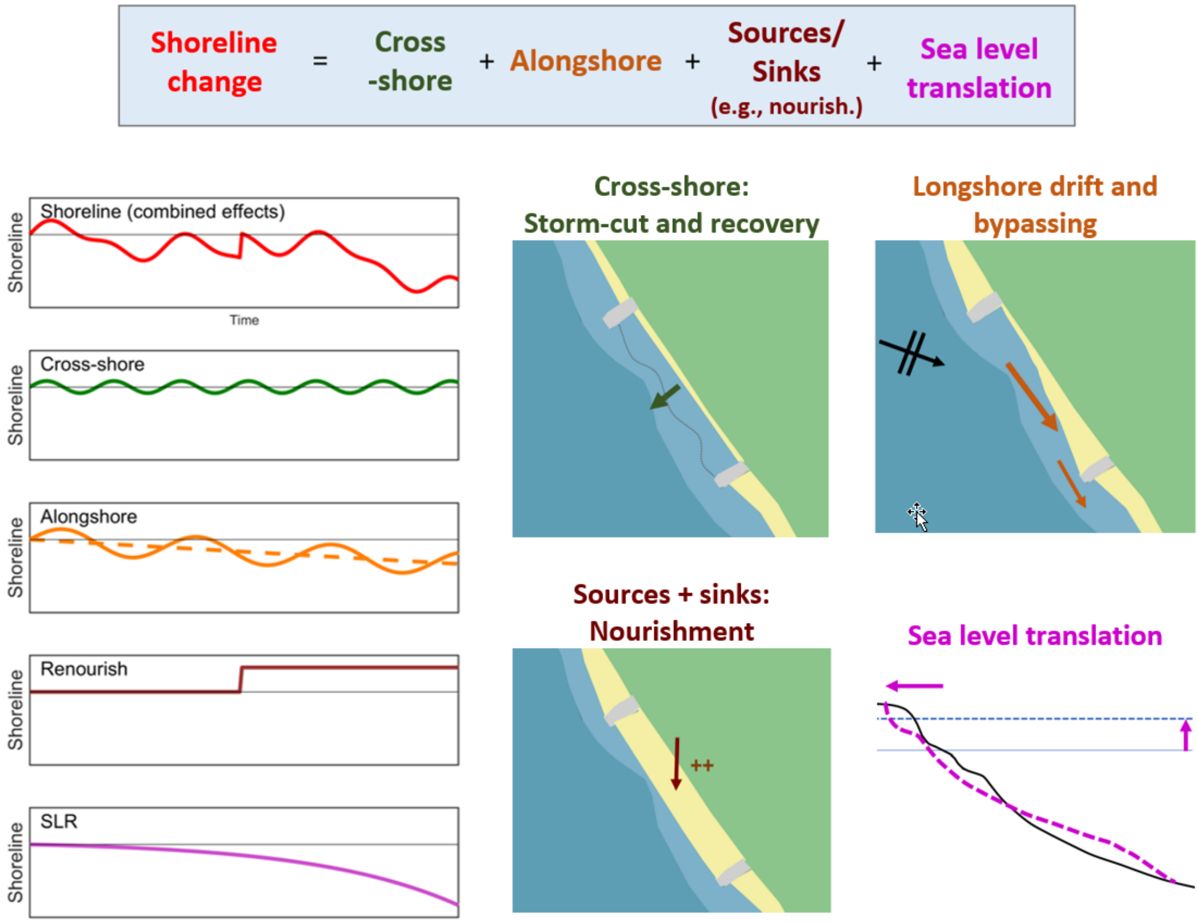


Fig. 1.1. Sediment budget components. The red “combined effects” shoreline is the sum of the components: cross-shore, alongshore, nourishment and SLR.

“Source/sinks” includes nourishment. A detailed description of the approach is given in McCarroll et al. (2021a). The above sediment budget components (excepting SLR) can be broken down into:

- *Trend* or *underlying* rates (a steady change over many years)
- Short-term *variability* or *fluctuations* (an envelope of change that can vary unpredictably from year to year)

Budgets can be reported in units of:

- Shoreline position (m or m/yr)
- Profile volume (m^3 or m^3/year for a compartment, or m^3/m [i.e., ‘*cubic metres per metre alongshore*’] for a profile)

By assessing a total sediment budget, we can:

- Identify/isolate components of the budget that are unknown, and direct future efforts to determine these.
- Estimate required nourishment volumes more effectively.
- Better estimate when hard interventions will be required.
- Assess the system as a whole, assisting decision making on interventions.

A sediment budget can be calculated for an entire compartment, for a section of shoreline, or for an individual profile. For each section of shoreline, the sediment budget (ΔV) can be estimated (Fig. 1.2) as

$$\Delta V\ (m^3/m\ /yr) = h_a \Delta X$$

where h_a is the height of the active shoreface and ΔX is the rate of shoreline change (m/yr). The volume change per metre alongshore can be converted to volume for a full compartment by multiplying ΔV by the alongshore length of the compartment.

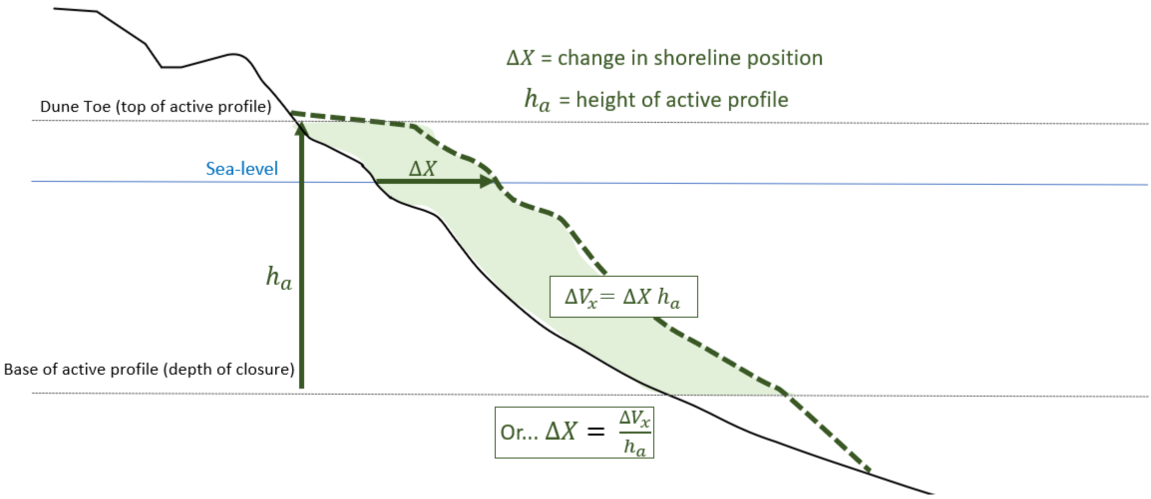


Fig. 1.2. Profile cross-section with volume change calculation. Volume change per unit alongshore is approximated as shoreline position multiplied by active profile height.

IMPORTANT NOTE: In this document, sediment budgets will be reported and referred to in two ways:

- Inclusive of nourishment volumes (**"Nourishment inclusive"**)
- Excluding nourishments volumes (**"Nourishment exclusive"**)

The latter (exclusive) method gives the 'natural' rate of underlying shoreline change. It can be difficult to identify nourishments in the record (when / where / how much), so in many instances, sediment budgets must be reported as nourishment inclusive.

1.3 Beach nourishment processes and sediment budget

The components of a nourishment sediment budget and the relevant processes are summarised in Fig. 1.3, these include:

Cross-shore equilibration. The amount of sand that will be moved offshore from the beach to the shallow subtidal, in the first days or weeks after the nourishment, as wave events reshape the profile (Fig. 1.3, top). This occurs because nourishment profiles are generally much steeper than the equilibrium.

Alongshore spread. Nourishments may be gradually dispersed (spread out) alongshore (Fig. 1.3, middle row) if they are not effectively contained by cross-shore boundaries (e.g., groynes or headlands). This may take several years. Larger volumes and/or nourishments over a greater alongshore length will take longer to disperse.

Underlying shoreline trend. The underlying shoreline trend is the background rate of shoreline change due to a deficit (erosion) or surplus (accretion) in the sediment budget. This may be due to 'natural processes', or due to the modifying effects of coastal interventions. Nourishment act as a periodic boost to the budget, as demonstrated in Fig. 1.1.

Sea level rise (SLR). Long-term projection for nourishment performance requires an estimate of SLR magnitude, and how the shoreface will translate for a given level of SLR (FIg. 1.1).

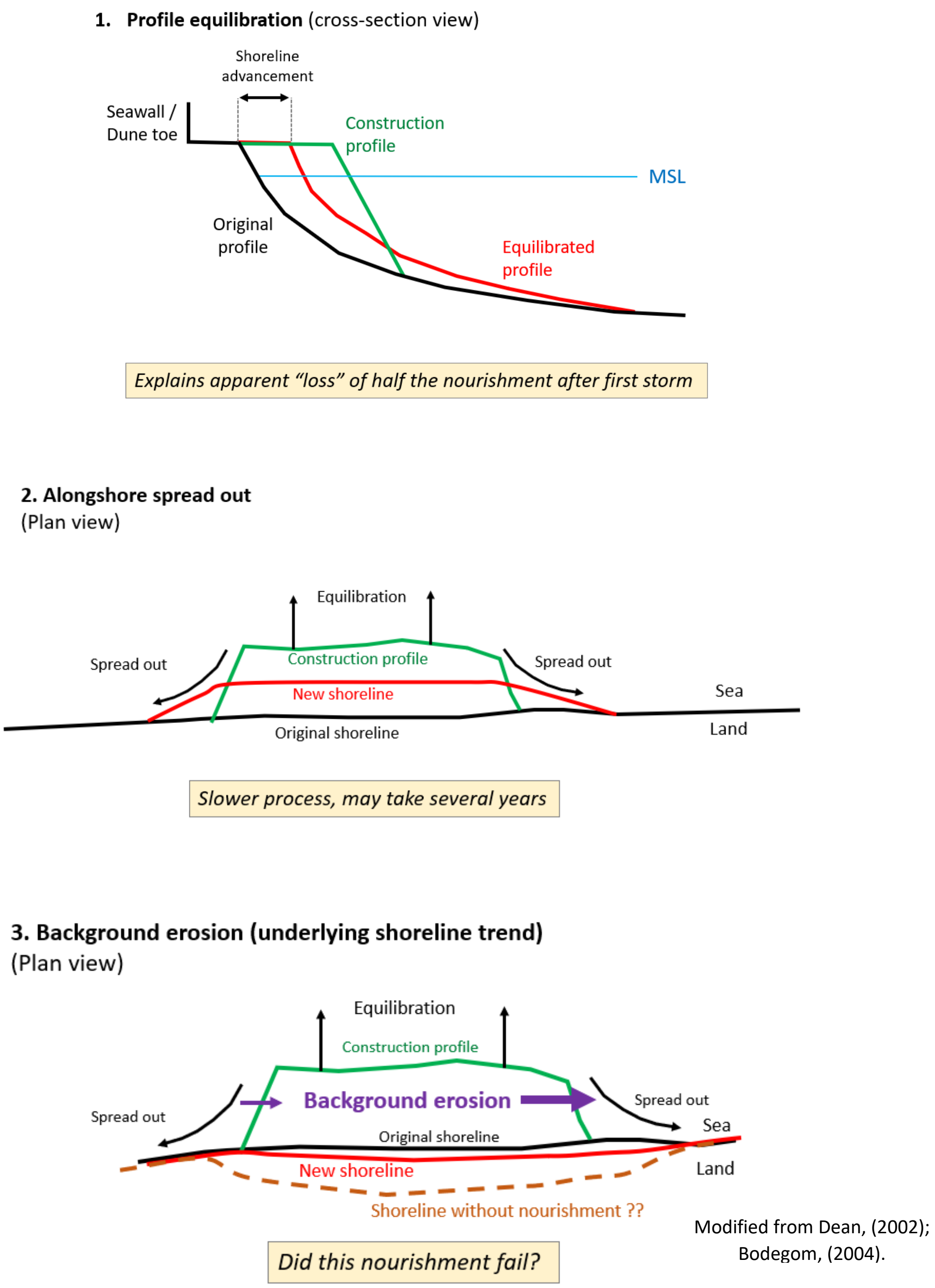


Fig. 1.3. Sand renourishment sediment transport processes.

PART 2: BACKGROUND - SITES, DATA AND METHODS

2.1 Datasets and methods

2.1.1 Shoreline data

Shorelines have been extracted across multiple datasets at 50-m alongshore intervals around PPB. All shorelines are interpreted to the same transects and chainage benchmarks, so that data are comparable across datasets. Shoreline datasets include:

- VCMP drone surveys (2018 to present, further detail in next section)
- Satellite, Digital Earth Australia (DEA; 1988 – 2018; Bishop-Taylor et al., 2019a,b)
- Satellite, CoastSat (using Landsat 8, 2013 – present; Vos et al., 2019a,b)
- Aerial Imagery (DEECA IWS, 1930 – present).

VCMP drone surveys

The Victorian Coastal Monitoring Programs (VCMP) has conducted drone surveys at multiple sites across PPB since 2018, most of the monitoring sites are also nourishment sites. VCMP survey coverage includes:

Surveyed since 2018: Mt Martha, Portarlington, St Leonards, Queenscliff Dog Beach, Point Lonsdale.

Surveyed since Dec 2020: Blairgowrie, Dromana-McCrae, Patterson River, Sandringham

- Survey regions are typically 2 to 3-km alongshore, covering the sub-aerial beach and the back shore (including dunes, cliffs, structures, and vegetation).
- Orthomosaics and Digital Surface Models (DSM) are produced using photogrammetry methods, vertical uncertainty is on the order of 0.1 m.
- Data are processed and hosted on PropellerAero.
- Transects extracted from DSMs at 50-m intervals alongshore.
- The cross-shore position of the 0.5 m contour is extracted as a proxy for ‘shoreline position’ (some drone surveys do not extend below this level, due to water interference).
- Volumes analysis has been conducted in some instances.

A summary of data collected in PPB since Dec 2020 as part of the VCMP-PPB Expansion are summarised in Table 2.1.

Table 2.1. VCMP survey observations in Port Phillip Bay

Survey method	Description	Total
Drone	Total PPB sites	9
	Total PPB surveys (from 2018)	109
	New PPB monitoring sites (from Dec 2020)	4
	New site surveys	23
Topographic	PPB topographic surveys (from Dec 2020)	5
Bathymetric	PPB bathymetric surveys (from Dec 2020)	5

2.1.2 Digital Elevation Model (DEM)

The 2017 Victorian Coastal DEM, a merged topo-bathymetry covering the full extent of coastal Victoria (Allemand et al., 2017), was used to extract cross-shore profiles.

2.1.3 Wave data

Wave data for PPB has been sourced from modelled hindcasts and buoy observations.

- **Wave model hindcast (Sec. 2.3.1).** SCHISM-WWM3, 1990 – 2016, produced by Huy Tran (UoM). Model nodes have been extracted every 1-km along the PPB coastline, 500-m offshore.
- **Wave buoys (Sec. 2.3.2).** Six buoys were deployed across PPB by the VCMP in Dec 2020. Data are available from Vicwaves.com.au.

2.1.4. Alongshore sediment flux

Alongshore sediment flux is estimated by converting the wave model hindcast, from the node location (500-m offshore) to the breakpoint, then a parametric formula is used estimate alongshore sediment flux (Van Rijn, 2014).

2.2 Selection of sites for detailed analysis

Extensive sand nourishment activities have been conducted across Port Phillip Bay (PPB) for many decades. A recent evaluation of potential nourishment sites was conducted by Cardno (2019). The current selection of nourishment sites is in part informed by that assessment. Five sites were selected for detailed analysis (Sec. 3). These sites are all recently nourished, or are scheduled for nourishment, and are being actively monitored by the VCMP, they include (Fig. 2.1):

1. Blairgowrie
2. Dromana-McCrae
3. Sandringham (including Half Moon Bay)
4. Anderson Reserve
5. St Leonards (including Wrathalls Reserve)

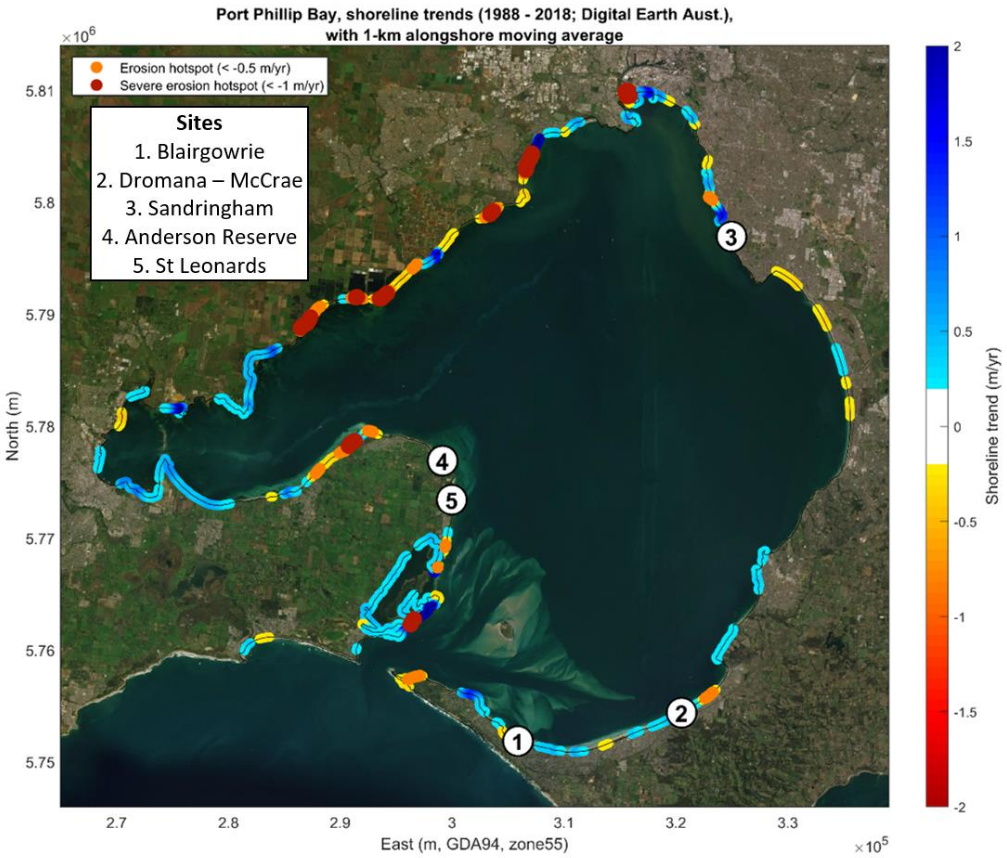


Fig. 2.1. PPB shoreline trends and sites selected for analysis. Shoreline trend data are from Digital Earth Australia (DEA) satellite extracted shorelines (1988 – 2018).

2.3 Wave climate: Model and buoy data

Wave climate in PPB is comprised of locally generated, short-period (< 5 s) wind waves, with the exception of the shorelines around the entrance, which experience a mixed wave climate of locally generated wind waves, and refracted long-period (> 8 s) swell waves, that have passed into the bay form the open ocean. Wave climate across PPB is briefly presented as background, using model data (Sec. 2.3.1) and wave buoy observations (Sec. 2.3.2).

2.3.1 Wave model hindcast

Wave model data were obtained from the SCHISM-WWM3 hindcast for 1990 – 2016. Mean wave heights around most of the bay, away from the entrance, are predicted to be low (Fig. 2.2, left). Significant wave height (Hs) on the eastern side of the bay is 0.3 to 0.4 m, while the western side of the bay is lower energy with Hs of 0.15 m to 0.3 m. Wave period averages < 4 s away from the entrance (Fig. 2.2, right), following a similar east-west distribution to wave height.

Wind direction (and therefore wind wave direction) is dominated by more southerly conditions in summer, and more northerly conditions in winter (Fig. 2.3). This results in strong seasonality on the east and west sides of the bay (with somewhat less seasonality to north and south). Shorelines that experience this seasonal variation typically exhibit northerly sediment transport in summer and southerly sediment transport in winter.

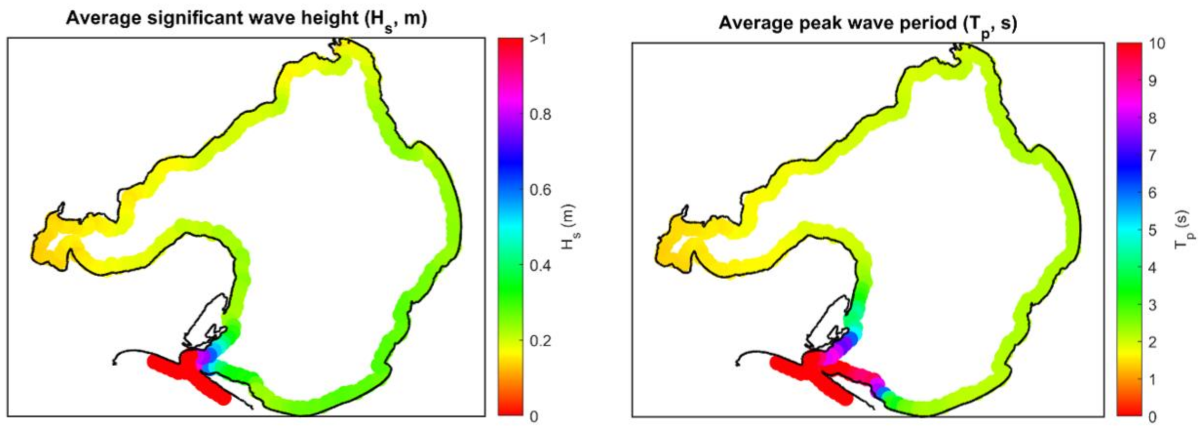


Fig. 2.2. Long-term averages for significant wave height (left) and peak period (right).

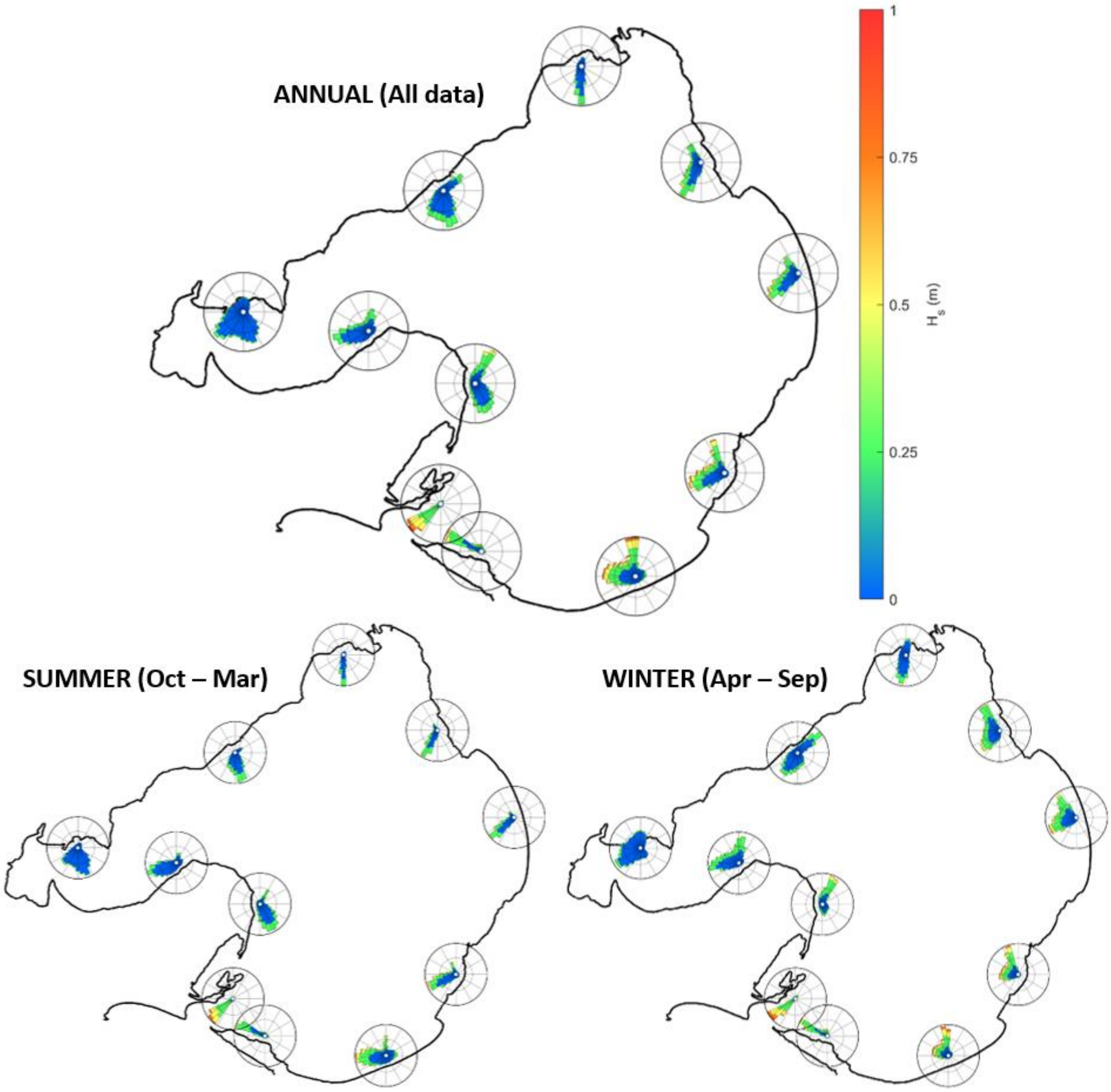


Fig. 2.3. Wave roses, based on SCHISM hindcast (1990 – 2016), for all data (top); ‘summer’ (Oct-Mar; bottom left); and ‘winter’ (Apr-Sep; bottom right).

2.3.2 Wave buoy observations

Six directional wave buoys were deployed around PPB in Dec 2020, locations are indicated in Fig. 2.4 (left). A summary of wave statistics across the buoys (Fig. 2.4, right) indicates wave heights of 0.3 – 0.5 m across all sites, with peak period of ~3 s. Wave heights and periods are marginally higher for the Central PPB buoy and for Sandringham. Average wave direction for Central PPB is from the southwest, for other buoys the mean direction is close to shore normal (i.e., the average wave direction is from the direction the shoreline faces towards).

Time series of significant wave height (Hs), peak wave period (Tp) and peak direction (Dp) for all PPB wave buoys are displayed in Fig. 2.5. A distinct seasonal shift in direction is observed for all buoys, with predominantly southerly winds and wave direction over summer, shifting to dominant northerly direction by June. Wave heights are generally observed to be larger in winter. Maximum wave heights during observed storm events range from 1.7 m to 2.2 m across the buoys.

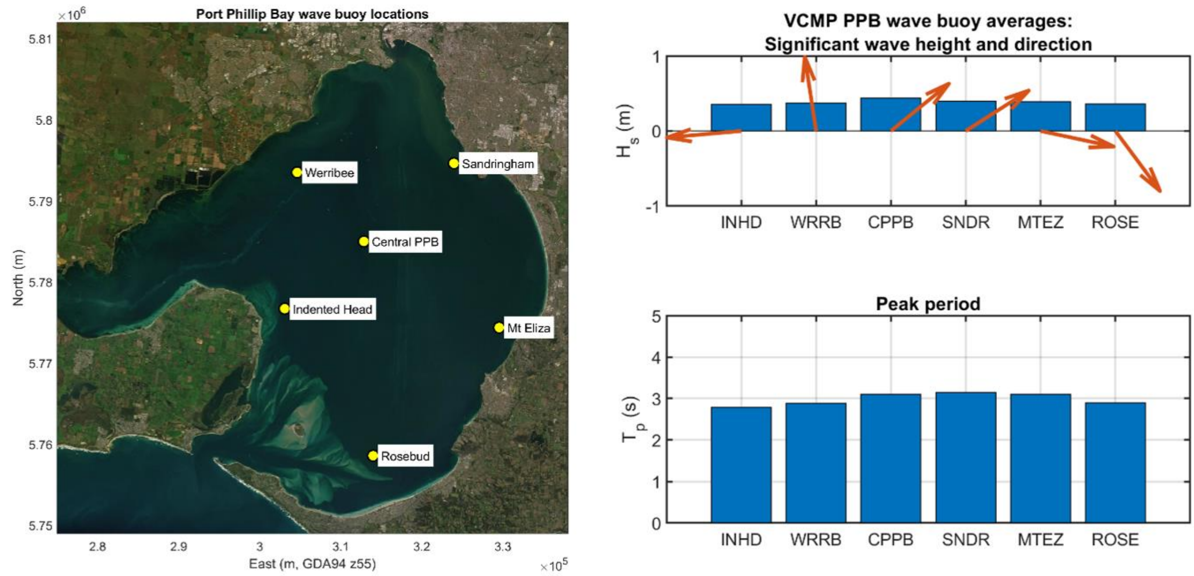


Fig. 2.4. Port Phillip Bay wave buoy locations. Site abbreviations in right panel include: Indented Head (INHD); Werribee (WRRB); Central Port Phillip Bay (CPPB); Sandringham (SNDR); Mt Eliza (MTEZ); and Rosebud (ROSE).

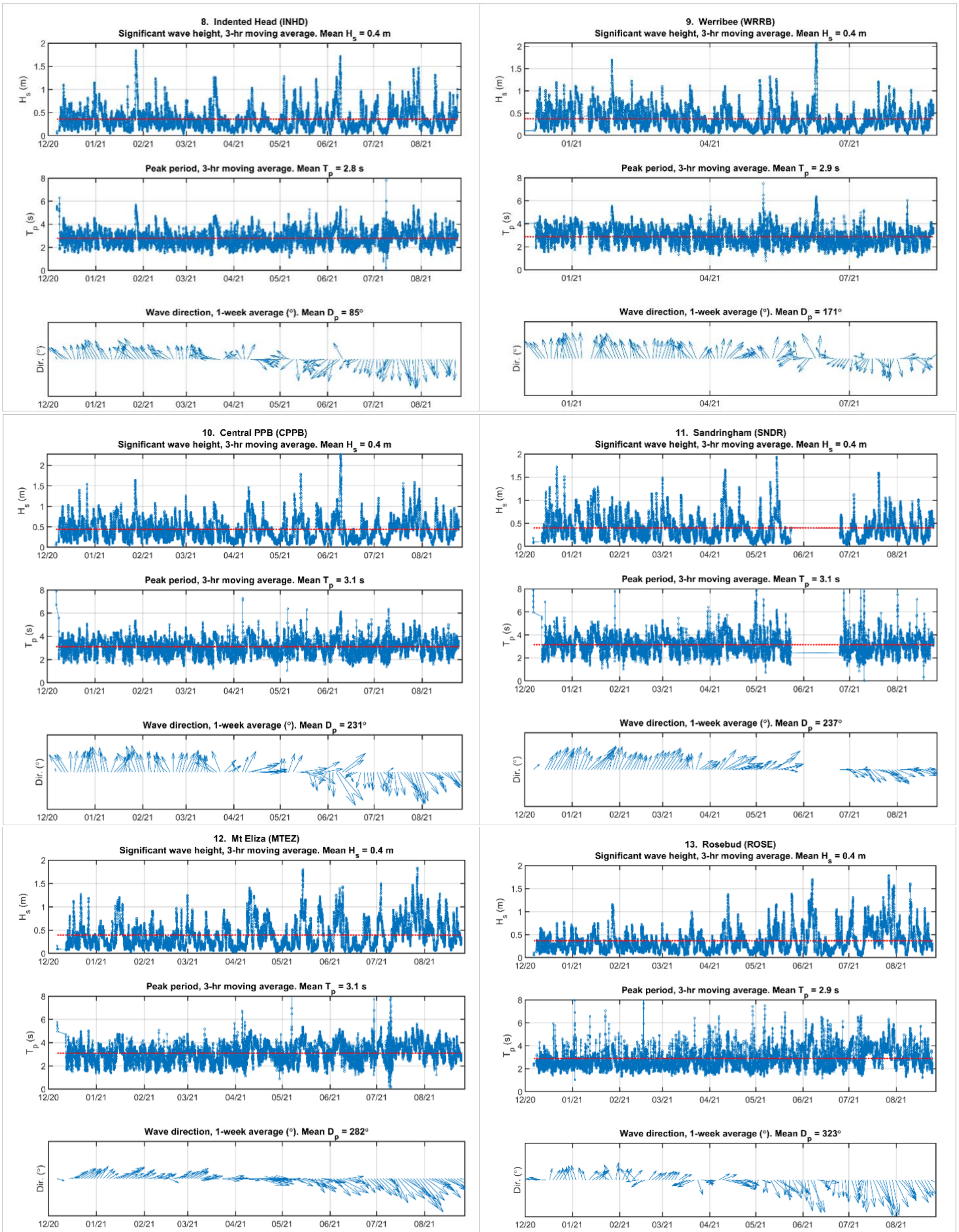


Fig. 2.5. Wave timeseries for PPB buoys, including signficant wave heigth (Hs), peak period (Tp) and peak direction (Dp).

2.4 Historical shoreline change trends

A brief analysis of shoreline change trends in PPB is provided here as background, based on the satellite extracted shorelines from Digital Earth Australia (DEA), for the period 1988 – 2018. Shoreline change trends were calculated for transects every 50-m alongshore, around the full extent of PPB.

The mean shoreline trend for PPB is +0.14 m/yr (Fig. 2.6; the positive value indicates accretion), while 10% of the bay is experiencing 'high erosion' (defined as < -0.5 m/yr) and 4% of the total shoreline is experiencing 'severe erosion' (< -1 m/yr).

Areas of high and severe erosion hotspots are concentrated (Fig. 2.1) around the northwest of the bay (between Altona and Point Wilson), and also on the Bellarine Peninsula, west of Portarlington.

Based on the division in Fig. 2.7, most sectors of the bay are accreting on average, at around 0.2 m/yr. Exceptions are the EAST sector (Frankston to Mentone) and the NORTHWEST sector (Altona to Point Wilson), which have both eroded slightly on average over the measurement period.

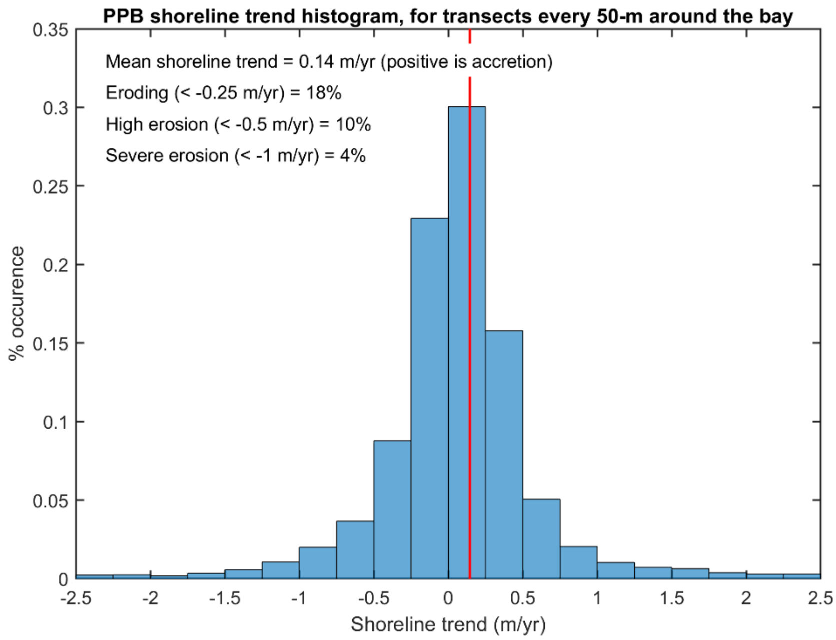


Fig. 2.6. PPB shoreline trend histogram, using DEA satellite data for 1988 – 2018, based on transects every 50-m alongshore around the bay.

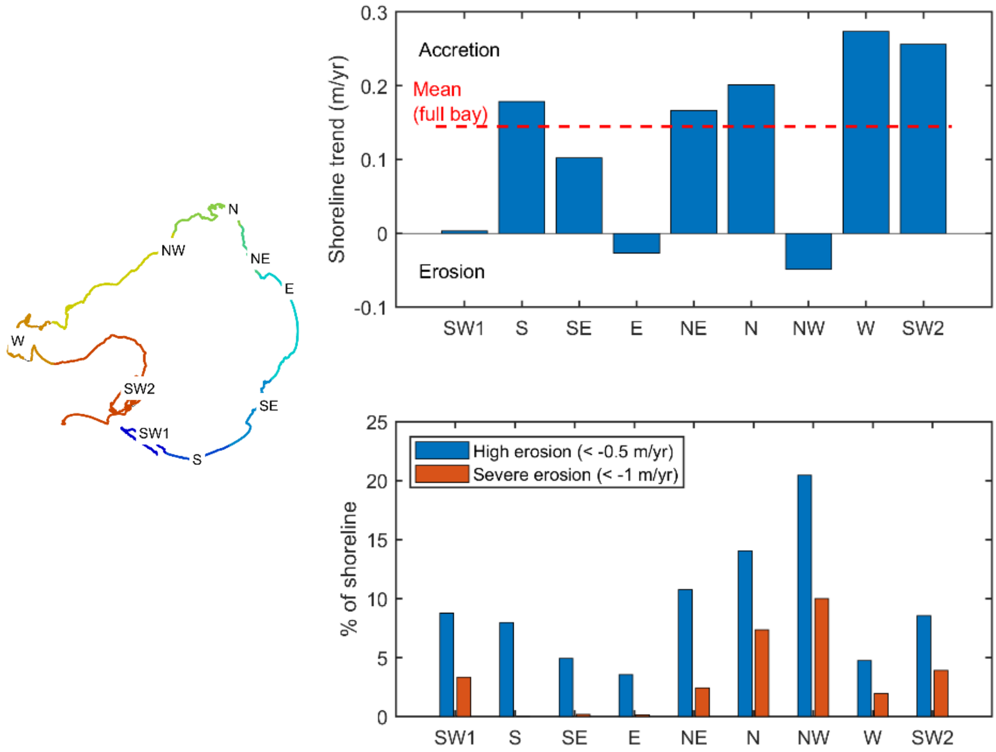


Fig. 2.7. PPB sectors, (left) map of sectors, (top right) shoreline trend by sector; and (bottom right) incidence of 'high' and 'severe erosion' by sector, based on DEA satellite data, 1988 – 2018.

PART 3: DETAILED SITE ASSESSMENTS

3.1 Blairgowrie

3.1.1 Site setting

Blairgowrie is located on the Mornington Peninsular to the south of the bay, at the western end of 24-km long sandy embayment. The beach is low-energy and narrow, with a low dune, with varying degrees of vegetation and infrastructure built on the dune. A major road (Nepean Hwy) runs directly behind the barrier. The proposed nourishment runs from the Blairgowrie Marina, eastward for ~2-km. Within the nourishment, key sites of interest occur where erosion of the coastline may cause hazard to the road (Fig. 3.1.1), including:

- BLR-01: Mackie Ct (around profile P552). A zone of terminal scour opposite Mackie Ct, downdrift of a groyne-field and a short seawall.
- BLR-02: St Johns Wood Rd (around profile P559). A narrow section just east of St John Wood Rd, that has experienced recent erosion, with a high level of historical variability, related to addition and removal of groynes

Geomorphology:

- Sediment: Medium sand; 0.25 – 0.3 mm
- Beach width:
  - Mostly very narrow, 3 – 8 m;
  - No high tide beach exists in a few eroded spots (e.g., down-drift of terminal groynes).
- Beach and nearshore morphology:
  - A steep beach face (1:10 slope) flattens to a very wide shallow subtidal terrace (depth <1 m below spring low tide level), extending up to 500 m offshore, with multiple linear to rhythmic bars.
- Back shore morphology:
  - A low dune (1.5 – 4 m AHD) backs the beach, up to 50 m wide, vegetated by low trees in some areas, and with a greater degree of development / infrastructure in other zones (see 'Infrastructure' below).

Coastal structures:

Cross-shore structures: Wooden groynes, with 20 m average length, comprise an irregularly spaced groyne-field (100 – 200 m spacing), covering most of the nourishment site (Fig. 3.1.1) from the marina, eastward 1.4 km. Many of these are in poor condition and are ineffective at trapping sediment.

Alongshore structures: *Note: The "CAMS Assets 20201112" layer was used, which may not be the most updated version. An most recent version will be used in all future work.* Four sections within the Blairgowrie monitoring site are backed by walls., extending 50 – 400 m alongshore, with various construction designs (wooden, concrete blocks, rock armour). Several other short, irregular walls are apparent in the aerial imagery.

Infrastructure:

The Nepean Hwy runs behind the vegetated-developed dune, as close 12 m to the high-tide line, just east of St Johns Wood Rd, with a maximum buffer of 50 m, at the vegetated section 350 m east of the marina. Erosion to the road is considered the primary hazard to be mitigated by nourishment.

The dune is highly developed at the western end (adjacent the marina), with no natural vegetation. The mid- to eastern end of the nourishment zone has a greater amount of vegetation, with some structures (e.g., toilet block, small sheds/beach shacks).

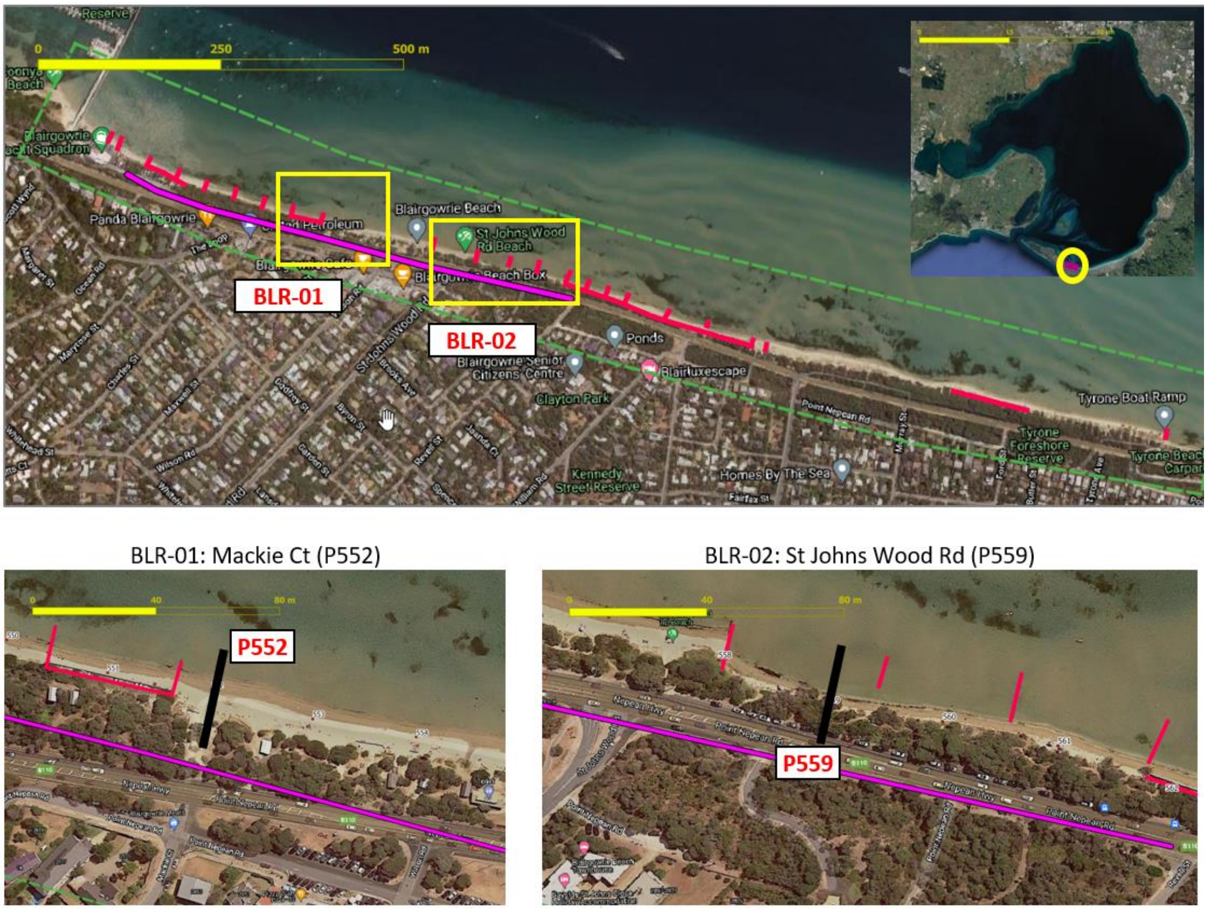


Fig. 3.1.1. Blairgowrie. Drone survey area (green dashed); structures (red); nourishment area (pink)

Historical nourishments:

- 2010 – Blairgowrie (Fig. 3.1.1a, top)
  - See document "*2010BlairgowrieRenourishmentInfor.pdf*"
  - Fill volume of 10,000 m3, mostly in the vicinity of Mackie Ct (BLR-01 in Fig. 3.1.1).
  - Borrow site was the salient formed onshore of the marina.
  - Evident in aerial imagery (Fig. 3.1.4).
  - Undocumented with unknown volume.
- 2013 – Camerons Bight, west of Blairgowrie marina (Fig. 3.1.1a, bottom)
  - Documentation includes a design report by Oldfield (2012).
  - Volume thought to be ~5,000 m^3 (from design report, Oldfield, 2012)
  - Borrow site was the salient formed onshore of the marina.

Note: Both known Blairgowrie historical nourishments redistributed sediment within the system, rather than adding new sand. Therefore, these nourishments do not add or subtract from the sediment budget (Sec. 3.1.3).

Fig. 3.1.1a. (Top) 2010 Blairgowrie renourishment of 10,000 m^3 from "*2010BlairgowrieRenourishmentInfo.pdf*" flyer released by the Department of Sustainability and Environment; (bottom) Camerons Bight 2013 nourishment of 5,000 m^3, location from Oldfield (2012).

3.1.2 Coastal processes and dynamics

Wave climate

Wave roses and longshore sediment flux potential are shown in Fig. 3.1.2, sourced from a SCHISM 25-year wave model hindcast for a node located 500 m offshore the monitoring site. The site experiences a low energy wind wave climate (no swell wave energy from the entrance). Wave statistics comprise:

- Mean significant wave height = 0.2 m.
- Mean peak period = 2.3 s.
- Mean wave direction = -11° (NNW)
- Seasonality: Bigger waves in winter, more concentrated from the north and NNW.

Tidal regime

Tides are microtidal and semi-diurnal with approximate spring range of 0.8 m. Maximum water levels in a 1-year modelled time series are 0.5 m above MSL.

Longshore drift

Predicted sediment flux potential is shown in Fig. 3.1.2.

- Net (annual) flux is eastward, 1,000 – 2,000 m^3/yr.
- Flux in summer is near zero (may be some east to west transport, based on groyne build-up observations, though this is not picked up in the model).
- Majority of transport is predicted to occur during winter.

Longshore sediment transport gradients interacting with cross-shore structures are likely to be the dominant processes controlling shoreline change at this site.

Cross-shore variability

Storm demand at this site is likely to be minimal. SBEACH modelling (Cardno, 2018) predicts 3 m^3/m erosion for nearby Rye beach for a 1-in-100 yr event, this would equate to 1-2 m of shoreline change.

Potential exchange between the beach and the subtidal bars could result in multi-year variability in shoreline position, but has not been quantified.

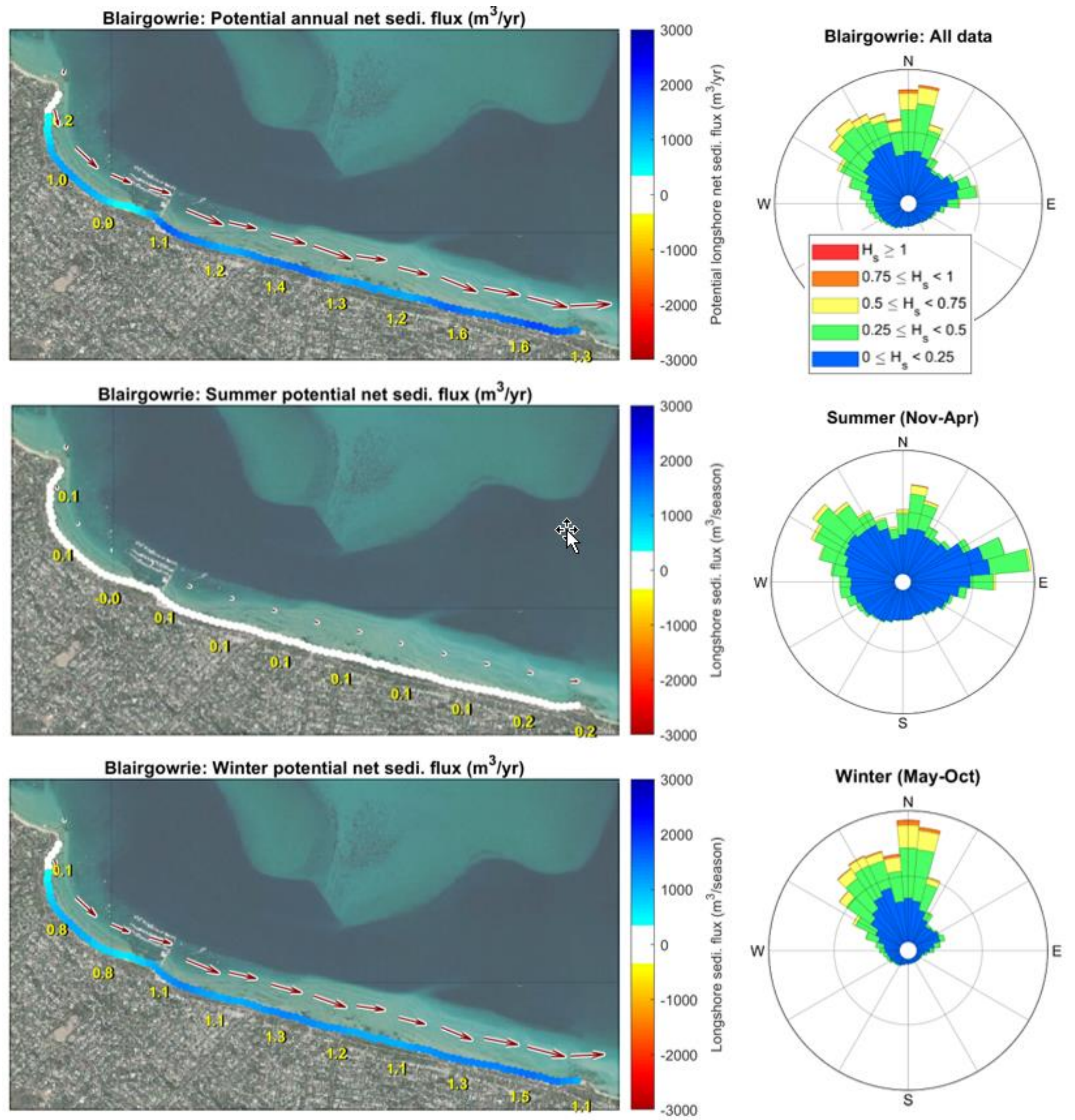


Fig. 3.1.2. Blairgowrie potential sediment flux (left) and wave roses for a model node located 500 m from shore.

Historical shoreline change

Long- (50+ year), medium- (30-year) and short-term (8-year) shoreline trends are summarised in Fig. 3.1.3. Location along the beach is referred to by profile number (Transect ID). The site as a whole is described here, then detailed analyses of the targeted profiles (BLR-01, P552 and BLR-02, P559) are provided in the following sections.

Camerons Bight: The far western area, around Cameron's Bight, has experienced multiple phases of erosion-accretion, and various hard and soft coastal interventions, which are not examined in detail here.

Marina reclamation zone: The zone just west of the marina has seen moderate to rapid shoreline growth over the short- to long-term. Much of this could be due to historical nourishments (details not obtained) and a large foreland of reclaimed land has extended the shoreline >50 m offshore from historical levels, with vegetation becoming established across some of this new land.

Nourishment site: The nourishment site is mostly stable over the long term (Fig. 3.1.3, top right, green bars); however, the entire nourishment zone has experienced rapid rates of shoreline recession over the short-term (Fig. 3.1.3, top right, blue bars). It appears as though a large nourishment occurred in ~2010 – 2011 and the zone has been eroding steadily since that time.

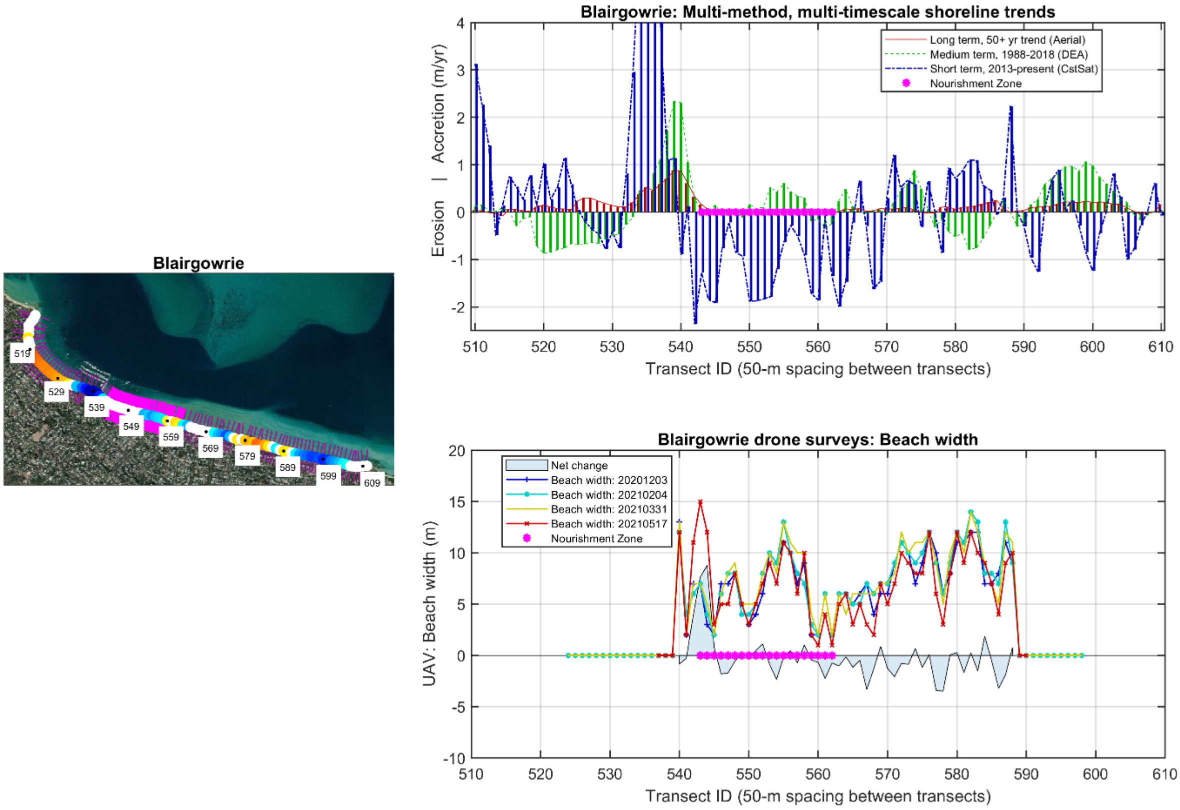


Fig. 3.1.3. Blairgowrie, (top) shoreline trends over different time scales [1930 – 1988; 1988 – 2013; 2013 – 2022]; (bottom left) site map with transect ID's, coloured dots indicate erosion [hot colours] and accretion [cold colours]; (mid right) multi-timescale shoreline trends; and (bottom right) beach width from drone surveys.

Detailed analysis: BLR-01, Mackie Ct, P552

- A zone of terminal scour is observed opposite Mackie Ct, downdrift of a groyne-field and a short seawall (transect ID - P552).
- Long- and short-term trends are neutral (Fig. 3.1.3, top-right), with a large amount of inter-annual variability (Fig. 3.1.4), with fluctuations of 10-20 m occurring over a few years. Some of these may be due to 'erosion – nourishment' cycles.
- Since the 2010-2011 nourishment, the short-term trend (2011 - 2021) is highly erosive at a steady rate (- 1.5 to -2 m/yr shoreline position; Fig. 3.1.3 top-right; Fig. 3.1.4 time series for P552).
- The site presents an immediate risk for erosion of vegetation (large trees may become uprooted (Fig. 3.1.5, left).
- A cross-section extracted from VCMP drone surveys (Fig. 3.1.5, bottom left) shows a reasonable buffer of vegetation exists between the beach and the main road (>25 m), indicating the road is not at short-term risk (within 10-years).

Detailed analysis: BLR-02, St Johns Wood Rd, P559

- A narrow section just east of St John Wood Rd has experienced recent erosion, with a high level of historical variability, related to addition and removal of groynes (transect ID – P559).
- Historical changes to groynes (installing/removing) have led to localised shifts in beach width (large beach updrift / narrow beach downdrift).
- Presently, the beach is extremely narrow at this site (0 – 3 m; Fig. 3.1.3, bottom right).
- The groyne immediately downdrift of this site (to the right of P559 in Fig. 3.1.4, 2021 image) is disconnected from the shoreline and is ineffective at trapping sediment.
- A groyne was removed from downdrift in the late 2000's, with steady shoreline recession since that time (Fig. 3.1.4, bottom panel).
- A cross-section extracted from drone surveys (Fig. 3.1.5, bottom right) shows the beach is within 10 m of the main road.
- At the present rate of shoreline recession, the road would be eroded within ~6 years (10 m buffer to road, recent rate of erosion ~1.5 m/yr).

Fig. 3.1.4. Blairgowrie east of Marina nourishment target, (rows 1-5) aerial and drone image time series, (bottom row) multi-method shoreline position time series. Pink line in top panels show location of profile (P552) analysed in bottom panel.

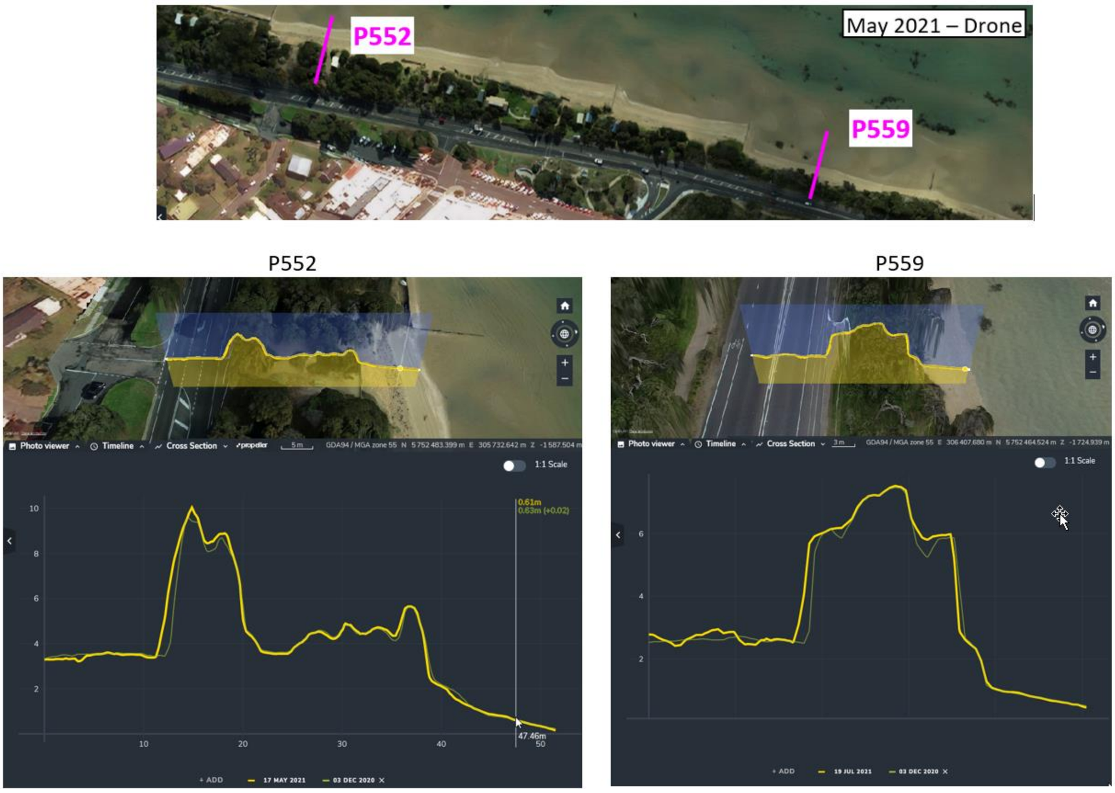


Fig. 3.1.5. Blairgowrie drone survey cross-sections for profiles P552 and P559

3.1.3 Sediment budget

An interpreted sediment budget for Blairgowrie is presented in Fig. 3.1.5. Due to the high uncertainty associated with the input data, the budget is considered an order of magnitude approximation. Data used to analyse and interpret this budget include:

- Modelled estimates of alongshore sediment flux (Sec. 3.1.2).
- DEA satellite shorelines for 1988 – 2018 (Sec. 3.1.2).
- Historical nourishment data (Sec. 3.1.1). *Some historical nourishments may be unaccounted for, and/or nourishment volumes may be highly inaccurate.*
- Shoreline change is converted to approximate volume change using:
    - [volume change = shoreline change * height of active profile]
    - Height of active profile was estimated as [h_a = 3 m].
- For simplicity, volume fluxes associated with natural processes are attributed entirely to longshore drift gradients. However, cross-shore exchange and SLR (especially in the long-term) may also occur.
- This budget is for the **entire site**, some sections within the site may be acting against the overall trend (e.g., some areas may be eroding while the site as a whole is accreting).

Blairgowrie sediment budget: Accretion across site as a whole (1988 – 2018)

The Blairgowrie site gradually accreted over 1988 – 2018 (Fig. 3.1.6). Nourishment volumes do not account for any of this growth, as the known renourishments have redistributed sediment with the compartment, from the marina salient, to adjacent eroding areas, without adding or removing any sand.

- Positive net sediment budget (+0.1 m/yr shoreline; +1,600 m^3/yr)
    - 'Natural' processes (longshore drift) = +1,600 m^3/yr
    - Nourishments = +0 m^3/yr (both known nourishments redistributed sand in the compartment, without adding or removing anything).

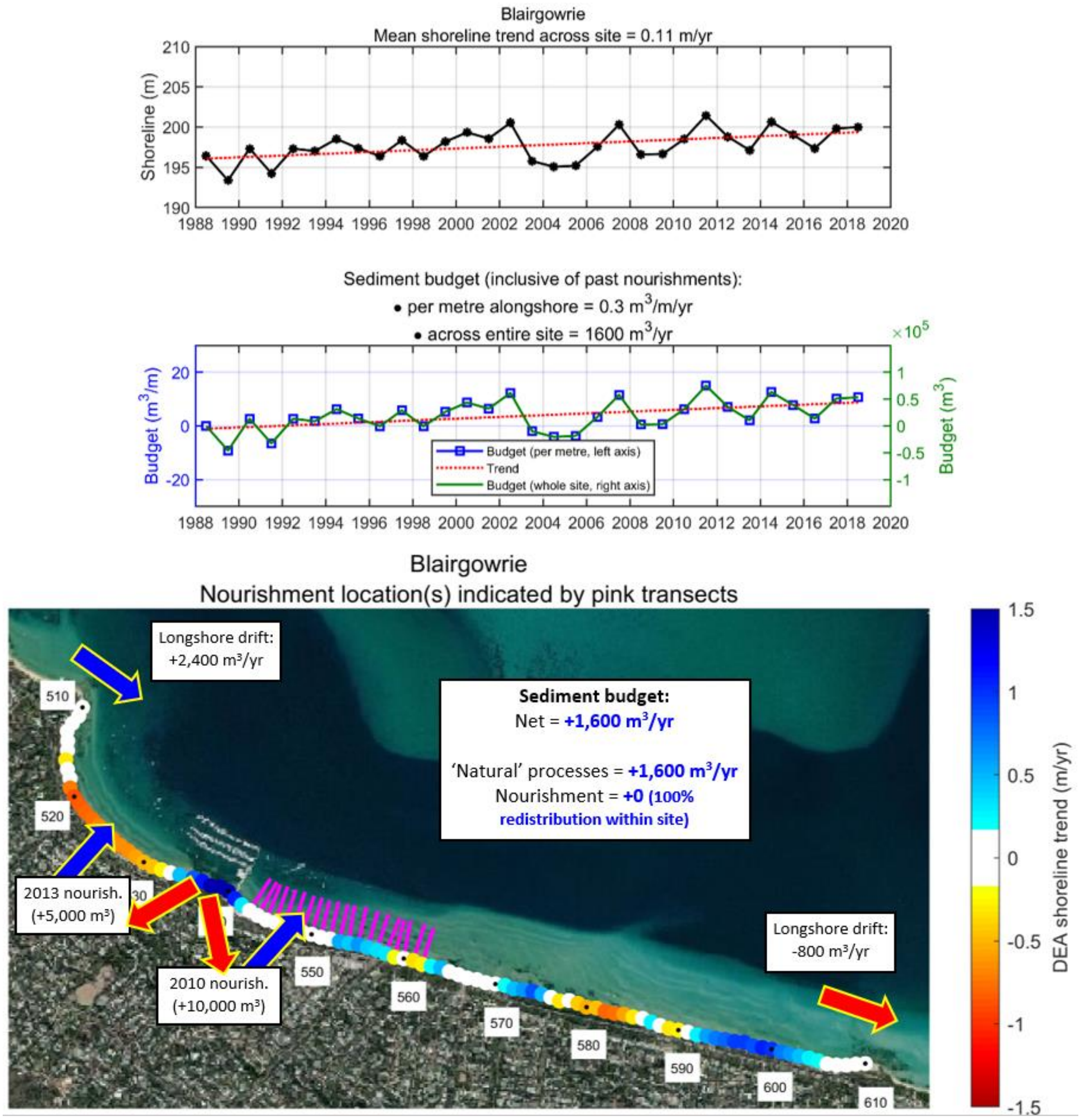


Fig. 3.1.6. Blairgowrie system, (top) mean shoreline trend time series for 1988 – 2018 using DEA satellite data, averaged across the entire site; (middle) whole-system sediment budget time series; and (bottom) interpretation of sediment budget, to order of magnitude precision.

Blairgowrie sediment budget: Erosion around nourishment location (last 8 years)

Even though the Blairgowrie site as a whole is accreting, the nourishment target is eroding:

- The area has a longshore sediment budget deficit, i.e., more sand is leaving to the east than is coming in from the west, due to the groynes west of the site blocking alongshore sediment flux.
- Approximate sediment budget calculation for last 8 years around nourishment location:
    - (1.5 km) x (-1 m/yr) x (active shoreface height of 3 m)
    - Annual deficit = -4,500 m^3/yr (+/- 3,000 m^3/yr)
    - I.e., approx. 4,500 m^3/yr is required to nourish the site
    - Given the broader Blairgowrie site is accreting, the borrow location could be within the site (e.g., the accreting salient just west of the marina).

3.1.4 Summary / assessment / interpretation

BLR-01 (Mackie Ct, P552) and BLR-02 (St Johns Wood Rd, P559):

1. What are the goal(s) of nourishing this site?

- The road is close to the beach (~15 m at narrowest), nourishing would provide a greater buffer to the road.
- Infrastructure built on the dune (e.g., a public toilet) may also be protected.
- Is beach amenity a consideration?

2. What is the sediment budget for the site?

- The site as a whole has been marginally accreting over the medium term (+1,600 m^3/yr; 1988 – 2018).
- None of the accretion can be attributed to known nourishments (2010 and 2013), as these have only redistributed sand within the compartment, from the marina salient to adjacent areas, without adding anything.
- The localised area around the nourishment target has been rapidly eroding in recent years (-1 m/yr).

3. Is nourishment required to prevent an imminent hazard occurring?

- At BLR-01 (P552, Fig. 3.1.5), yes, but the road is not at immediate risk. Nourishment is required in the short-term (<10 years) to reduce the erosion risk to large trees, which could present a significant hazard.
- At BLR-02 (P559, Fig. 3.1.5), yes. Pt Nepean Rd just east of St Johns Wood Rd (Fig. 3.1.5, P559) could be directly impacted by erosion within 6 years.

4. How have previous nourishments performed?

- A large nourishment (unknown volume) appears to have been placed around P552 in 2010-2011. The shoreline has eroded steadily since that time at 1 – 2 m/yr. The nourishment lifetime is therefore on the order of 10 years.
- This 2010-2011 Blairgowrie nourishment could be a useful target for future research.

5. What alternative coastal management options exist?

- Medium-term options (beyond this nourishment cycle)

- Nourishment: The sediment budget deficit could be filled with a ~45,000 m^3 nourishment every 10 years (if extending several decades, there is also a need to account for SLR).
- Groynes:
  - (Re-) installing groynes will retain more sediment with this zone (reducing or eliminating the deficit).
  - Groynes will displace the sediment budget deficit downdrift; however, the region immediately downdrift is protected by a seawall.
  - Re-moving groynes updrift (west) of the erosion sites would reduce the deficit for the currently eroding sites (but would potentially create a problem for the updrift sites).
- Extend seawall: The seawall at the beginning at Revell St could be extended westward.

3.2 Dromana-McCrae

3.2.1 Site setting

Dromana and McCrae are on the Mornington Peninsular to the south of the Port Phillip Bay, toward the eastern end of 24-km long, north-facing, sandy embayment. The beach is low-energy and narrow, with a low dune. McCrae, to the west, has varying degrees of vegetation and minor infrastructure (e.g., carparks) built on the dune. Dromana, to the east, has a dune densely built-up with residential buildings. A major road (Nepean Hwy) runs behind the barrier. Recent nourishments were completed at Dromana and McCrae in Feb 2021. A key profile is selected at each site for detailed analysis:

- MCR-01: 'McCrae Beach Carpark', a carpark built at the front of the foredune (profile P837).
- DRM-01: 'Dune Houses', residential buildings close to the active beach (profile 876).

Geomorphology

- Sediment: Medium sand; beach – 0.5 mm, dune – 0.4 mm
- Beach width:
  - 10-15 m at mid-tide at the nourishment sites.
  - Narrow/no beach at the mid-section, in front of the seawall.
- Profile gradient:
  - A steep beach face (1:10 slope) flattens to a very wide shallow subtidal terrace, extending up to 400 m offshore, with multiple linear to rhythmic bars.
- Back shore morphology:
  - Dromana site: Low foredune (~2 m AHD), vegetated with trees. Wide (80 m) at western end, narrowing to 20 at eastern end where seawall starts.
  - McCrae site: Low foredune mostly occupied by structures (see next section).
  - Mid-section (between nourishment sites): Steep with no accommodation space, backed by a seawall, road, then a steep bluff/cliff.

Coastal structures

Dromana

- Alongshore structures: A seawall extends from the west to Anthony's Boat Ramp, with small sections of revetment or rock armour at the western and eastern ends of the nourishment.

McCrae

- Groynes: Wooden groynes (20 m – 40 length) covering the nourishment zone.
  - Constructed early 2000's.
  - Reinforced/extended during the 2020-21 nourishment.
- Seawall/revetment:
  - Minimal seawall / revetment coverage around the nourishment zone.

Central section (between nourishments)

  - Narrow / no beach with a seawall protecting the Nepean Highway.

Infrastructure

Dromana

- The low foredune is covered with beach shacks, caravans, and a few more permanent structures (dense private / residential).

McCrae

- The dune is mostly covered with vegetation, with some sandy paths, and carparking areas, with one paved carpark built at the front of the foredune (profile 837).

Historical nourishments

Dromana

- 2014 – Design Report by AME (Atkins Maritime Engineering; 2014)
- Volume unknown (5,000 m^3 used as an approximation for sediment budget calculation)

McCrae

- No nourishments are listed in the available record.

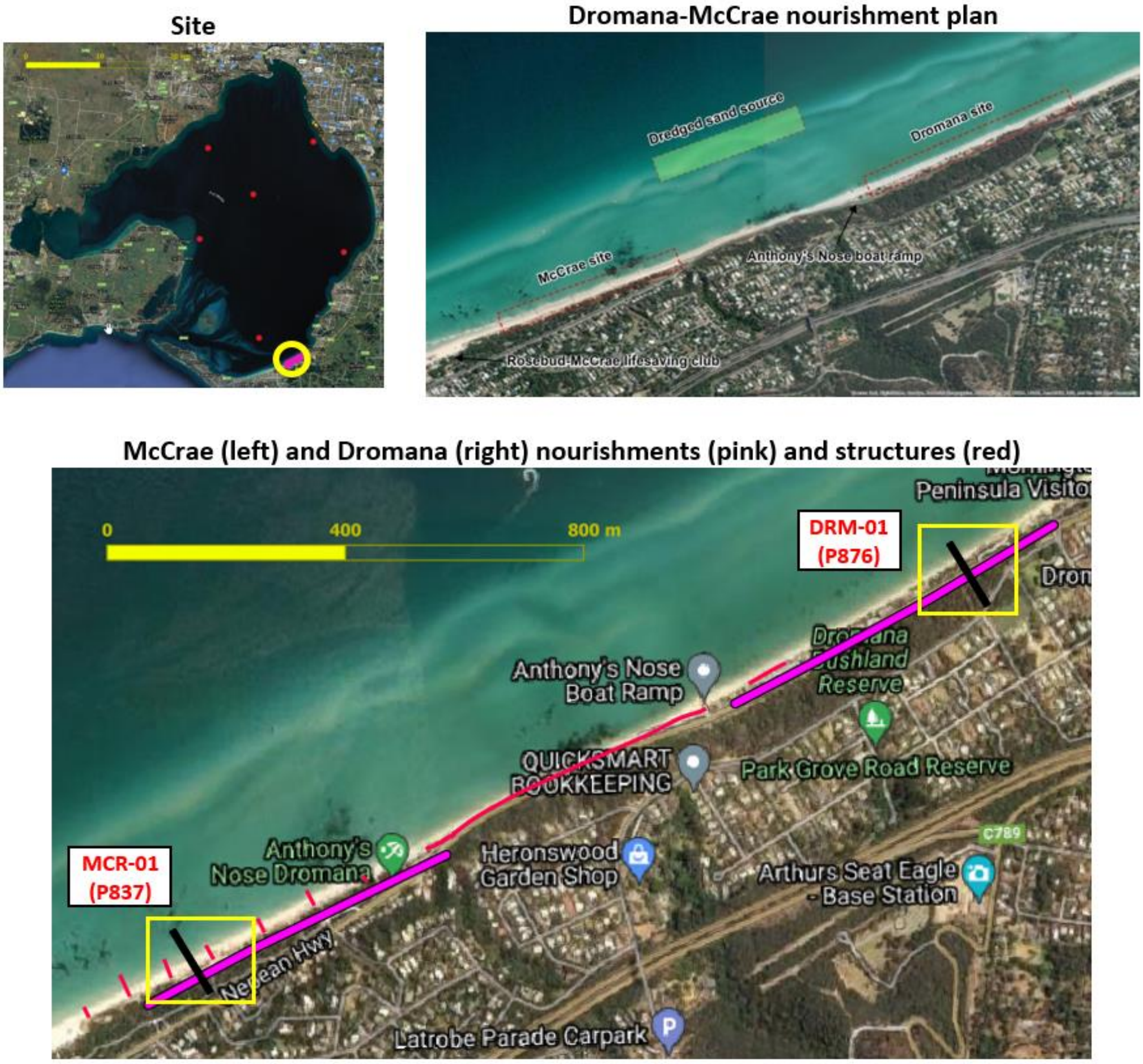


Fig. 3.2.1. Dromana-McCrae 2020-21 site location.

3.2.2 Coastal processes and dynamics

Wave climate

Wave roses and longshore sediment flux potential are shown in Fig. 3.2.2, sourced from a SCHISM 25-year wave model hindcast for a node located 500 m offshore the monitoring site. This model is presently unvalidated and all model results should be treated as indicative. The site experiences a low energy wind wave climate (no swell wave energy from the entrance). Wave statistics comprise:

- Mean significant wave height = 0.3 m
- Mean peak period = 2.1 s
- Mean wave direction = 310°
- Seasonality:
    - Dominant W conditions in summer, driving eastward transport.
    - Dominant NW conditions in winter, also driving eastward transport.

Tidal regime

Tides are microtidal and semi-diurnal with approximate spring range of 0.9 m. Maximum water levels in a 1-year modelled time series are 0.6 m above MSL.

Longshore drift

Predicted sediment flux potential is shown in Fig. 3.2.2.

- Net (annual) flux is eastward at 1000 to 1500 m^3/yr.
- Flux in summer eastward at 500 to 600 m^3/yr.
- Flux is winter is southward at 500 to 900 m^3/yr.
- Note: This is based on an unvalidated model and should be taken purely as indicative, actual rates may vary substantially.
- Longshore sediment transport gradients are likely to be the dominant process on shoreline erosion at this site.

Cross-shore variability

Storm demand at this site is likely to be minimal. SBEACH modelling (Cardno, 2018) predicts 6 m^3/m erosion for McCrae beach for a 1-in-100 yr event, this equates to 2 - 3 m of shoreline change.

Potential exchange between the beach and the subtidal bars could result in multi-year variability in shoreline position, but has not been quantified.

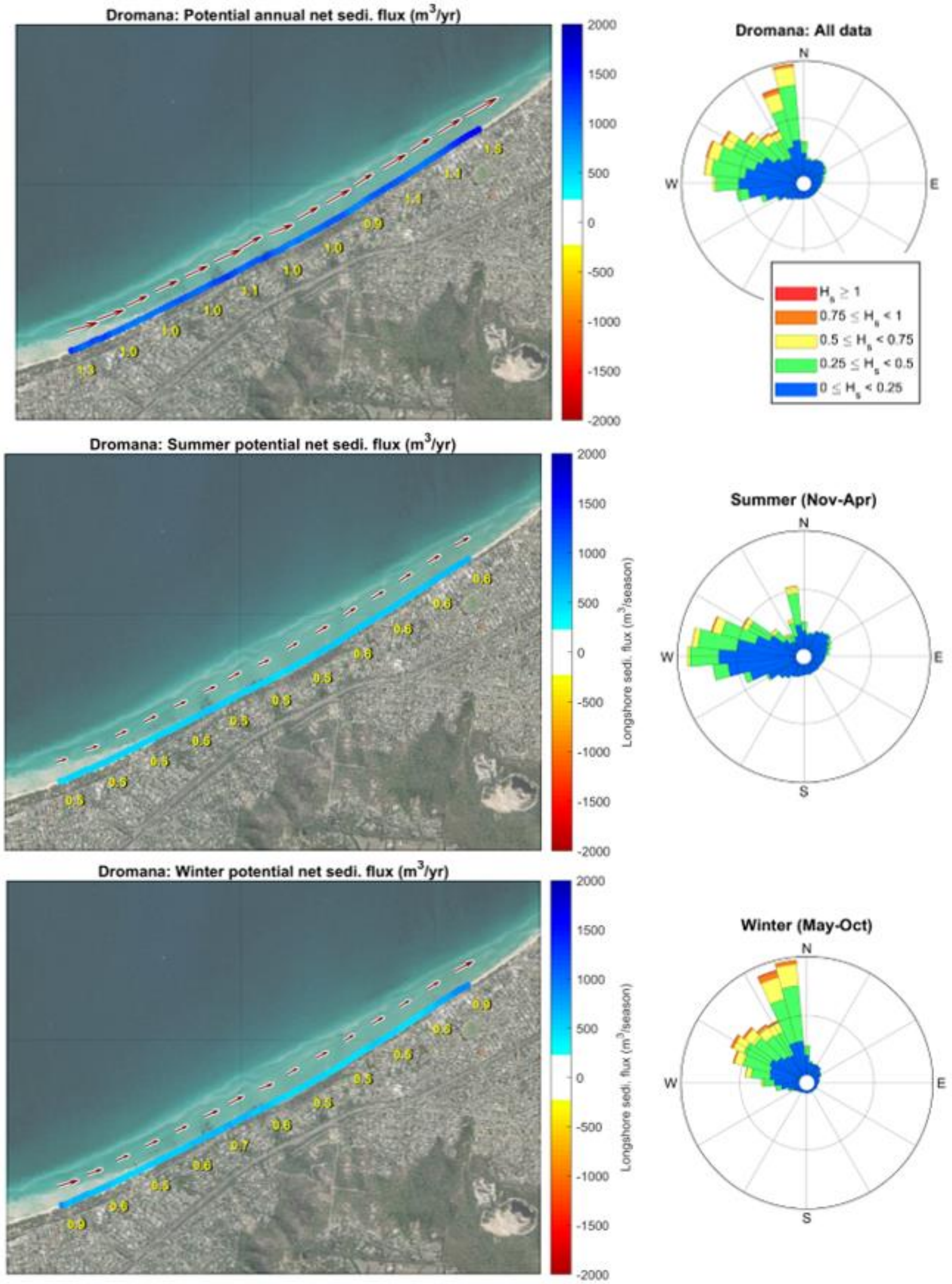


Fig. 3.2.2. Dromana-McCrae potential longshore sediment flux (left), and wave roses (right), annual and seasonal.

Historical shoreline change

Long- (50+ year), medium- (30-year) and short-term (8-year) shoreline trends are summarised in Fig. 3.2.3. Location along the beach is referred to by profile number (Transect ID). The sites McCrae and Dromana are described below separately, with detailed analyses of the targeted profiles (MCR-01, P837) and (DRM-01, P876).

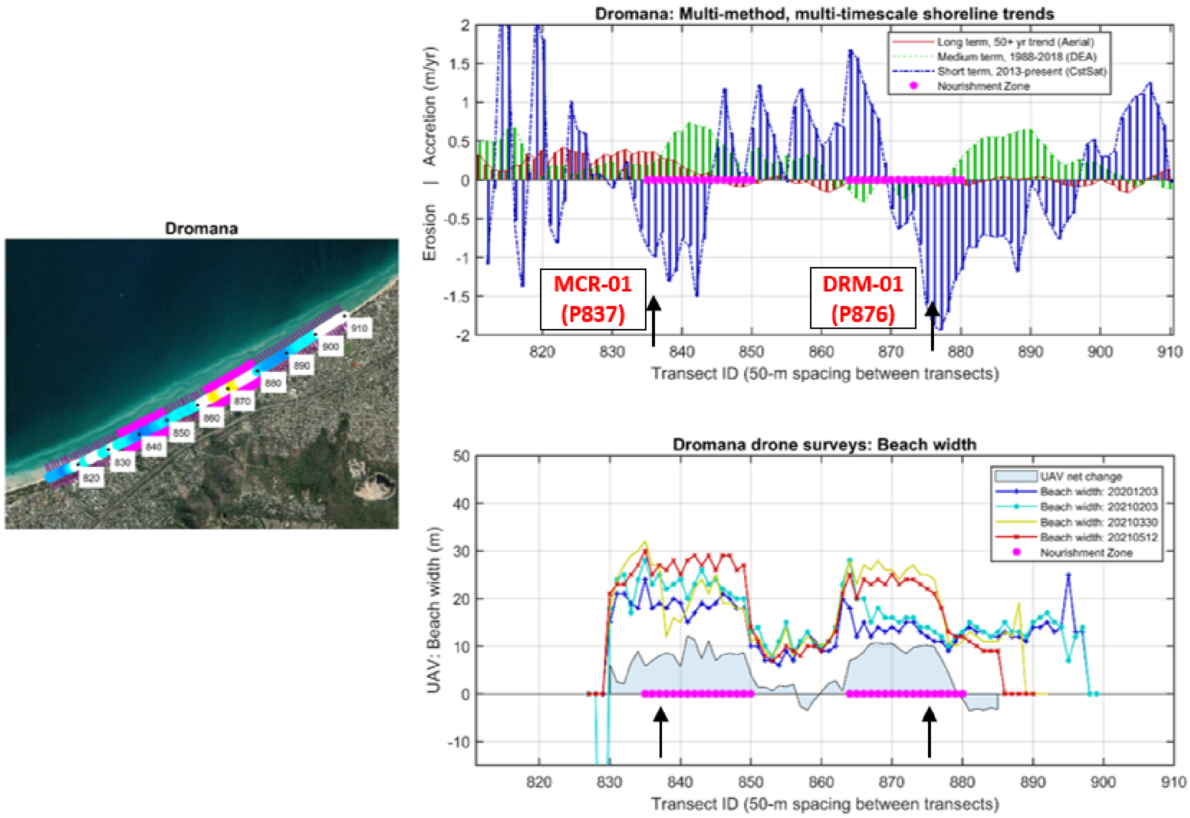


Fig. 3.2.3. Dromana-McCrae; (left) map showing transect numbers [TID]; (top right) shoreline trends at different time scales for multiple datasets; and (bottom right) beach width for each drone survey (coloured lines) and net change in beach width (shaded area), where areas of large positive net change indicate nourishment zones.

McCrae historical shoreline change

- The shoreline has been relatively stable for decades, with relatively low seasonal-interannual variability (Fig. 3.2.3).
- Progradation occurred from 1930 – 1960 (Fig. 3.2.4; Fig. 3.2.5, top row) though early images are poor quality. The most eroded point post-1960 was 1990, however the beach was still reasonably wide (~10 m). Vegetation (low shrubs) on incipient dunes was cleared in 1990, but the line at which large trees occur did not move at all. Incipient vegetation returned to previous levels by 2005, and has maintained similar levels since then.
- Recovery occurred from 1990 to 2000 (Fig. 3.2.5, top row). There may have been nourishment in this period.
- The carpark was built on the active incipient foredune in the 1950's, the vegetation line has been stable (or has prograded) since that time. This infrastructure was built too close to the

active zone initially, and remains at risk of erosion hazard (the risk has not increased significantly, it was built in an at risk area to begin with).

- Buildings to the east of the carpark are 10 – 15 m from the vegetation line. Given the long-term stability of the vegetation line, these buildings are not at short-term risk.
- Vegetated foredune behind beach provides an ample buffer (80+ m) to the Nepean Hwy. The highway is not at short to medium term risk of erosion hazard. However, the road is very low-lying (1.4 m AHD), and therefore will come under inundation risk over the long-term (e.g., well after 2050).
- Shoreline recession occurred around the western end of the McCrae site over the 2013- 2020 period (Fig. 3.2.5, top; CoastSat trend); however, the beach remained relatively wide throughout this period, and there is no recession of the vegetation line.
- Time to failure…
    - The carpark is 10 m from the high tide line.
    - If the recent trend of 1 m/yr shoreline recession continues, the front edge of the carpark could potentially be eroded in 10 years.
- Sediment budget: Over the long-term, the budget is stable or positive, and the site is not experiencing significant underlying shoreline erosion. The short-term trend of erosion should continue to be monitored.
- Reasons to nourish this site:
    - To protect infrastructure: There does not appear to be any critical infrastructure at risk (the Nepean Hwy is >100 m from the beach). The carpark could potentially be moved back into the vegetated dune; however, the area is very low-lying so potential inundation risk would have to be investigated.
    - If the purpose of this nourishment is to maintain a wide beach for public usage, then it may be a suitable nourishment target.
- Impact of the structures:
    - Groynes were built in 2000's. The beach was relatively wide before and after introduction of groynes. It is uncertain as to why the groynes were initially required. There is some sign of westward transport in summer (dominant transport is eastward) but the beach remains wide to either side of groyne in all aerial images.

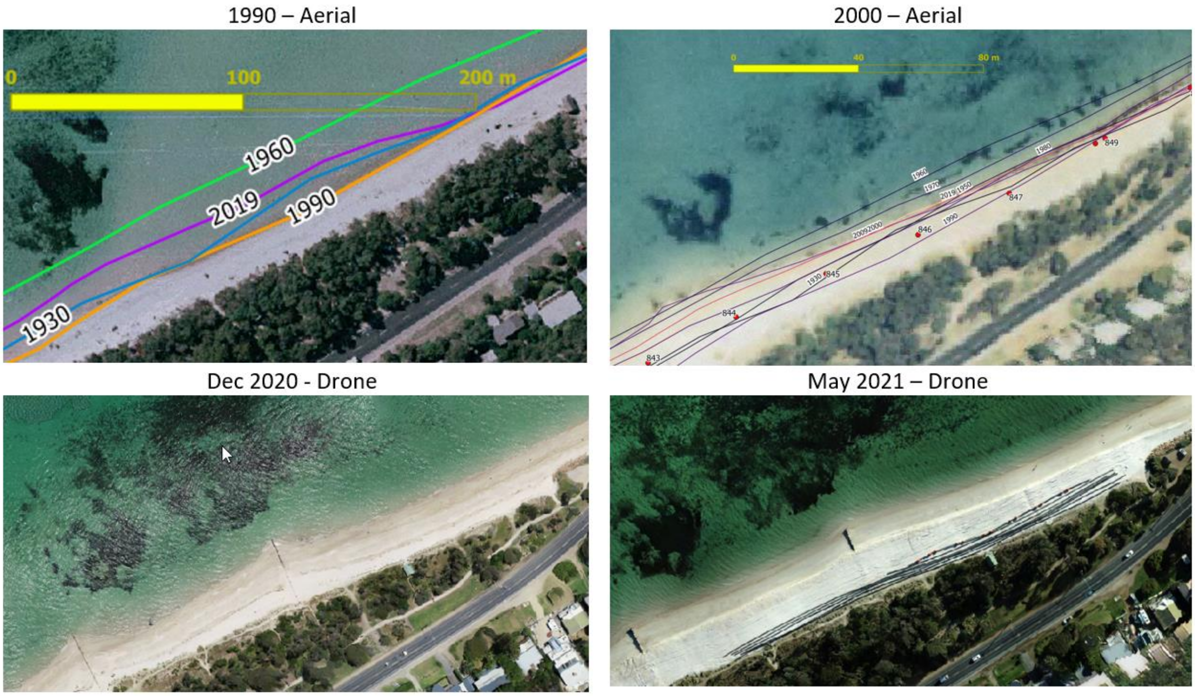


Fig. 3.2.4. McCrae aerial and drone image time series

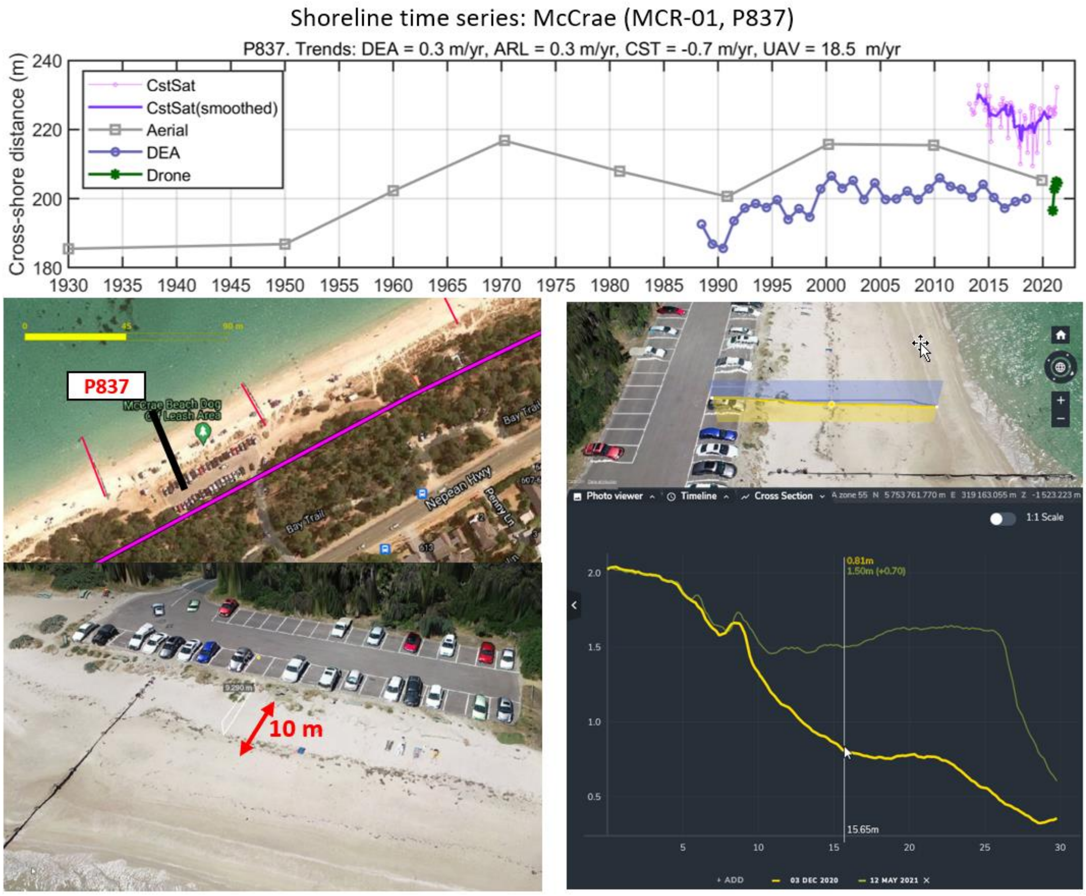


Fig. 3.2.5. McCrae site (MCR-01), profile P837. (Top) Multi-method shoreline time series; (bottom left) plan and oblique view of carpark on foredune; and (bottom right) drone survey cross-section analysis.

Dromana historical shoreline change

West, close to the boat ramp (P866), is stable 1930 – 1990 (Fig. 3.2.3, top right; Fig. 3.2.6). Satellite (DEA) shows decadal oscillations of <10 m. Recession of up to 20 m occurred from 2000 to 2013, with a more stable shoreline after 2015.

East, near the end of the nourishment (zone DRM-01, profile P876) has been fairly stable over the long-term, with up to 10 m of interannual variability. Rapid recession is observed after 2013 (>12 m), up until the 2021/22 renourishment (Fig. 3.2.7, time series, red box). Development of an erosion scarp in front of the houses has occurred at P876.

The cause of the 2013 – 2020 period of shoreline recession is unknown. It peaks around P874 – P880 at -2 m/yr, but continues a further 700 m northward at lower rates. It may potentially be related to the groynes at McCrae. Investigation is required to determine if there are there any other interventions along this stretch that may have modified the longshore transport system.

The building shown in cross-section in Fig. 3.2.7 is only ~5 m from the dune erosion scarp. Are the buildings on the foredune permanent residential structures? If they are private residential, this should be rated a low priority for DEECA. The highway behind the dwellings is not at short-term risk.

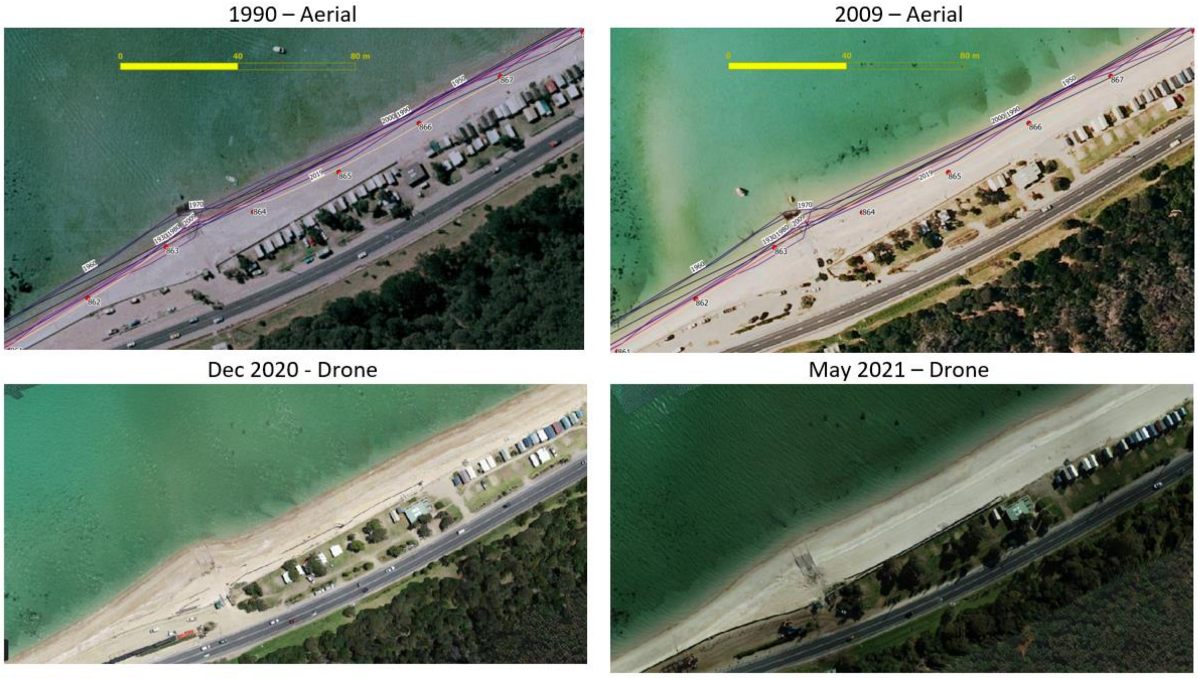
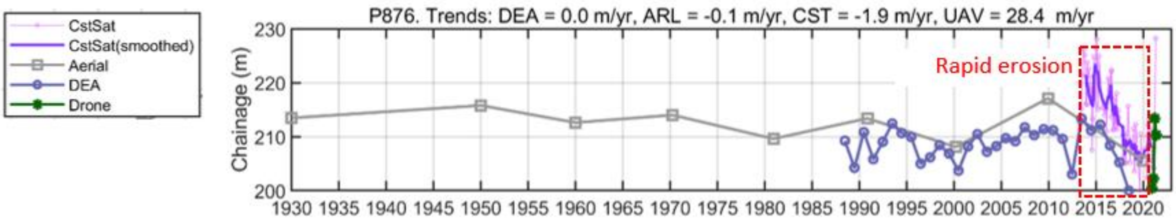


Fig. 3.2.6. Dromana aerial and drone image time series

Dromana: East end of nourishment zone

Shoreline position: P876



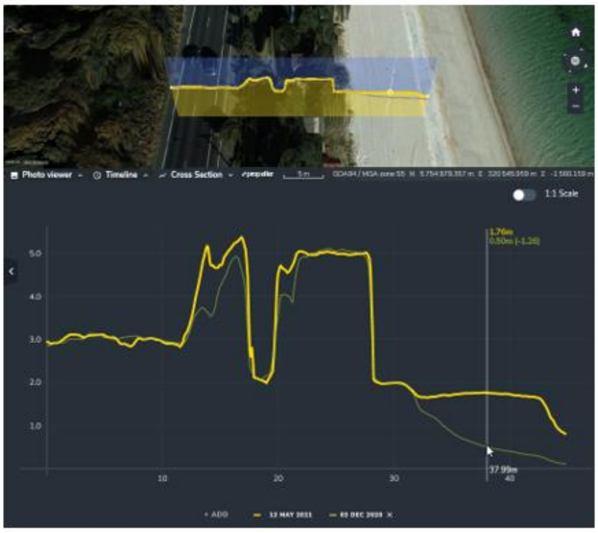


Fig. 3.2.7. Dromana site (DRM-01), profile P876. (Top) Plan view; (second row) multi-method shoreline time series; (bottom left) zoomed plan view; (bottom right) drone survey cross-section analysis.

3.2.3 Nourishment performance analysis

Dromana-McCrae has the most robust monitoring before and after the nourishment. Cross-sections of profiles from the Dromana and McCrae nourishments are provided in Fig. 3.2.8.

McCrae (Fig. 3.2.8, middle row, P834)

- Nourishment resulted in a 23-m offshore shift of the 1-m contour, and an 8-m seaward shift of the 0 m AHD contour.
- Per unit alongshore nourishment volume at P834 was ~25 m^3/m.
- Initial equilibration of the profile resulted a loss of 6 m^3/m (likely deposited in the shallow subtidal, still within the system).
- Net increase in profile volume after 5 months was 19 m^3/m.
- Most of this volume is still retained on the upper beach, with a relatively steep profile (compared to pre-nourishment). Therefore, the equilibration process is likely to continue.

Dromana (Fig. 3.2.8, bottom row, P876)

- Nourishment resulted in a 12 to 15-m offshore shift of the full sub-aerial profile.
- Per unit alongshore nourishment volume at P834 was 17 m^3/m.
- Initial equilibration of the profile resulted a loss of 7 m^3/m (likely deposited in the shallow subtidal, still within the system).
- Net increase in profile volume after 5 months was 10 m3/m.
- The resulting profile is less steep than the Dromana example, though some further equilibration may still occur.

A time series of Dromana-McCrae beach volume over the full extent of the nourishment (Fig. 3.2.8a) indicates that Dromana was nourished first, with nourishment volume above 0 m AHD of approx. 15,000 m^3 by Apr 2021, and equilibration losses of 1,000 – 2,000 m^3 by May. McCrae was only partially nourished by Apr 2021 (~2,000 m3), with the nourishment volume increasing to 15,000 m^3 by the May survey.

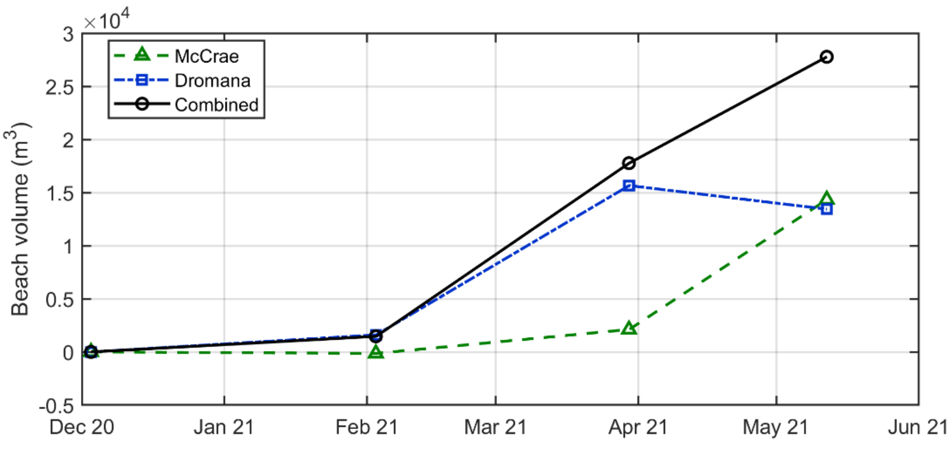


Fig. 3.2.8a. Dromana-McCrae beach volume time series indicating nourishment volumes.

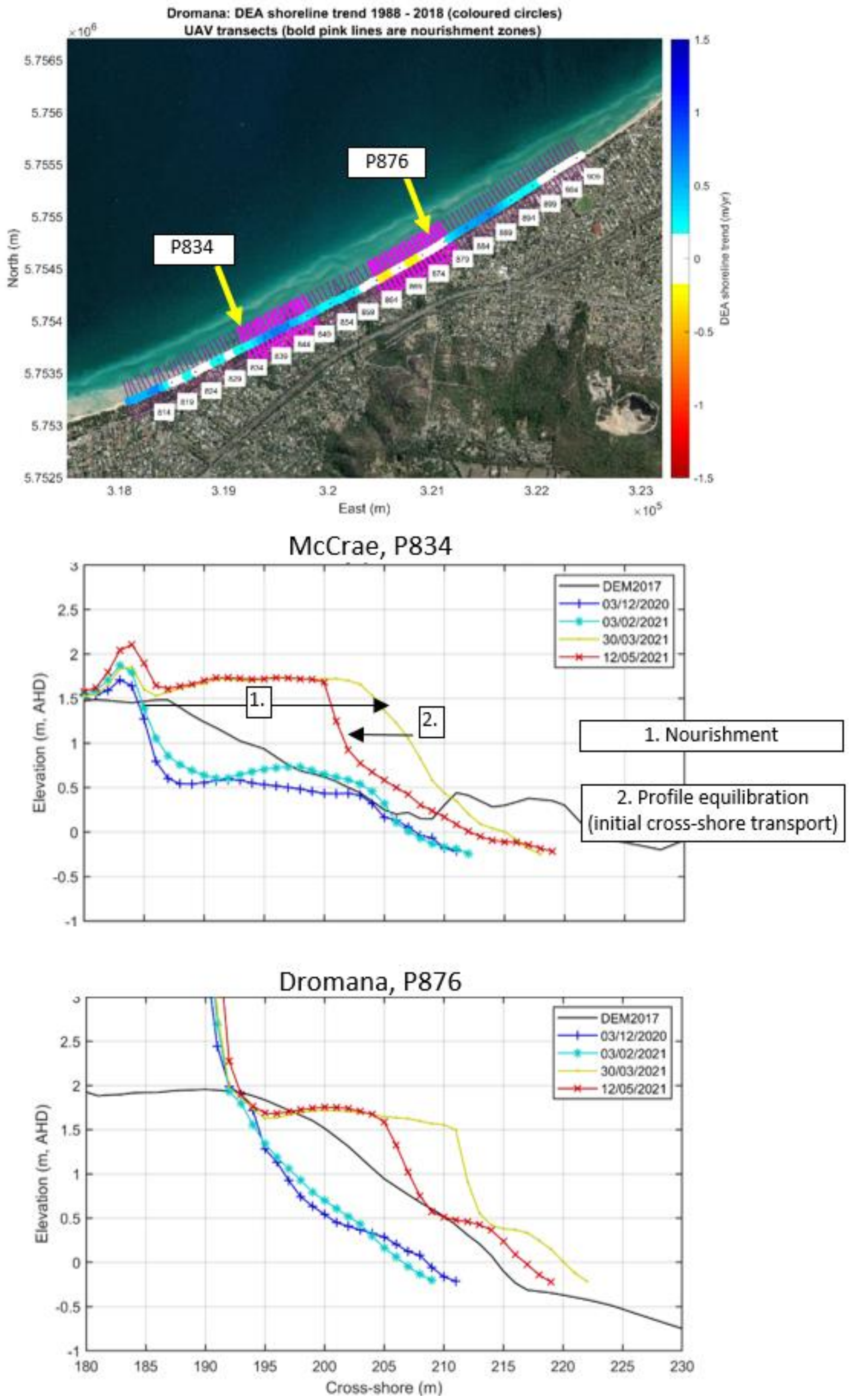


Fig. 3.2.8. Dromana-McCrae profile cross-sections extracted from drone surveys, pre- and post-nourishment.

3.2.4. Sediment budget

An interpreted sediment budget for Dromana-McCrae is presented in Fig. 3.2.9. Due to the high uncertainty associated with the input data, the budget is considered an order of magnitude approximation. Data used to analyse and interpret this budget include:

- Modelled estimates of alongshore sediment flux (Sec. 3.2.2).
- DEA satellite shorelines for 1988 – 2018 (Sec. 3.2.2).
- Historical nourishment data (Sec. 3.2.1). *Some historical nourishments may be unaccounted for, and/or nourishment volumes may be highly inaccurate.*
- Shoreline change is converted to approximate volume change using:
    - [volume change = shoreline change * height of active profile]
    - Height of active profile was estimated as [h_a = 3 m].
- For simplicity, volume fluxes associated with natural processes are attributed entirely to longshore drift gradients. However, cross-shore exchange and SLR (especially in the long-term) may also occur.
- This budget is for the **entire site**, some sections within the site may be acting against the overall trend (e.g., some areas may be eroding while the site as a whole is accreting).

Dromana-McCrae sediment budget: Accretion across site as a whole (1988 – 2018)

The broader site (5-km alongshore from McCrae to Dromana) accreted at a moderate rate over 1988 to 2018 (Fig. 3.2.9). Nourishment volumes account for <10% of observed shoreline growth.

- Positive net sediment budget (+0.24 m/yr shoreline; +3,500 m^3/yr)
    - ‘Natural’ processes (longshore drift) = +3,300 m^3/yr
    - Nourishments = +200 m^3/yr

Erosion around nourishment site (2013 - 2021)

Even though the site as a whole is accreting, the nourishment target location have eroded over the recent period (2013 – 2021):

- Sediment budget calculation (approximate, combined across Dromana-McCrae):
    - (1.5 km) x (-1 m/yr) x (active shoreface height of 3 m)
    - Annual deficit = -4500 m^3/yr (+/- 3000 m^3/yr)
    - I.e., approx. 4500 m^3/yr is required to nourish these locations, based on the recent erosional trend.

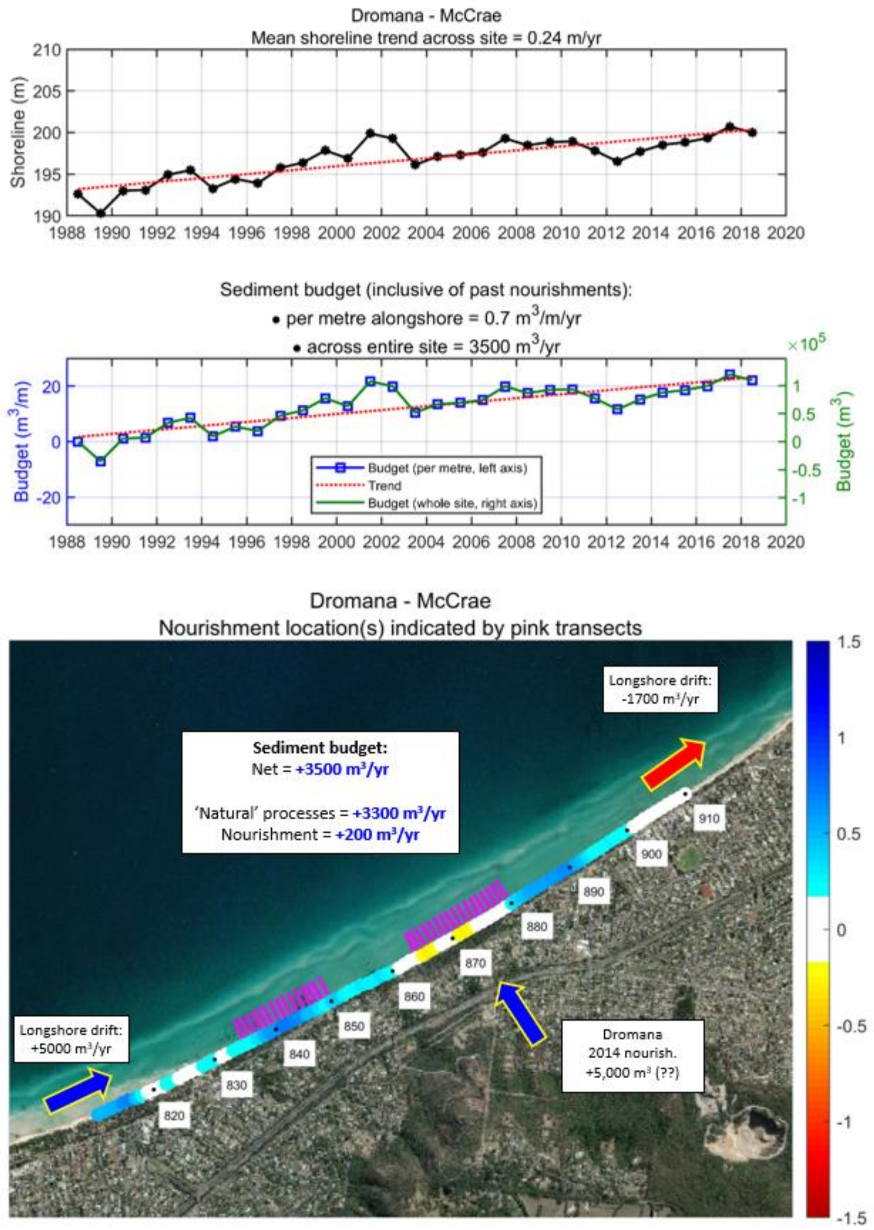


Fig. 3.2.9. Dromana-McCrae system, (top) mean shoreline trend time series for 1988 – 2018 using DEA satellite data, averaged across the entire site; (middle) whole-system sediment budget time series; and (bottom) interpretation of sediment budget, to order of magnitude precision. [Blue arrows = sediment inputs; Red arrows = sediment outputs].

3.2.5. Summary / assessment / interpretation

McCrae

1. What are the goal(s) of nourishing this site?

- The only piece of infrastructure at risk appears to be the car park.
- The goal in this instance may be to maintain a wide beach for public amenity and protect the vegetation.

2. What is the sediment budget for the site?

- The area is stable to accreting over the long-term but has experienced recent moderate erosion around the nourishment locations.

3. Is nourishment required to prevent an imminent hazard occurring?

- If the recent trend continued (without the present nourishment), the front edge of the carpark may have been at risk of erosion within ~10 years.
- If the site had not already been nourished, it would have been reasonable to continue monitoring the site without urgent need of nourishment, given the moderate rate of recent erosion.

4. How have previous nourishments performed?

- Unknown.

Dromana

1. What are the goal(s) of nourishing this site?

- The goal appears to be to protect infrastructure built on the foredune which is at risk of erosion based on the recent rapid erosion trend. The buildings appear to be private dwellings. Some of the infrastructure may be public and the responsibility of DEECA (unknown).

2. What is the sediment budget for the site?

- The budget is fairly stable over the long-term but with a period of rapid recession from 2013 – 2021 (>12 m). The cause of this recent phase of erosion is unknown.

3. Is nourishment required to prevent an imminent hazard occurring?

- Some of the dwellings on the foredune may have been at risk within 10 years if current erosive trends continued without the recent nourishment.

4. How have previous nourishments performed?

- Unknown.

3.3. Sandringham

Sandringham is a 2.5-km embayment to the northeast of Port Phillip Bay, separated by a small headland from Half Moon Bay, a 350-m long pocket embayment to the south. The beach is low energy intermediate, backed by high cliffs and bluffs. The current nourishment (ongoing as of July 2021) is being placed at the south end of Sandringham and the south end of Half Moon Bay. Profiles selected for detailed analysis are indicated in Fig. 3.3.1, and include:

- P2060 at south Sandringham
- P2049 at Half Moon Bay

3.3.1. Site setting

Geomorphology

- Sediment: Medium-coarse sand, 0.6 – 0.8 mm.
- Beach width:
  - 20 - 35 m at north Sandringham.
  - 0 – 10 m at south Sandringham.
  - 5 – 15 m at Half Moon Bay.
  - Substantial seasonal variability in beach width occurs at ends of beach and around groynes, due to seasonal wave direction (see Sec. 3.2. and 3.3).
- Beach and nearshore morphology:
  - Low energy intermediate.
  - Berm at ~1.5 m AHD for wider beach sections.
  - Steep beach face (1:10).
  - Intertidal features include a step-trough and bar-terrace at approx. -1 m AHD.
  - Bathymetric surveys indicate a perched barrier, with a relatively steep subtidal slope (1:30 to 1:20) extending to ~ -5 m AHD, beyond that the seabed becomes irregular and rocky.
  - A section of cliff protrudes north of the mid-point of Sandringham. A rock platform extends offshore of the cliff, with little to no sandy beach along this section.
  - A small headland-ridge and rock-platform ("The Black Pin") divides Sandringham Beach from Half Moon Bay.
- Back shore morphology:
  - The Sandringham – Half Moon Bay embayment is backed by steep bluffs and sections of vertical cliff, with elevations of 12 m AHD (north Sandringham) to 30 m AHD (south Sandringham).

Coastal structures

Cross-shore structures:

- Two large groynes, 40 – 50 m long, have been installed at Sandringham, south of the mid-point of the beach.
- The groynes experience sand build-up to the south in summer (northerly transport), and build-up to the north in winter (southerly transport).
- A small wooden groyne was originally placed at the southern location pre-1960.
- The southern groyne was upgraded to a large rock armour groyne in the 1990's, this appears to have resulted in a sediment deficit to the north of the groyne (one image, Mar 2000, shows no beach at all, immediately north of the southern groyne).

- The northern groyne was built in 2006.
- The northern groyne was shortened from 80 m to 50 m c. 2018.

Alongshore structures:

- Black Rock Wharf at Half Moon Bay was expanded to reclaim land around the point between 1930 to 1970. The carpark at the tip of the point is reclaimed land (completed by 1960). An extension to the carpark occurred by 1970, extending out to the present day coastline.
- A seawall and ramp extend northward from Black Rock Wharf to cover the southernmost 20 m of Half Moon Bay beach.
- Approx. 6 sections of seawall / revetment, from 10 m to 160 m length, have been constructed along the length of Sandringham.
- At the northern end of Sandringham, a seawall extends northward to the Sandringham Yacht Club jetty.

Fig. 3.3.1. Sandringham and Half Moon Bay, drone surveys cover the full extent of left panel. (Top right) South Sandringham nourishment; and (bottom right) Half Moon Bay nourishment. Red lines indicate coastal structures, pink lines are nourishment targets. Two transects indicated in right panels (P2024, P2018) are analysed in detail in Fig. 3.3.6.

Infrastructure

The main road behind the embayment (Beach Rd) is situated on the crest of plateau behind the beach. The nearest point of the road to the cliff edge is 12 m, and ~50 m to the high tide line. There appears to be no evidence of cliff falls / slumps along this stretch. The rate of cliff recession is unknown. Cliff erosion hazard to the road is considered low over the time frames considered in this report (<20 years), though may be a concern over longer time frames.

Carparks, parks and walking paths are also constructed along the crest of the plateau. These are more concentrated toward the north end of Sandringham. Various access paths have been constructed for access from the cliff-top down to the beach. On initial inspection, there appears to be one cliff-top access path at Half Moon Bay in the nourishment zone that could be subject to erosion hazard and is relevant to the analysis. At the southern end of Half Moon Bay a combined ramp and seawall gives access from the beach to Black Rock Wharf and Yacht Club.

Hazards:

At the south end of Sandringham, within the targeted nourishment site, large (~1 m^2) slabs of concrete and what appears to be asphalt road surface are partially buried within the steep bluff and under the beach itself. This material becomes fully exposed with seasonal erosion (analysis in Sec. 3.3.2 and Fig. 3.3.7). The material may pose a hazard, and detracts from the visual appeal of the site. Remediation of this material is being conducted concurrent with the 2021 nourishment. The majority of the hazardous material was removed by Bayside Council in April-May 2021.

3.3.2. Coastal processes and dynamics

Wave climate

Wave roses and longshore sediment flux potential are shown in Fig. 3.3.2, sourced from a SCHISM 25-year wave model hindcast for a node located 500 m offshore the monitoring site. The site experiences a low energy wind wave climate (no swell wave energy from the entrance). Wave statistics include:

- Mean significant wave height = 0.2 m – 0. 4 m (wave buoy observations indicate a value at the top of this range).
- Max. annual wave height = 1.5 - 2 m (based on buoy observations)
- Mean peak period = 2.2 s
- Mean wave direction = 245° (WSW)
- Seasonality: Dominant SW wind waves in summer, mix of SW and NW conditions in winter, with NW dominant.

Tidal regime

Tides are microtidal and semi-diurnal with approximate spring range of 0.8 m. Maximum water levels in a 1-year modelled time series are 0.6 m above MSL.

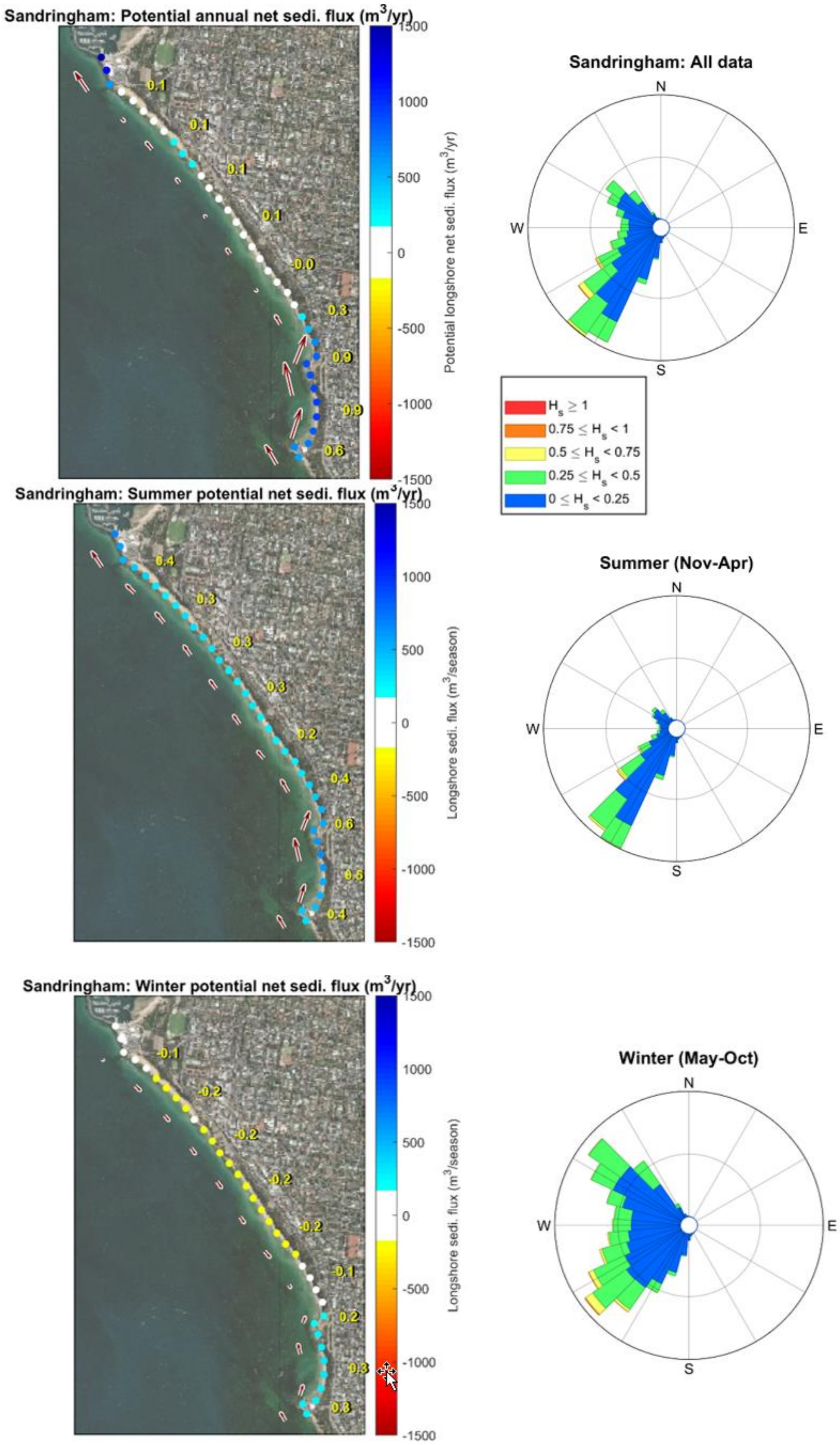


Fig. 3.3.2. Sandringham modelled wave climate (right panels) and potential longshore sediment flux (left panels). Yellow numbers in left panels are sediment flux in units of 1000's m^3/yr.

Longshore drift and seasonal beach rotation

Predicted sediment flux potential is shown in Fig. 3.3.2.

Sandringham experience strong seasonality, or 'beach rotation', this involves:

- More southwesterly waves in summer drive northward transport (Fig. 3.3.2, middle row), resulting in a widening of the beach to the north and narrowing the beach to the south (counter-clockwise rotation).
- More northwesterly waves in winter drive southward transport (Fig. 3.3.2, bottom row), widening the beach at the south end and narrowing the north end (clockwise rotation).
- Groynes and small headlands (e.g., between Half Moon and Sandringham, and halfway along Sandringham) act to disrupt/reduce the longshore transport, resulting in rotation within sub-compartments (e.g., between the groynes at the south end).
- The effect is for less rotation of the full embayment, but more concentration of rotation of the sub-compartments between the groynes.
- The magnitude of this rotation on the order of 5 – 15 m at the ends of sub-compartments. Several years of drone survey data is required to be more accurate.
- A 15 m change in shoreline position between summer and winter was observed next to one of the groynes.
- A 5 – 10 m seasonal change in shoreline position (up to 1 m change in beach elevation) has been observed at the nourishment sites.

Predicted potential longshore sediment flux rates (Fig. 3.3.2, left panels) are:

- Net (annual) flux is northward, up to 1000 m^3/yr.
- Flux in summer is northward, at up to 600 m^3/yr
- Flux in winter is southward along Sandringham, up to 200 m^3/yr

Cross-shore variability

Changes in shoreline position due to storm demand and recovery are likely to be observable, but small relative to alongshore sediment transport. SBEACH modelling (Cardno, 2018) predicts temporary volume loss from the beach of up to 10 m^3/m for a 1-in-100 year storm (based on the neighbouring Hampton beach). This equates to a <5 m change in shoreline position for an extreme event.

Long-term exchange with the lower shoreface is considered unlikely at this site as the bed appears to be mostly rocky below -5 m AHD.

Historical shoreline change

Over the long-term (Fig. 3.3.3, top-right, red bars), slight accretion is observed at the southern end of Half Moon Bay and the north of Sandringham.

Over the medium to short-term, the groynes have had a significant influence on shoreline position. E.g., over the 1988-2018 period, the beach to the south of the groynes has accreted, while just north of the groynes has eroded (Fig. 3.3.3, top-right, green bars). However, over the recent period (2013 – 2021), there is a trend for erosion just south of each groyne, with accretion north of each groyne.

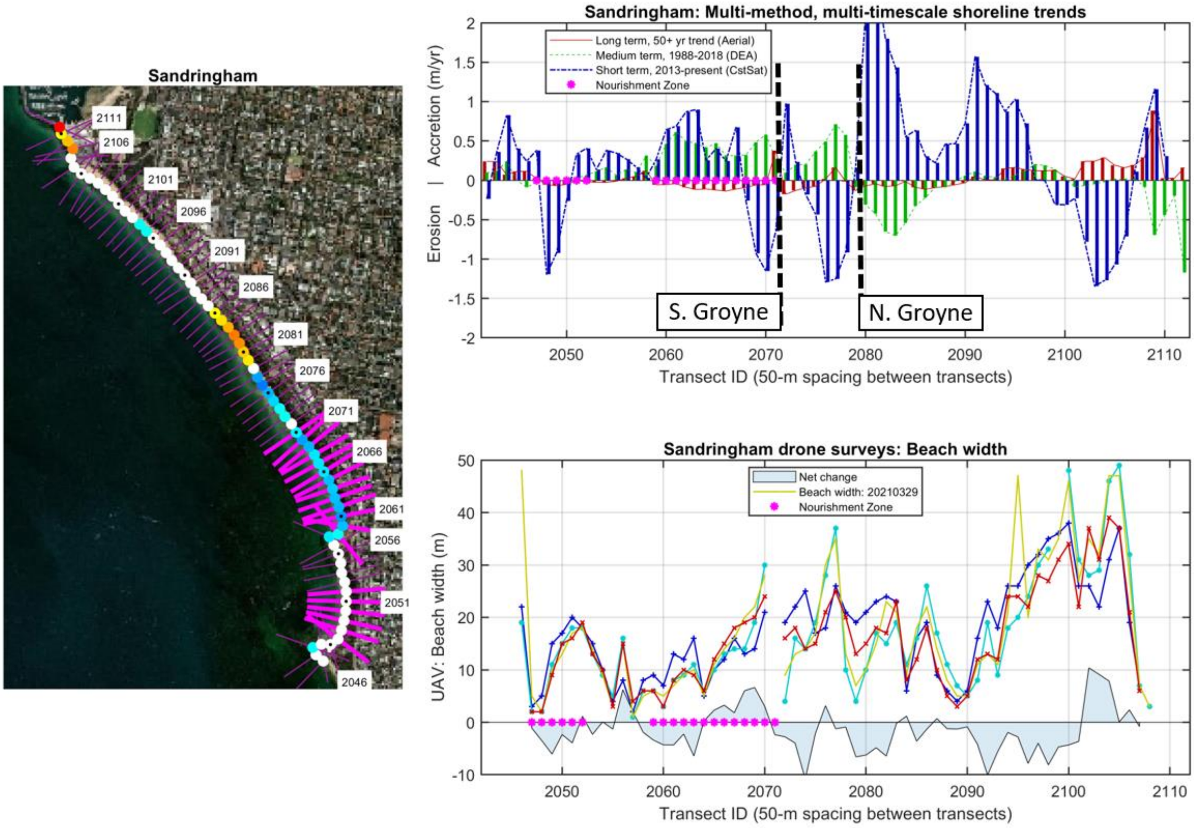


Fig. 3.3.3. Sandringham; (left) map showing transect numbers [TID], coloured dots show erosion [hot colours] and accretion [cold colours] for 1988 – 2018 satellite data; (top right) shoreline trends at different time scales for multiple datasets; and (bottom right) beach width for each drone survey (coloured lines) and net change in beach width (shaded area), where areas of large positive net change indicate nourishment zones.

South Sandringham nourishment site (profile P2060)

- The medium to short-term trend is for slight accretion, except for immediately south of the southern groyne (Fig. 3.3.3, top right).
- Beach width increases from the southern to northern end of the nourishment (Fig. 3.3.3, bottom right).
- Aerial imagery time series (Fig. 3.3.4), shows the narrowest beach at the south end occurred during March 2020 (note this is end of summer, where the beach is in the most northward rotated state).
- A cross-section comparing Dec 2020 to Feb 2021 drone surveys (Fig. 3.3.6, top left), shows the beach was 1 m higher in Dec (end of winter, southward / clockwise rotation), than in Feb (end of summer, northward / counter-clockwise rotation).
- Multi-method time series (Fig. 3.3.6, P2060) indicates the long-term aerial trend is flat. Large annual and inter-annual oscillations are indicated in the satellite data, though it is suspected the large cliffs and shadows in this area impacts on the satellite shoreline method.
- The large seasonal variability is best illustrated graphically in Fig. 3.3.7, showing how the landfill material (concrete slabs, road surface) becomes exposed over summer, then is re-buried in autumn.

Fig. 3.3.4. Sandringham (south end) aerial photo time series (1930 – 2021).

Half Moon Bay nourishment site (profile P2049)

- A short-term erosive trend is observed around P2049 (Fig. 3.3.3, top right).
- Beach width decreased 10 m at P2049 between Dec 2020 and Feb 2021 (Fig. 3.3.3, bottom right), likely a seasonal oscillation (rotate south in winter, north in summer).
- Aerial image time series (Fig. 3.3.5) indicate the narrowest beach occurred in 2000, as per south Sandringham.
- A cross-section comparing Dec 2020 to Feb 2021 drone surveys (Fig. 3.3.6, top left), shows the beach was 0.7 m higher in Dec, than in Feb (low point at end of summer, same pattern as south Sandringham).
- Multi-method time series (Fig. 3.3.6, P2018) indicate the long-term aerial trend is flat. As per south Sandringham, the large cliffs may cause excess noise with satellite detection. The recent trend (across both aerial and CoastSat shorelines) is erosive.
- The beach here seems reasonably stable, i.e., there does not seem to be an impending need to nourish in order to protect an asset. This suggests the nourishment inclusive sediment budget is stable (i.e., accounting for any periodic nourishments to date).

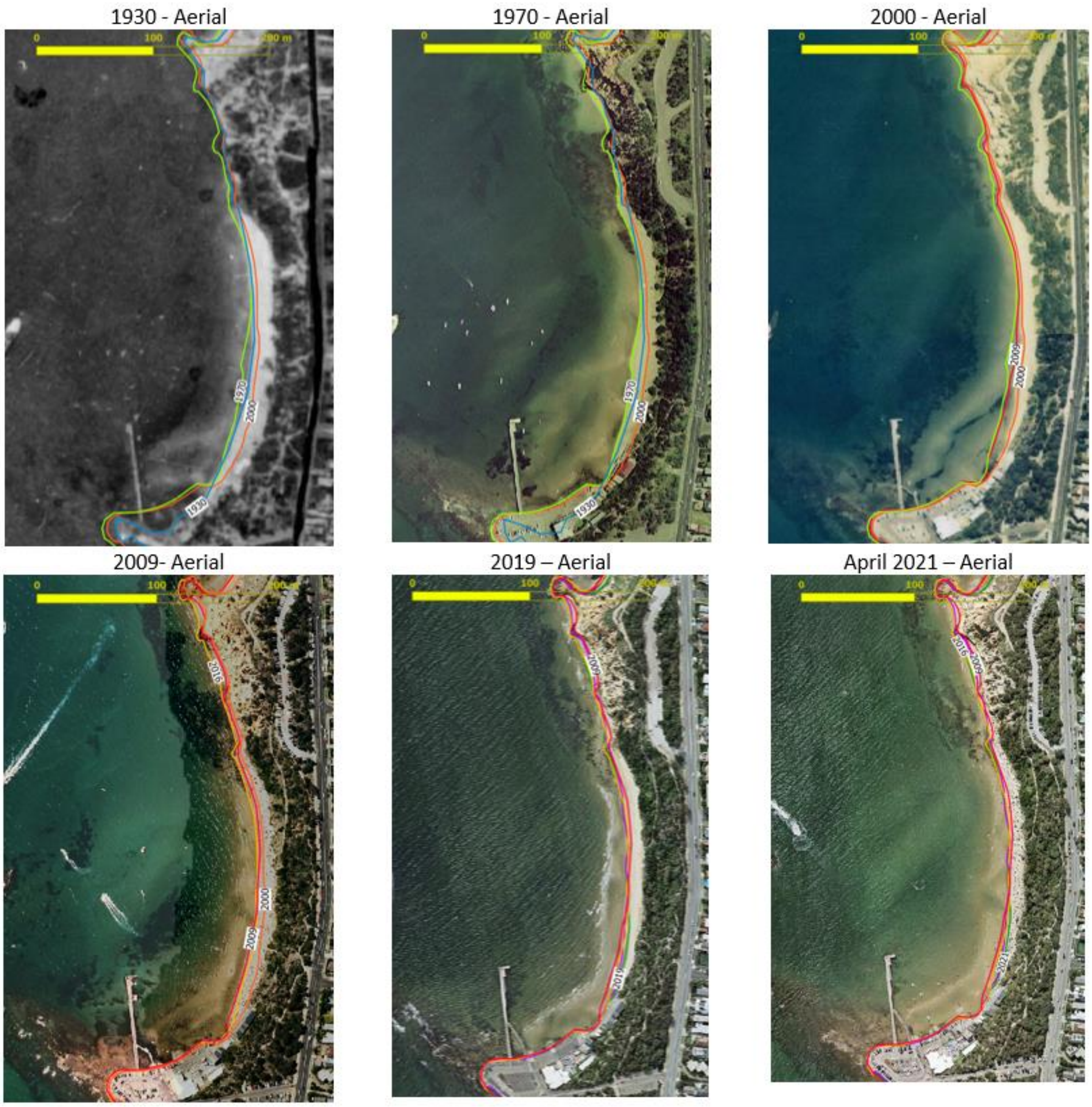


Fig. 3.3.5. Half Moon Bay (Sandringham) aerial imagery time series (1930 – 2021).

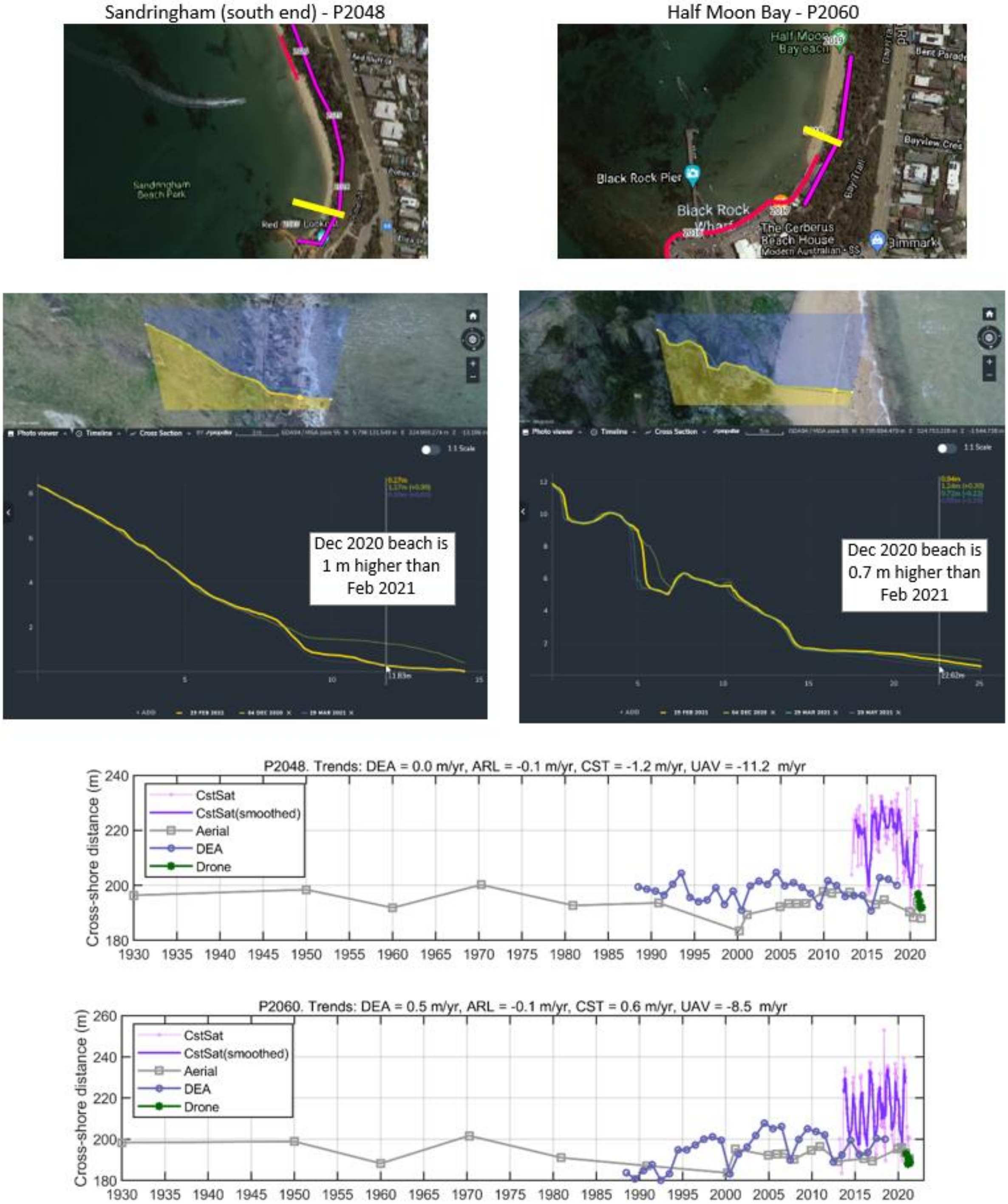


Fig. 3.3.6. Sandringham south and Half Moon Bay nourishment sites (top row); with drone survey cross-sections (second row); Half Moon Bay P2048 shoreline time series (third row); and Sandringham south end P2060 multi-method shoreline time series (bottom row).

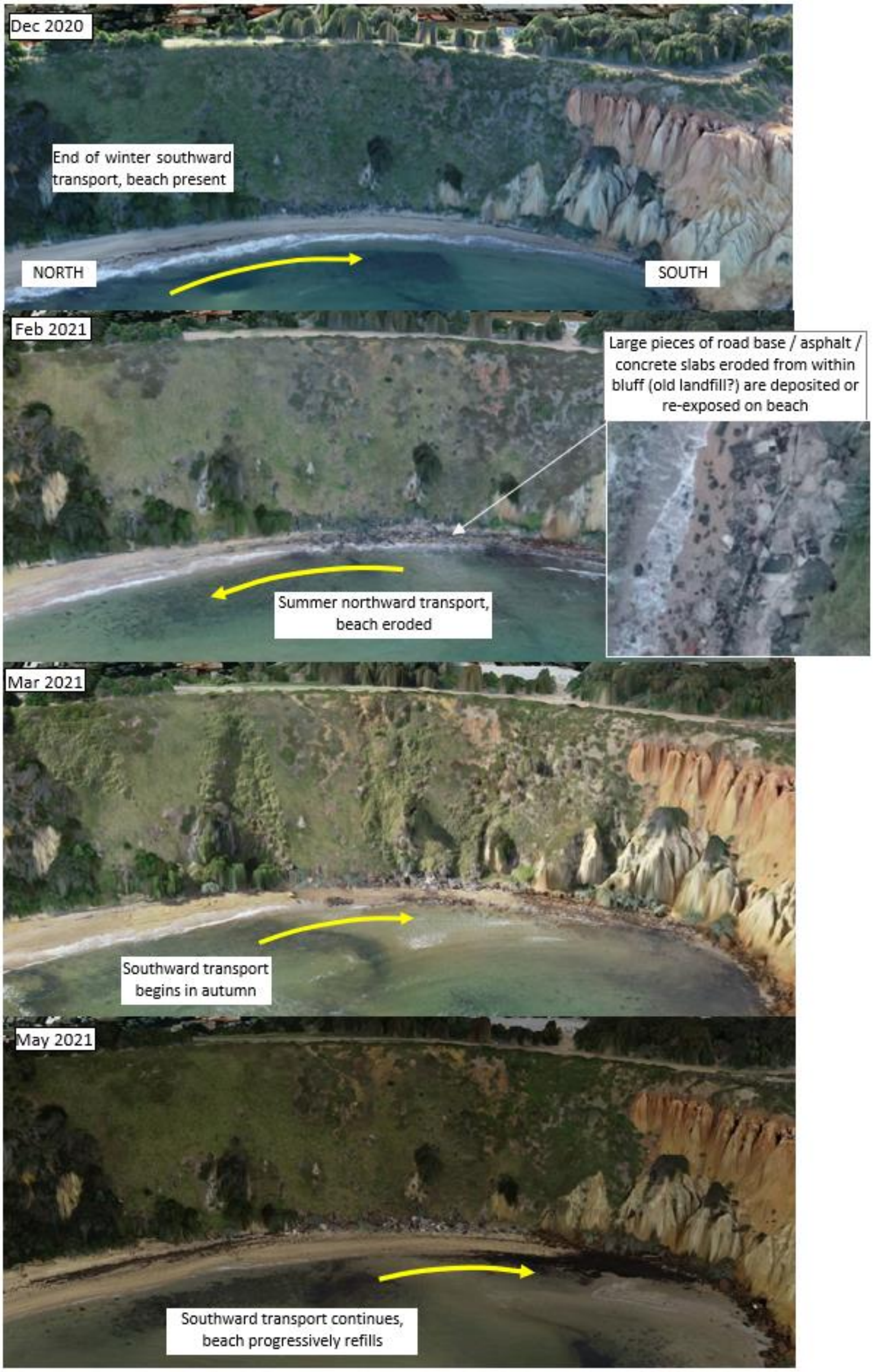


Fig. 3.3.7. Sandringham south end June 2021 nourishment site, drone 3D-orthomosaic time series. Note: The site was remediated by Bayside Council in April/May 2021 and accessible asphalt slabs where removed, some buried debris may still be present.

3.3.4. Sediment budget

An interpreted sediment budget for Sandringham is presented in Fig. 3.3.8. Due to the high uncertainty associated with the input data, the budget is considered an order of magnitude approximation. Data used to analyse and interpret this budget include:

- Modelled estimates of alongshore sediment flux (Sec. 3.3.2).
- DEA satellite shorelines for 1988 – 2018 (Sec. 3.3.2).
- Historical nourishment data (Sec. 3.3.1). *Some historical nourishments may be unaccounted for, and/or nourishment volumes may be highly inaccurate.*
- Shoreline change is converted to approximate volume change using:
    - [volume change = shoreline change * height of active profile]
    - Height of active profile was estimated as [h_a = 4 m].
- For simplicity, volume fluxes associated with natural processes are attributed entirely to longshore drift gradients. However, cross-shore exchange and SLR (especially in the long-term) may also occur.
- This budget is for the **entire site**, some sections within the site may be acting against the overall trend (e.g., some areas may be eroding while the site as a whole is accreting).

Sandringham sediment budget: Neutral to slight accretion across site (1988 – 2018)

The full site (3-km alongshore with Half Moon Bay and Sandringham combined) accreted at a marginal rate over 1988 to 2018 (Fig. 3.3.8). Nourishment volumes during this period are unknown. The total influx over this 30-year period was 24,000 m^3, which is equivalent to 2 to 5 average sized Port Phillip Bay nourishments.

- Positive net sediment budget (+0.06 m/yr shoreline; +800 m^3/yr)
    - 'Natural' processes (longshore drift) = +800 m^3/yr
    - Nourishments = (Unknown)

Sediment budgets at the nourishment locations (pink transects in Fig. 3.3.8) over this period were neutral to slightly accretive.

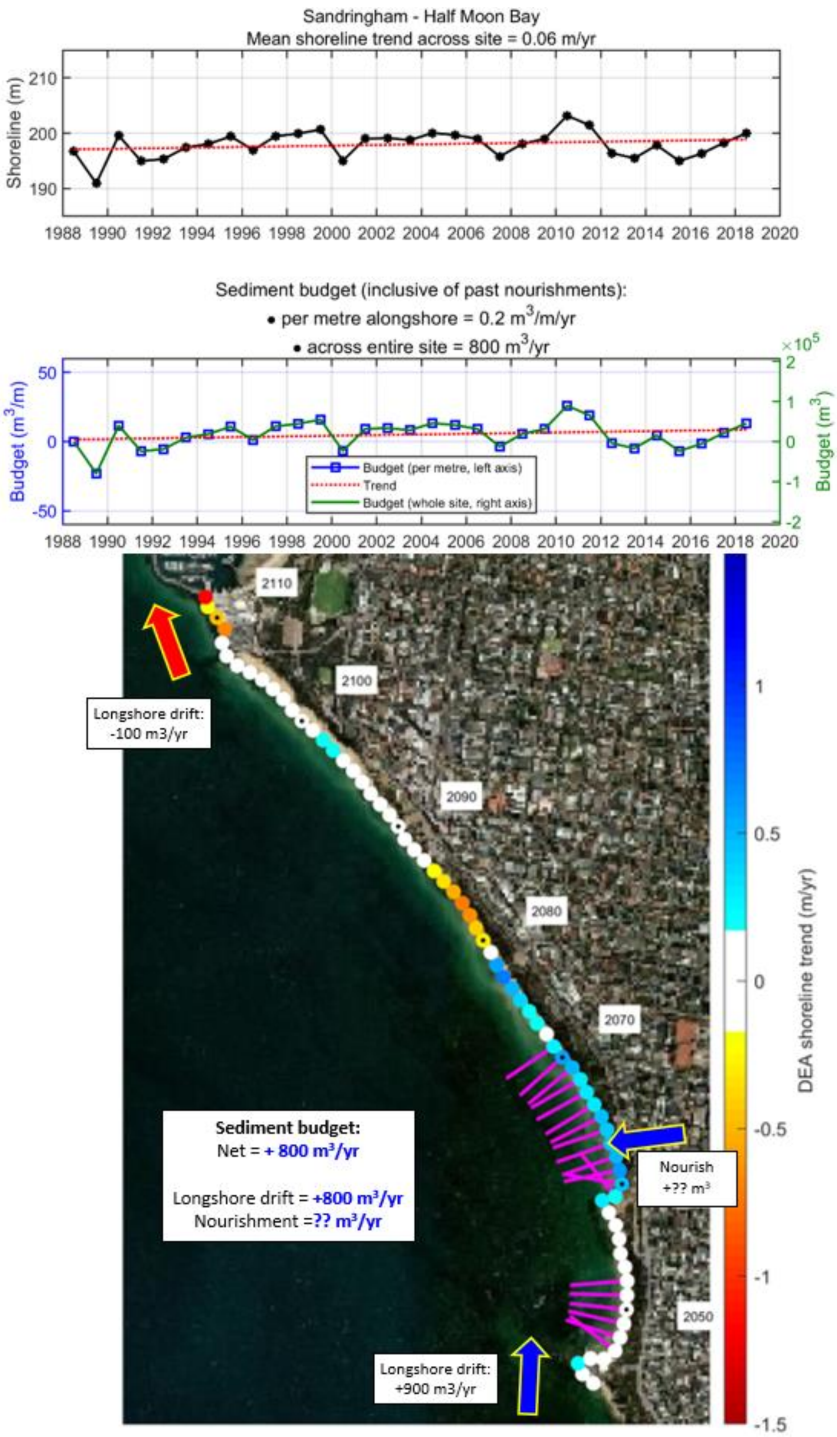


Fig. 3.3.8. Sandringham system, (top) mean shoreline trend time series for 1988 – 2018 using DEA satellite data, averaged across the entire site; (middle) whole-system sediment budget time series; and (bottom) interpretation of sediment budget, to order of magnitude precision. [Blue arrows = sediment inputs; Red arrows = sediment outputs].

3.3.4. Summary / assessment / interpretation

South Sandringham (P2060)

1. What are the goal(s) of nourishing this site?

- Possibly, to protect against cliff erosion and the exposure of the road surface landfill.

2. What is the sediment budget for the site?

- The dominant process is seasonal rotation due to shifts in the wave direction.
- Medium-term sediment budget seems relatively stable to slightly accretive.
- The budget has been changed several times due to the introduction, then modification, of the two large groynes. Further work could be done to understand the subtleties of how the balance may have shifted over time.

3. Is nourishment required to prevent an imminent hazard occurring?

- The landfill may present a hazard, and is unsightly.
- Due to the seasonality, nourishment material will be shifted back and forth between the southern groyne and the south Sandringham headland on a seasonal basis, though more sediment will remain in the sub-compartment for a period of a few years.
- The slabs of road surface in the hillside and under the beach may still be at risk of exposure due to these seasonal oscillations.

4. How have previous nourishments performed?

- Unknown.

Half Moon Bay (P2048)

1. What are the goal(s) of nourishing this site?

- Bayside Council requested nourishment of the site after erosion in winter 2020 that led to a steep drop from the main access ramp to the beach and potential undercutting of the seawall, presenting a safety risk.

2. What is the sediment budget for the site?

- Initial drone survey data suggests there is also strong seasonal variability around the south end of Half Moon Bay (i.e., similar to Sandringham).
- No long-term erosive trend is observed in this location, possibly some more recent erosion has occurred, localised around P2048.
- The sediment budget appears balanced. If there has been ongoing renourishment at this site in the past, then that rate of nourishment would need to be continued to maintain the budget.

3. Is nourishment required to prevent an imminent hazard occurring?

- Possibly a path up the hillside may be at risk if this profile were to erode excessively.

4. How have previous nourishments performed?

- Unknown.

3.4. Anderson Reserve

3.4.1. Site setting

Anderson Reserve (Fig. 3.4.1) is located to the southwest of Port Phillip Bay on the Bellarine Peninsula. The section of coastline of interest is a 750 m stretch facing ENE, between Point George to the north and Taylor Reserve to the south. The site of the nourishment is around two groynes installed in 2017. The profile between the groynes (P5241) is analysed in detail.

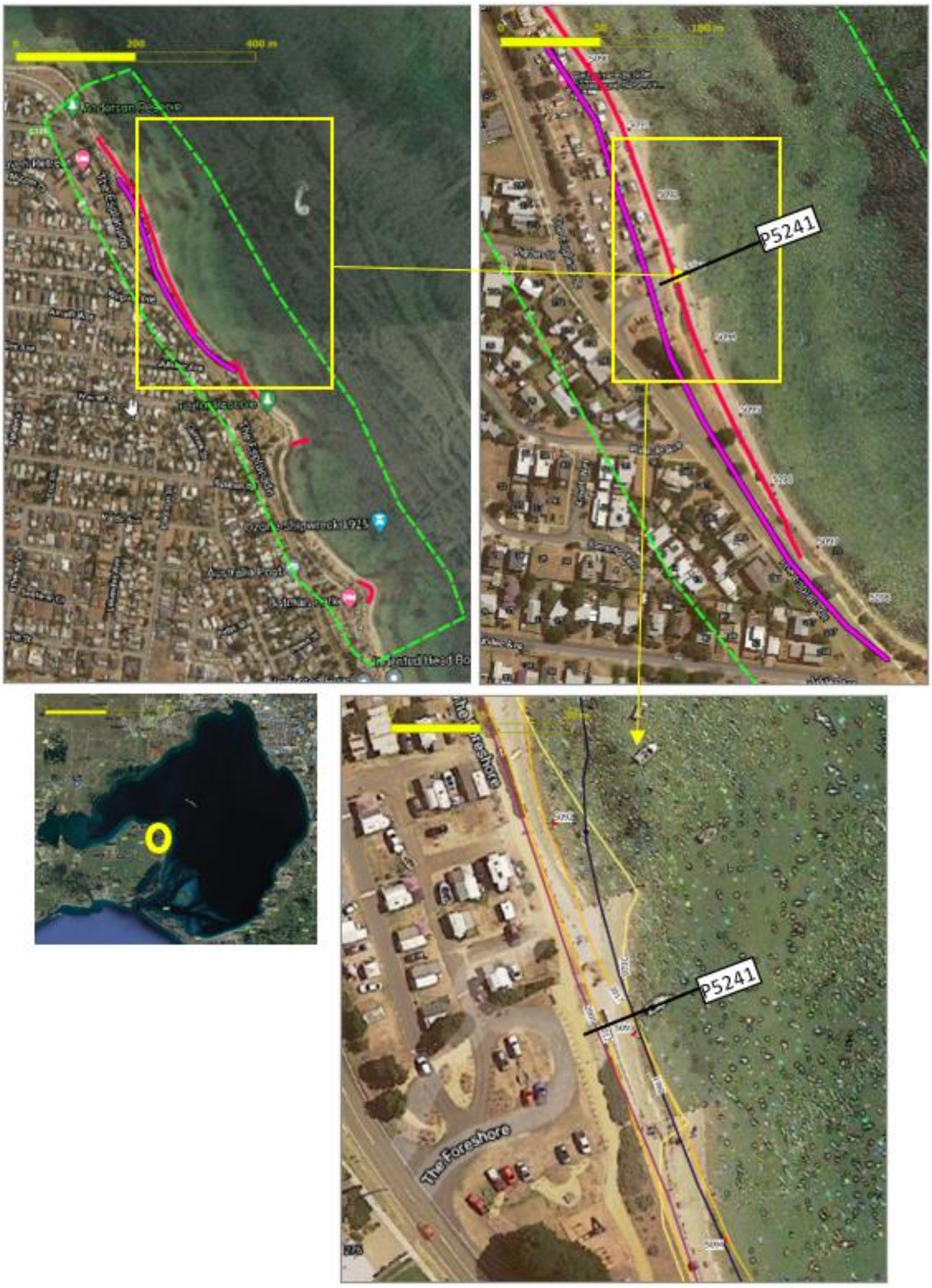


Fig. 3.4.1 Anderson reserve monitoring and nourishment site. Green dashed line is minimum area of drone survey coverage, red lines are coastal structures, pink line is nourishment zone, yellow boxes show progresses levels of zoom.

Geomorphology

- Sediment: Medium-coarse sand (0.4 – 0.8 mm)
- Beach width: 5 – 10 m.
- Beach and nearshore morphology: Steep beach face, flattening to a multi-barred subtidal terrace, extending ~100 m offshore.
- Back shore morphology: Most of the site is backed by a low wall. Prior to the wall, a low dune was present.

Coastal structures

Alongshore structures:

A low wall backs most of the site, built in the early 2000's. Some sections of the wall may be in poor condition.

Cross-shore structures:

Two wooden groynes were built in 2017 after a period of sustained moderate rates of erosion (location shown in Fig. 3.4.1).

Infrastructure

Carparks, a caravan park and pathways occupy the space immediately behind the low wall, on a low dune at elevation from 1.5 to 2 m AHD.

3.4.2. Coastal processes and dynamics

Wave climate

Wave roses and longshore sediment flux potential are shown in Fig. 3.4.2, sourced from a SCHISM 25-year wave model hindcast for a node located 500 m offshore the monitoring site. The site experiences a low energy wind wave climate (no swell wave energy from the entrance). Wave statistics include:

- Mean significant wave height = 0.2 m – 0.3 m.
- Mean peak period = 2 s
- Mean wave direction = 56 °
- Seasonality:
    - Dominant SE conditions in summer.
    - Dominant NNE conditions in winter.

Tidal regime

Tides are microtidal and semi-diurnal with approximate spring range of 0.9 m. Maximum water levels in a 1-year modelled time series are 0.6 m above MSL.

Longshore drift

Predicted sediment flux potential is shown in Fig. 3.4.2.

- Net (annual) flux is southward, up to 800 m3/yr.
- Flux in summer is northward. The model predicts low rates of northward flux in summer but based on qualitative observations, this is likely an underprediction.
- Flux in winter is southward, up to 800 m3/yr.

Cross-shore variability

Storm demand at this site is likely to be minimal, estimated at <3 m change in shoreline position for an extreme event. This section of coast was not modelled in the 2018 ABM-Cardno report; therefore, quantitative modelling is not available.

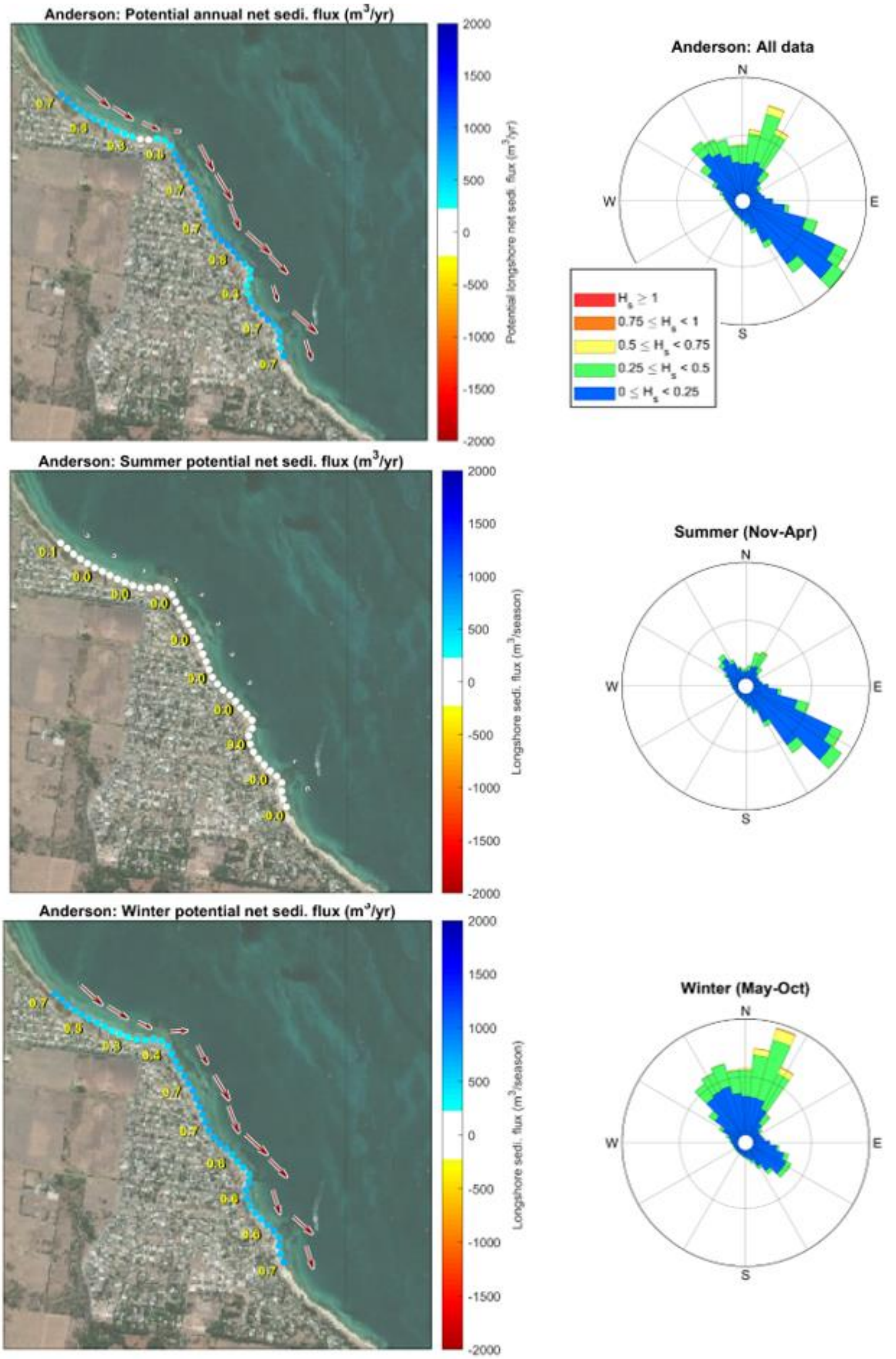


Fig. 3.4.2. Anderson Res. potential longshore sediment flux, annual and seasonal (left column), and wave climate (right column).

Historical shoreline change

Long-, medium- and short-term shoreline trends are given in Fig. 3.4.3, location along the beach is referred to by profile number (transect ID).

A period of erosion occurred between approximately 1980 to 2017 (Fig. 3.4.4, Fig. 3.4.6, time series), after which the groynes were installed). Over the period of available satellite observations (1988 – 2018) an underlying shoreline erosion trend of -0.2 m/yr occurred from the current groyne location to +/-200 m north and south (Fig. 3.4.3).

A seawall was constructed in the early 2000's. The beach eroded entirely back to the seawall in 2004 (Fig. 3.4.4) and 2016. The seawall may act to exacerbate cross-shore storm erosion but is not the cause of the long-term sediment budget deficit, which is likely due to longshore transport gradients.

The periodic complete erosion of the beach (to the seawall) is an indication of large interannual variability, due to fluctuations in the relative strength of the winter and summer winds.

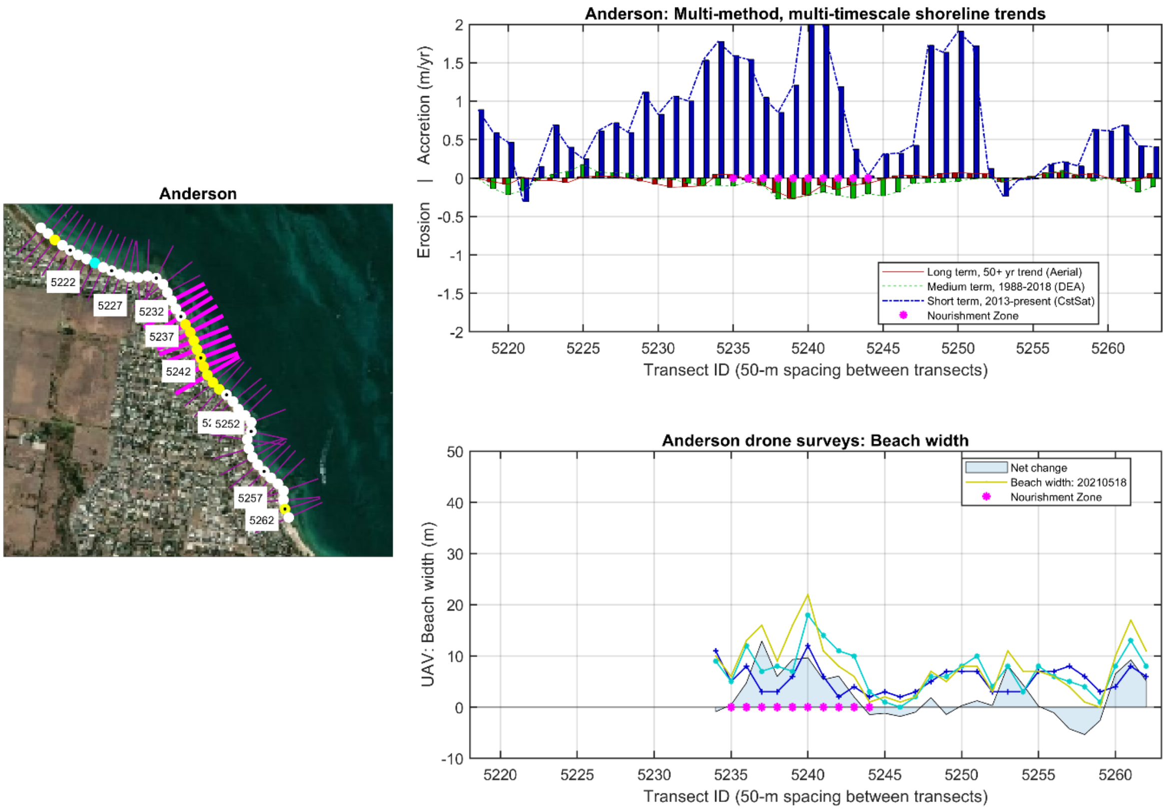


Fig. 3.4.3. Anderson Reserve, (top) , (left) site map with transect ID's, coloured dots indicate erosion [hot colours] and accretion [cold colours], based on 1988 – 2018 satellite imagery; (top right) multi-timescale shoreline trends; and (bottom right) beach width extracted from drone surveys.

Fig. 3.4.4. Anderson Reserve: Aerial, and drone imagery time series.

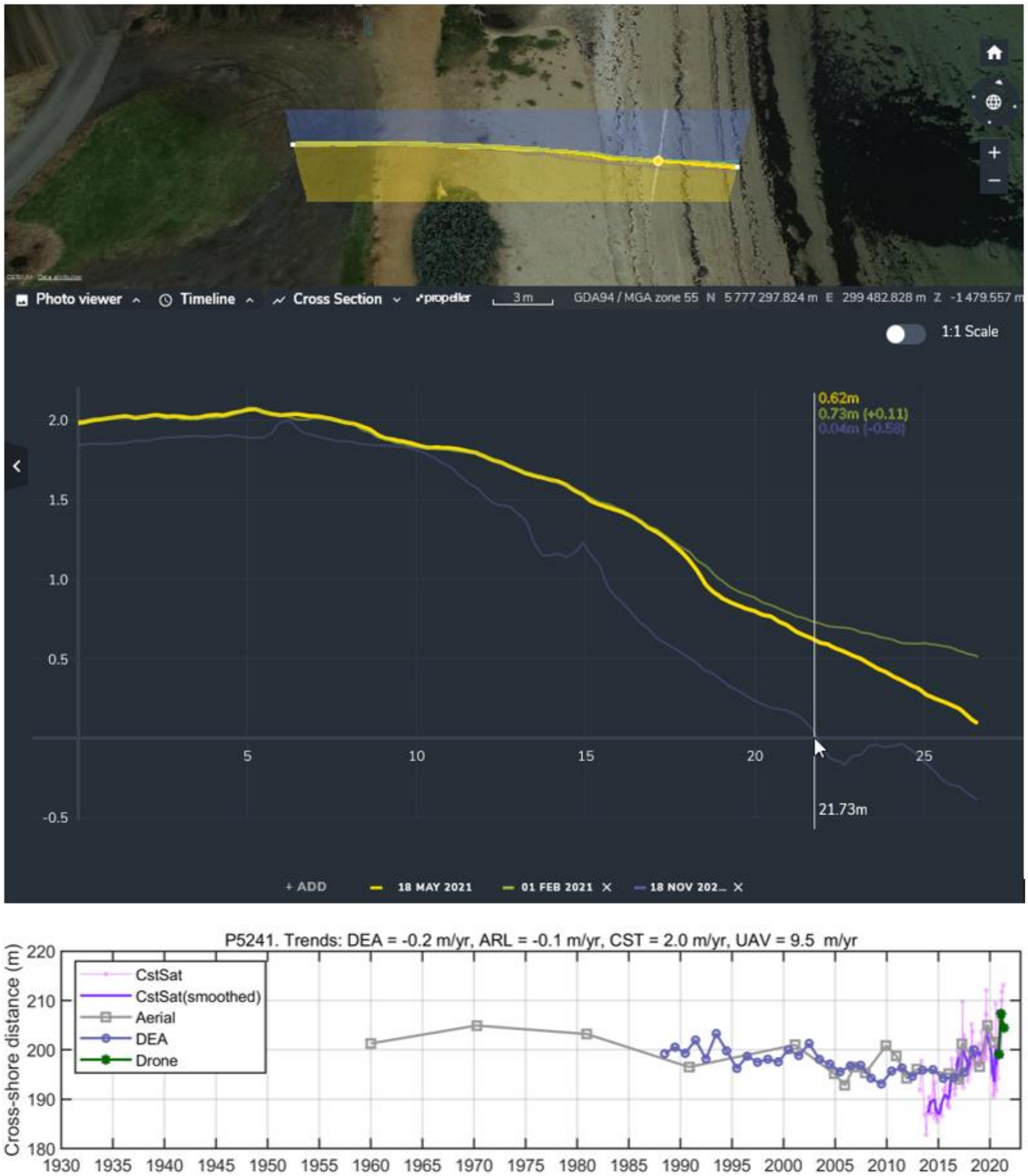


Fig. 3.4.5. Anderson Reserve, cross-section time series (top); and multi-method shoreline change time series for selected transects (bottom; see Fig. 3.4.1 for transect location).

3.4.3 Nourishment performance analysis

- The beach between the groynes appears to have generally been wider since the introduction of the groynes in 2017 (Fig. 3.4.5).
- The positive impact of the groynes is they will act to reduce the net southward transport, keeping nourishment volumes within the system for longer and maintaining higher beach widths on average.
- The negative impact of groynes is that during times of low sediment availability, areas downdrift of a groyne may become eroded, while a small beach is maintained immediately updrift the groyne.
- The Dec 2020 nourishment added 8 m to beach width (+6 m^3/m, above MSL) after 6 weeks, which has been maintained out to 5 months (Fig. 4.6).
- Little to none of the nourishment volume has left the general vicinity of the groynes, and is acting as a net positive to beach width and volume (Fig. 4.5 – 4.6)..
- Some degree of equilibration (cross-shore transport to the shallow subtidal) is apparent, as was anticipated.
- A large lobe of sand from the nourishment is currently positioned north of the groynes, which will act to supply the net southward sediment flux (Fig. 4.7).
- While this supply lasts, and the beach around the groynes remains wide, impedance to southward transport will be minimal, and erosion to the beach south of the groynes will be insignificant (Fig. 4.8).
- Over time, the nourishment will gradually move south and spread out (Fig. 4.8), to the point where it cannot easily be tracked. The groynes at some point will become re-exposed and the beach south of the groynes may experience erosion, particularly in winter.
- No further intervention is recommended at present. Continued monitoring should occur and when the nourishment volume is depleted, further action can be considered, including: no further intervention, reduce the cross-shore extent of groynes, or additional nourishment.

Fig. 3.4.6. Anderson Reserve, oblique view of site, looking northwest, taken pre- and post-nourishment, from orthomosaics generated from drone imagery (available on Propeller).

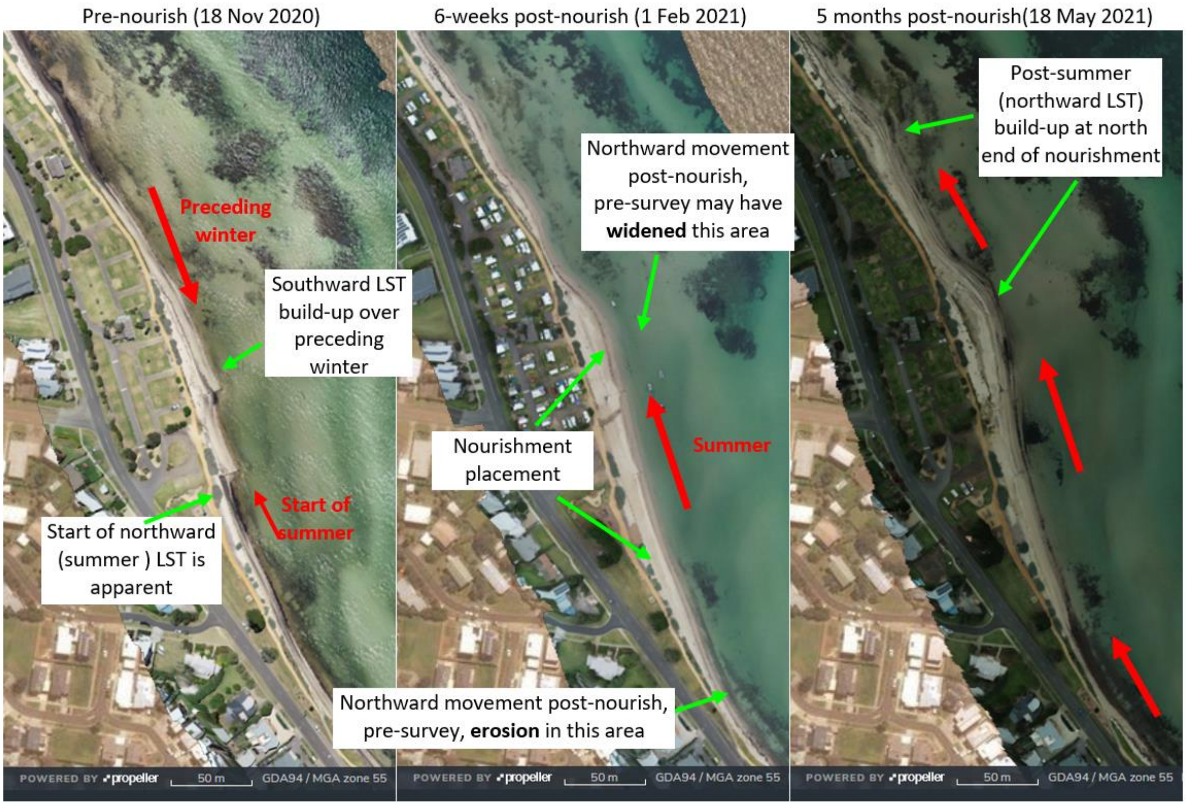


Figure 3.4.7. Plan view of site, looking northwest, taken pre- and post-nourishment, from orthomosaics generated from drone imagery (obtained from Propeller). Red arrows indicate longshore sediment transport (LST) fluxes, green arrows highlight areas of interest.

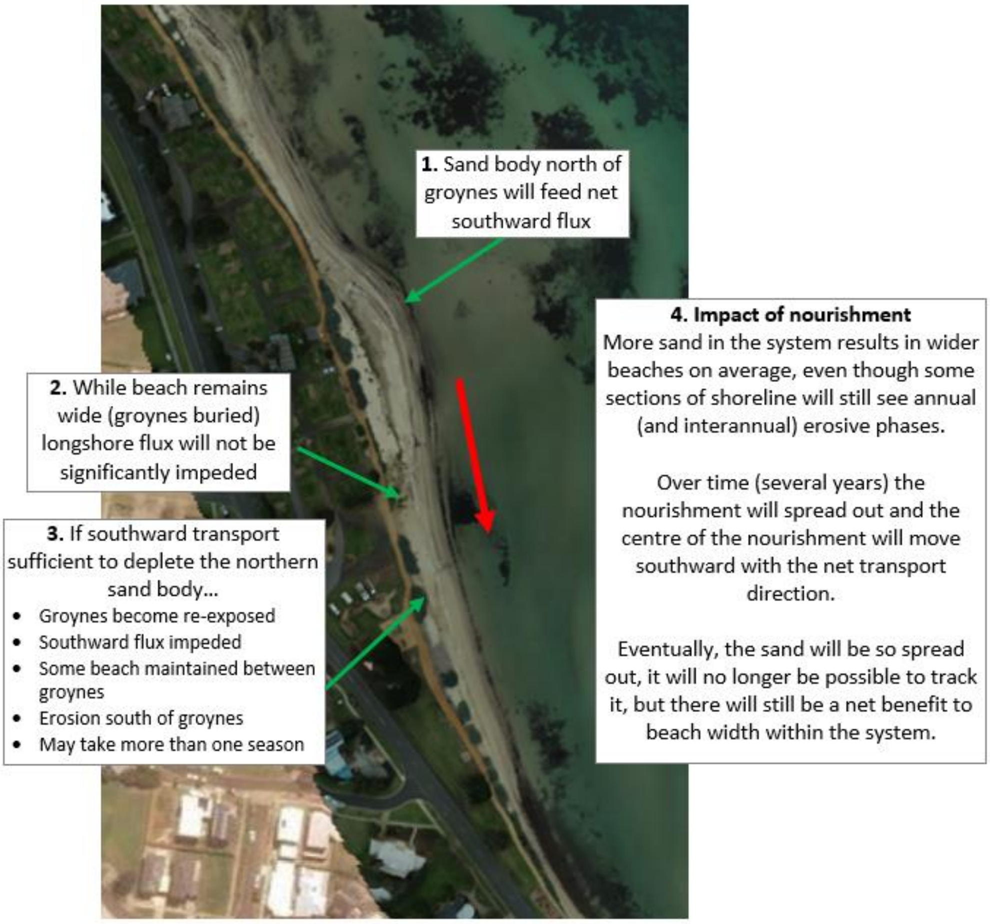


Figure 3.4.8. Conceptual projection of shoreline change for Anderson Reserve over winter 2021.
Red arrows indicate longshore sediment transport (LST) fluxes, green arrows highlight areas of interest.

3.4.4. Sediment budget

An interpreted sediment budget for Anderson Reserve is presented in Fig. 3.4.9. Due to the high uncertainty associated with the input data, the budget is considered an order of magnitude approximation. Data used to analyse and interpret this budget include:

- Modelled estimates of alongshore sediment flux (Sec. 3.4.2).
- DEA satellite shorelines for 1988 – 2018 (Sec. 3.4.2).
- Historical nourishment data (Sec. 3.4.1). *Some historical nourishments may be unaccounted for, and/or nourishment volumes may be highly inaccurate.*
- Shoreline change is converted to approximate volume change using:
    - [volume change = shoreline change * height of active profile]
    - Height of active profile was estimated as [h_a = 2.5 m].
- For simplicity, volume fluxes associated with natural processes are attributed entirely to longshore drift gradients. However, cross-shore exchange and SLR (especially in the long-term) may also occur.
- This budget is for the **entire site**, some sections within the site may be acting against the overall trend (e.g., some areas may be eroding while the site as a whole is accreting).

Anderson Reserve sediment budget: Neutral to slight erosion across site (1988 – 2018)

The site (2-km alongshore that is a subset of a larger sediment sharing system across the Bellarine) eroded at a marginal rate over 1988 to 2018 (Fig. 3.4.9). Nourishment volumes during this period are unknown. The total deficit over the 30-year period was -12,000 m^3, which is equivalent to 2 to 3 average sized Port Phillip Bay nourishments.

- Marginally negative net sediment budget (-0.07 m/yr shoreline; -400 m^3/yr)
    - 'Natural' processes (longshore drift) = -400 m^3/yr
    - Nourishments [1988 – 2018] = (Unknown)

Sediment budget at the nourishment location over this period was slightly more negative (-0.2 m/yr, -0.5 m^3/m/yr). The more pronounced erosion trend at the nourishment location accounts for the marginally negative budget across the full site.

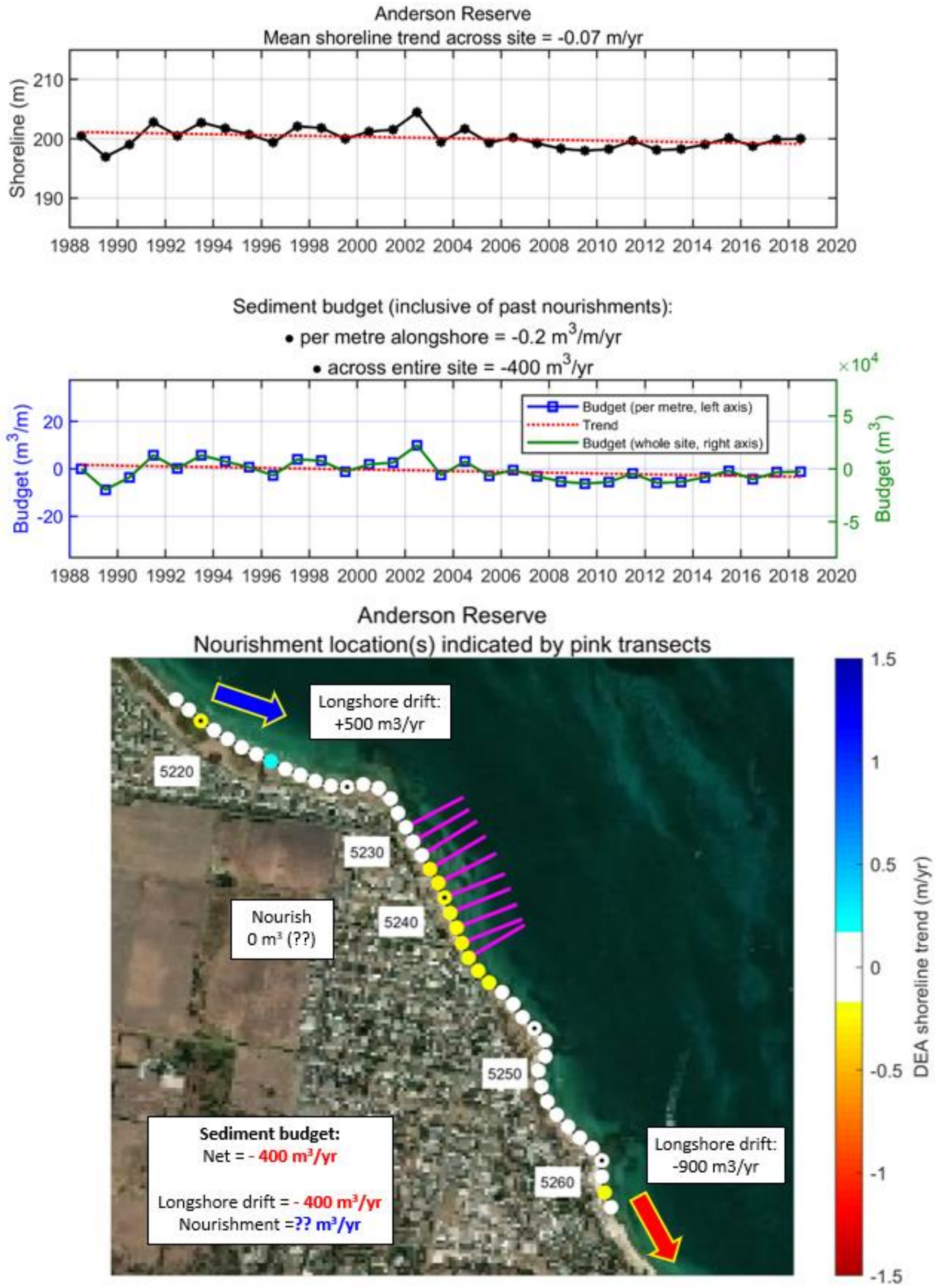


Fig. 3.4.9. Anderson Reserve system, (top) mean shoreline trend time series for 1988 – 2018 using DEA satellite data, averaged across the entire site; (middle) whole-system sediment budget time series; and (bottom) interpretation of sediment budget, to order of magnitude precision. [Blue arrows = sediment inputs; Red arrows = sediment outputs].

3.5.4. Summary / assessment / interpretation

Anderson Reserve

1. What are the goal(s) of nourishing this site?

- To maintain beach width for amenity.
- To buffer / protect the existing seawall.

2. What is the sediment budget for the site?

- A moderate rate of erosion occurred between approximately 1980 to 2017.
- The periodic complete erosion of the beach (to the seawall) is an indication of large interannual variability, due to fluctuations in the relative strength of the winter and summer winds.
- The beach between the groynes appears to have generally been wider since the introduction of the groynes (but the downdrift beach has been narrower).

3. Is nourishment required to prevent an imminent hazard occurring? Over what time frame is the hazard likely to occur?

- This is not clear. More needs to be known on whether the nourishment is being used to protect the seawall from damage.

4. How has the current nourishment performed?

- Nourishment volumes are being maintained 5 months after the initial nourishment.
- Further monitoring is required after winter to determine volume loss, in order to better estimate nourishment longevity at this location.

3.5. St Leonards

3.5.1. Site setting

St Leonards is located to the southwest of Port Phillip Bay on the Bellarine Peninsula. A 2 km long east facing embayment runs between two small headlands. The sites of interest for nourishment are Wrathalls Reserve at the northern end (Fig. 5.1, top right, profile P5139), and St Leonards 'Northern Beach' and 'Soft cliffs, south end groyne' areas (Fig. 5.1., bottom right), located to the south of the embayment. The beach is low-energy and narrow, with a low back-barrier, and a main road ('The Esplanade') running behind the beach.

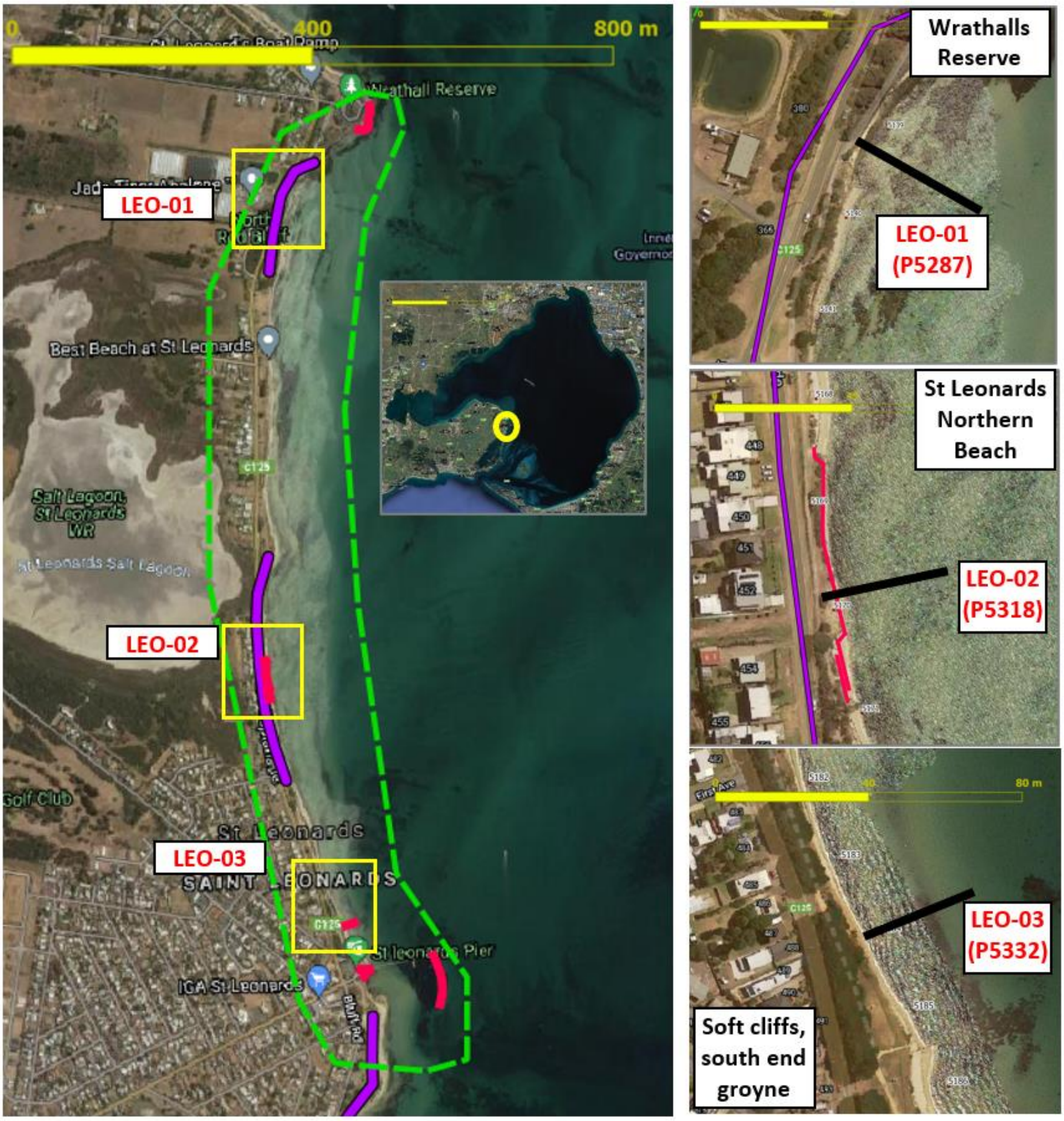


Fig. 3.5.1. St Leonards site. Drone survey area (green dashed); structures (red); nourishment area (purple). Yellow boxes in left panel are shown as insets in right column.

Geomorphology

- Sediment: Medium sand, 0.3 – 0.4 mm.
    - The northern end is backed by eroding soil.
    - What appear to be dark coloured gravel / cobbles are exposed around the water line where beach erosion has occurred, mostly toward the south end.
- Beach width: Very narrow, mostly <5 – 10 m wide.
- Beach and nearshore morphology:
    - Low energy reflective beachface (1:5 to 1:20 slope), flattening into a wide (~200 m), multi-barred, low gradient, shallow subtidal terrace. Narrowing to the south and widening to the north.
- Back shore morphology:
    - Very low barrier (1 – 1.5 m AHD) along most of the embayment, in parts buffered by a low vegetated dune (10 – 15 m wide).
    - Toward the south of the embayment (Fig. 5.1., bottom right), is a 270 m long section of low (2 - 8 m AHD), soft eroding cliffs comprised of semi-consolidate or soil material.

Coastal structures

Cross-shore structures: At the southern end of the embayment, approx. 200 – 400 m north of the southern headland, are a single groyne and St Leonards Pier. The inner section of the pier partially blocks longshore transport.

Alongshore structures:

- A low wooden retaining wall backs the narrow section at Northern Beach (Fig. 5.1., P5318), a small number of sandbags are visible at the southern end.
- A section of old, scattered rock armour sparsely covers a section of the northern headland.
- A low wire fence bounds the soft eroding cliff at the southern end, the structure does not provide any erosion protection, it appears intended to keep people from going too near to the cliffs.

Infrastructure

The road behind the beach ('The Esplanade') is assessed regarding erosion hazard. In some sections, the road is buffered by the vegetated low barrier, in other areas, the road runs directly behind the beach (10 m from high tide line to the road), as is the case with the two selected profiles in Fig. 5.1.

A pathway runs between the road and the beach along most of the embayment. The path is variously comprised of gravel, pavement, and wooden sections. A wooden walkway is installed at the northern Wrathalls Reserve site. The section of pathway that runs behind the soft eroding cliffs is considered in regard to erosion hazard. Parkland has been developed along some wider sections of the barrier, around the path.

3.5.2. Coastal processes and dynamics

Wave climate

Wave roses and longshore sediment flux potential are shown in Fig. 5.2, sourced from a SCHISM 25-year wave model hindcast for a node located 500 m offshore the monitoring site. The site experiences a low energy wind wave climate (no swell wave energy from the entrance). Wave statistics include:

- Mean significant wave height = 0.2 m
- Mean peak period = 2.4 s
- Mean wave direction = 104°

- Seasonality:
  - Dominant SE conditions in summer, driving northward transport.
  - Dominant NE conditions in winter, driving southward transport.
  - Comments: Easterly summer storms seen in the wave buoy data may be missed by the current version of the model.

Tidal regime

Tides are microtidal and semi-diurnal with approximate spring range of 0.9 m. Maximum water levels in a 1-year modelled time series are 0.6 m above MSL.

Longshore drift

Predicted sediment flux potential is shown in Fig. 3.5.2.

- Net (annual) flux is southward at 0 to 700 m^3/yr.
- Flux in summer northward at 0 to 200 m^3/yr.
- Flux is winter is southward at 100 to 700 m^3/yr.
- Note: This is based on an unvalidated model and should be taken purely as indicative, actual rates may vary substantially.

Cross-shore variability

Storm demand at this site is likely to be minimal, estimated at <3 m change in shoreline position for an extreme event. This section of coast was not modelled in the 2018 ABM-Cardno report; therefore, quantitative modelling is not available.

Historical nourishments

A nourishment was conducted in 2014 of 4250 tonnes (approx. 3000 m^3) at south St Leonards, just around the headland to the south of the area focussed on in this study (Fig. 3.5.1a). Note the net direction of drift is southward, therefore little of this material is likely to have entered the section of sediment sharing system covered here (Fig. 3.5.1).

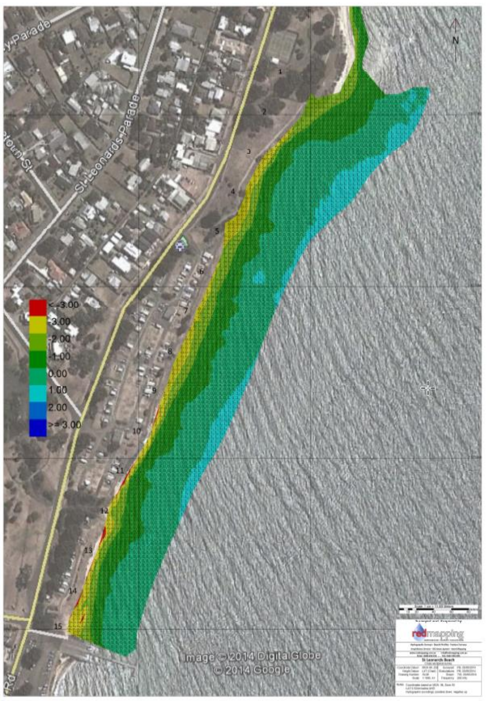


Fig. 3.5.1a. St Leonards south 2014 nourishment site.

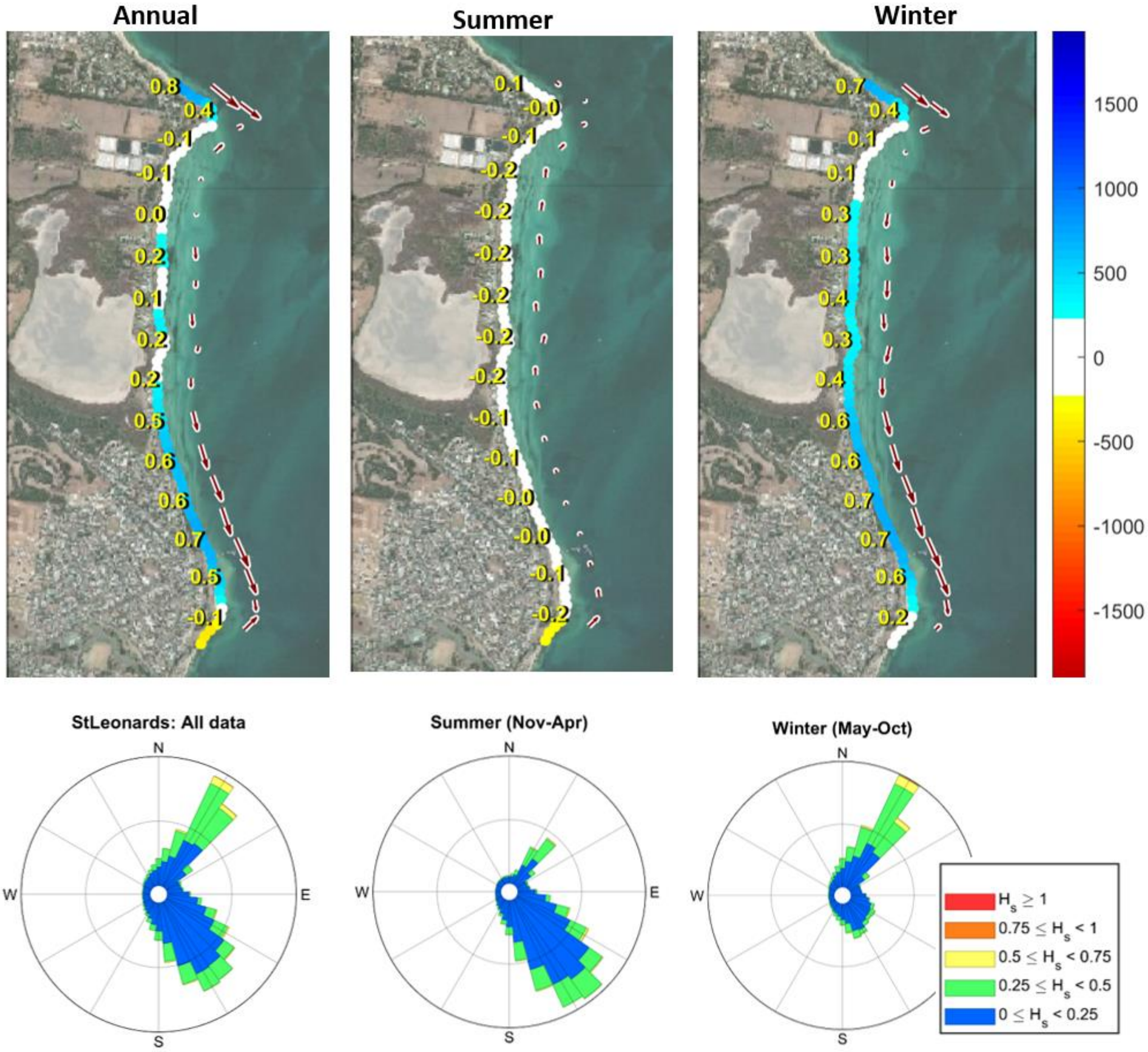


Fig. 3.5.2. St Leonards potential longshore sediment flux

Historical shoreline change

Long-, medium- and short-term shoreline trends are given in Fig. 3.5.3, location along the beach is referred to by profile number (or transect ID). The site as a whole is described here, then detailed analyses of each profile (P5287, 5318, P5332) are provided in the following sections.

Over the medium to long-term, erosional trends are observed at:

- The Wrathalls Reserve nourishment target, around profile P5287, at up to -0.3 m/yr.
- Along the St Leonards nourishment target, from P5310 to P5332, at -0.1 to -0.5 m/yr.

For the recent trend, covered by VCMP drone data (2018-2021):

- Beach width is generally 5 – 10 m (Fig. 5.3, bottom right).
- The Wrathalls Reserve site (P5287) has accreted slightly, with the beach width expanding 4 m over the last year.
- The 'Northern Beach' site (P5318) has remained near near-zero beach width, with some erosion to either side of P5318.
- Large variability in beach width is seen around St Leonards Pier and the south headland (P5338 – P5344), and also around the Wrathalls Reserve nourishment target (around P5287)

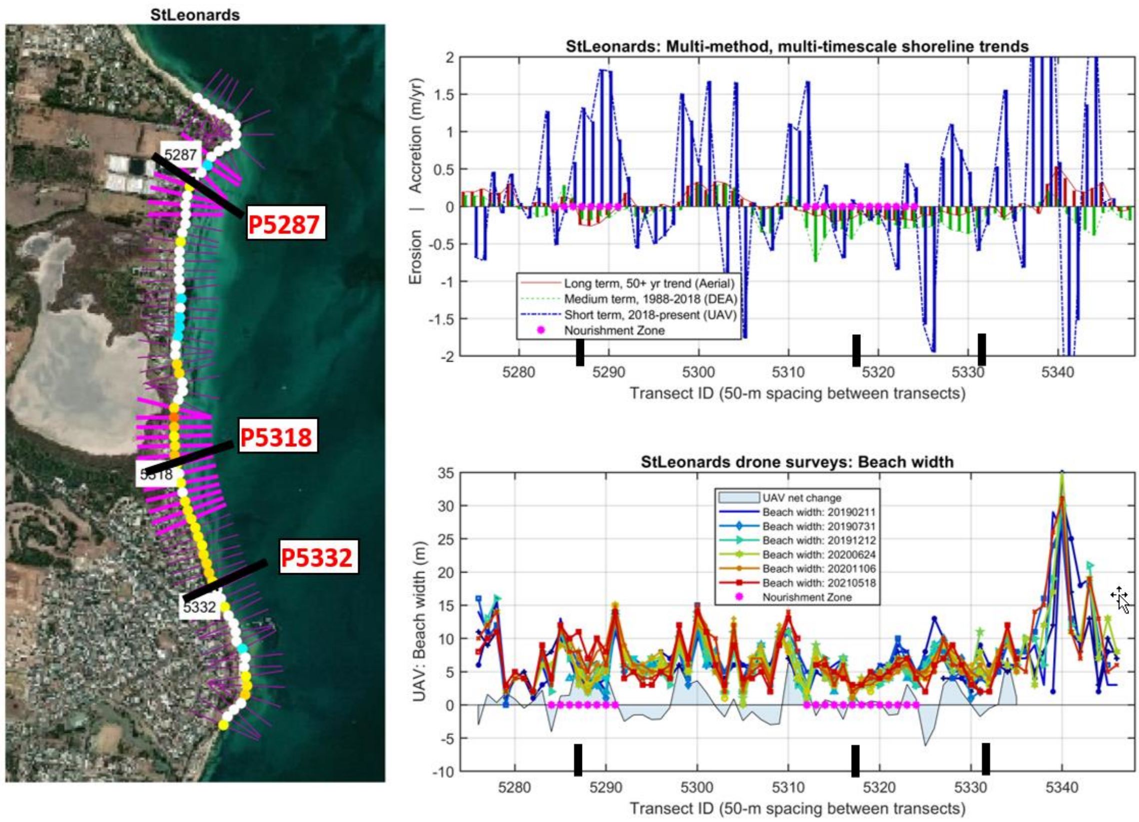


Fig. 3.5.3. St Leonards historical shoreline change; (left) map showing transect numbers [TID]; (top right) shoreline trends at different time scales for multiple datasets; and (bottom right) beach width for each drone survey (coloured lines) and net change in beach width (shaded area), where areas of large positive net change indicate nourishment zones.

LEO-01: Wrathalls Reserve nourishment target (P5287)

Over the aerial photo observation period (Fig. 3.5.4) the shoreline has receded 15 m from 1960 to the present, at the section where the road is closest to the beach.

A detailed analysis of P5287 (Fig. 3.5.5., second row time series) suggests that an erosive period occurred from approx. 1970 to 1990, with recovery from 1990 to 2000, then another erosive period from 2000 to the present. The cause of these long term fluctuations is not determined.

A cross-section analysis over the drone survey period (2018 – 2021; Fig. 5.5., bottom right), shows the lower part of the profile is more variable (0.5 m increase in beach elevation over recent years), but the upper beach at this profile has been stable since 2018.

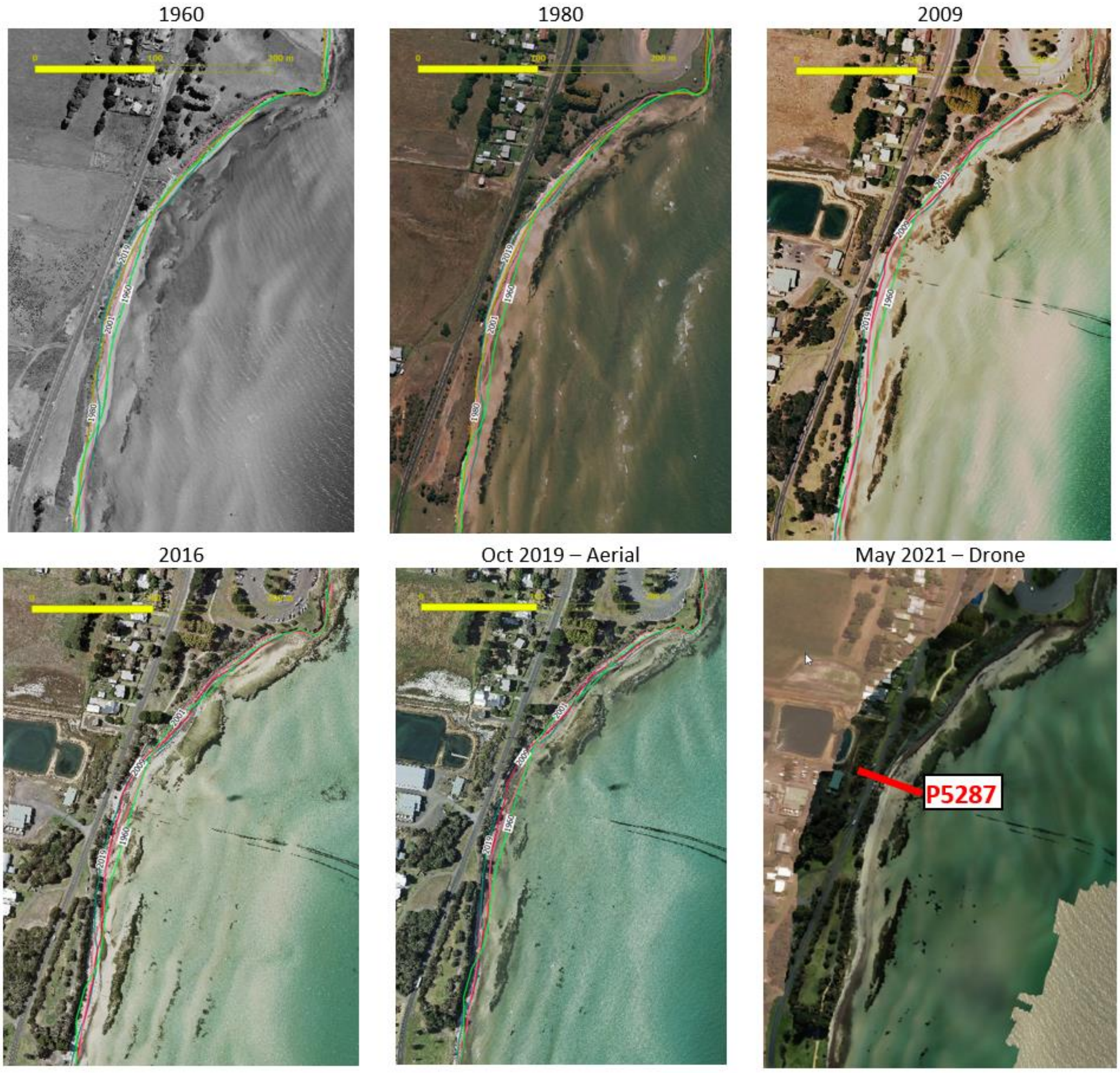


Fig. 3.5.4. Wrathalls Reserve (north St Leonards) proposed nourishment site, aerial and drone image time series.

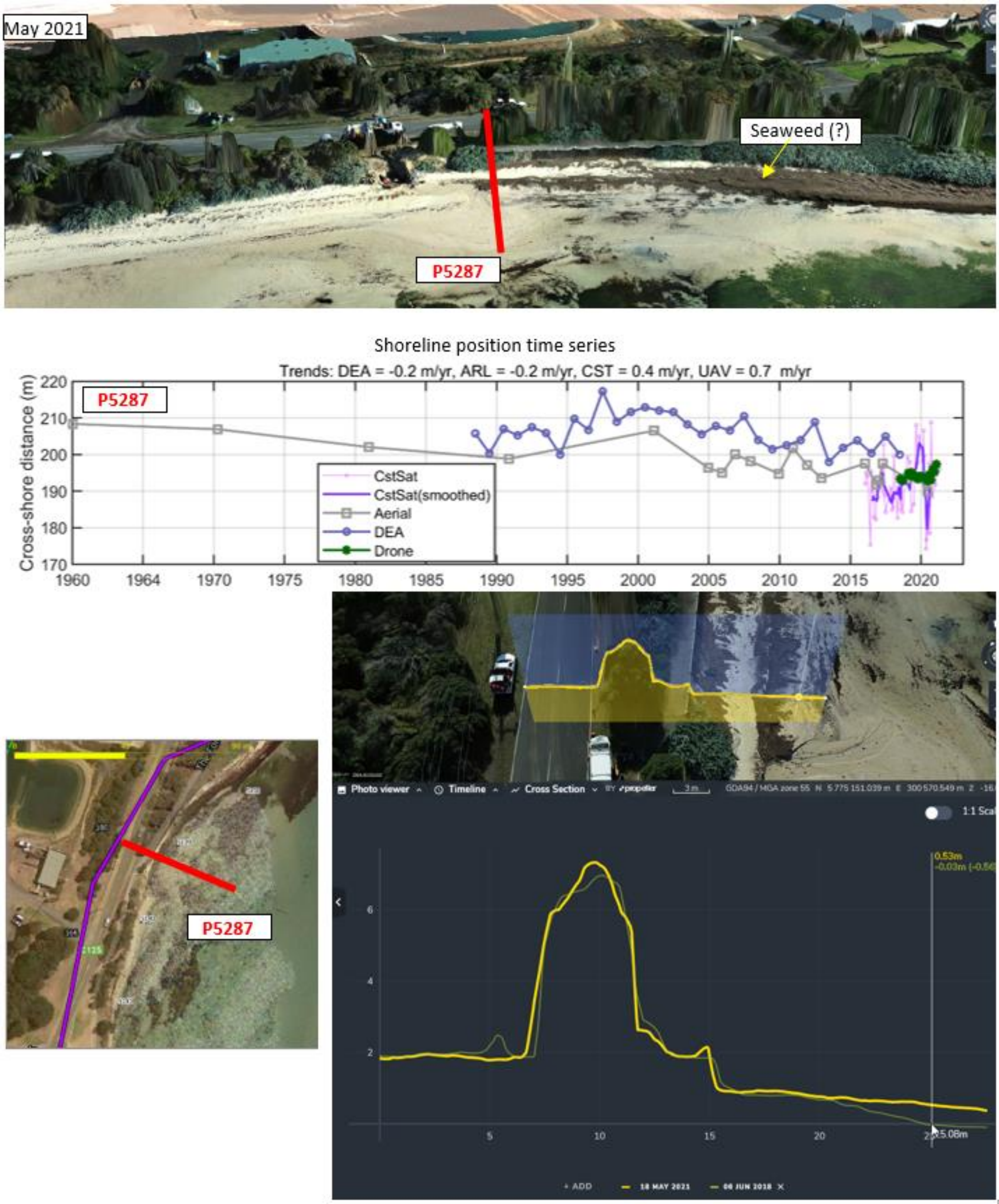


Fig. 3.5.5. Wrathalls Reserve (north of St Leonards) proposed nourishment site, profile P5287. (Top) oblique drone orthomosaic; (second row) multi-method shoreline time series; (bottom left) profile location; and (bottom right) cross-sections extracted from Jun 2018 (green) and May 2021 (yellow) drone surveys.

LEO-02: St Leonards Northern Beach nourishment target (P5170)

Over the aerial photo observation period (Fig. 3.5.6) the beach was narrow in 1960 (~8 m width). The wooden retaining wall is present by the mid-2000's and the beach reached close to zero width by 2009, and has remained in a similar state since that time.

The cross-section and detailed time series analysis of P5170 (Fig. 3.5.7) shows the shoreline has been relatively stable over time, this reflects that the shoreline has maintained a near fixed position since the beach eroded back to the wooden wall.

The drone survey cross-section (Fig. 3.5.7, bottom right) indicates the profile has not changed significantly over the 2018 – 2021 survey period.

Fig. 3.5.6. St Leonards 'North Beach' proposed nourishment site: Aerial and drone image time series.

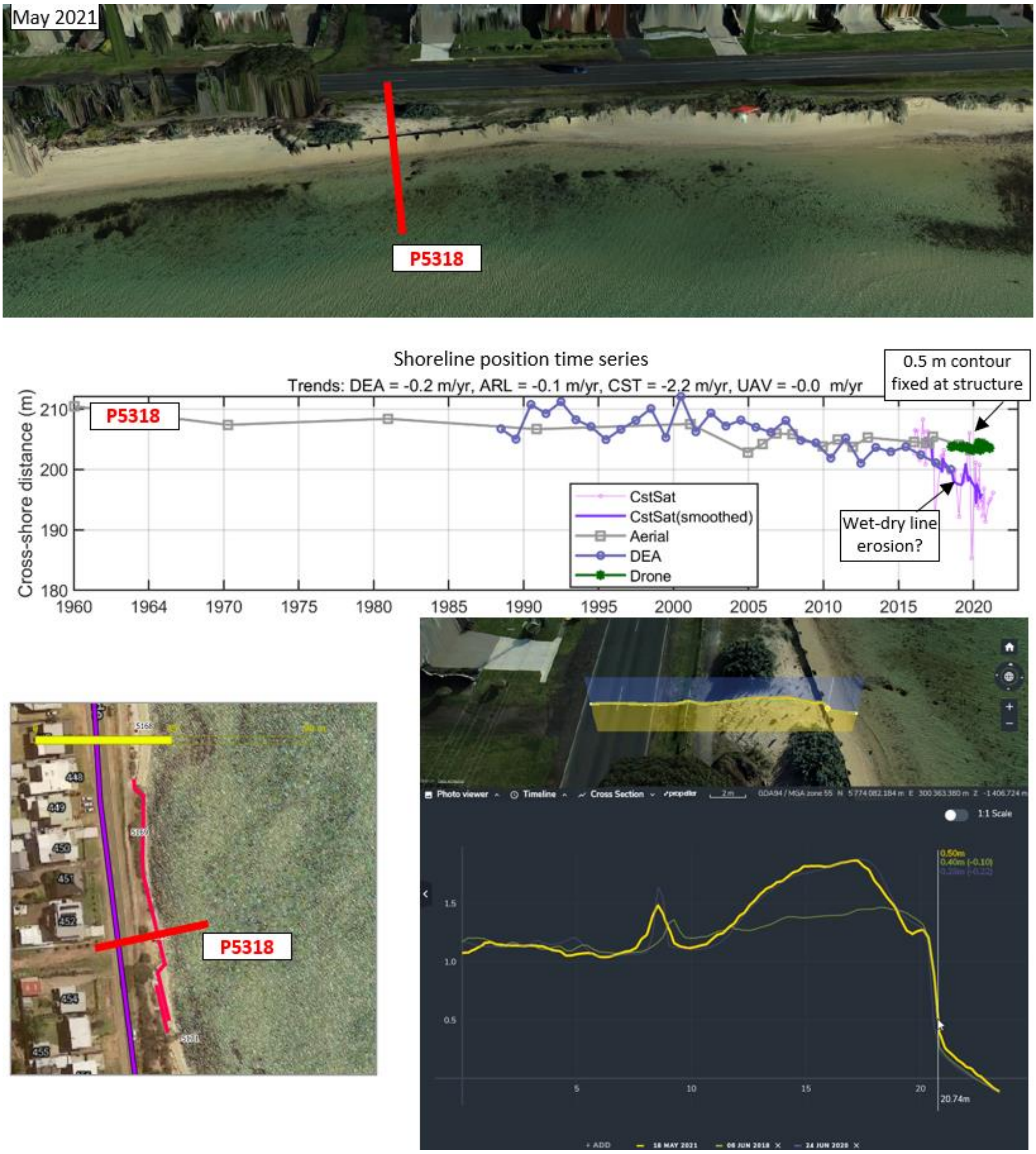


Fig. 3.5.7. St Leonards 'Northern Beach' proposed nourishment site, profile P5318. (Top) oblique drone orthomosaic; (second row) multi-method shoreline time series; (bottom left) profile location; and (bottom right) cross-sections extracted from Jun 2018 (green) and May 2021 (yellow) drone surveys.

LEO-03: St Leonards soft cliffs and south groyne (P5332)

This area is not scheduled as a target for the next round of renourishment, but is of interest as due to the potential erosion hazard to the path above the low, soft cliffs.

The detailed shoreline time series (Fig. 3.5.8, second row), suggests a slight erosional trend (-0.1 m/yr) over the medium-term (1988 – 2018, DEA satellite data).

The soft-cliffs have not eroded at all over the drone period (2018 – 2021; Fig. 3.5.8, bottom right), suggesting this is not a short-term erosion hazard.

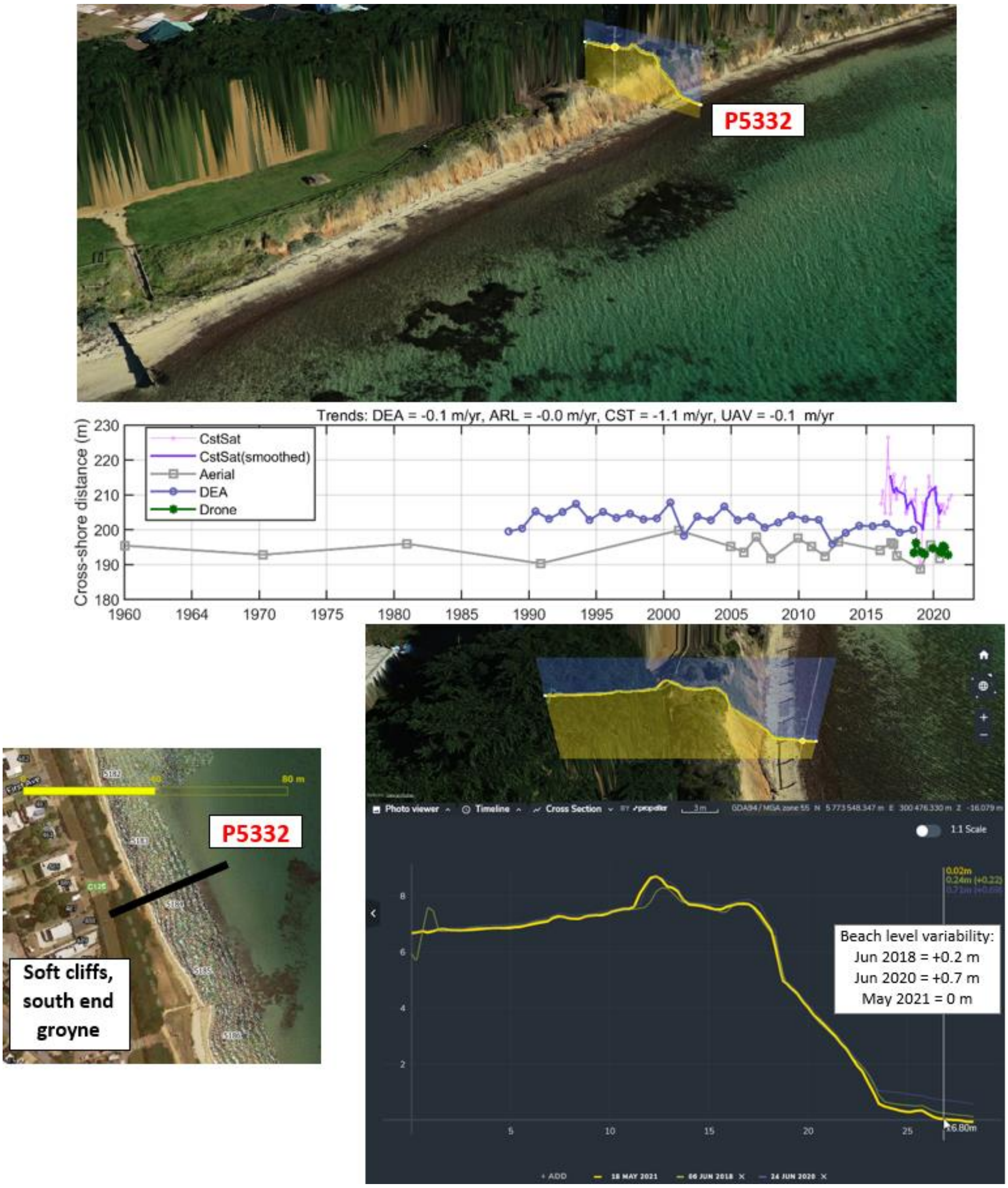


Fig. 3.5.8. St Leonards 'South end soft cliffs, south groyne' proposed nourishment site, profile P5332. (Top) oblique drone orthomosaic; (second row) multi-method shoreline time series; (bottom left) profile location; and (bottom right) cross-sections extracted from Jun 2018 (green), Jun 2020 (purple), and May 2021 (yellow) drone surveys.

3.5.4. Sediment budget

An interpreted sediment budget for St Leonards is presented in Fig. 3.5.9. Due to the high uncertainty associated with the input data, the budget is considered an order of magnitude approximation. Data used to analyse and interpret this budget include:

- Modelled estimates of alongshore sediment flux (Sec. 3.5.2).
- DEA satellite shorelines for 1988 – 2018 (Sec. 3.5.2).
- Historical nourishment data (Sec. 3.5.1). *Some historical nourishments may be unaccounted for, and/or nourishment volumes may be highly inaccurate.*
- Shoreline change is converted to approximate volume change using:
    - [volume change = shoreline change * height of active profile]
    - Height of active profile was estimated as [h_a = 2.5 m].
- For simplicity, volume fluxes associated with natural processes are attributed entirely to longshore drift gradients. However, cross-shore exchange and SLR (especially in the long-term) may also occur.
- This budget is for the **entire site**, some sections within the site may be acting against the overall trend (e.g., some areas may be eroding while the site as a whole is accreting).

St Leonards Reserve sediment budget: Neutral to slight erosion across site (1988 – 2018)

The site (a leaky 3-km alongshore compartment) eroded over 1988 to 2018 (Fig. 3.5.9) at -1000 m^3/yr. The only known nourishment over this time was in 2014, south (downdrift) of the site. The total deficit over the 30-year period was -30,000 m^3, which is equivalent to 3 to 6 average sized Port Phillip Bay nourishments.

- Negative net sediment budget (-0.1 m/yr shoreline; -1000 m^3/yr)
    - 'Natural' processes (longshore drift) = -1000 m^3/yr
    - Nourishments [1988 – 2018] = 0 (no known nourishments)

Sediment budget at the nourishment locations over this period was neutral to negative (-0.2 m/yr, -0.5 m^3/m/yr). Erosion across the southern section of the St Leonards embayment is the main contributor to the negative budget.

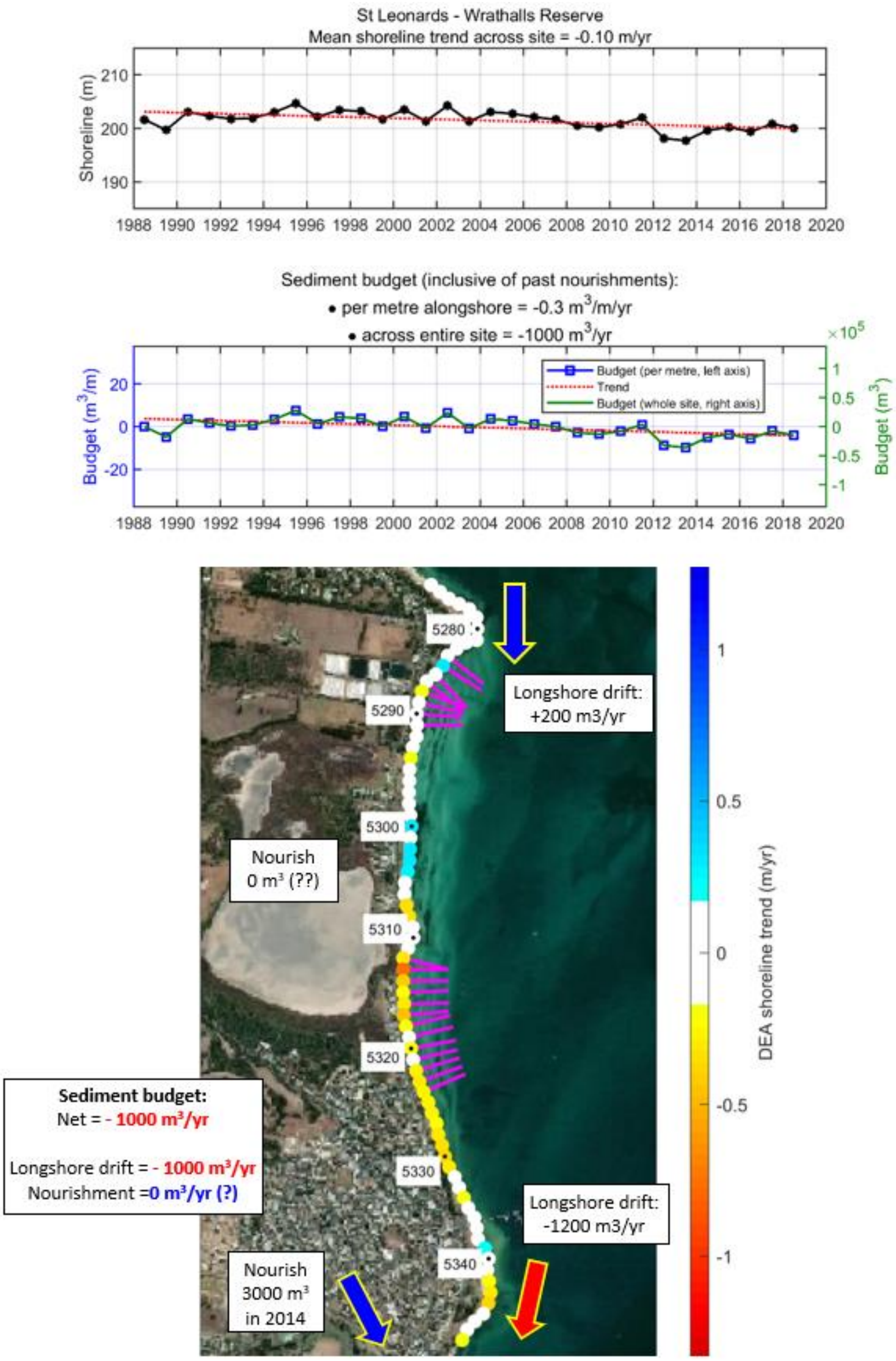


Fig. 3.5.9. St Leonards system, (top) mean shoreline trend time series for 1988 – 2018 using DEA satellite data, averaged across the entire site; (middle) whole-system sediment budget time series; and (bottom) interpretation of sediment budget, to order of magnitude precision. [Blue arrows = sediment inputs; Red arrows = sediment outputs].

3.5.4. Summary / assessment / interpretation

LEO-01: Wrathalls Reserve (around P5287):

1. What are the goal(s) of nourishing this site?

- The road is close to the beach (~10 m at narrowest), nourishing would provide a greater buffer to the road.
- A nourishment may protect the wooden path behind the nourishment.
- Beach amenity may be a consideration.

2. What is the sediment budget for the site?

- Erosion has been a problem over the long-term, but recently the profile has been stable.
- Sediment budget is neutral, maintaining the budget (including maintaining any existing nourishment rate) should maintain the shoreline over the medium term (absent SLR).

3. Is nourishment required to prevent an imminent hazard occurring? Over what time frame is the hazard likely to occur?

- There is no imminent danger to the road (within ~10 years).

4. How have previous nourishments performed? What is the short term equilibration shoreline loss?

- Unknown.

LEO-02: St Leonards Northern Beach (around P5318):

1. What are the goal(s) of nourishing this site?

- The road is close to the beach (~10 m at narrowest), nourishing would provide a greater buffer to the road.
- Protecting the existing wooden retaining wal may be a motivating factor.

2. What is the sediment budget for the site?

- Erosion has been a problem over the long-term, but once the profile receded to the wooden retaining wall (i.e., little to no beach), it has remained stable.
- Sediment budget is neutral, maintaining the budget should maintain the beach over the short to medium term.

3. Is nourishment required to prevent an imminent hazard occurring? Over what time frame is the hazard likely to occur?

- No imminent danger to the road (within ~10 years).

4. How have previous nourishments performed? What is the short term equilibration shoreline loss?

- Unknown.

LEO-03: St Leonards 'soft cliffs and south groyne' (around P5332):

1. What are the goal(s) of nourishing this site?

- This site is not a near-term nourishment target, but the site was investigated to see if the eroding cliffs present a hazard.

2. What is the sediment budget for the site?

- A slight erosional trend may be occurring over the medium term (-0.1 m/yr).

- However, the soft cliffs have been very stable over the 3-years of drone monitoring (2018-2021)

3. Is nourishment required to prevent an imminent hazard occurring? Over what time frame is the hazard likely to occur?

- There is no imminent danger to the path (within ~5 years) based on recent trends, but these soft cliffs appear highly erodible and should be monitored.

4. How have previous nourishments performed? What is the short term equilibration shoreline loss?

- Unknown.

PART 4: DATA SYNTHESIS AND SITE COMPARISONS

This section synthesises the data from the five sites (Sec. 3), analysing shoreline trends and variability across the nourishment locations.

Historical shoreline change rates across all sites for different time periods are summarised in Fig. 4.1, highlighting 'early period' (1930 – 1988) , 'middle period' (1988 – 2013), and 'recent period' (2013 – 2022) changes. Trends are averaged across satellite, aerial and drone imagery, where data exists for a given period. The period trends for each nourishment location (yellow boxes in Fig. 4.1) include:

- Blairgowrie: Mostly stable in the early and middle periods, with more erosion over the recent period.
- McCrae: Accretive in earlier periods, with recent erosion.
- Dromana: Stable to slight erosion in earlier periods, with recent severe erosion at the eastern end of the site.
- Sandringham south end: Neutral to accretive across all time periods.
- Half Moon Bay: Neutral across time periods.
- Anderson Reserve: Erosion in earlier time periods with some recovery over the recent period.
- Wrathalls Reserve: Strong erosion in early period, neutral to accretive over middle and recent periods.
- St Leonards: Neutral to erosive over all time periods.

Shoreline variability is displayed across sites in Fig. 4.2, using the detrended annual satellite shorelines for 1988 – 2018. This metric will mostly smooth out seasonal oscillations; however, DEA is the only available long-term dataset with regular sampling, and relatively low noise (compared to CoastSat). Based on this metric, the sites listed from lowest to highest variability are:

- Anderson Reserve, St Leonards (south end) and Half Moon Bay (*low to moderate variability*)
- Dromana-McCrae, Blairgowrie, Wrathalls Reserve (*moderate to high variability*)
- Sandringham (*high to very high variability*)

Time series plots comparing across all sites are displayed for drone surveys (Fig. 4.3, top) and satellite shoreline (Fig. 4.3, bottom). For both panels, the site as a whole is shown as a black dash-dot line, while the nourishment location(s) are shaded blue/red (see Fig. 4.1 yellow boxes for nourishment locations). These figures indicate:

- Recent nourishments at Dromana-McCrae and Anderson Reserve are clearly apparent (Fig. 4.3, top), increasing beach width by 5 to 8 m. With no erosion of the nourishment apparent yet at either site (this will be expected over coming surveys).
- Blairgowrie, Dromana-McCrae and Sandringham all accreted over the 1988 – 2018 period. For Sandringham in particular, the nourishment site accreted faster than the embayment as a whole.
- Anderson Reserve and St Leonard nourishment zones experienced erosion through the 2000's, with some recovery over recent years.

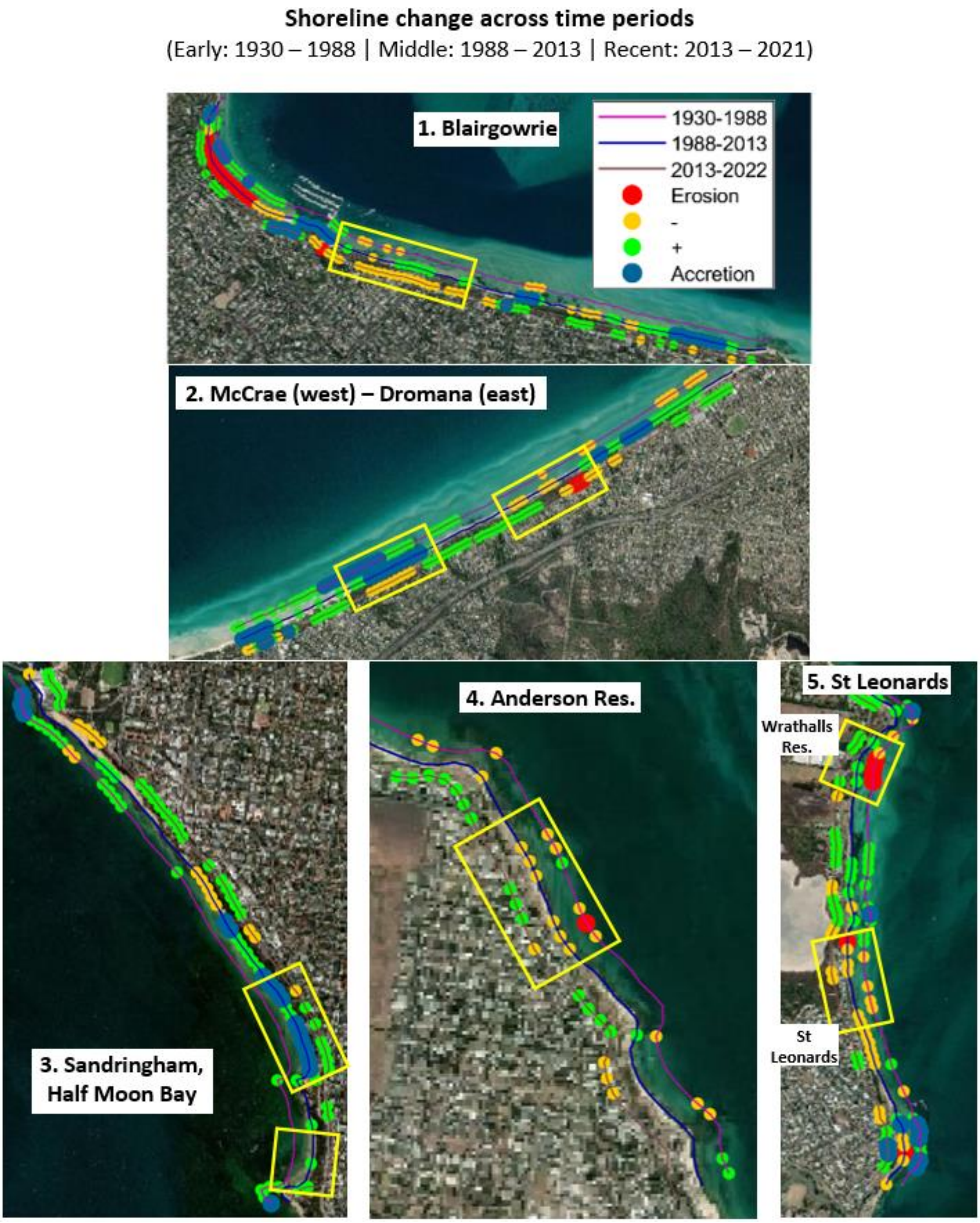


Fig. 4.1. Historical shoreline change across five nourishment monitoring sites, for 'early period' (1930 – 1988) , 'middle period' (1988 – 2013), and 'recent period' (2013 – 2022) periods. For the long- and medium term, high rate of erosion/accretion (red/blue dots) are >0.5 m/yr movement; for short-term high erosion/accretion dots are > 2 m/yr.

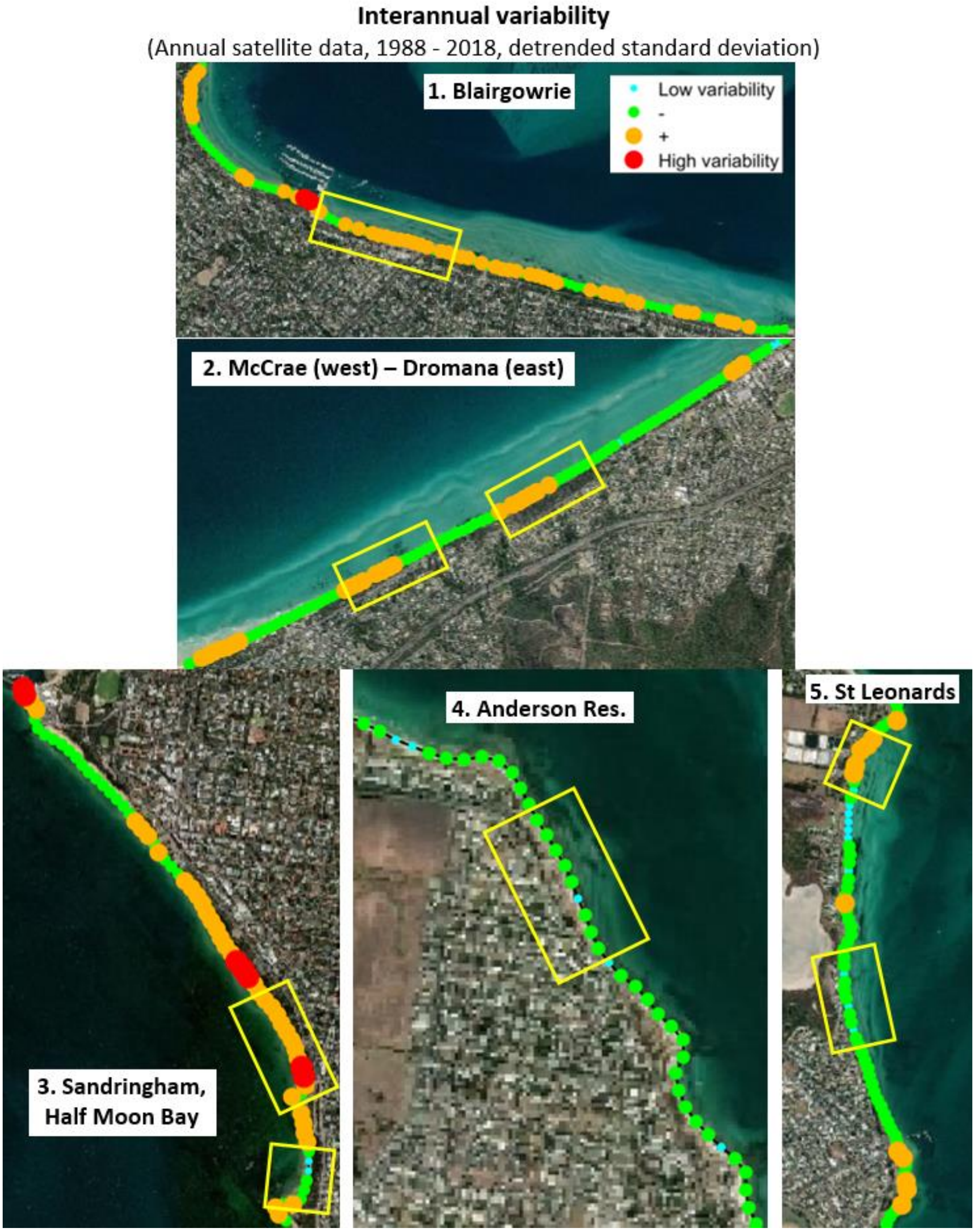


Fig. 4.2. Shoreline variability across the five sites, showing the detrended standard deviation (m) for annual DEA shorelines. Colour coding: Blue, <2 m; green, 2 to 4 m; orange, 4 to 8 m; and red, >8 m.

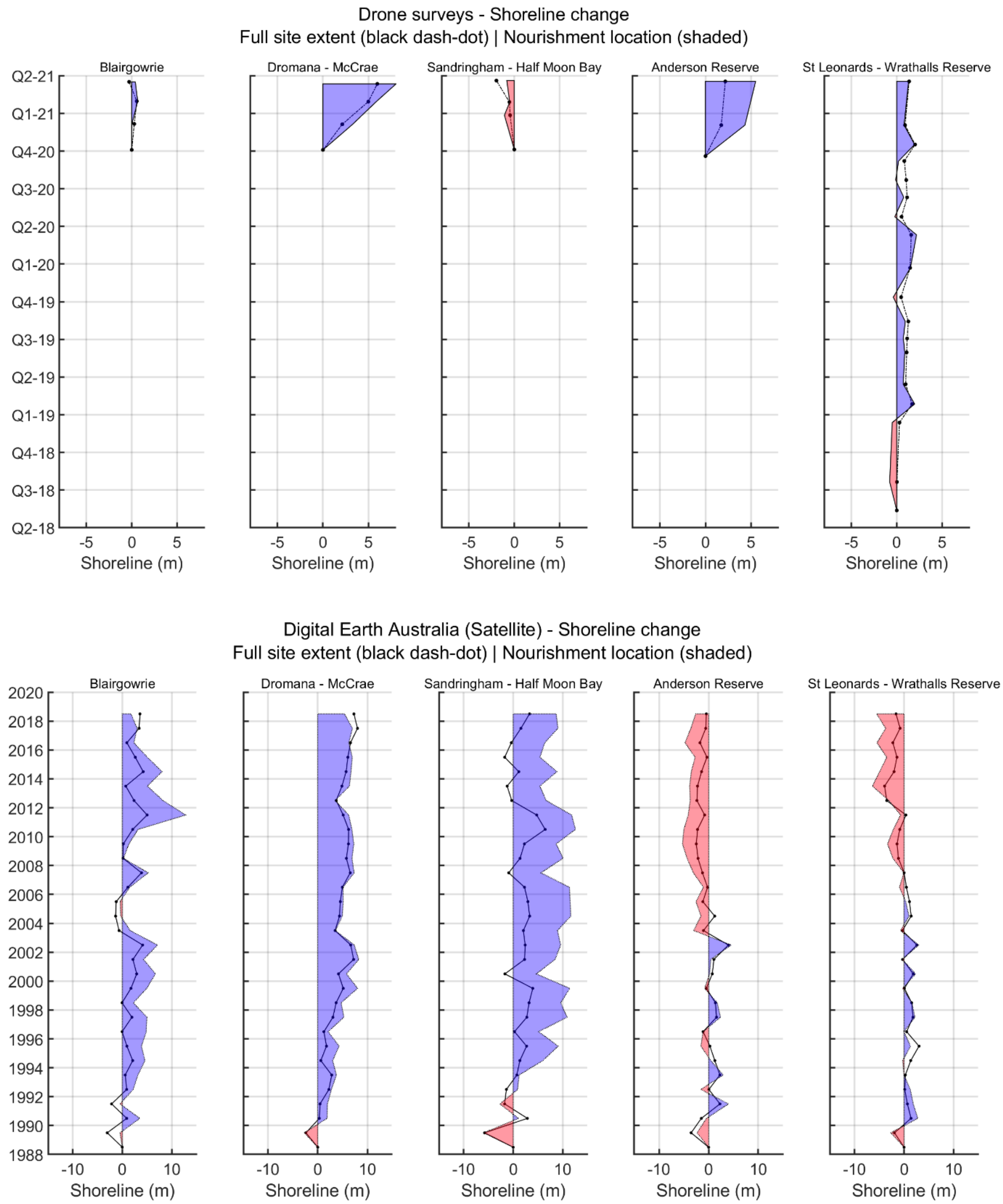


Fig. 4.3. Shoreline time series for drone surveys (top) and satellite shorelines (bottom). For all panels, shoreline averaged across the full site is shown as a black dash-dot line, and nourishment location (see Fig. 4.1, yellow boxes) mean shoreline is shown as shaded red/blue.

The spatio-temporal shoreline trends shown in Fig. 4.1 – 4.3 are collapsed down to a simple representation of 'long-term vs. short-term trends' in Fig. 4.4, comparing the trend across the full site, to just the nourishment location. In this instance, 'long-term' is 1988 – 2018; and 'short-term' is 2013 – 2018

- Sandringham has experienced a steady accretive trend.
- Dromana-McCrae and Blairgowrie have seen steady accretion across the full site, but both have short-term erosion around the nourishment sites. Blairgowrie in particular.
- Both Anderson Reserve and St Leonards have a long-term erosion trend, which is worse at the nourishment locations than the site as a whole. However, both sites have recently seen a neutral to slightly accretive trend (compare with Fig. 4.3).
- Interestingly, none of the sites have experienced 'chronic erosion' (defined here as a negative short- and long-term trend, plotted to the bottom-left of Fig 4.4).

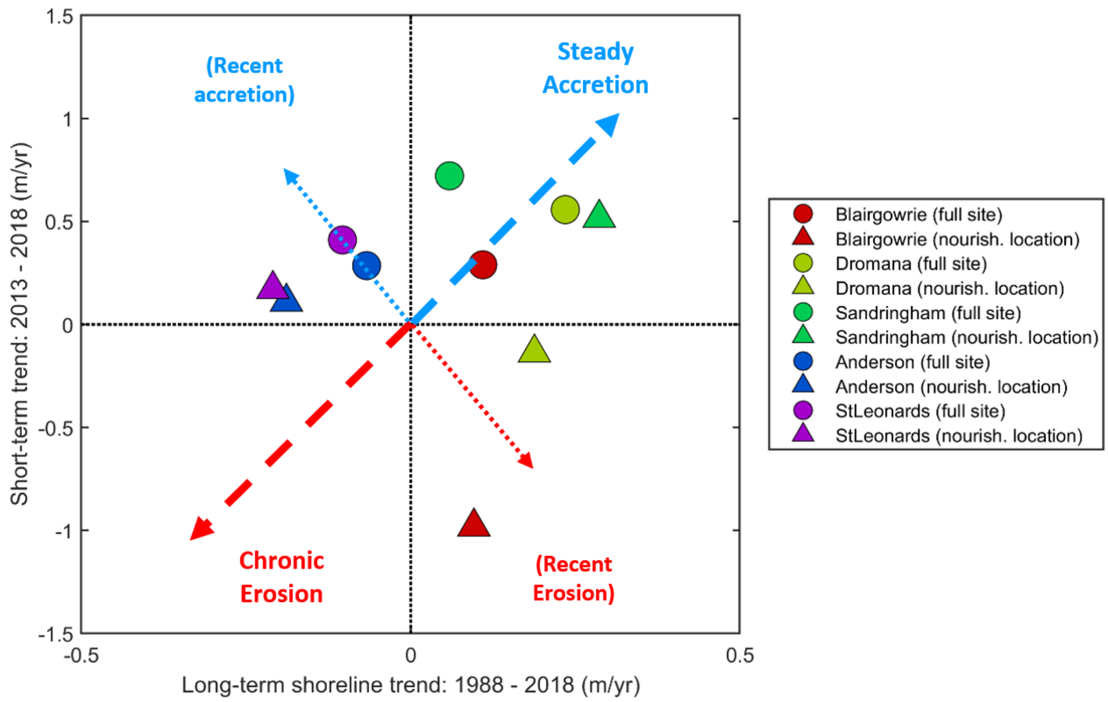


Fig. 4.4. Short-term vs. long-term trends using Digital Earth Australia annual satellite shorelines. Note: 'Dromana' in legend is Dromana-McCrae.

PART 5: INSIGHTS FOR THE NOURISHMENT PLANNING PROCESS

This section uses the site analysis (Section 3 and 4) to demonstrate how data can be used to inform planning and implementing nourishments.

The steps of the planning process are numbered below. Some aspects are similar to the Cardno (2019) approach and/or may be currently included in DEECA practices, though these may require more formalisation to establish the practice.

- 5.0. Preliminary site selection
- 5.1. Site assessment: reasons to nourish
- 5.2. Nourishment goal (restore, maintain, grow)
- 5.3. Coastal processes: Wave, tides, shoreline change
- 5.4. Past performance of nourishments
- 5.5. Expected performance of proposed nourishment
- 5.6. Summary assessment, final site selection

See the following Sections 5.0 to 5.6 for a detailed description of each step in the process.

Many nourishments occur as part of combined soft- and hard-intervention approach, e.g., groynes and nourishment. The complexities of this combined approach are only dealt with briefly, and require further attention.

Note: *The tables introduced below as part of the planning process are examples only. In most cases only some of the monitoring / nourishment sites have been included. In all instances, the process requires discussion and revision before being applied to select additional nourishment sites.*

5.0 Preliminary site selection

The nourishment process begins with a preliminary selection of a large number of sites, which are subsequently narrowed down to the final list through the following steps (Sec. 5.1 – 5.6). This report does not deal extensively with preliminary site selection as this will be the subject of future work. However, some comments on choosing future sites is given in Sec. 6.2.

5.1 Site assessment: Reasons to nourish

For a proposed nourishment site, reasons / needs for nourishment can be summarised as:

- Infrastructure protection:
  - DEECA controlled: High priority, varies with asset importance.
  - Private and non-DEECA public: Generally low-priority.
- Vegetation protection: Varies, can be high priority, e.g., large trees at risk of falling due to erosion, represent a loss of amenity and potential hazard.
- Habitat protection: Can be high priority, for specific sites.
- Beach amenity: Can be high priority, not necessarily related to 'natural' coastal processes, e.g., a beach that is naturally very narrow and prone to erosion may be targeted for widening to provide a bathing area for the public.
- Protection of existing coastal structures: This is initially counter-intuitive, as the thought is that a seawall or revetment should be targeted for repair or removal, rather than temporary protection by a nourishment. However, structure protection may have a motivation for some nourishments in the past, and should be further discussed as to how it should be weighted in future.

For each proposed site, a low/moderate/high ranking for each need, as indicated in Table 5.1.

Table 5.1. Needs / reasons to nourish

		Blairgowrie	***Dromana***	***McCrae***	***Sandringham***	***Half Moon Bay***
5.1. Need/reason to nourish						
Infrastructure protection	*Public*	High	Low (?)	Mod - High	Low	Low-Mod
	Private	Med	High (?)	Low	Low	Low
Vegetation protection		High	Mod	High	Low-Mod	Low-Mod
Habitat protection		??	??	??	??	??
Beach amenity		High	Mod - High	High	Mod	Mod
Coastal structure protection		Low	Low - Mod	Low	Low	Low - Mod

5.2 Nourishment goal

For each site, state whether the aim of the nourishment is intended to:

1. **Restore** an eroded shoreline to a previous level (e.g., the beach has been entirely eroded, or is much narrower than at a known point in the past)
2. **Maintain** beach width for a shoreline undergoing ongoing chronic erosion (e.g., as part of a regular nourishment program)
3. **Widen** the beach compared to past levels (e.g., the beach width may have been relatively stable, but a wider beach is desired)

If uncertain, use a range, e.g., "1 – 2" and "2 – 3". An example is given in Table 5.2.

Table 5.2. Shoreline nourishment goal

	Blairgowrie	*Dromana*	*McCrae*	*Sandringham*	*Half Moon Bay*	*Anderson Res.*	*St Leonards*
5.2. Shoreline goal	Restore	Restore - Maintain	Maintain - Grow	Maintain	Maintain - Grow	Restore	Maintain

5.3 Coastal processes assessment I: Waves, tides, shorelines

An assessment of coastal processes for each site should be conducted. Section 3 provides relatively detailed examples for five PPB sites. Producing a detail coastaled hazards assessment requires a degree of expertise and can be time consuming, Section 6 discusses how DEECA could handle such site assessments in future.

At a minimum, the coastal processes assessment should include:

- Waves: Mean wave climate statistics, extreme events, seasonality.
- Tides: Tidal range, extreme water levels.
- Site specific forcing processes: Include if relevant, e.g., inlets/river mouths or wind-driven dune processes.
- Shoreline and/or beach width trends: These are critical for establishing a history of erosion, which is often difficult to demonstrate on narrow estuarine beaches, and is often left out of consultant assessments.
    - This report (Section 4) gives SHORT / MEDIUM / LONG-TERM shoreline change estimates, which can provide context when decided on whether to nourish a site.
- Shoreline variability:
    - Storm demand (cross-shore).
    - Seasonal to inter-annual rotation (alongshore).

Table 5.3 provides an example coastal processes summary for a selection of the test sites.

Table 5.3. Coastal processes

4.3. Processes and setting	***Blairgowrie***	***Dromana***	***McCrae***	***Sandringham***	***Half Moon Bay***
Geomorphology					
Sediment size / type	Medium sand	Medium sand	Medium sand	Med-Coarse sand	Med-Coarse sand
Beach width	0 - 8 m	10 - 15 m	10 - 15 m	0 - 10 m	5 - 15 m
Backshore composition	Low dune (w/ trees), seawall	Low foredune (trees), partial seawall	Low, wide foredune (trees)	Steep bluff / cliffs	Steep bluff / cliffs
Wave climate					
Wave height	0.2 m	0.3 m	0.3 m	0.2 - 0.3 m	0.2 - 0.3 m
Height seasonality	Winter	Winter	Winter	Winter	Winter
Peak period	2.3 s	2.3 s	2.3 s	2.2 s	2.2 s
Direction (annual avg.)	NNW	NW	NW	WSW	WSW
Direction (summer)	N - NNW	W	W	SW	SW
Direction (winter)	W - N - E	NW - N	NW - N	Mix SW + NW	Mix SW + NW
Longshore drift					
Net drift	E	E	E	near balanced	N
Summer	(E, very weak)	E	E	N	N (strong)
Winter	E	E	E	S	N (weak)
Flux blocks (headlands/groynes etc)	Multi- groynes	?	Groyne field	Groyne (N), headland (S)	Pocket beach, headlands
Historical shoreline trends					
Long term (>50 years)	3 - stable	3 - stable	2 - accreting	3 - stable	3 - stable
Medium term (1988 - present)	2 - accreting	3 stable	1 - rapid accretion	1 - rapid accretion	3 - stable
Short term (2013 - present)	4 - eroding	4 - eroding	4 - eroding	2 - accreting	3 - stable
Shoreline variability					
Seasonal rotation	Mod	Weak	Weak	Strong	Mod (?)
Interannual variability	Mod-High	Mod - High	Low - Mod	High	Mod (?)
Storm demand	Low	Low	Low	Low	Low
Structures					
Seawall / revetment	Partial	Partial	Partial	Partial	Partial
Groynes	Y (wooden, some broken)	N (?)	Y (wooden groynes)	Y (rock groynes to north)	N

5.4 Past nourishment performance

Regarding the history of nourishments at the site, provide as much detail as is available:

- Are there past nourishments at the site on record? What were the dates? If dates are unknown, provide a best estimate.
- What were the locations and volumes of past nourishments?
- Are detailed monitoring data available? (e.g., pre- and post-nourishment drone surveys).
- What was the immediate increase in beach width due to the nourishment? Give volume increase per metre alongshore if possible.

Note that for any nourishment where dates are known, some degree of shoreline and nourishment longevity analysis can be made based on aerial and satellite data.

Based on the available data and analysis:

- What was the shoreline change trend before and after previous nourishments?
- What was the cross-shore equilibration rate shortly after the nourishment? This is the process of cross-shore adjustment as a steep placement profile is rapidly slumped by the first storms after the initial placement. If possible, provide shoreline position (and volume if available), for:
    - Pre-nourishment.
    - Immediately post-nourishment.
    - 3-months (approx.) post-nourishment (or whenever survey data are available).
- How long did it take for the shoreline to return to pre-nourishment position? (i.e., nourishment longevity).

An example assessment of past nourishment performance is given in Table 5.4.

Table 5.4. Past nourishment performance

		Units / scale	Site
5.4. Past nourishment performance			Blairgowrie
Have previous nourishments been conducted?		Y / N / ??	Y
Years conducted		(List years if known)	~2010
Alongshore extent		m	??
Volume	Total	m^3	??
	Per metre	m^3/m alongshore	??
Equilibration %		% Width or volume lost soon after nourishment	??
Shoreline trend pre-nourish		m/yr	- 0.5 to -1 m/yr
Shoreline trend post-nourish		m/yr	- 1 to -2 m/yr
Lifetime (before re-nourish position reached)		Years (use "<" and ">" to approximate if needed)	~ 10 years

5.5 Expected nourishment performance

It is important that we set benchmarks on what we expect to achieve with nourishments, this allows DEECA to objectively assess the performance of a nourishment in the years after it has been conducted, these can be refined over time. For public communication, given the large uncertainty around nourishment lifetimes, it is suggested that a maximum lifetime of 5 years is cited. More discussion on this point is given in Section 6.3.

5.5.1 Watch points

Extra care should be taken to assess the expected performance of nourishments where the forcing controls are more complex, these includes, but are not limited to:

Seasonal rotation: Nourishments near headlands and groynes

- Many beaches in PPB experience ‘rotation’, where seasonal changes in the wind and wave direction push sand alongshore in one direction in winter, and the opposite direction in summer.
- This effect can be most pronounced at the alongshore end-points of sediment compartments, adjacent to headlands or groynes, resulting in these sections of the beach being entirely eroded back to the seawall or cliff face on a seasonal or multi-annual basis (e.g., south Sandringham and around the new groynes at Anderson Reserve).
- Nourishments placed in these regions may be moved rapidly alongshore away from the initial placement location, due to the seasonal shifts, giving the false impression the nourishment has ‘failed’. In reality, as long as the nourishment volume remains within the sediment compartment, it will continue to provide a benefit. I.e., the beach within the compartment

will be wider on average, notwithstanding the seasonal shifts in beach width on a seasonal basis.

Inlets and river-mouths

- Inlets are associated with additional sediment fluxes due to interacting wave, river and tidal processes.
    - Sediment transfers may occur between flood- and ebb-tide deltas and adjacent beaches (e.g., Inverloch).
    - Stream flows may directly erode dunes or areas of the beach proximal to the channel e.g., Wye River).
    - Streams may change course, rapidly modifying the beach morphology (e.g., Wye River).
- These processes can be highly variable, of large magnitude and hard to predict, making estimates of nourishment performance more uncertain.
- The rivers within PPB are less energetic, though caution should still be applied (e.g., Patterson River).

An example assessment of expected nourishment performance is given in Table 5.5.

Table 5.5. Predicted nourishment performance

		Units / Scale	Site
5.5. Predicted nourishment performance			Blairgowrie
Date planned		(Date)	Late 2021 - 2022
Location(s)		(Transect IDs)	P542 - 562
Alongshore length		m	1,000 m
Volume	Total	m^3	??
	per metre	m^3/m alongshore	??
Predicted lifetime (before re-nourish position reached)	(Assume 5-yr lifetime if no data exists)	years	5 - 10 years
Beach width	Pre-nourish	m	0 - 5 m
	Post-nourish	m	30 m (?)
	3-months post	m	15 m (?)
	1-year post	m	5 - 15 m
	5-years post	m	0 - 10 m
Shoreline trend	Pre-nourish	m/yr	- 1 to 2 m/yr
	Equilibration %	% Lost in first 3 months (width or volume)	50%
	Post-nourish	m/yr	- 1 to 2 m/yr

5.6 Summary assessment, final site selection

Some form of summary quantitative rating is required to aid in decision making. This should be informed by the previous summary tables (Sec. 5.1 – 5.5). Table 5.6 provides a draft rating scale and example assessments for three of the test sites. *This is a draft rating scale, it requires discussion prior to further development.*

Table 5.6. Summary site assessment

		Sites		
5.6. Summary assessment	**Scale**	***Blairgowrie***	***Dromana***	***McCrae***
Urgency	4 - Imminent hazard (<5 years) and or severe consequence (major asset loss) 3 - Short-term hazard if no action taken (<10 years) 2 - Hazard may occur in the medium term (> 10 years) 1 - Hazard may occur at over the long-term 0 - Hazard unlikely / not a reason for the nourishment	4	3	2
Importance - to DEECA goals and community	2 - High 1 - Medium 0 - Low	2	1	1
Importance - to nourishment research program	2 - High 1 - Medium 0 - Low	2	2	2
SUMMARY SCORE (Total of above 3 ratings)	**(MIN = 0 ---> MAX = 8)**	**8**	**6**	**5**

PART 6: GUIDELINES, GENERAL ISSUES, AND RECOMMENDATIONS

6.1 Nourishment monitoring program: Issues and recommendations

The section provides brief thoughts on how nourishments have been conducted in PPB in the past, the present, and how the process may be improved in future.

6.1.1. THE PAST - How has nourishment monitoring been handled in PPB in the past? What data are available?

- Ad-hoc surveys have been conducted by consultants, generally before and after nourishments.
- No centralised effort has been made at data curation (prior to the VCMP).
- As a consequence, many past nourishments have no recoverable record.
- Sam Monkiewicz in June 2021 assembled all past data into a single folder. Access to this folder is currently limited to a shared One Drive folder (see “Shared network drive” below).
- Cardno (2019), Nourishment Planning Report, drone data: Cardno was engaged to conduct a bay-wide assessment of potential nourishments. Over 20 drone site surveys were conducted. This data may be available within the VCMP but has not been analysed.

6.1.2. THE PRESENT - How is monitoring being handled currently in PPB?

- Nourishment contracting: Contractors are engaged to conduct nourishments, often with pre- and post-nourishment surveys.
    - There is still no formalised process to obtain contractor survey data and curate it within DEECA.
- VCMP monitoring:
    - The VCMP began drone surveys at PPB sites in 2018 and expanded in late 2020.
    - Approx. 10 sites are currently surveyed on a regular basis (every 6 – 8 weeks), surveys at some sites are more infrequent.
    - Covering proposed nourishment sites was a consideration for choosing new PPB VCMP drone sites, but this was not the only consideration
- Ad-hoc VCMP surveys:
    - Ad-hoc VCMP surveys are conducted at additional sites based on non-formalised communications between the VCMP and project teams (e.g., Hannah Fallon for 2020-21 Bellarine nourishments).
- Without a formal process or policy between the Coastal Programs and the VCMP on how / when / where nourishment monitoring should be conducted, there is a greater chance for sub-optimal outcomes (e.g., a nourishment being placed before an adequate survey can be conducted).

6.1.3. THE FUTURE - Recommendations for nourishment monitoring program

Data curation (including CoastKit)

- Collecting monitoring data and curating the collected data are separate tasks, in terms of both the skills and resources required, therefore these areas (monitoring and data curation) should be managed and budgeted separately.

- Data curation and management is required so that data are easily accessible for present and future usage, by users both within and outside DEECA.
  - Much of the (hard-earned and expensive) data collected in the past cannot be made use of due to a lack of data curation.
  - Data curation can be led by the VCMP, but requires cooperation with the Coastal Programs teams.
- **CoastKit:** Selected datasets are progressively being made available through CoastKit, by Trent Hobley.
  - Data for the five test sites (Blairgowrie, Dromana-McCrae, Sandringham, Anderson Reserve and St Leonards) assessed in this report have been uploaded to CoastKit (available publicly as of Aug 2021).
  - Additional sites will be added over coming months.
  - Data on CoastKit include:
    - Multi-method shorelines (drone survey, satellite, aerial imagery).
    - Shoreline change trends.
    - Cross-shore profiles.
    - Wave buoy data.
    - Hindcast model wave and water level data (to be included in a future update).

Review of survey methodology (e.g., drone, ground-based, bathymetric surveys)

- At present, there is dominance of drone surveys. Often this is the only survey method used for a given site.
- There are major limitations to doing “drone-only” surveys, including:
  - No bathymetry, only the sub-aerial beach is surveyed. Without a survey of the full active profile, it is impossible to fully gauge nourishment performance, a lot of the action goes on below the surface.
  - No ground-truthing. Drones data are remotely sensed, and prone to various types of errors, such as around the water line or vegetation. It is important to have ground-based data to compare against.
- A comprehensive nourishment monitoring program should include a mix of:
  - Drone surveys (this may remain the dominant survey method)
  - Combined walked-topography profiles and single-beam bathymetry profiles (multi-beam is problematic in the bay). This is the method being trialled at Sandringham.
  - Fixed and/or mobile camera observations.

- Potential changes to nourishment monitoring methods can be discussed in relation to modification to the VCMP as a whole. More comprehensive data (bathymetric data in particular) will ultimately lead to a better understanding of nourishment behaviour.
- Data will continue to be collected across a variety of surveying groups and methods, including though not limited to:
  - VCMP “Science Team” and “Citizen Science” groups
  - Contracted drone surveys (e.g., Cardno in 2019)
  - Multi- and single-beam bathymetry, by contractors and Deakin University.
  - Satellite shoreline data.
- No preference is expressed for a particular method, as long as the data quality can be demonstrated.

- Regardless of the method and the team collecting the data, it is recommended that data synthesis and curation is conducted within DEECA. The risk of not doing this is that data is lost, or if retained, is in a format that is not of practical use, and cannot be used in future analysis.

Setup of a shared network drive

- A common network drive (e.g., a NAS drive) accessible to the parties involved in nourishments would make it much easier to share data, and facilitate workflow between Coastal Programs and the VCMP.

Formalisation of monitoring requirements

- It is recommended to formalise the standard monitoring requirements for all nourishments, including the procedures between the VCMP and Coastal Programs, for example:
  - Mandatory pre- and post-nourishment surveys.
  - Follow-up surveys (3-month, 6-month, then annual for 5-years?).
  - Data must be processed to a given standard.
  - Data must be saved / uploaded to specified locations.

6.2 Choosing future nourishment sites: Recommendations

Selecting future sites will be the basis of an upcoming report, brief thoughts to inform this future work are given below.

We are in a 'testing phase'

The current program should be considered a test-phase, every site selected during this phase acts as a test case to inform future nourishments. This should influence how we plan and discuss nourishments, both within DEECA and to stakeholders:

- Nourishment longevity should not be considered in terms of 'success' or 'failure', e.g., if a site is nourished and the shoreline returns to the pre-nourishment position within a single year, this is still useful data.
- Rather, our measure of success during this phase should be: Have we effectively monitored the nourishment over its lifetime, and used this to inform future nourishments at this, or similar, sites?
- As long as we do not intervene at a site in ways that actively draw a negative response from the community, then any given nourishment, if properly monitored, serves a purpose.

Watch points / Where to exercise caution

Below is a non-exhaustive list of issues that may complicate the planning, design, and performance of individual nourishments.

- For any nourishment project that also involves groynes, or other cross-shore structures that impede longshore drift:
  - How is the nourishment expected to interact with the cross-shore structures?
  - Have implications for narrowing of the down-drift shoreline been adequately considered?
- Seasonal and interannual variability:

  - Does the site experience seasonal changes in wind and wave direction?
  - Has seasonal rotation been quantified?
  - Has beach width varied substantially in the past over periods of a few years?
- Is the nourishment site near a river or inlet?
  - Has the impact of the river or inlet on nourishment performance been adequately assessed?

PART 7: SUMMARY AND CONCLUSIONS

Prior to the commencement of the VCMP in 2018, no centralised effort was made to monitor Victoria beaches, either open coast or estuarine. In particular, no concerted effort had been undertaken to study the dynamics of beach nourishments within PPB.

The goal of this report was to provide a first-pass assessment of beach nourishments within PPB, in order to understand nourishment dynamics, and assist in choosing future nourishment sites. Data are analysed from the VCMP as well as other sources, such as satellite and aerial imagery.

Conclusions and recommendations from the report include:

- The 5 selected sites cover a wide range of morphology and wave conditions found across PPB, shoreline trends across the sites included areas of short-term erosion, in particular around zones targeted for nourishment, while other sites were found to be accreting.
- Historical nourishment volumes were found to comprise only a small proportion of the sediment budget for each compartment, indicating that areas of concern are mostly localised hotspots, that can continue to be nourished with relatively small volumes, into the medium term.
- Short-term variability, including seasonal rotation was found to be an important factor in choosing and designing nourishments at some sites (e.g., Sandringham).
- None of the sites were found to be chronically eroding.
- A draft 7-step process for site selection was proposed.
- Risk of an erosion hazard to infrastructure was ***not*** a necessary factor for determining current beach nourishment targets. Other reasons to nourish may include:
    - Maintaining or increasing beach amenity, by widening the beach.
    - Protecting vegetation, including large trees, from erosion.
    - Protecting aging / failing coastal protection structures, such as seawalls (this needs further examination).
- It is recommended that nourishment monitoring procedures between the Statewide Coastal Programs group and the VCMP are formalised (e.g., mandatory pre- / post-nourishment surveys).
- Modifications to the VCMP methodology may be required (e.g., more bathymetric surveys) and are currently being developed.

Selecting future sites will be the basis of an upcoming report. It must be emphasised that DEECA is in a 'testing phase'. Every site selected during this phase acts as a test case to inform future nourishments. This should influence how nourishments are planned and discussed, both within DEECA and to stakeholders:

- Nourishment longevity should not be considered in terms of 'success' or 'failure', e.g., if a site is nourished and the shoreline returns to the pre-nourishment position within a single year, this is still useful data.
- Rather, a measure of success during this phase should be: Have DEECA effectively monitored the nourishment over its lifetime, and used this to inform future nourishments at this, or similar, sites?
- As long as DEECA does not intervene at a site in ways that actively draw a negative response from the community, then any given nourishment, if properly monitored, serves a purpose.

This report must be considered a preliminary assessment given that 2020-21 nourishment activities were still in progress at the time of writing. A follow-up report is required once this round is complete, in addition to an assessment of potential new sites for the next round in 2022 and beyond.

REFERENCES

Allemand, J., Keysers, J., Quadros, N. & Deen, R. (2017). 2017 Victorian Coastal DEM Report. Internal report available on the DEECA NAS (../Marine/_Bathy-VCDEM 2017 – 14 July 2017/VicCoastal_DEM_Report_FINAL_July_2017.docx).

Bird, E. (2011) Changes on the Coastline of Port Phillip Bay. Office of the Environmental Monitor, State Government Victoria.

Bishop-Taylor, R., Sagar, S., Lymburner, L., & Beaman, R. J. (2019a). Between the tides: Modelling the elevation of Australia's exposed intertidal zone at continental scale. Estuarine, Coastal and Shelf Science, 223, 115-128. Available: https://doi.org/10.1016/j.ecss.2019.03.006

Bishop-Taylor, R., Sagar, S., Lymburner, L., Alam, I., & Sixsmith, J. (2019b). Sub-pixel waterline extraction: Characterising accuracy and sensitivity to indices and spectra. Remote Sensing, 11(24), 2984. Available: https://doi.org/10.3390/rs11242984

Cardno (2018). "Managing Better Now". A series of 5 reports for the Association of Bayside Municipalities (ABM), available on the DEECA CoastKit NAS drive.

Cardno (2019). "Beach Nourishment Priorities in Port Phillip, 2018/19 to 2022/23". Prepared for DEECA. Available on the DEECA CoastKit NAS drive.

Holdgate, G. R., Geurin, B., Wallace, M. W., & Gallagher, S. J. (2001). Marine geology of Port Phillip, Victoria. Australian Journal of Earth Sciences, 48(3), 439-455.

McCarroll, R. J., Masselink, G., Valiente, N. G., Scott, T., Wiggins, M., Kirby, J. A., & Davidson, M. (2021). A rules-based shoreface translation and sediment budgeting tool for estimating coastal change: ShoreTrans. Marine Geology, 106466.

Van Rijn, L. C. (2014). A simple general expression for longshore transport of sand, gravel and shingle. Coastal Engineering, 90, 23-39.

Vos, K., Splinter, K. D., Harley, M. D., Simmons, J. A., & Turner, I. L. (2019a). CoastSat: A Google Earth Engine-enabled Python toolkit to extract shorelines from publicly available satellite imagery. Environmental Modelling & Software, 122, 104528.

Vos, K., Harley, M. D., Splinter, K. D., Simmons, J. A., & Turner, I. L. (2019b). Sub-annual to multi-decadal shoreline variability from publicly available satellite imagery. Coastal Engineering, 150, 160-174.

APPENDIX 1: SUMMARY COMMENTS FOR NOURISHMENT SITES

This appendix contains a copy of the summary questions from the end of each site from Section 3.

1. Blairgowrie

1. What are the goal(s) of nourishing this site?

- The road is close to the beach (~15 m at narrowest), nourishing would provide a greater buffer to the road.
- Infrastructure built on the dune (e.g., a public toilet) may also be protected.
- Is beach amenity a consideration?

2. What is the sediment budget for the site?

- The site as a whole has been marginally accreting over the medium term (+1,600 m^3/yr; 1988 – 2018).
- None of the accretion can be attributed to known nourishments (2010 and 2013), as these have only redistributed sand within the compartment, from the marina salient to adjacent areas, without adding anything.
- The localised area around the nourishment target has been rapidly eroding in recent years (-1 m/yr).

3. Is nourishment required to prevent an imminent hazard occurring?

- At BLR-01 (P552, Fig. 3.1.5), yes, but the road is not at immediate risk. Nourishment is required in the short-term (<10 years) to reduce the erosion risk to large trees, which could present a significant hazard.
- At BLR-02 (P559, Fig. 3.1.5), yes. Pt Nepean Rd just east of St Johns Wood Rd (Fig. 3.1.5, P559) could be directly impacted by erosion within 6 years.

4. How have previous nourishments performed?

- A large nourishment (unknown volume) appears to have been placed around P552 in 2010-2011. The shoreline has eroded steadily since that time at 1 – 2 m/yr. The nourishment lifetime is therefore on the order of 10 years.
- This 2010-2011 Blairgowrie nourishment could be a useful target for future research.

5. What alternative coastal management options exist?

- Medium-term options (beyond this nourishment cycle)
    - Nourishment: The sediment budget deficit could be filled with a ~45,000 m^3 nourishment every 10 years (if extending several decades, there is also a need to account for SLR).
    - Groynes:
        - (Re-) installing groynes will retain more sediment with this zone (reducing or eliminating the deficit).
        - Groynes will displace the sediment budget deficit downdrift; however, the region immediately downdrift is protected by a seawall.
        - Re-moving groynes updrift (west) of the erosion sites would reduce the deficit for the currently eroding sites (but would potentially create a problem for the updrift sites).
    - Extend seawall: The seawall at the beginning at Revell St could be extended westward.

2. Dromana-McCrae

McCrae

1. What are the goal(s) of nourishing this site?

- The only piece of infrastructure at risk appears to be the car park.
- The goal in this instance may be to maintain a wide beach for public amenity and protect the vegetation.

2. What is the sediment budget for the site?

- The area is stable to accreting over the long-term but has experienced recent moderate erosion around the nourishment locations.

3. Is nourishment required to prevent an imminent hazard occurring?

- If the recent trend continued (without the present nourishment), the front edge of the carpark may have been at risk of erosion within ~10 years.
- If the site had not already been nourished, it would have been reasonable to continue monitoring the site without urgent need of nourishment, given the moderate rate of recent erosion.

4. How have previous nourishments performed?

- Unknown.

Dromana

1. What are the goal(s) of nourishing this site?

- The goal appears to be to protect infrastructure built on the foredune which is at risk of erosion based on the recent rapid erosion trend. The buildings appear to be private dwellings. Some of the infrastructure may be public and the responsibility of DEECA (unknown).

2. What is the sediment budget for the site?

- The budget is fairly stable over the long-term but with a period of rapid recession from 2013 – 2021 (>12 m). The cause of this recent phase of erosion is unknown.

3. Is nourishment required to prevent an imminent hazard occurring?

- Some of the dwellings on the foredune may have been at risk within 10 years if current erosive trends continued without the recent nourishment.

4. How have previous nourishments performed?

- Unknown.

3. Sandringham

South Sandringham (P2060)

1. What are the goal(s) of nourishing this site?

- Possibly, to protect against cliff erosion and the exposure of the road surface landfill.

2. What is the sediment budget for the site?

- The dominant process is seasonal rotation due to shifts in the wave direction.
- Medium-term sediment budget seems relatively stable to slightly accretive.

- The budget has been changed several times due to the introduction, then modification, of the two large groynes. Further work could be done to understand the subtleties of how the balance may have shifted over time.

3. Is nourishment required to prevent an imminent hazard occurring?

- The landfill may present a hazard, and is unsightly.
- Due to the seasonality, nourishment material will be shifted back and forth between the southern groyne and the south Sandringham headland on a seasonal basis, though more sediment will remain in the sub-compartment for a period of a few years.
- The slabs of road surface in the hillside and under the beach may still be at risk of exposure due to these seasonal oscillations.

4. How have previous nourishments performed?

- Unknown.

Half Moon Bay (P2048)

1. What are the goal(s) of nourishing this site?

- Bayside Council requested nourishment of the site after erosion in winter 2020 that led to a steep drop from the main access ramp to the beach and potential undercutting of the seawall, presenting a safety risk.

2. What is the sediment budget for the site?

- Initial drone survey data suggests there is also strong seasonal variability around the south end of Half Moon Bay (i.e., similar to Sandringham).
- No long-term erosive trend is observed in this location, possibly some more recent erosion has occurred, localised around P2048.
- The sediment budget appears balanced. If there has been ongoing renourishment at this site in the past, then that rate of nourishment would need to be continued to maintain the budget.

3. Is nourishment required to prevent an imminent hazard occurring?

- Possibly a path up the hillside may be at risk if this profile were to erode excessively.

4. How have previous nourishments performed?

- Unknown.

4. Anderson Reserve

1. What are the goal(s) of nourishing this site?

- To maintain beach width for amenity.
- To buffer / protect the existing seawall.

2. What is the sediment budget for the site?

- A moderate rate of erosion occurred between approximately 1980 to 2017.
- The periodic complete erosion of the beach (to the seawall) is an indication of large interannual variability, due to fluctuations in the relative strength of the winter and summer winds.
- The beach between the groynes appears to have generally been wider since the introduction of the groynes (but the downdrift beach has been narrower).

3. Is nourishment required to prevent an imminent hazard occurring? Over what time frame is the hazard likely to occur?

- This is not clear. More needs to be known on whether the nourishment is being used to protect the seawall from damage.

4. How has the current nourishment performed?

- Nourishment volumes are being maintained 5 months after the initial nourishment.
- Further monitoring is required after winter to determine volume loss, in order to better estimate nourishment longevity at this location.

5. St Leonards

Wrathalls Reserve:

1. What are the goal(s) of nourishing this site?

- The road is close to the beach (~10 m at narrowest), nourishing would provide a greater buffer to the road.
- A nourishment may protect the wooden path behind the nourishment.
- Beach amenity may be a consideration.

2. What is the sediment budget for the site?

- Erosion has been a problem over the long-term, but recently the profile has been stable.
- Sediment budget is neutral, maintaining the budget (including maintaining any existing nourishment rate) should maintain the shoreline over the medium term (absent SLR).

3. Is nourishment required to prevent an imminent hazard occurring? Over what time frame is the hazard likely to occur?

- There is no imminent danger to the road (within ~10 years).

4. How have previous nourishments performed? What is the short term equilibration shoreline loss?

- Unknown.

St Leonards Northern Beach:

1. What are the goal(s) of nourishing this site?

- The road is close to the beach (~10 m at narrowest), nourishing would provide a greater buffer to the road.
- Protecting the existing wooden retaining wal may be a motivating factor.

2. What is the sediment budget for the site?

- Erosion has been a problem over the long-term, but once the profile receded to the wooden retaining wall (i.e., little to no beach), it has remained stable.
- Sediment budget is neutral, maintaining the budget should maintain the beach over the short to medium term.

3. Is nourishment required to prevent an imminent hazard occurring? Over what time frame is the hazard likely to occur?

- No imminent danger to the road (within ~10 years).

4. How have previous nourishments performed? What is the short term equilibration shoreline loss?

- Unknown.

St Leonards soft cliffs near southern groyne:

1. What are the goal(s) of nourishing this site?

- This site is not a near-term nourishment target, but the site was investigated to see if the eroding cliffs present a hazard.

2. What is the sediment budget for the site?

- A slight erosional trend may be occurring over the medium term (-0.1 m/yr).
- However, the soft cliffs have been very stable over the 3-years of drone monitoring (2018-2021)

3. Is nourishment required to prevent an imminent hazard occurring? Over what time frame is the hazard likely to occur?

- There is no imminent danger to the path (within ~5 years) based on recent trends, but these soft cliffs appear highly erodible and should be monitored.

4. How have previous nourishments performed? What is the short term equilibration shoreline loss?

- Unknown.