City of Wanneroo Coastal Monitoring Report

October 2023

City of Wanneroo

Document Control

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1 Introduction

1.1 Coastal Foreshore Monitoring

A long-term coastal monitoring program has been undertaken by the City of Wanneroo (CoW) since 2014. The purpose of the program is to evaluate the seasonal, annual and long-term trends in erosion and accretion along the City's coastline. This helps to better inform future coastal management measures, identify key areas requiring future management and to provide data for future coastal hazard studies.

At present, the coastal monitoring program involves the acquisition and assessment of the following data sets.

- Biannual manual images taken at 51 beach monitoring sites;
- Hourly automatic photographic monitoring taken at five sites along Quinns Beach and Yanchep;
- 6 monthly LiDAR aerial surveys undertaken across all vulnerable areas;
- Aerial imagery taken across the entire CoW coastline;
- Metocean conditions including:
    - Half-hourly wave data from the Department of Transport (DoT) Rottnest Island Wave Station; and
    - 5-minute water level data from the DoT Fremantle Fishing Boat Harbour Tide Station.

This document outlines the methodology and results obtained from the seasonal and long-term assessments of coastline changes at priority locations along the City's coastline.

1.2 Coastal Structures Monitoring

The City's coastal monitoring program also includes 6 monthly monitoring of coastal structures and includes photographic monitoring of coastal infrastructure assets within the City's vulnerable coastal locations. This is used to capture a photographic record of the assets, identify and address any public safety and minor maintenance requirements and to flag any major structural concerns that may require further detailed investigation.

1.3 Condition Assessments

Each year the City also undertakes detailed condition assessments of each of its nine coastal protection structures. This is undertaken in October each year following the seasonal winter period to identify any structural issues that may have developed over the year.

Additional detailed condition assessments for all other coastal structural assets are undertaken every 5 years by an external structural engineering consultant.

2 Metocean Conditions

Metocean conditions including wave and water level data are assessed as part of the coastal monitoring program. Data is obtained from the following instrumentation managed by the Department of Transport (DoT) and the Bureau of Meteorology (BoM).

- Half-hourly wave data from the DoT Rottnest Island Wave Station; and
- 5-minute water level data from the DoT Fremantle Fishing Boat Harbour Tide Station; and
- Half-hourly wind data from the Ocean Reef Weather Station.

Locations of these instruments are presented in Figure 2-1.

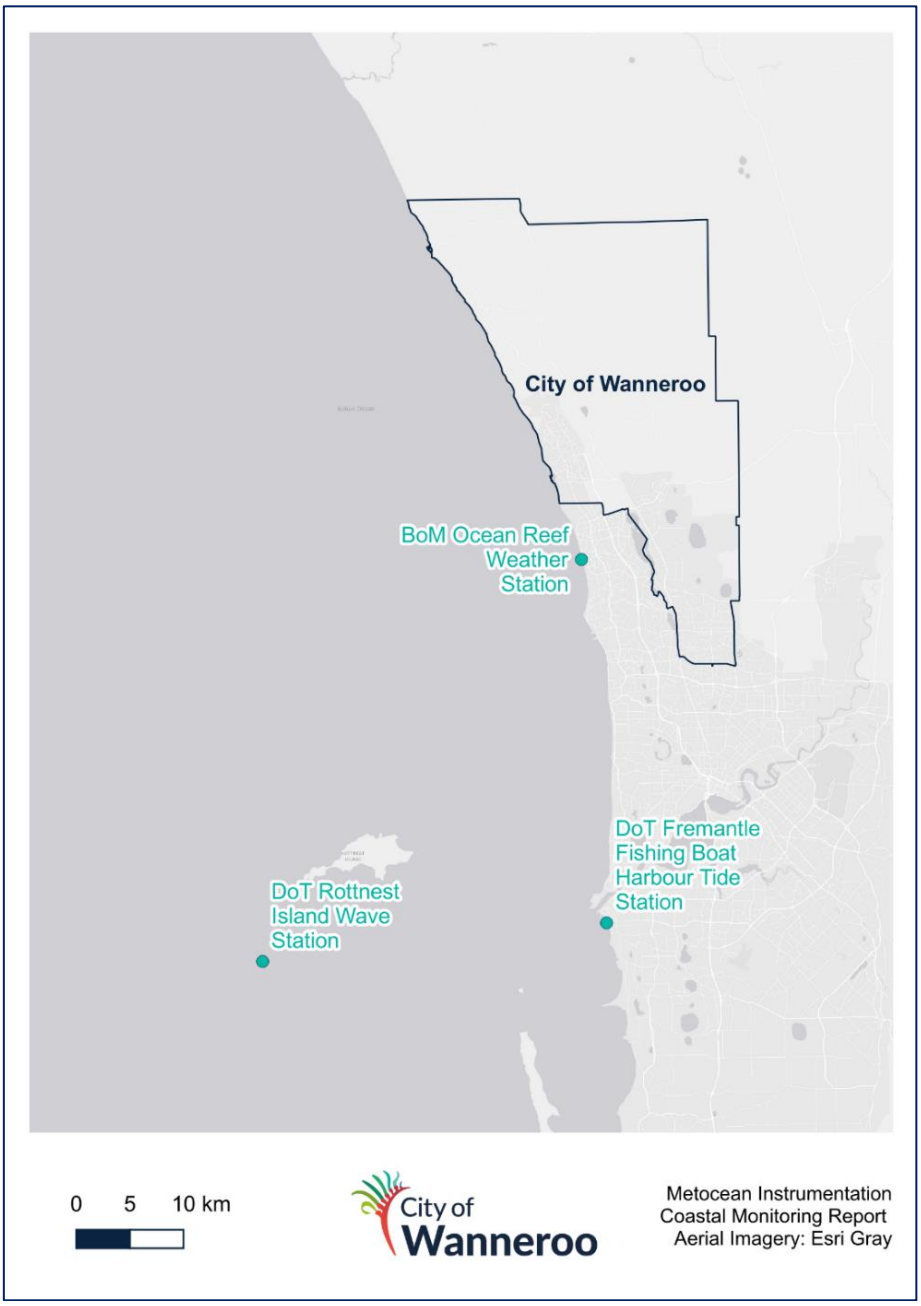


Figure 2-1 Location of Instruments

2.1 Assessment Methodology

The data from these instruments is obtained from the DoT and BoM for the annual monitoring period October 2022 to October 2023. The data is assessed using time series and rose plots where trends and major weather events are analysed.

The metocean conditions at the time of manual photographic monitoring is noted and used to interpret qualitative observations from visual assessments of photo comparison (both seasonal and long term).

2.2 Results

2.2.1 Annual

A time series plot of the total significant wave height (Hs) recorded at the Rottnest Island Wave Station from October 2022 to October 2023 is presented below in Figure 2-2.

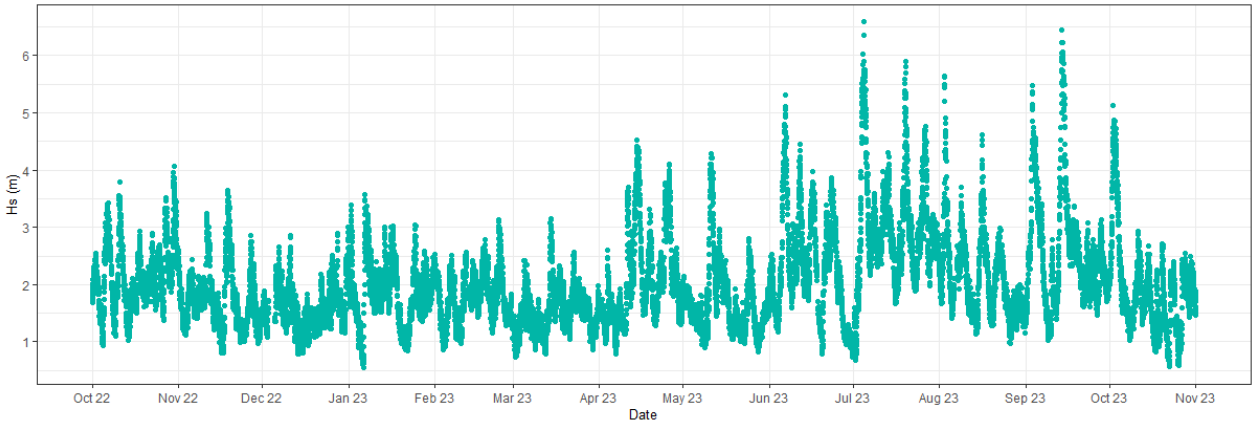


Figure 2-2 Total Significant Wave Height (Hs) recorded at the Rottnest Island Wave Station from October 2022 to October 2023.

The most notable observations from Figure 2-2 are the storm events that were recorded on the 4th of July 2023 and 13th of September 2023. Notably, the conditions of the 2023 winter period were calm relative to recent years, with these storm events resulting in peak significant wave heights of 6.59m and 6.44m respectively. Comparatively, the peak significant wave height for the 2022 winter period was 8.67m which was recorded on the 3rd of August 2022. Calm winter conditions resulted in minimal storm damage and limited coastal erosion as outlined in Sections 3, 4 and 5.

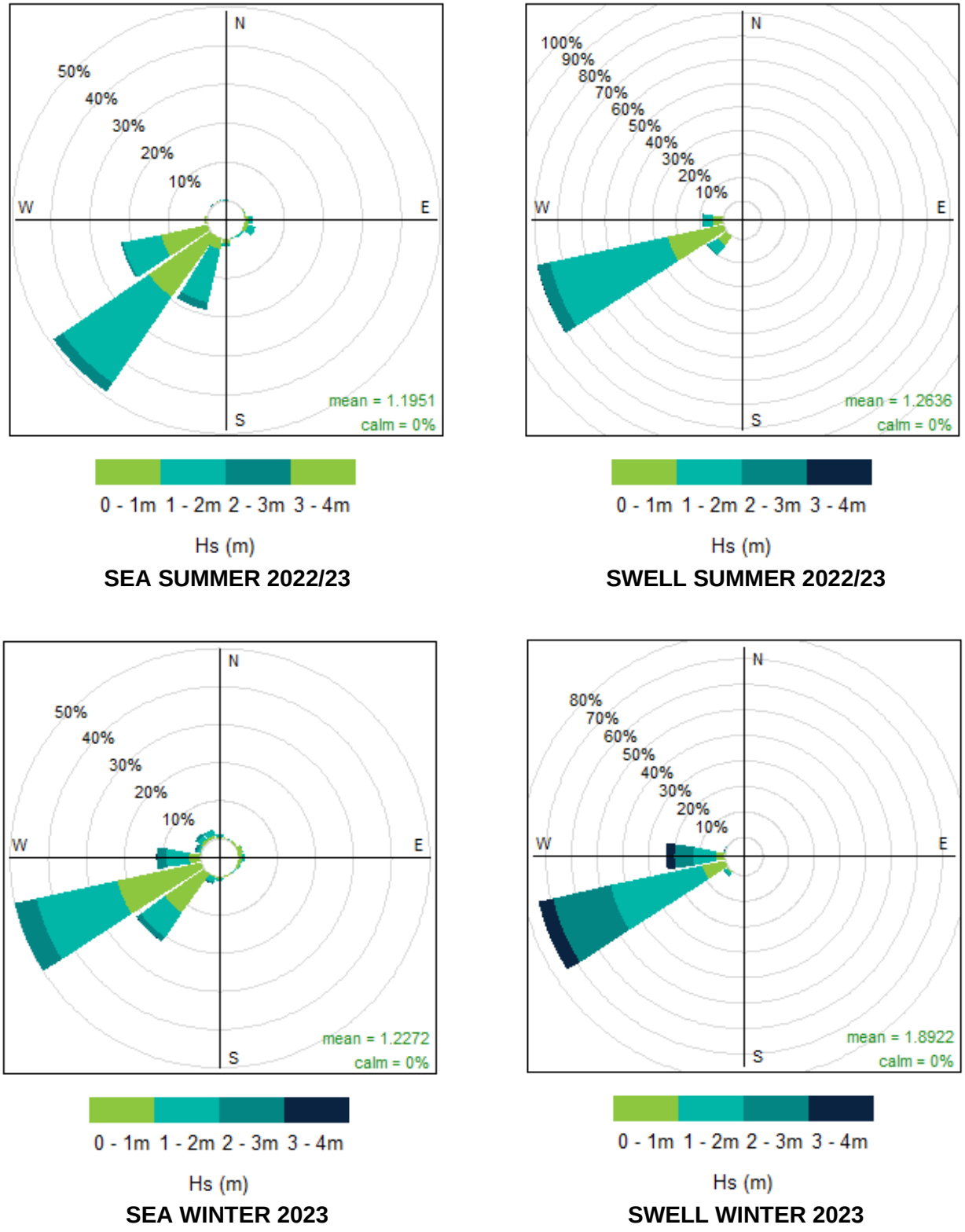


Figure 2-3 *Wind rose plots of sea and swell significant wave heights from the summer season (October 2022 to March 2023) and the winter Season (April to September 2023)*

As seen in Figure 2-3, the wave climate for both the summer and winter periods is characterised by west south westerly waves and, as expected, there is an increase in swell height during the winter

period. Notably, for this study period, wave direction remained consistent for most of the year, with less than 10% of readings captured outside of the consistent west south westerly direction.

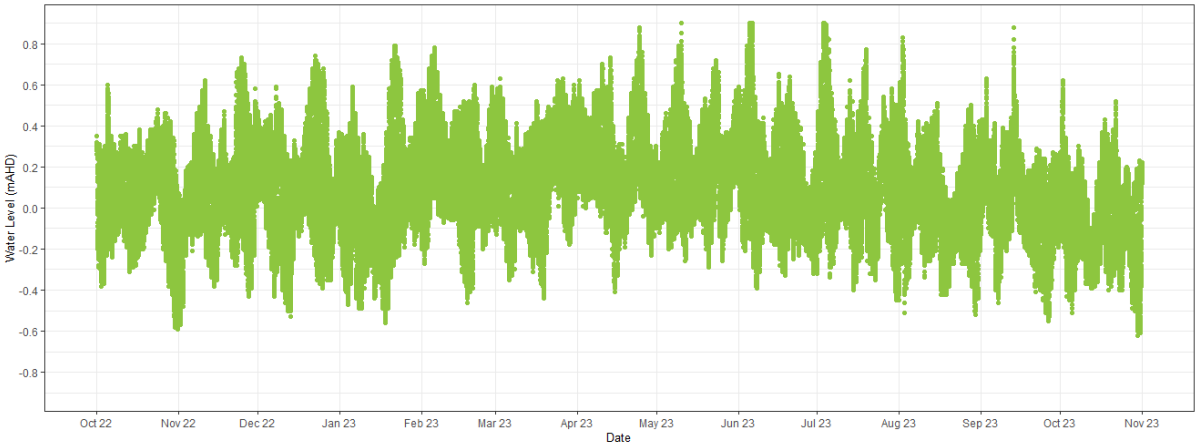


Figure 2-4 *Water level (mAHD) recorded at the Fremantle Fishing Harbour Tide Station from October 2022 to October 2023.*

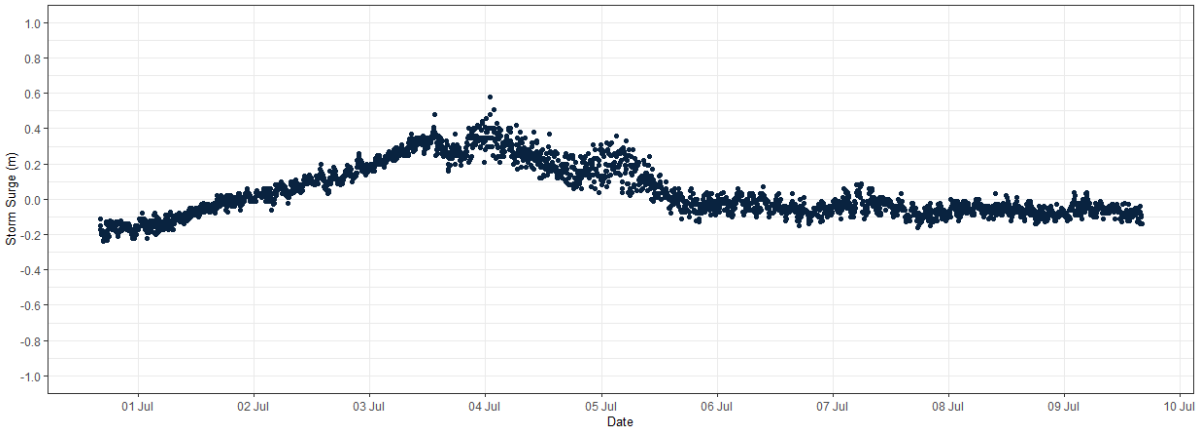
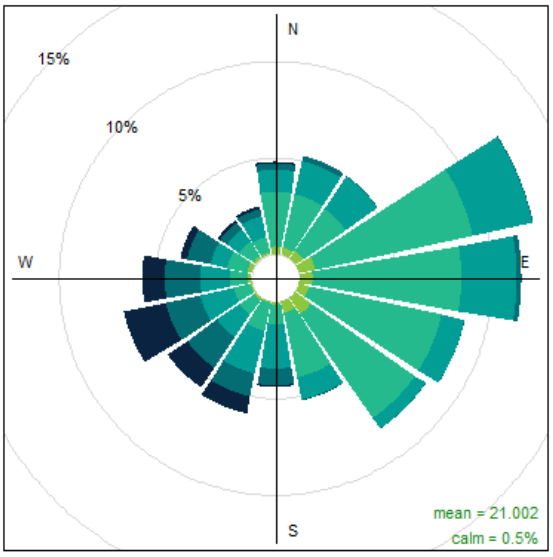
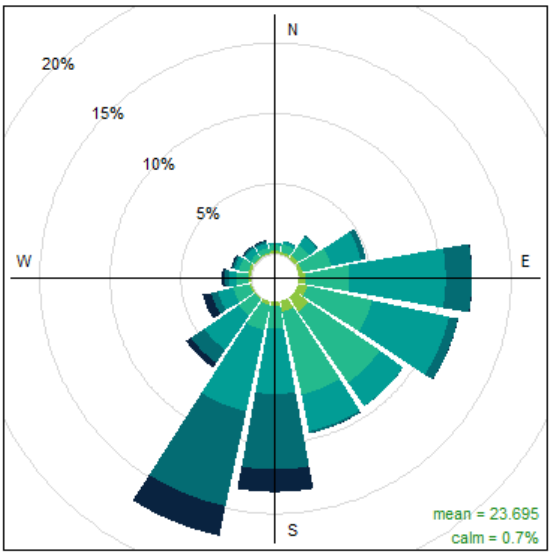


Figure 2-5 *Non tidal residual recorded at the Fremantle Fishing Harbour Tide Station during the July 4th storm event.*

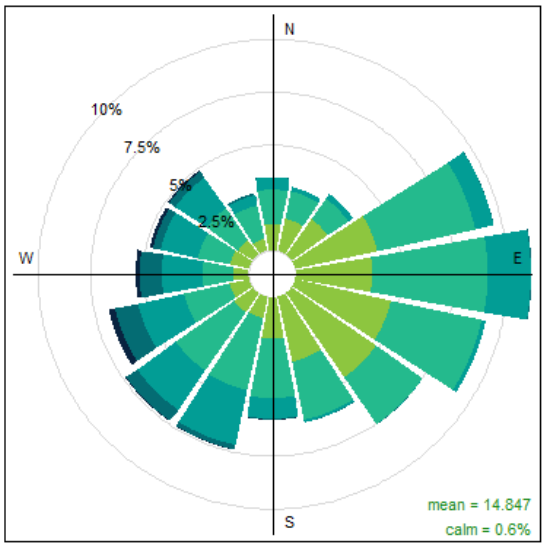
Total recorded water level at the Fremantle Tide Station for October 2022 to October 2023 is presented in Figure 2-4. The highest water level recorded was 1.05 mAHD recorded at 10:20AM on 6 June 2023 and the peak non tidal residual (storm surge), 0.76m, was observed on 13 September 2023 at 1:00PM. As outlined above, conditions during the 2023 winter period were extremely mild and storm events caused very little damage to infrastructure. Further assessment on the impacts of the mild winter period are outlined in Section 4, 5 and 6.



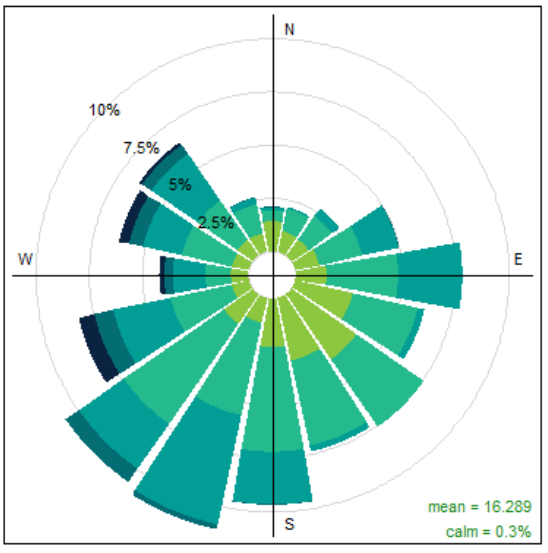
OCEAN REEF WINTER 2023 WIND SPEED



OCEAN REEF SUMMER 2022/23 WIND SPEED



SWANBOURNE WINTER 2023 WIND SPEED



SWANBOURNE SEP23 TO OCT23 WIND SPEED

Figure 2-3 Rose plots showing wind speeds recorded during the summer season (October 2022 to March 2023) and the winter season (April to August 2023) at the Ocean Reef Weather Station and the winter season (April to October 2023) and September to October 2023 at the Swanbourne Weather Station.

The summer of 2022/23 was largely characterised by strong southerly and south-south westerly winds, which are typical conditions along the West Australian coastline during the summer months. Notably, this year, south-south westerly winds were more prominent than southerly winds and a larger percentage of winds over 40km/h were recorded than previous years. The winter period was mostly characterised by easterly winds with significant periods of strong westerly winds, which is typical of

winter storm events. The wind conditions for the 2023 winter period were considerably less extreme than previous years, with notably fewer strong south westerly wind events. This is consistent with the low wave heights and limited storm damage observed across the monitoring period. It is important to note that the Ocean Reef Weather Station stopped recording data from 17 August 2023 and therefore recordings for the winter period are only representative of April to August 2023. Data from the Swanbourne Weather Station for April to October 2023 was analysed to better understand wind conditions across the entire winter period. The conditions recorded at the Swanbourne Weather Station are quite similar to those recorded at the Ocean Reef Weather Station with reduced wind speeds and more frequent north westerly events.

The rose plot depicting conditions between September and October 2023 at the Swanbourne Weather Station show a significant increase in the percentage of southerly wind events compared to the whole seasonal winter period. Between 1 September 2023 and 30 October 2023, approximately 40% of winds were recorded coming from a south-westerly, south-south-westerly, southerly or south-easterly direction.

2.2.2 During Monitoring

Manual imagery and aerial surveys for this monitoring period were undertaken between 17 October 2023 and 19 October 2023. The water levels during these monitoring periods are presented below in Figure 2-6.

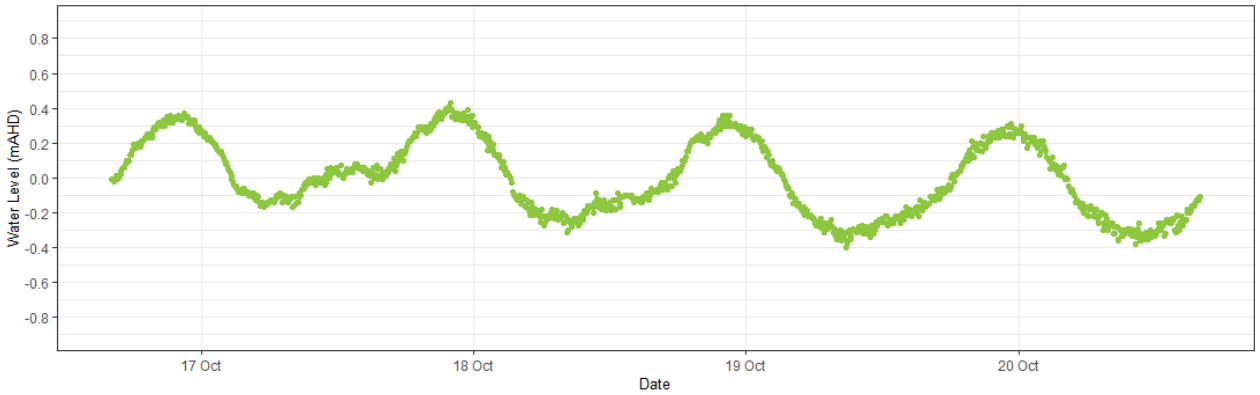


Figure 2-6 Recorded water level during October 2023 monitoring activities.

Most monitoring was undertaken at low tide. Changes in beach volumes are calculated from the area above the waterline so the rising tide will not affect the survey results however, it is important to note when assessing manual imagery that most images were taken at a water level between -0.1 and 0.1 mAHD.

3 Storm Damage

As outlined above in Section 2, the 2023 winter period was relatively calm with only two notable storm events experienced within the study period. With the maximum offshore wave height for the year recorded as 6.59m, the storm damage along the City's coastline was fortunately minimal. Minor damage to the dune systems was still observed during the study period and this is outlined in Table 3-1.

Table 3-1 Examples of major damage to infrastructure and dune systems caused by storm events.

Damaged Asset	Damage	Action Taken by the City	Photograph of the asset following actions
Dune and Wind Break Fencing, Quinns Dog Beach		The wind break fencing was repaired. The City completed beach scraping at this site in February 2023 following a significant build up of sand over the summer months. Sand had built up to the south of Groyne 4 and had started to bypass the Groyne and was moving further north. Sand was taken from the area to the south of Groyne 4 and placed at the base of the dunes to provide a buffer for this dune system. By October 2023 vegetation had established on the reworked sand and further build up of sand was identified at the base.	

Damaged Asset	Damage	Action Taken by the City	Photograph of the asset following actions
Northern Fisherman's Hollow Twin Beach Access, Yanchep		A significant drop off was observed at the base of the beach access structure following a number of storm events in 2022. An extension was added to beach access staircase in August 2023 to ensure safe access the beach.	

4 Manual Imagery

There are a total of 51 manual imagery beach monitoring sites located in key vulnerable coastal areas along the CoW coastline. The position of these sites are presented in Figure 4-1 to Figure 4-5. Images are taken 6 monthly in April and October each year to assess seasonal and long term changes to beach morphology. Images are taken by CoW's Coastal Engineer and are taken at the same location and with same field of view each time.

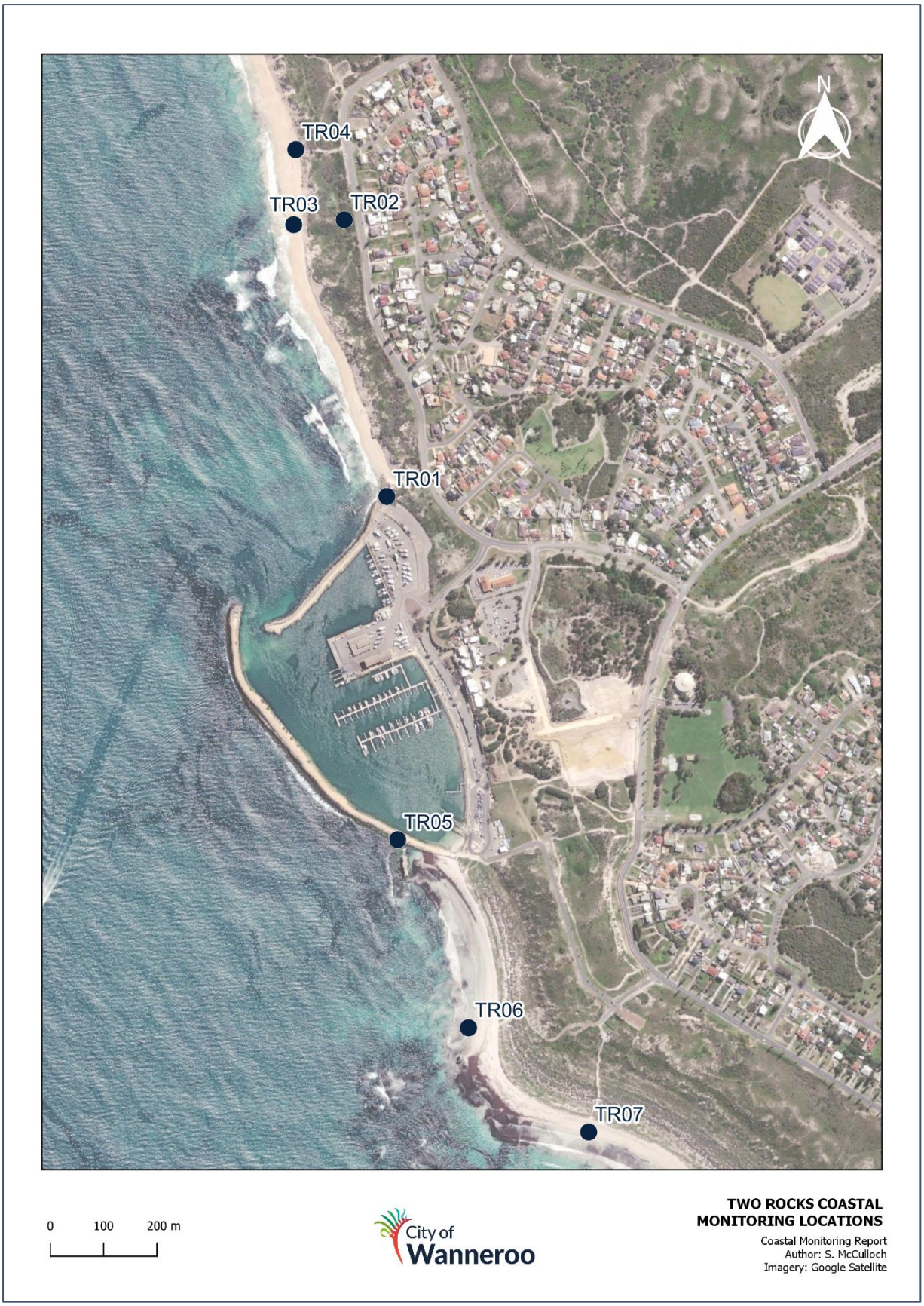


Figure 4-1 Two Rocks Coastal Monitoring Locations

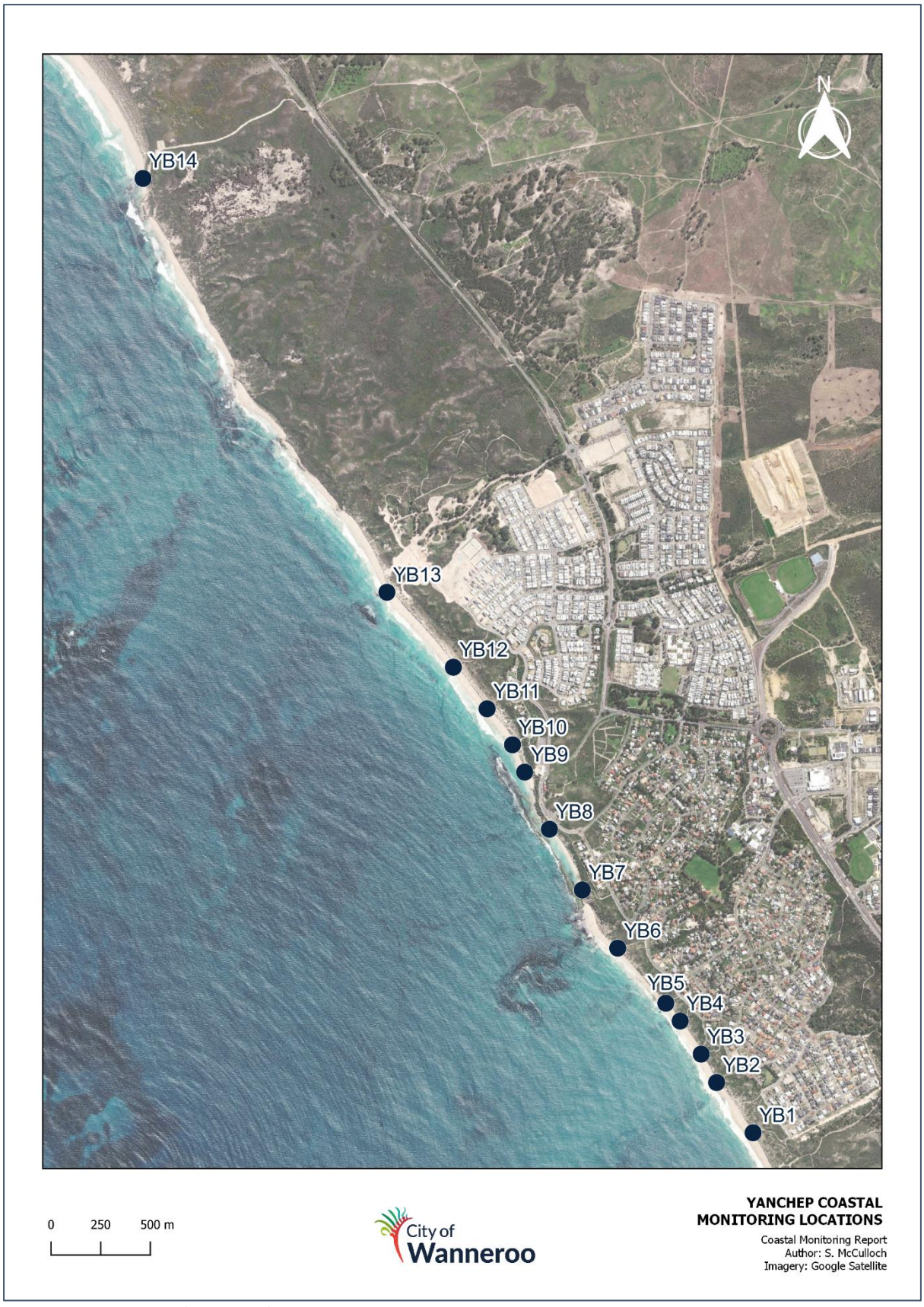


Figure 4-2 Yanchep Coastal Monitoring Locations

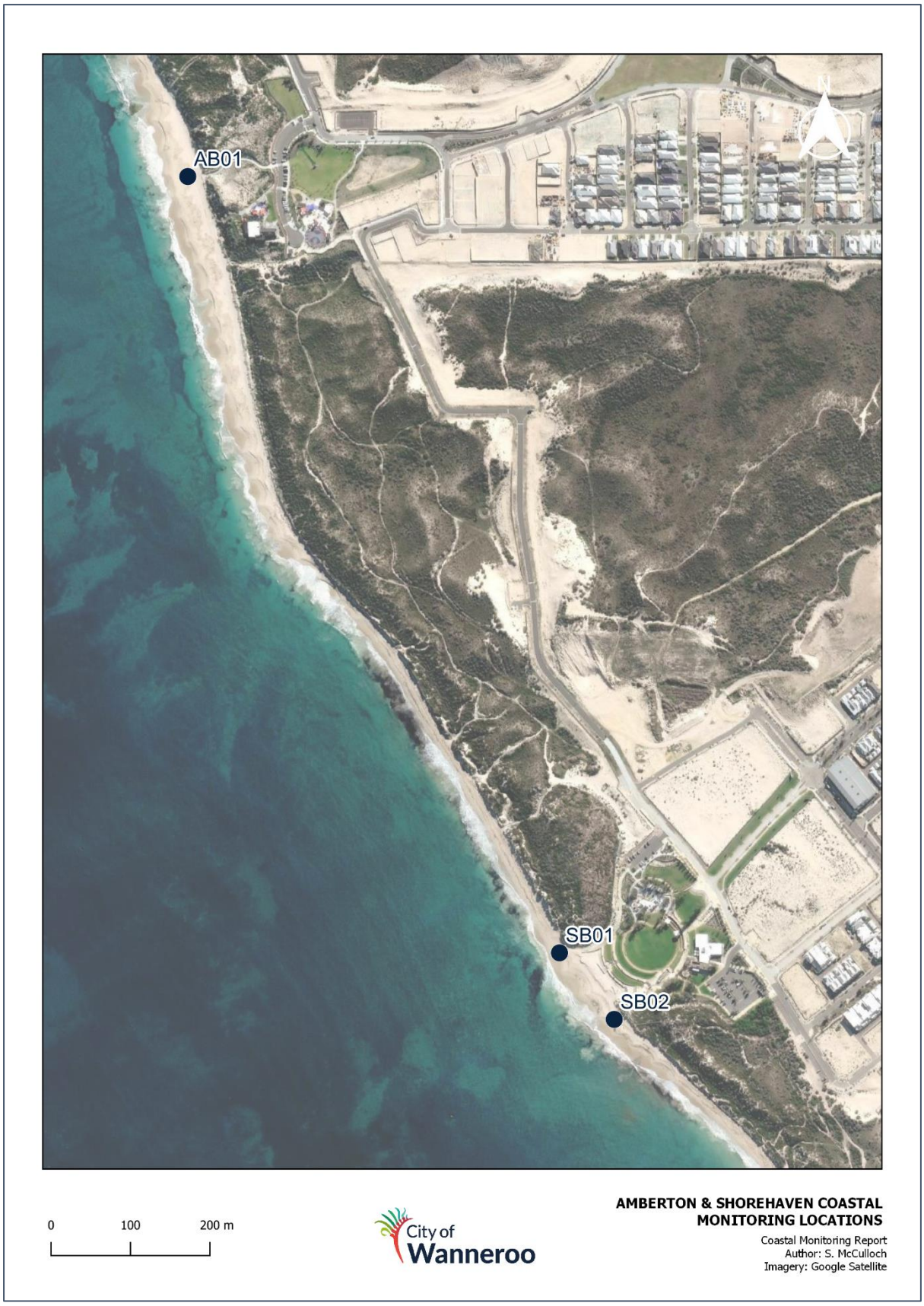


Figure 4-3 Amberton and Shorehaven Coastal Monitoring Locations

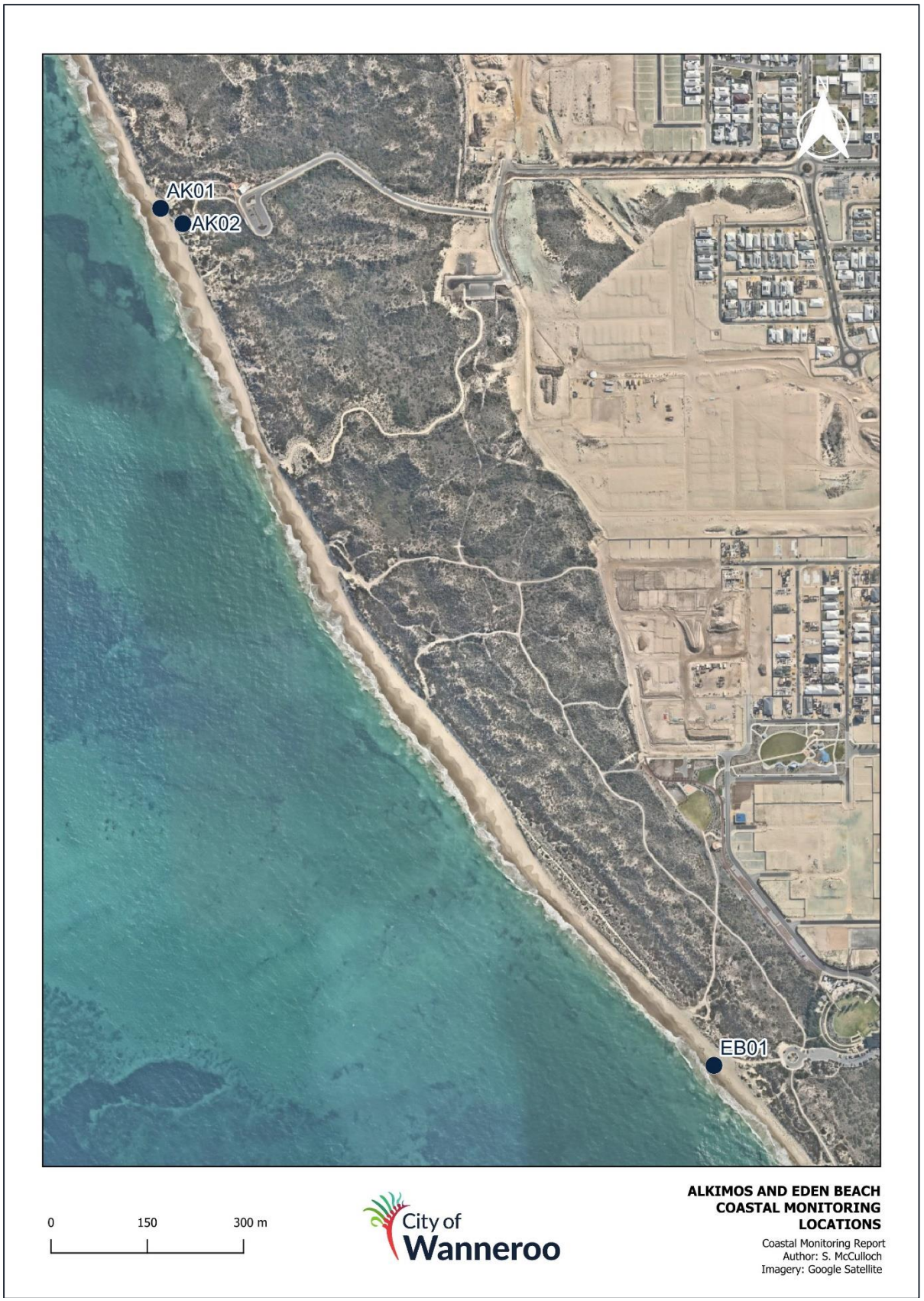


Figure 4-4 Alkimos and Eden Beach Coastal Monitoring Locations

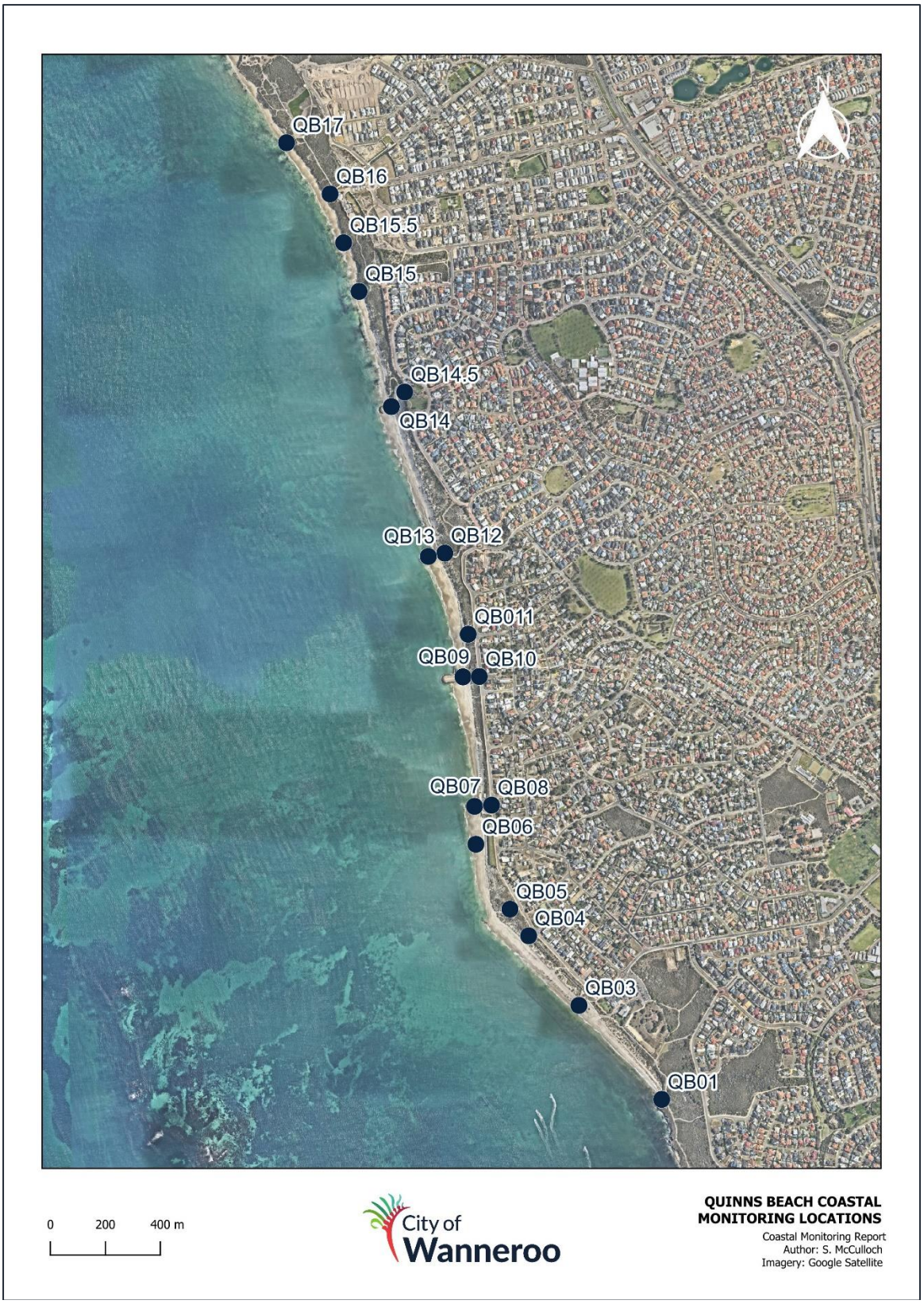


Figure 4-5 Jindalee and Quinns Rocks Coastal Monitoring Locations

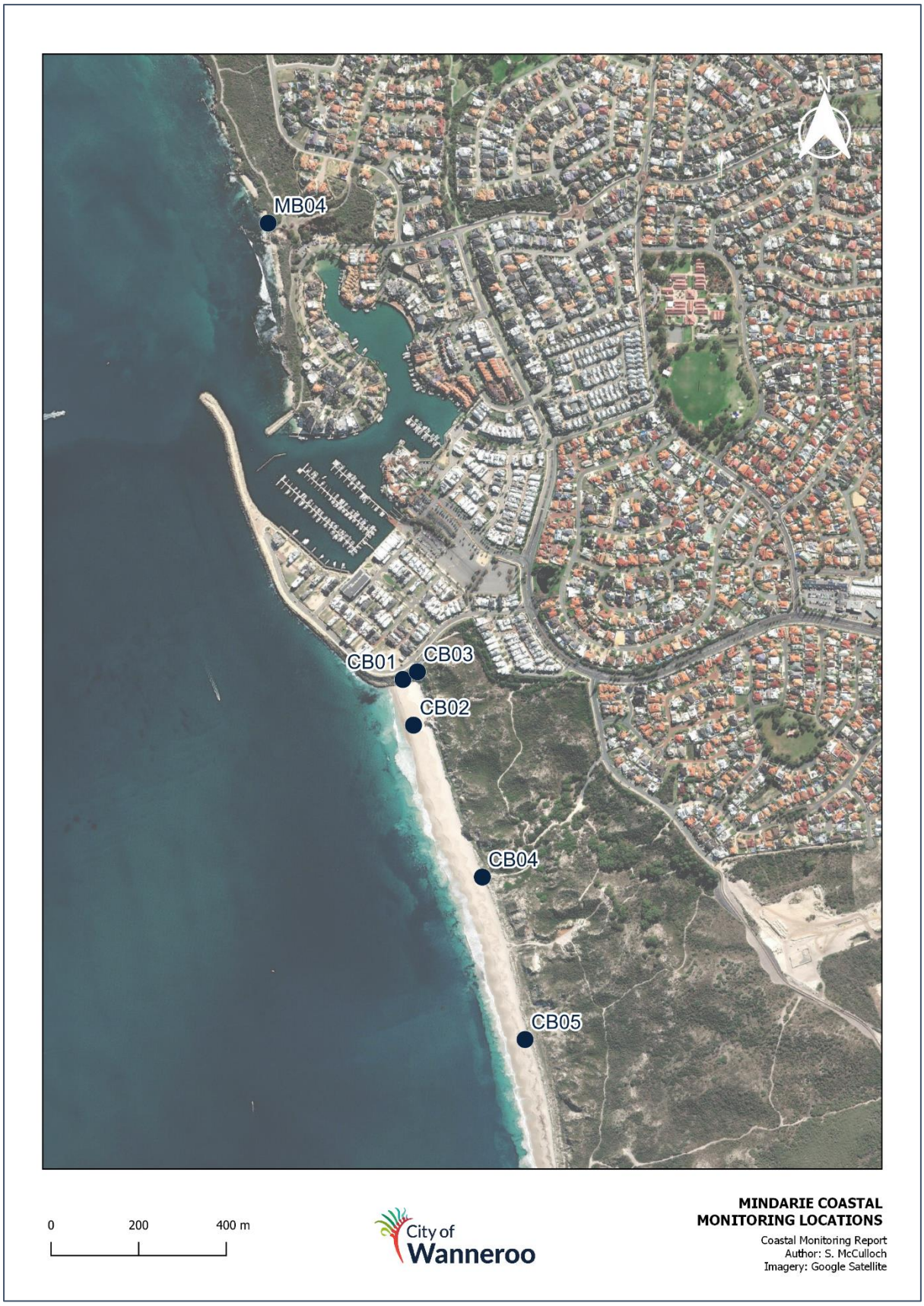


Figure 4-6 Mindarie Coastal Monitoring Locations

4.1 Assessment Methodology

Manual imagery is assessed via visual comparison. Images, once taken, are filed individually for each monitoring site allowing for an effective analysis of long-term and seasonal beach changes.

Seasonal changes are assessed by comparing the images taken in April (current year) with October (previous year) and October (current year) with April (current year). Long-term changes are assessed by comparing current images with the earliest images taken at the same time of year for each monitoring location.

Comments are made on the severity of beach changes observed at each monitoring site following the visual assessment. The severity of beach change is based upon the definitions as defined in Table 4-1.

Table 4-1 Severity of Beach Change Definitions

Accretion	• Increase in beach width; • Notable sand build up; or • Improvement in dune condition.
No change	• No identifiable change in beach width, slope or dune condition.
Minor Erosion	• Slight or minor decrease in beach width; • Slight or nil impact to dune condition; and • Remaining beach is sufficient to protect the dunes or infrastructure that lie landward of the beach.
Major Erosion	• Major decrease in beach width; • Some impact to dune condition; and • Remaining beach is not sufficient to protect dunes or infrastructure landward of the beach in the event of erosion.

4.2 Results

The severity of beach change and comments are presented in Table 4-2, Table 4-3, Table 4-4, Table 4-5, Table 4-8 and Table 4-9.

Images of sites with notably severe beach changes are presented in **Section 4.2.1**.

Table 4-2 Visual observations of beach changes at manual imagery monitoring sites in Two Rocks

Photo Monitoring Site	Winter Seasonal Changes (April 2023 to October 2023)		Summer Seasonal Changes (October 2022 to April 2023)		Long-term Changes (October 2014 to October 2023)		Long-term Changes (March 2015 to April 2023)	
	Severity of Beach Change	Beach Change Comments	Severity of Beach Change	Beach Change Comments	Severity of Beach Change	Beach Change Comments	Severity of Beach Change	Beach Change Comments
Two Rocks								
B01	Accretion	Slight increase in beach width with build up at the base of the dunes.	Minor erosion	Slight reduction in beach width. Bedrock exposed.	Minor erosion	Slight reduction in beach width noted.	Minor erosion	Slight reduction in beach width noted.
B02 UP-COAST	Accretion	Slight increase in beach width.	Minor erosion	Slight reduction in beach width.	Minor erosion	Bedrock visible in 2023 suggests a reduction in beach volume however beach width and dune condition appear largely unchanged.	Minor erosion	Notable reduction in beach width.
B03 UP-COAST	Accretion	Notable build up of sand at the base of the dunes and wider beach.	Minor erosion	Slight reduction in beach width.	Minor erosion	Bedrock visible in 2023 suggests a reduction in beach volume however beach width and dune condition appear largely unchanged.	Minor erosion	Notable reduction in beach width and slight erosion at the base of the dunes.
B03 DOWN-COAST	Accretion	Significant build up of sand at the base of the dunes.	Minor erosion	Slight reduction in beach width.	Minor erosion	Notable degradation in dune condition.	Minor erosion	Notable reduction in beach width and slight erosion at the base of the dunes.
B04 UP-COAST	Accretion	Very wide beach with no notable erosion scarp.	Major erosion	Notable reduction in beach width with erosion scarp. Dunes remain in good condition.	No change	Location of monitoring has changed due to the relocation of the staircase however beach condition appears unchanged and the dune condition appears to have improved.	Minor erosion	Notable reduction in beach width with a significant erosion scarp.
B04 DOWN-COAST	Accretion	Very wide beach with no notable erosion scarp.	Major erosion	Notable reduction in beach width with erosion scarp. Dunes remain in good condition.	Minor erosion	Location of monitoring has changed due to the relocation of the staircase however bedrock is now visible in 2023 indicating a loss of beach volume.	Minor erosion	Notable reduction in beach width with a significant erosion scarp.
B05	Minor erosion	Slight reduction in beach width however beach remains very wide.	Accretion	Significant increase in beach width.	Accretion*	Very significant increase in beach width.	Accretion**	Significant increase in beach width noted.
B06 UP-COAST	Minor erosion	Slight reduction in beach width however beach remains very wide.	Accretion	Significant increase in beach width.	*Unable to assess, manual imagery capture began in 2021.*			
B06 DOWN-COAST	Minor erosion	Slight reduction in beach width however beach remains very wide.	Accretion	Notable increase in beach width.				
B07 UP-COAST	Minor erosion	Notable reduction in beach width however beach remains very wide with dunes in good condition.	Accretion	Significant increase in beach width.	Accretion*	Notable increase in beach width and improvement of dune condition.	Accretion*	Significant increase in beach width noted.
B07 DOWN-COAST	Minor erosion	Notable reduction in beach width however beach remains very wide with dunes in good condition.	Accretion	Significant increase in beach width.	Accretion*	Notable increase in beach width and improvement of foredune condition.	Accretion*	Significant increase in beach width noted.

**Long-term changes have been assessed through images taken in 2019.*
***Long-term changes have been assessed through images taken in 2014.*

Table 4-3 Visual observations of beach changes at manual imagery monitoring sites in Yanchep

Photo Monitoring Site	Seasonal Changes (April 2023 to October 2023)		Seasonal Changes (October 2022 to April 2023)		Mid-term Changes (October 2018 to October 2023)		Mid-term Changes (April 2019 to April 2023)	
	Severity of Beach Change	Beach Change Comments	Severity of Beach Change	Beach Change Comments	Severity of Beach Change	Beach Change Comments	Severity of Beach Change	Beach Change Comments
Yanchep								
B01 UP-COAST	Accretion	Notable increase in beach width and build up in beach volume. Dune in good condition.	Minor erosion	Reduction in beach width. Dunes remain in good condition.	Minor erosion	Loss of some dune vegetation at the base of the dunes.	Minor erosion	Very minor erosion at the base of the dunes.
B01 DOWN-COAST	Accretion	Notable increase in beach width and build up in beach volume. Dune condition.	Minor erosion	Reduction in beach width. Dunes remain in good condition.	No change	No notable change in beach width or dune condition.	Minor erosion	Very minor erosion at the base of the dunes.
B02 UP-COAST	Accretion	Notable increase in beach width and build up in beach volume.	Minor erosion	Notable reduction in beach width. Dunes remain in good condition.	Minor erosion	Slight erosion at the base of the dunes.	Minor erosion	Very minor erosion at the base of the dunes.
B02 DOWN-COAST	Accretion	Significant increase in beach width and improvement in dune condition.	Minor erosion	Notable reduction in beach width. Dunes remain in good condition.	Minor erosion	Notable erosion at the base of the dunes.	Minor erosion	Notable erosion at the base of the dunes.
B03 UP-COAST	Accretion	Significant increase in beach width and improvement in dune condition.	Minor erosion	Notable reduction in beach width. Dunes remain in good condition.	Minor erosion	Dune erosion evident.	Minor erosion	Notable erosion at the base of the dunes.
B03 DOWN-COAST	Accretion	Significant increase in beach width and notable build up of sand at the base of the dunes.	Minor erosion	Notable reduction in beach width.	Minor erosion	Loss of dune vegetation is evident.	Minor erosion	Notable erosion at the base of the dunes.
B05 UP-COAST	Accretion	Notable increase in beach width.	Minor erosion	Notable reduction in beach width. Dunes remain in good condition.	Minor erosion	Loss of dune vegetation is evident.	Minor erosion	Reduction in beach width and notable erosion at the base of the dunes.
B05 DOWN-COAST	Accretion	Significant increase in beach width.	Minor erosion	Notable reduction in beach width. Dunes remain in good condition.	Minor erosion	Significant loss of dune vegetation wit notable dune erosion.	Minor erosion	Reduction in beach width and notable erosion at the base of the dunes.
B06 UP-COAST	Accretion	Significant increase in beach width.	Minor erosion	Notable reduction in beach width. Dunes remain in good condition.	Minor erosion	Notable erosion at the base of the dunes with loss of dune vegetation.	Minor erosion	Significant erosion at the base of the dunes.
B06 DOWN-COAST	Accretion	Significant increase in beach width and build up of sand at the base of the dunes.	Minor erosion	Notable reduction in beach width. Dunes remain in good condition.	Minor erosion	Slight erosion at the dune toe with some loss of dune vegetation.	Minor erosion	Significant erosion at the base of the dunes.
B07 UP-COAST	Minor erosion	Notable reduction in beach width however beach remains sufficiently wide enough to protect the dunes.	Accretion	Significant increase in beach width.	Minor erosion	Some erosion at the dune toe.	No change	No notable change to dune or beach condition.
B07 DOWN-COAST	Minor erosion	Notable reduction in beach width however beach remains sufficiently wide enough to protect the dunes.	Accretion	Significant increase in beach width.	No change	No notable change to dune or beach condition.	No change	No notable change to dune or beach condition.
B08 UP-COAST	Minor erosion	Notable reduction in beach height indicating minor erosion.	Accretion	Slight increase in beach width.	No change	No notable change in beach width or dune condition.	Accretion	Slight improvement in beach condition and beach width.
B08 DOWN-COAST	Minor erosion	Notable reduction in beach width however beach remains sufficiently wide enough to protect the dunes.	Accretion	Slight increase in beach width.	Accretion	Wide beach with some improvement to dune condition.	Accretion	Slight improvement in beach condition and beach width.
B09 UP-COAST	Accretion	Notable increase in beach width with 2022 nourishment sand transported northward.	Major erosion	Significant reduction in beach width.	No change	No notable change in beach width or dune condition. Nourishment has been undertaken at this site on numerous occasions between 2018 and 2023.	Minor erosion	Notable reduction in beach width and dune condition. Noting the significant volume of nourishment that has been undertaken at this site.

Photo Monitoring Site	Seasonal Changes (April 2023 to October 2023)		Seasonal Changes (October 2022 to April 2023)		Mid-term Changes (October 2018 to October 2023)		Mid-term Changes (April 2019 to April 2023)	
	Severity of Beach Change	Beach Change Comments	Severity of Beach Change	Beach Change Comments	Severity of Beach Change	Beach Change Comments	Severity of Beach Change	Beach Change Comments
Yanchep								
B09 DOWN-COAST	Accretion	Slight increase in beach width.	Accretion	Slight increase in beach width. Particularly notable around the headland.	No change	No notable change in beach width or dune condition. Nourishment has been undertaken at this site on numerous occasions between 2018 and 2023.	No change	No notable change in beach width or dune condition. Noting the significant volume of nourishment that has been undertaken at this site.
B10 UP-COAST	Accretion	Very significant increase in beach width and improvement of dune condition.	Major erosion	Significant reduction in beach width and notable damage to the dunes.	Minor erosion	Notable dune erosion with loss of dune vegetation.	Minor erosion	Significant erosion at the base of the dunes.
B10 DOWN-COAST	Accretion	Significant increase in beach width and improvement in dune condition.	Major erosion	Significant reduction in beach width and notable damage to the dunes.	Minor erosion	Notable erosion of the dunes with loss of dune vegetation.	Major erosion	Significant erosion of the dunes. Limited beach width.
B11 UP-COAST	Accretion	Significant increase in beach width and improvement in dune condition.	Major erosion	Significant reduction in beach width and notable damage to the dunes.	No change	No notable change in beach width or dune condition.	Minor erosion	Reduction in beach width and erosion evident at the base of the dunes.
B11 DOWN-COAST	Accretion	Significant increase in beach width and improvement in dune condition.	Major erosion	Significant reduction in beach width and notable damage to the dunes.	No change	No notable change in beach width or dune condition.	Major erosion	Significant erosion of the dunes. Limited beach width.
B12 UP-COAST	Accretion	Significant increase in beach width and improvement in dune condition.	Minor erosion	Notable reduction in beach width. Dunes remain in good condition.	No change	No notable change in beach width or dune condition.	Minor erosion	Notable reduction in beach width and very minor erosion at the base of the dunes.
B12 DOWN-COAST	Accretion	Significant increase in beach width and improvement in dune condition.	Minor erosion	Notable reduction in beach width. Dunes remain in good condition.	No change	No notable change in beach width or dune condition.	No change	No notable change in beach width or dune condition.
B13 UP-COAST	Accretion	Notable improvement in dune condition and increase in beach width.	Minor erosion	Slight reduction in beach width. Dunes remain in good condition.	Accretion	Improvement to dune condition with growth in dune vegetation.	Minor erosion	Dune erosion is evident.
B13 DOWN-COAST	Accretion	Significant increase in beach width and improvement in dune condition.	Minor erosion	Notable reduction in beach width. It is important to note that there was a storm surge of 0.2m during the April monitoring period which led to higher waterlines throughout the monitoring period.	Accretion	Improvement to dune condition with growth in dune vegetation.	Minor erosion	Minor erosion is evident at the base of the dunes.

Table 4-4 Visual observations of beach changes at manual imagery monitoring sites in Amberton

Photo Monitoring Site	Seasonal Changes (April 2023 to October 2023)		Seasonal Changes (October 2022 to April 2023)		Long-term Changes		Long-term Changes	
	Severity of Beach Change	Beach Change Comments	Severity of Beach Change	Beach Change Comments	Severity of Beach Change	Beach Change Comments	Severity of Beach Change	Beach Change Comments
Amberton								
B01 UP-COAST	Minor erosion	Slight reduction in beach width however dunes remain in good condition.	Accretion	Notable improvement in dune condition.	*Unable to assess – photo monitoring began in 2021.*			
B01 DOWN-COAST	Minor erosion	Slight reduction in beach width however dunes remain in good condition.	Accretion	Notable improvement in dune condition.				

Table 4-5 Visual observations of beach changes at manual imagery monitoring sites in Shorehaven

Photo Monitoring Site	Seasonal Changes (April 2023 to October 2023)		Seasonal Changes (October 2022 to April 2023)		Long-term Changes		Long-term Changes	
	Severity of Beach Change	Beach Change Comments	Severity of Beach Change	Beach Change Comments	Severity of Beach Change	Beach Change Comments	Severity of Beach Change	Beach Change Comments
Shorehaven								
B01 UP-COAST	Accretion	Slight increase in beach width.	Minor erosion	Notable reduction in beach width. Dunes remain in good condition.	*Unable to assess – photo monitoring began in 2020.*			
B01 DOWN-COAST	Accretion	Notable increase in beach width.	Minor erosion	Notable reduction in beach width. Dunes remain in good condition.				
B02 UP-COAST	Accretion	Notable increase in beach width.	Minor erosion	Notable reduction in beach width. Dunes remain in good condition.				
B02 DOWN-COAST	Accretion	Slight increase in beach width.	Minor erosion	Notable reduction in beach width. Dunes remain in good condition.				

Table 4-6 Visual observations of beach changes at manual imagery monitoring sites in Alkimos

Photo Monitoring Site	Seasonal Changes (April 2023 to October 2023)		Seasonal Changes		Long-term Changes		Long-term Changes	
	Severity of Beach Change	Beach Change Comments	Severity of Beach Change	Beach Change Comments	Severity of Beach Change	Beach Change Comments	Severity of Beach Change	Beach Change Comments
Alkimos								
B01 UP-COAST	Minor erosion	Slight reduction in beach width.	*Unable to assess – photo monitoring began in April 2023.*					
B01 DOWN-COAST	Accretion	Slight increase in beach width.						
B02 DOWN-COAST	Accretion	Slight increase in beach width.						

Table 4-7 Visual observations of beach changes at manual imagery monitoring sites in Eden

Photo Monitoring Site	Seasonal Changes (April 2023 to October 2023)		Seasonal Changes (October 2022 to April 2023)		Long-term Changes		Long-term Changes	
	Severity of Beach Change	Beach Change Comments	Severity of Beach Change	Beach Change Comments	Severity of Beach Change	Beach Change Comments	Severity of Beach Change	Beach Change Comments
Eden								
B01 UP-COAST	Accretion	Increase in beach width.	Minor erosion	Notable reduction in beach width. Dunes remain in good condition.	*Unable to assess – photo monitoring began in October 2021.*			

Photo Monitoring Site	Seasonal Changes (April 2023 to October 2023)		Seasonal Changes (October 2022 to April 2023)		Long-term Changes		Long-term Changes	
	Severity of Beach Change	Beach Change Comments	Severity of Beach Change	Beach Change Comments	Severity of Beach Change	Beach Change Comments	Severity of Beach Change	Beach Change Comments
Eden								
B01 DOWN-COAST	Accretion	Increase in beach width.	Minor erosion	Notable reduction in beach width. Slight erosion at the base of the dunes.	*Unable to assess – photo monitoring began in October 2021.*			

Table 4-8 Visual observations of beach changes at manual imagery monitoring sites in Quinns Rocks

Photo Monitoring Site	Seasonal Changes (April 2023 to October 2023)		Seasonal Changes (October 2022 to April 2023)		Long-term Changes (November 2013 to October 2023)		Long-term Changes (April 2014 to April 2023)	
	Severity of Beach Change	Beach Change Comments	Severity of Beach Change	Beach Change Comments	Severity of Beach Change	Beach Change Comments	Severity of Beach Change	Beach Change Comments
Quinns Beach								
B01	Accretion	Significant increase in beach width.	Major erosion	Notable reduction in beach width with notable erosion at the base of the dunes.	Accretion	Notable improvement in dune condition with increased vegetation density.	Accretion	Slight increase in beach width and improvement of dune condition and width.
B03 UP-COAST	Accretion	Significant increase in beach width.	No change	No notable reduction in beach width. Dunes remain in good condition.	No change	No notable change in beach condition, dunes remain in good condition and beach width is sufficiently wide.	Accretion	Slight increase in beach width and improvement in dune condition.
B03 DOWN-COAST	Accretion	Significant increase in beach width.	Minor erosion	Slight reduction in beach width. Dunes in good condition.	No change	No notable change in beach condition, dunes remain in good condition and beach width is sufficiently wide.	Minor erosion	Slight reduction in beach width.
B04 UP-COAST	No change	No notable change in beach width. Dunes remain in similar condition.	No change	No notable change in beach width. Dunes remain in similar condition.	Minor erosion	Beach in similar condition, slight reduction in beach width.	Minor erosion	Slight reduction in beach width.
B04 DOWN-COAST	No change	No notable change in beach width. Dunes remain in similar condition.	No change	No notable change in beach width. Dunes remain in similar condition.	Accretion	Improvement in dune condition with established vegetation.	Minor erosion	Slight reduction in beach width.
B06 UP-COAST	Minor erosion	Notable reduction in beach width however sufficient beach with to protect GSC revetment and adjacent infrastructure.	Accretion	Significant increase in beach width.	Minor erosion	Notable reduction in beach width however as there was no GSC revetment in 2013 it makes it difficult to assess the extent of the erosion. Dune condition has improved since construction of the GSC.	Minor erosion	Notable reduction in beach width however as the GSC was being constructed in 2014 which makes it difficult to assess the extent of erosion.
B06 DOWN-COAST	Minor erosion	Notable reduction in beach width however sufficient beach with to protect GSC revetment and adjacent infrastructure.	Accretion	Significant increase in beach width.	Accretion	Slight increase in beach width however as there was no GSC revetment in 2013 it makes it difficult to assess the extent of the erosion. Dune condition has improved since construction of the GSC	Minor erosion	Notable reduction in beach width however as the GSC was being constructed in 2014 which makes it difficult to assess the extent of erosion.
B07 UP-COAST	Accretion	Notable increase in beach width noting that sand nourishment was undertaken in May 2023 following manual imagery.	Minor erosion	Notable erosion in front of the carpark however there is still a significant beach in front of the revetment.	Accretion	Slight improvement in beach condition. It is important to note that ~75,000 m^3 of nourishment has been undertaken at this site since 2013.	No change	No change in beach condition. It is important to note that 70,000 m^3 of nourishment has been undertaken at this site since 2013.
B07 DOWN-COAST	Minor erosion	Notable reduction in beach width however sufficient beach with to protect GSC revetment and adjacent infrastructure.	Accretion	Significant increase in beach width.	Minor erosion	Slight reduction in beach width however as there was no GSC revetment in 2013 it makes it difficult to assess the extent of the erosion. Dune condition has improved since construction of the GSC	Minor erosion	Notable reduction in beach width however as there was no GSC revetment in 2014 it makes it difficult to assess the extent of the erosion.

Photo Monitoring Site	Seasonal Changes (April 2023 to October 2023)		Seasonal Changes (October 2022 to April 2023)		Long-term Changes (November 2013 to October 2023)		Long-term Changes (April 2014 to April 2023)	
	Severity of Beach Change	Beach Change Comments	Severity of Beach Change	Beach Change Comments	Severity of Beach Change	Beach Change Comments	Severity of Beach Change	Beach Change Comments
Quinns Beach								
B09 UP-COAST	Accretion	Notable increase in beach width.	Minor erosion	Notable reduction in beach width. Dunes remain in good condition.	Accretion	Notable improvement in dune condition.	Accretion	Notable improvement in dune condition.
B09 DOWN-COAST	Minor erosion	Very slight reduction in beach width.	Accretion	Notable increase in beach width.	Minor erosion	Notable erosion at the base of the dunes and slight reduction in beach width.	Minor erosion	Notable reduction in beach width and slight reduction in dune width.
B11 UP-COAST	Accretion	Increase in beach width.	No change	No notable change in beach condition. Dunes remain in good condition.	Accretion	Slight reduction in beach width however dune condition appears to have improved.	Minor erosion	Reduction in dune width.
B11 DOWN-COAST	Accretion	Notable increase in beach width.	No change	No notable change in beach condition. Dunes remain in good condition.	No change	Dunes and beach are in a similar condition.	No change	Dunes are in a similar condition.
B13 UP-COAST	Accretion	Notable increase in beach width noting that sand nourishment was undertaken at this site in May 2023 following manual imagery.	Major erosion	Significant reduction in beach width and notable erosion at the base of the dunes.	Accretion	Notable improvement in dune condition with increased density of dune vegetation. It is important to note that ~25,000m^3 of nourishment has been undertaken at this site since 2016, including nourishment that was undertaken in April 2023.	Minor erosion	Notable reduction in beach width with notable erosion at the base of the dunes.
B13 DOWN-COAST	No change	No notable change in beach condition. Dunes remain in good condition.	Accretion	Increase in beach width and improvement in dune condition.	Minor erosion	Notable erosion at the base of the dunes.	Minor erosion	Notable erosion at the base of the dunes.
B14 UP-COAST	Accretion	Notable accretion with increase in beach width.	Minor erosion	Notable reduction in beach width.	Minor erosion	Significant reduction in beach width and erosion evident at the base of the dunes.	Minor erosion	Notable reduction in beach width.
B14 DOWN-COAST	Accretion	Improvement in dune condition with vegetation growth.	Accretion	Improvement in dune condition as a result of beach scraping works undertaken in February 2023.	Minor erosion	Significant reduction in beach width and erosion evident at the base of the dunes.	Minor erosion	Notable reduction in beach width.
B15 UP-COAST	Accretion	Significant increase in beach width.	Minor erosion	Notable reduction in beach width.	Accretion**	Significant build up of beach condition and beach width. It is important to note that the 2014 image was taken in September and not in October.	Minor erosion*	Notable reduction in beach width.
B15 DOWN-COAST	Accretion	Significant increase in beach width.	Minor erosion	Notable reduction in beach width. Dunes remain in good condition.	Accretion**	Significant build up of beach condition and beach width. It is important to note that the 2014 image was taken in September and not in October.	Minor erosion*	Notable reduction in beach width.
B16 UP-COAST	Accretion	Significant increase in beach width.	No change	No notable change in dune condition.	Accretion**	Notable increase in beach width.	Minor erosion*	Significant reduction in beach width.
B16 DOWN-COAST	Accretion	Significant increase in beach width.	No change	No notable change in dune condition.	Accretion**	Notable increase in beach width.	Minor erosion*	Significant reduction in beach width.
B17 UP-COAST	Accretion	Notable increase in beach width.	Accretion	Slight increase in beach width.	*Unable to assess – Monitoring began in 2021.*			
B17 DOWN-COAST	Accretion	Notable increase in beach width.	Accretion	Slight increase in beach width.				

**Long-term changes have been assessed through images taken in 2015.*
***Long-term changes have been assessed through images taken in 2014.*

Table 4-9 Visual observations of beach changes at manual imagery monitoring sites in Mindarie

Photo Monitoring Site	Seasonal Changes (April 2023 to October 2023)		Seasonal Changes (October 2022 to April 2023)		Long-term Changes		Long-term Changes	
	Severity of Beach Change	Beach Change Comments	Severity of Beach Change	Beach Change Comments	Severity of Beach Change	Beach Change Comments	Severity of Beach Change	Beach Change Comments
Mindarie								
B01	Minor erosion	Notable reduction in beach width however sufficient beach remains to protect adjacent dunes.	Accretion	Significant increase in beach width. Noting that there was a significant storm surge during the monitoring period which resulted in a high-water line.	*Unable to assess – monitoring began in 2020.*			
B02 UP-COAST	No change	The high waterline present in Aprill 2023 monitoring images makes it difficult to assess beach condition. Dunes appear to be in similar condition.	Accretion	Significant increase in beach width and improvement in dune condition. Noting that there was a significant storm surge during the monitoring period which resulted in a high-water line.				
B02 DOWN-COAST	No change	The high waterline present in Aprill 2023 monitoring images makes it difficult to assess beach condition. Dunes appear to be in similar condition.	Accretion	Significant increase in beach width and improvement in dune condition. Noting that there was a significant storm surge during the monitoring period which resulted in a high-water line.				
B03	Minor erosion	Notable reduction in beach width however sufficient beach remains to protect adjacent dunes.	Accretion	Significant increase in beach width and improvement in dune condition. Noting that there was a significant storm surge during the monitoring period which resulted in a high-water line.				
B04	Accretion	Notable build up of sand and improvement in beach condition.	Minor erosion	Slight reduction in beach width.				

4.2.1 Areas Experiencing Major Seasonal Erosion

While assessing seasonal changes, four areas were identified as having experienced major erosion over the summer period (October 2022 to April 2023) with no areas identified as having experienced major erosion over the winter months (April 2023 to October 2023). Images of the identified areas experiencing major seasonal erosion are shown below.

Two Rocks B04 – Major Erosion, Summer 2022/23

B04 UP-COAST October 2022

B04 UP-COAST April 2023

B04 DOWN-COAST October 2022

B04 DOWN-COAST April 2023

Figure 4-7 Major erosion over summer 2022/23 at Two Rocks B04.

Significant seasonal erosion was identified via manual imagery along northern Two Rocks beach, adjacent to the Sovereign Drive Beach Access Staircase. This site is situated within the Coastal Erosion Hotspot '*21 – Two Rocks Northern Coast*'. While seasonal erosion is identified at this site each year, major erosion is uncommon. The site is situated to the north of the Two Rocks Marina which interrupts the summer longshore sediment transport resulting in a narrow beach following the summer months.

Yanchep B09 UP-COAST, B10 UP-COAST and B11 – Major Erosion, Summer 2022/23

B04 UP-COAST October 2022

B09 UP-COAST April 2023

B10 UP-COAST October 2022

B10 UP-COAST April 2023

B11 DOWN-COAST October 2022

B11 DOWN-COAST April 2023

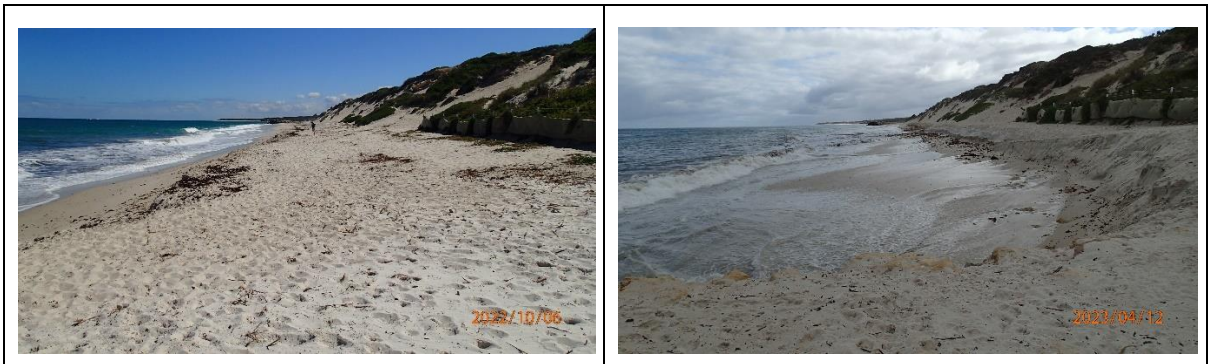
B11 UP-COAST October 2022

B11 UP-COAST April 2023

Figure 4-8 Major erosion over summer 2022/23 along Yanchep Lagoon Beach.

Significant seasonal erosion was identified at Yanchep Lagoon Beach following the 2022/23 summer period. Yanchep Lagoon Beach is bound by a rock headland to the south which interrupts the longshore transport of sediment during the summer months. By the April 2023 monitoring period sediment had begun to move around the headland and build up at the southern end of Yanchep Lagoon Beach (Figure 4-8) however the major erosion was observed along the northern end of the beach.

Quinns B13 UP-COAST – Major Erosion, Summer 2022/23

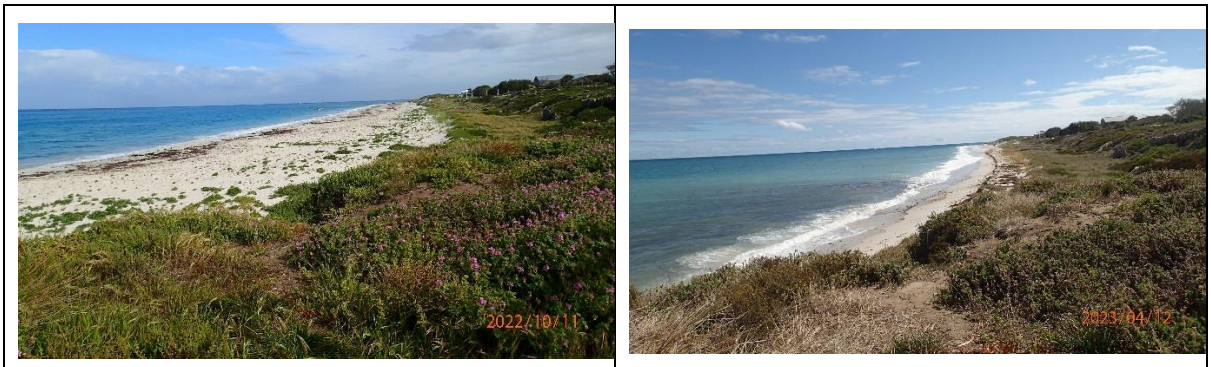


B13 UP-COAST October 2022	B13 UP-COAST April 2023

Figure 4-9 Major erosion over summer 2022/23 at Quinns B13 Up-Coast.

Quinns B13 manual imagery site is located at the base of Quinns Groyne 3. Significant seasonal erosion is experienced at this site each year following northward movement of sediment, away from the groyne, during the summer months. The City undertook renourishment at this site in May 2023, following the monitoring period, where 3,300 tonnes of sand was placed to protect the dune system from the impacts of winter storm events. While seasonal erosion is experienced at this site each year, there is evidence showing that sediment is retained within this section of beach and nearshore area by the groyne field (October 2022 Coastal Monitoring Report, City of Wanneroo).

Quinns B01 UP-COAST – Major Erosion, Summer 2022/23



B01 UP-COAST October 2022	B01 UP-COAST April 2023

Figure 4-10 Major erosion over summer 2022/23 at Quinns B01 Up-Coast.

Quinns Beach site B01 is situated at the southern end of Quinns Beach and captures the beach area to the north of the rocky headland that is situated between Quinns Beach and Mindarie. Seasonal erosion is experienced at this site each year due to the seasonal northward movement of sand, away from the headland, however major seasonal erosion is uncommon at this site. The beach has eroded to the dune area with some notable vegetation loss.

4.2.2 Areas Experiencing Major Long-Term Erosion

Two sites in Yanchep were identified through manual imagery as having experienced major erosion in the last four years of monitoring. These sites, which are outlined below in Figure 4-11, are situated to the north of Yanchep Lagoon.

Yanchep B10 Down-Coast and B11 Down-Coast – Major Erosion

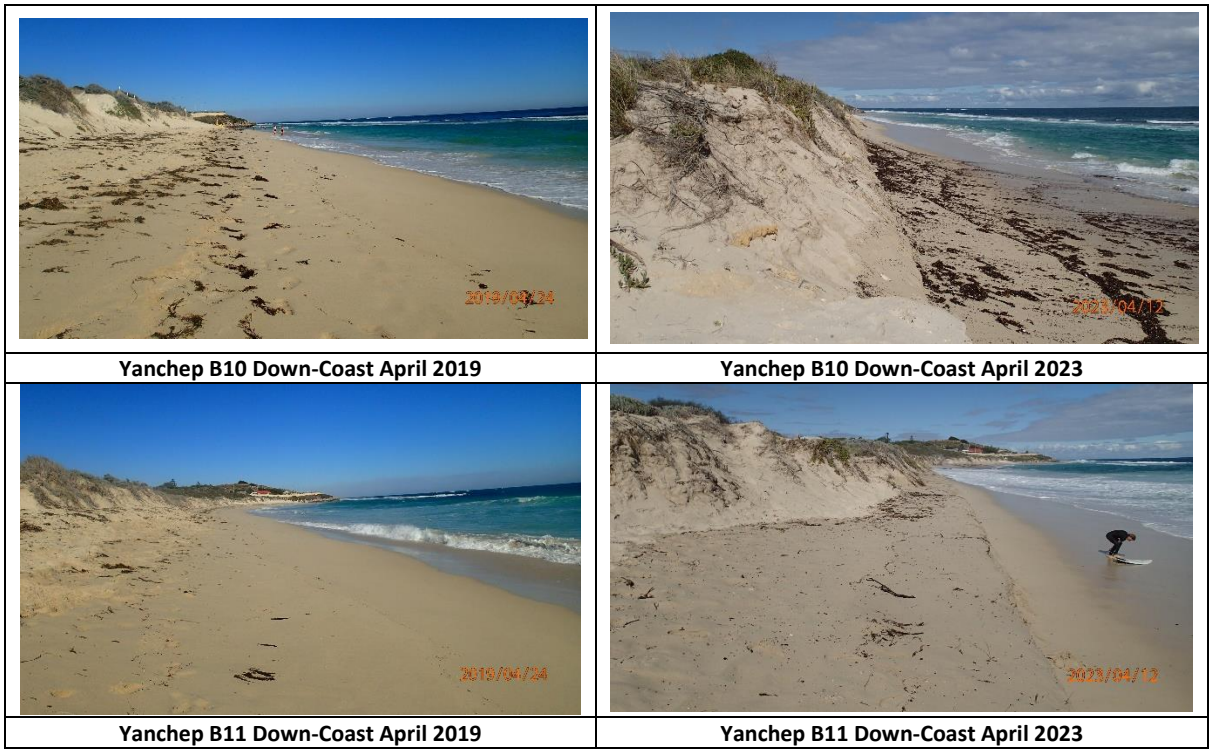


Figure 4-11 Significant long-term erosion at Yanchep Beach, north of Yanchep Lagoon.

Yanchep monitoring sites B10 and B11 are situated along the northern portion of the Yanchep Lagoon Beach. As outlined in Section 4.2.1 significant seasonal erosion was identified at Yanchep Lagoon Beach following the 2022/23 summer period which, when assessing long term changes to the coastline, resulted in major erosion at this site. Survey results (Section 5.2.3) also show a significant reduction in beach volume at this site between April 2019 and April 2023.

5 LIDAR and Ground Based Transect Surveys

Both LiDAR aerial surveys and nearshore ground based transect surveys are undertaken by MNG Surveyors including all post processing and analysis. LiDAR surveys are completed along the entire CoW coastal corridor including the following areas:

- Two Rocks Beach;
- Yanchep Beach;
- Quinns Rocks Beach; and
- Claytons Beach.

LiDAR Aerial Surveys can only capture areas above the waterline and when the shoreline has receded, the area of analysis is limited. Therefore, the City engaged MNG to capture an additional 129 nearshore ground based transect surveys to supplement the LiDAR data capture. These surveys are captured at the same time as the LiDAR aerial surveys and extend into the nearshore area, to a maximum water depth of one metre, to collect the data within the nearshore area that is otherwise missed.

These surveys are undertaken 6 monthly in April and October each year, in line with the timing of manual photographic monitoring.

5.1 Assessment Methodology

14 discrete study areas within the overall survey area are analysed for changes in beach volume. Note that for this survey technique, analysis is limited to dry areas landward of the waterline. Seasonal changes (April 2023 to October 2023) and annual changes (October 2022 to October 2023) to beach volume is assessed for each discrete area via difference plots of the two survey surfaces.

The data from ground-based survey transects has been interpolated to estimate changes in beach volume for the nearshore area below the waterline which is illustrated in the elevation difference plots. It is important to note that these volumes are estimates only.

129 beach cross sections are extracted from the LiDAR surfaces within each of the study areas. These cross sections are combined with the nearshore ground based survey transects and compared to earlier cross sections at the same location to further interrogate seasonal and long term changes to the beach profile.

5.2 Elevation Difference Plots

5.2.1 Seasonal Changes

Plots depicting the difference in elevation between the April 2023 surveys and October 2023 surveys are output by MNG and presented in Appendix A.

The change in beach volume between April 2023 and October 2023 is calculated for each of the 12 discrete study areas, the results of which are presented below in Table 5-1.

Table 5-1 Seasonal Net Volume Change of Beach Sections.

Beach Section	Section Description	Summer Net Volume Change April 2023 – October 2022	Winter Net Volume Change October 2023 – April 2023
Claytons Section 1A	Clayton's Beach, Mindarie above the waterline	+44,270 m^3	-28,120 m^3
Claytons Section 1B*	Clayton's Beach, Mindarie below the waterline	+51,329 m^3	-23,930 m^3
Quinns Section 1A	Quinns Main Beach – South of Artificial Headland above the waterline	+2,432 m^3	-1,262 m^3
Quinns Section 1B*	Quinns Main Beach – South of Artificial Headland below the waterline	-11,580 m^3	+8,881 m^3
Quinns Section 2A	Frederick Stubbs Park and GSC Revetment above the waterline	+9,592 m^3	-8,075 m^3
Quinns Section 2B*	Frederick Stubbs Park and GSC Revetment below the waterline	+14,156 m^3	-7,339 m^3
Quinns Section 3A	Frederick Stubbs Carpark, South of Groyne 2 above the waterline	+5,290 m^3	-199 m^3
Quinns Section 3B*	Frederick Stubbs Carpark, South of Groyne 2 below the waterline	+1,520 m^3	+37 m^3
Quinns Section 4A	North of Groyne 2, South of Groyne 3 above the waterline	+1,744 m^3	-936 m^3
Quinns Section 4B*	North of Groyne 2, South of Groyne 3 below the waterline	-163 m^3	-204 m^3
Quinns Section 5A	North of Groyne 3, South of Groyne 4 above the waterline	-1,065 m^3	-2,310 m^3
Quinns Section 5B*	North of Groyne 3, South of Groyne 4 below the waterline	-2,804 m^3	+662 m^3
Quinns Section 6A	North of Groyne 4, Jindalee above the waterline	+5,687 m^3	-1,340 m^3
Quinns Section 6B*	North of Groyne 4, Jindalee below the waterline	+26 m^3	-408 m^3
Yanchep Section 1A	South of Fisherman's Hollow Beach Access above the waterline	+1,534 m^3	-12,854 m^3
Yanchep Section 1B*	South of Fisherman's Hollow Beach Access above the waterline	-2,459 m^3	+2,891 m^3
Yanchep Section 2A	South of Headland, North of Fisherman's Hollow Beach Access above the waterline	+6,470 m^3	-5,251 m^3
Yanchep Section 2B*	South of Headland, North of Fisherman's Hollow Beach Access below the waterline	+21,101 m^3	-17,755 m^3
Yanchep Section 3A	Yanchep Lagoon above the waterline	-1,183 m^3	-668 m^3
Yanchep Section 3B*	Yanchep Lagoon below the waterline	-219 m^3	-303 m^3
Yanchep Section 4A	South of Capricorn Groyne above the waterline	+4,114 m^3	-9,777 m^3
Yanchep Section 4B*	South of Capricorn Groyne below the waterline	-6,005 m^3	+4,099 m^3
Yanchep Section 5A	North of Capricorn Groyne above the waterline	-614 m^3	-1,026 m^3
Yanchep Section 5B*	North of Capricorn Groyne below the waterline	-3,355 m^3	+2,245 m^3

Beach Section	Section Description	Summer Net Volume Change April 2023 – October 2022	Winter Net Volume Change October 2023 – April 2023
Two Rocks Section 1A	South of Two Rocks Marina above the waterline	+32,197 m^3	-10,538 m^3
Two Rocks Section 1B*	South of Two Rocks Marina below the waterline	+19,630 m^3	-33,029 m^3
Two Rocks Section 2A	North of Two Rocks Marina above the waterline	+3,116 m^3	-6,795 m^3
Two Rocks Section 2B*	North of Two Rocks Marina below the waterline	-2,731 m^3	+1,566 m^3

**These values are interpolated from the results of the ground based transects and are an estimate of the volume changes below the waterline. The volume changes above the waterline are calculated from LiDAR surveys that have a resolution of +10 points per square meter however volume changes below the waterline are calculated from ground based transects that have 100m separation.*

Overall, there was a decrease in beach volume across the 2023 winter period. The combined net volume changes of the Mindarie, Quinns, Yanchep and Two Rocks foreshore areas are as follows:

- The one beach section that is assessed within the Mindarie foreshore area had an estimated net beach volume loss of 52,050 m^3 between April 2023 and October 2023;
- The six beach sections along the Quinns foreshore area had an estimated combined net beach volume loss of 12,493 m^3 between April 2023 and October 2023;
- The five beach sections along the Yanchep foreshore area had an estimated combined net beach volume loss of 38,399 m^3 between April 2023 and October 2023; and
- The two beach sections along the Two Rocks foreshore area had an estimated combined net beach volume loss of 48,796 m^3 between April 2023 and October 2023.

These results represent a significant loss in beach volume over the 2023 winter period, particularly along Clayton's Beach, however the volume loss recorded at Clayton's was notably less than the 2022 winter period. Significant seasonal erosion is experienced at this site each year. The extent of beach volume loss within Two Rocks Section 1 is particularly notable considering the calm winter conditions experienced across 2023, the extent of beach volume loss is considerably larger than previous winter periods. There was, however, a significant increase in beach volume across the summer of 2022/23 where there were considerable gains in beach volume, particularly along Claytons Beach and the beach area to the south of Two Rocks Marina. As outlined in Section 2, the 2023 winter period was considered to be a mild winter, with offshore wave heights not exceeding 6.59m and a wave climate characterised by WSW waves. This likely contributed to the net beach volume loss in Quinns Section 1A as the lack of north-westerly storm events limited the transport of sand southward. Areas with significant seasonal changes in beach volume were consistent with manual imagery observations.

It is important to note that the areas below the waterline are an estimate only, however the data does provide an improved understanding of how sediment is transported locally within these beach segments.

5.2.2 Annual Changes – October 2022 to October 2023

Volume change plots depicting the difference in surface elevation between the October 2023 surveys and October 2022 surveys are output by MNG and presented in Appendix B.

The change in beach volume over the year is calculated for each of the 14 discrete study areas, the results of which are presented below in Table 5-2.

Table 5-2 Annual Net Volume Change of Beach Sections October 2023 –October 2022.

Beach Section	Section Description	Net Volume Change October 2023 – October 2022
Clayton Section 1A	Clayton's Beach above the waterline	+32,540 m^3
Clayton Section 1B*	Clayton's Beach below the waterline	+8,204 m^3
Quinns Section 1A	Quinns Main Beach – South of Artificial Headland above the waterline	-9,259 m^3
Quinns Section 1B*	Quinns Main Beach – South of Artificial Headland below the waterline	-7,604 m^3
Quinns Section 2A	Frederick Stubbs Park and GSC Revetment above the waterline	+6,642 m^3
Quinns Section 2B*	Frederick Stubbs Park and GSC Revetment below the waterline	+4,369 m^3
Quinns Section 3A	Frederick Stubbs Carpark, South of Groyne 2 above the waterline	+5,967 m^3
Quinns Section 3B*	Frederick Stubbs Carpark, South of Groyne 2 below the waterline	+2,192 m^3
Quinns Section 4A	North of Groyne 2, South of Groyne 3 above the waterline	+660 m^3
Quinns Section 4B*	North of Groyne 2, South of Groyne 3 below the waterline	-721 m^3
Quinns Section 5A	North of Groyne 3, South of Groyne 4 above the waterline	+6,703 m^3
Quinns Section 5B*	North of Groyne 3, South of Groyne 4 below the waterline	-4,391 m^3
Quinns Section 6A	North of Groyne 4, Jindalee above the waterline	+3,577 m^3
Quinns Section 6B*	North of Groyne 4, Jindalee below the waterline	-2,011 m^3
Yanchep Section 1A	South of Fisherman's Hollow Beach Access above the waterline	-12,371 m^3
Yanchep Section 1B*	South of Fisherman's Hollow Beach Access below the waterline	+1,988 m^3
Yanchep Section 2A	South of Headland, North of Fisherman's Hollow Beach Access above the waterline	+3,703 m^3
Yanchep Section 2B*	South of Headland, North of Fisherman's Hollow Beach Access below the waterline	+3,430 m^3
Yanchep Section 3A	Yanchep Lagoon above the waterline	-2,187 m^3
Yanchep Section 3B*	Yanchep Lagoon below the waterline	-268 m^3
Yanchep Section 4A	South of Capricorn Groyne above the waterline	-8,870 m^3
Yanchep Section 4B*	South of Capricorn Groyne below the waterline	-1,235 m^3
Yanchep Section 5A	North of Capricorn Groyne above the waterline	-2,853 m^3
Yanchep Section 5B*	North of Capricorn Groyne below the waterline	-639 m^3
Two Rocks Section 1A	South of Two Rocks Marina above the waterline	+33,791 m^3
Two Rocks Section 1B*	South of Two Rocks Marina below the waterline	+8,110 m^3
Two Rocks Section 2A	North of Two Rocks Marina above the waterline	-8,259 m^3
Two Rocks Section 2B*	North of Two Rocks Marina below the waterline	-3,296 m^3

It is apparent that there was a total gain in beach volume for the City's coastline across the year. It is important to note that as part of the annual beach renourishment program, 8,250 tonnes (~6,700 m^3) of sand was used in May 2023 for renourishment at Quinns Sections 3A and 5A.

The beach volume change maps developed by MNG show that in Quinns, while there was net volume loss for Sections 1A and 1B, there was a net volume gain of the same order of magnitude for Sections 2A and 2B. As Sections 2A and 2B are situated to the south of Quinns Groyne 1, sediment from Sections 1A and 1B were likely transported to Sections 2A and 2B across the summer season, as a result of strong southerly sea breeze events that drive incident wave energy, and retained in these sections by Groyne 1. The mild winter, characterised by WSW waves, likely resulted in limited southward longshore transport which resulted in a net loss of sediment in Quinns Sections 1A and 1B across the year.

There was a significant reduction in beach volume across the Yanchep coastline for the year, particularly in Yanchep Beach Sections 3, 4 and 5 which are situated to the north of the Yanchep Lagoon. The significant seasonal erosion observed within Section 4 of Yanchep Beach following the 2022/23 summer period likely contributed to the overall reduction in beach volume along Yanchep. Yanchep Lagoon Beach is bound by a rock headland to the south which interrupts the longshore transport of sediment during the summer months. By the April 2023 monitoring period sediment had begun to move around the headland and build up at the southern end of Yanchep Lagoon Beach however the major erosion was observed along the northern end of the beach.

Notably, there was also considerable net beach volume gain in Two Rocks Section 1A and 1B. This section is bounded by the Two Rocks Marina to the north, which interrupts longshore sediment transport, trapping sand to the south of the Two Rocks Marina Southern Breakwater. Similarly to Quinns Sections 2A and 2B, sediment was likely transported to this area across the summer season as a result of summer sea breezes driving incident wave energy and mild winter conditions limited the southerly transport of sediment.

5.2.3 Long Term Trends

Annual changes in beach volumes have been assessed by the City since 2020. To identify any long-term trends in annual beach volume change, net beach volume change per year, relative to length of coastline, was plotted for each beach section. As nearshore transects were only captured from April 2022 and later, long-term analysis could not be assessed for the nearshore area and therefore it is important to note that these plots only depict annual beach volume change above the waterline. These plots are presented in Figure 5-4, Figure 5-3, Figure 5-2 and Figure 5-1 below.

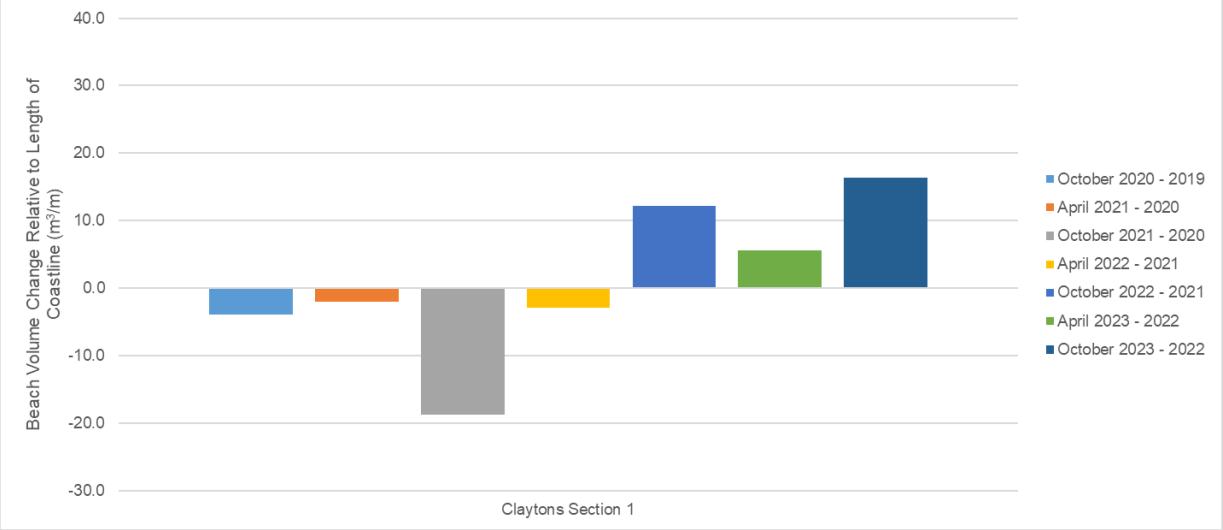


Figure 5-1 Seasonal net beach volume changes for Claytons Section 1.

Figure 5-1 shows an increase in beach volume along Claytons Beach in the three annual study periods assessed between October 2021 and October 2023. The net beach volume gain observed during the study periods October 2021 to 2022, April 2022 to 2023 and October 2022 to 2023 is likely attributed to strong seabreezes observed throughout the seasonal summer period. Claytons Section 1 is situated immediately south of the Mindarie Marina Breakwater, which interrupts the northward longshore sediment transport, trapping sand within the beach section defined by Claytons Section 1.

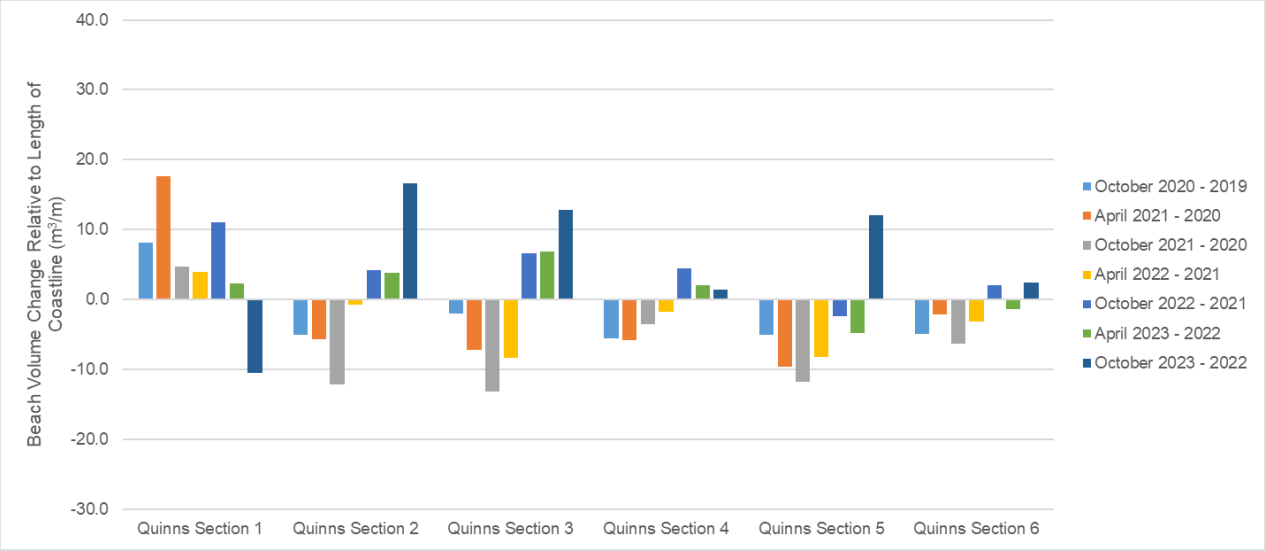


Figure 5-2 Annual net beach volume changes for Quinns Section 1, 2, 3, 4, 5 and 6.

Long term trends for Quinns Beach show a significant increase in beach volume in Sections 2, 3 and 5 for this study period relative to other years. Conversely, significant erosion was observed across Quinns Section 1 for this study period, relative to other years, which is likely due to the calm winter conditions as outlined in Section 5.2.2. Nourishment works were undertaken within Quinns Section 3 (4,950 tonnes) and Quinns Section 5 (3,300 tonnes) during this study period and this, coupled with the calm winter conditions, has likely contributed to the significant increase in beach volume in these beach sections.

Additionally, beach scraping was undertaken in the northern portion of Section 5 in February 2022, where sand was taken from the nearshore area and placed at the base of the dune system. While this

contributed to the increase in beach volume for the beach area above the waterline, Table 5-2 shows that there was a decrease in beach volume for Section 5B (below the waterline, in the nearshore). Beach scraping was undertaken at this site to protect the eroding dune system from the impacts of storm events.

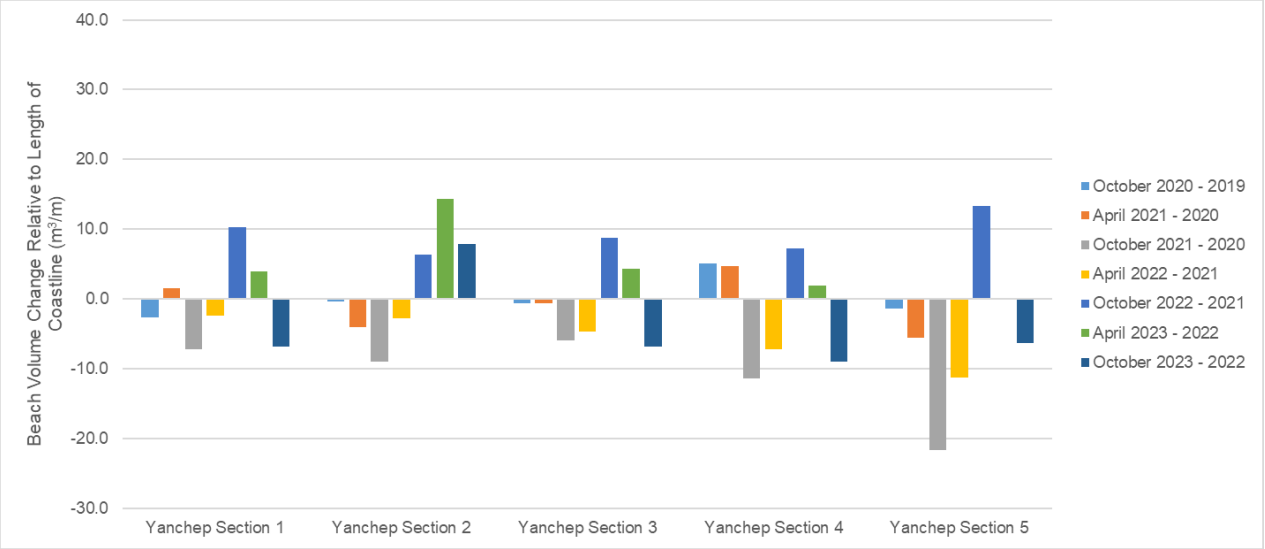


Figure 5-3 Annual net beach volume changes for Yanchep Section 1, 2, 3, 4 and 5.

Despite the calm winter conditions for 2023 there was a considerable loss in beach volume across Yanchep between October 2022 and October 2023 in all Sections aside from Section 2. It is possible that this is a result of strong summer seabreeze conditions transporting sediment further north, away from the Yanchep coastline, however further analysis is required to better understand sediment transport along the Yanchep coastline.

There was a net increase in beach volume for Section 2 across the last three study periods, which is similar to that observed at Claytons Section 1 and Quinns Sections 2, 3 and 4, and is likely a result of strong southerly seabreezes observed throughout the seasonal summer period transporting sand to the north which is then captured within Yanchep Section 2 by the northern headland.

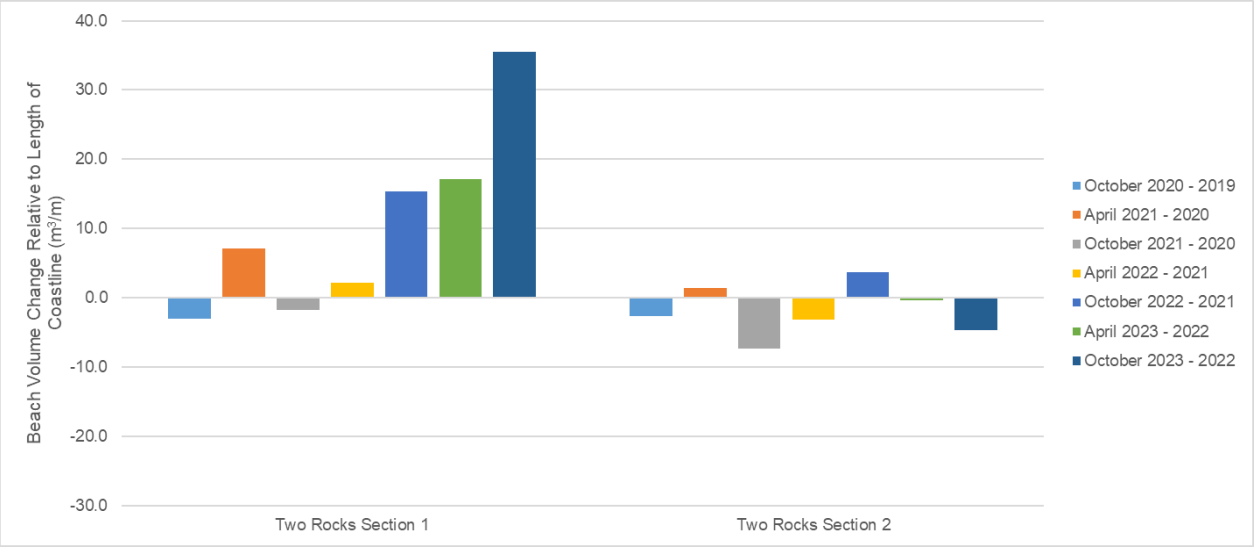


Figure 5-4 Seasonal net beach volume changes for Two Rocks Section 1 and 2.

As outlined in Figure 5-4 there has been a considerable increase in beach volume within Two Rocks Section 1 for the periods assessed between October 2021 and October 2023. This pattern is similar to other sections of the coastline and, as discussed, is likely a result of strong summer seabreeze conditions transporting sand northward. Sand is captured within Two Rocks Section 1 as northward sediment transport is interrupted by the Two Rocks Marina Southern Breakwater.

5.3 Beach Cross Section Results

Beach cross sections of areas that were identified as having experienced major erosion in the manual imagery analysis (**Section 4.2**) were analysed to assess the extent of erosion experienced in these areas. The results are presented below.

5.3.1 Two Rocks B04 – Major Erosion, Summer 2022/23

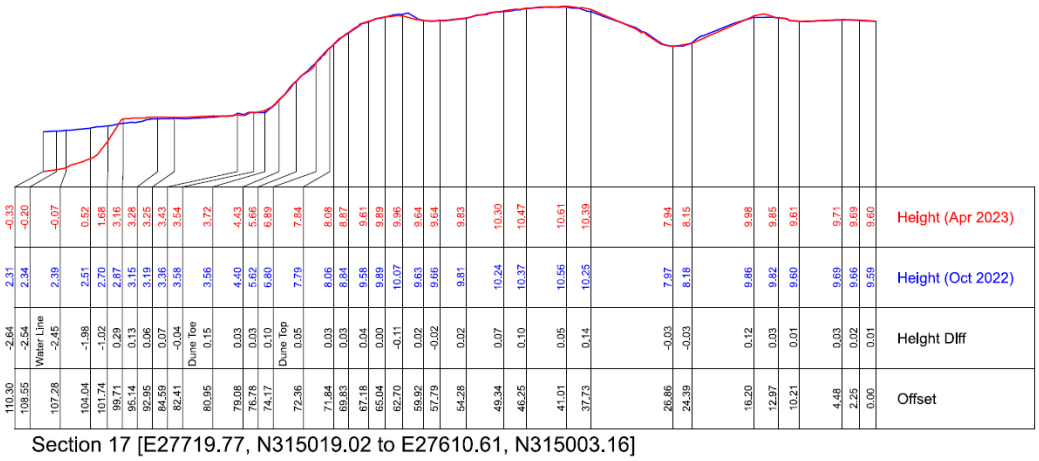


Figure 5-5 Two Rocks cross section 17 elevation comparison between April 2023 and October 2022 surveys.

Two Rocks beach cross-section 17 is situated within the field of view of manual imagery point 'Two Rocks B04 Up-Coast and Down-Coast'. The cross section shows a maximum height difference of 2.64m between surveys, just below the water line. The results of the cross section are consistent with manual imagery observations and show a significant reduction in elevation at this site.

5.3.2 Yanchep B09, B10 and B11 – Major Erosion, Summer 2022/23

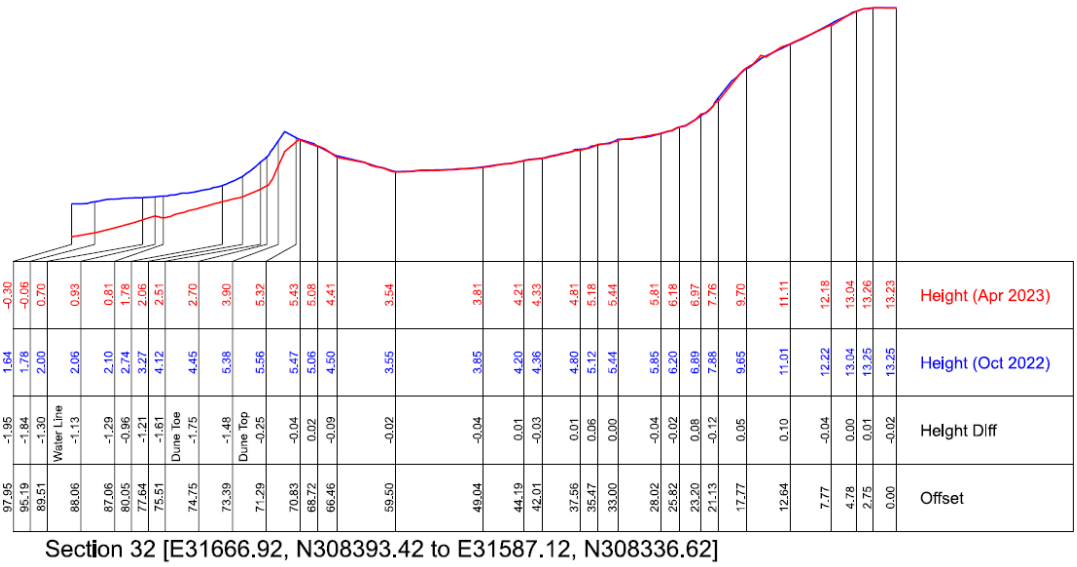


Figure 5-6 Yanchep cross section 32 elevation comparison between April 2023 and October 2022 surveys.

Cross section 32 is one of a number of cross-sections that are situated within the field of view of manual imagery sites B09, B10 and B11. The cross-sectional survey results show a maximum elevation difference of 1.95m between surveys and a recession of the dunes, which is consistent with manual imagery observations that show major erosion along this area between October 2022 and April 2023.

5.3.3 Quinns B01 Up-Coast – Major Erosion, Summer 2022/23

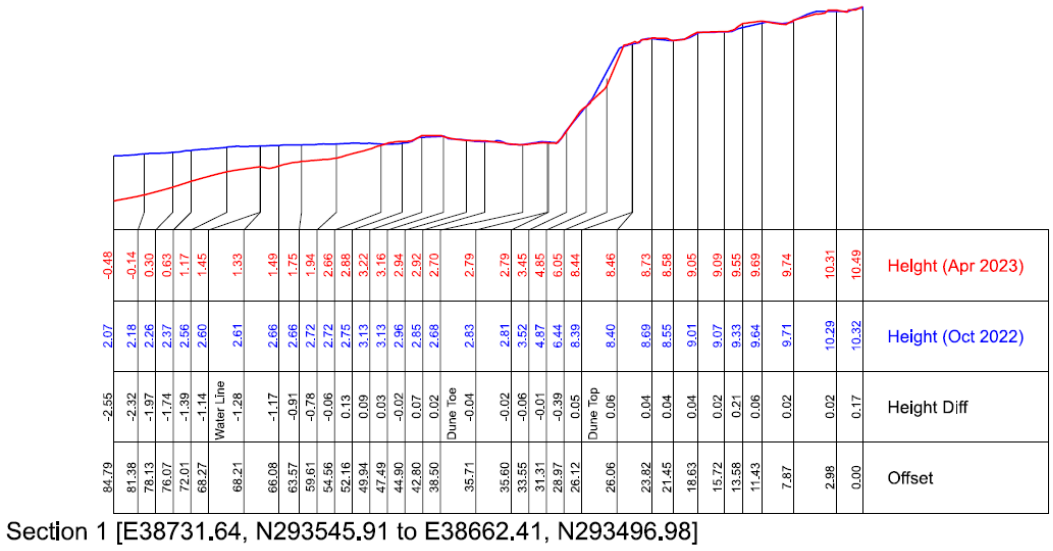


Figure 5-7 Quinns Beach cross section 1 elevation comparison between April 2023 and October 2022 surveys.

Quinns Beach cross-section 1 is situated within the field of view of manual imagery point 'Quinns Rocks B01'. The cross section shows a maximum reduction in elevation of 2.55m between the April 2023 and October 2022, just below the water line. The results of the cross section are consistent with manual imagery observations and show a significant reduction in elevation at this site.

5.3.4 Quinns B13 Up-Coast – Major Erosion Summer 2022/23

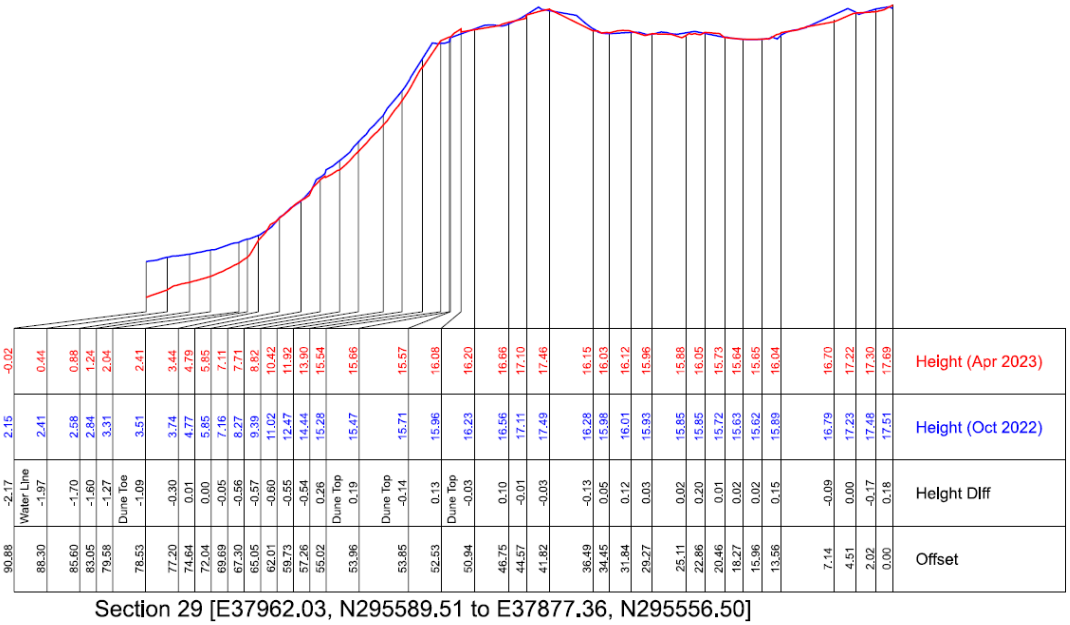


Figure 5-8 Quinns beach cross section 29 elevation comparison between October 2022 and April 2023 surveys.

Quinns beach cross-section 29 is situated within the field of view of manual imagery point 'Quinns Rocks B13 Up-Coast'. Figure 5-8 shows a significant reduction in elevation (2.17m) between the October 2022 and April 2023 surveys which is consistent with the major seasonal summer erosion that was identified at the site through manual imagery analysis (**Section 4.2.1**). Significant seasonal summer erosion is common at this site as strong sea breeze conditions promote the northward transport of sediment, away from Quinns Groyne 3.

5.3.5 Additional Transects with Significant Elevation Difference

A number of transects, additional to those identified through manual imagery, were identified as having significant elevation difference (greater than 2.0m) between surveys. These areas were not identified in manual imagery observations but represent areas of major erosion and are important to identify as part of the coastal monitoring program.

5.3.5.1 Mindarie

Results from beach profile cross-section comparisons show major erosion between April 2023 to October 2023 at an additional site along Mindarie that were not identified through manual imagery. This site, and the corresponding manual imagery site, is outlined below.

Cross Section 16 – Manual Imagery Site B02 Down-Coast

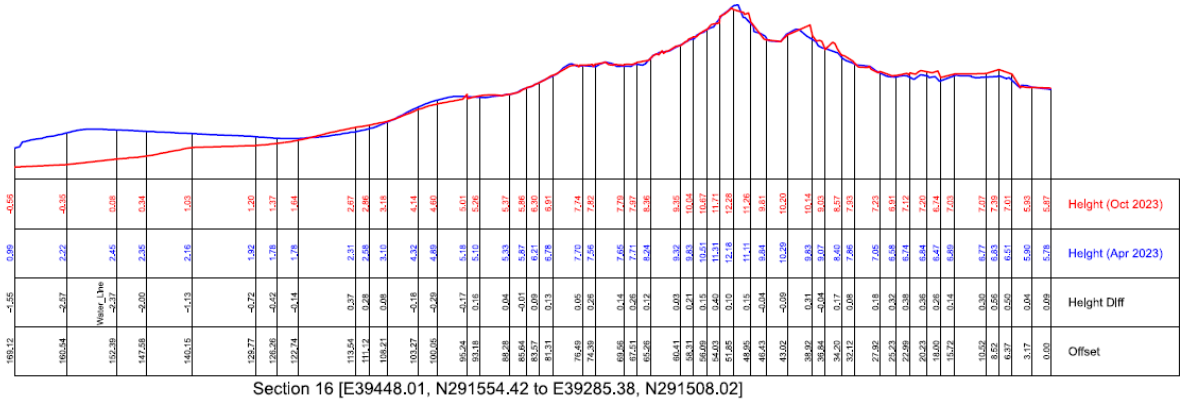
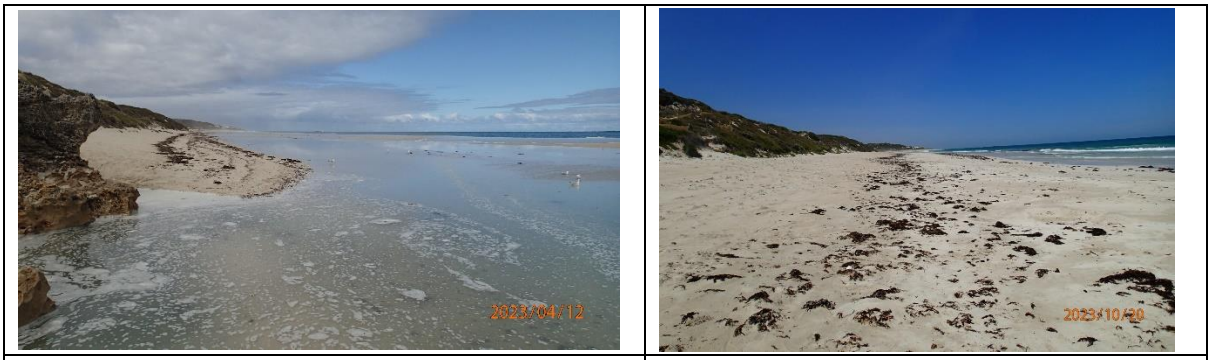


Figure 5-9 *Cross section 16 at Claytons Beach, Mindarie which shows a reduction in beach height of up to 2.6m just below the waterline between April 2023 and October 2023.*

The cross section presented in Figure 5-9 shows a significant reduction in the beach height between the April 2023 survey and the October 2023 survey. This was not identified in manual imagery (Figure 5-10) as there was a significant storm surge during the April 2023 monitoring period which led to high waterlines making it difficult to assess seasonal changes through manual imagery.



April 2023	October 2023

Figure 5-10 *Manual images taken at Mindarie B02 Down-Coast.*

5.3.5.2 Quinns Rocks

Cross Section 15 – Manual Imagery Site B07 Down-Coast

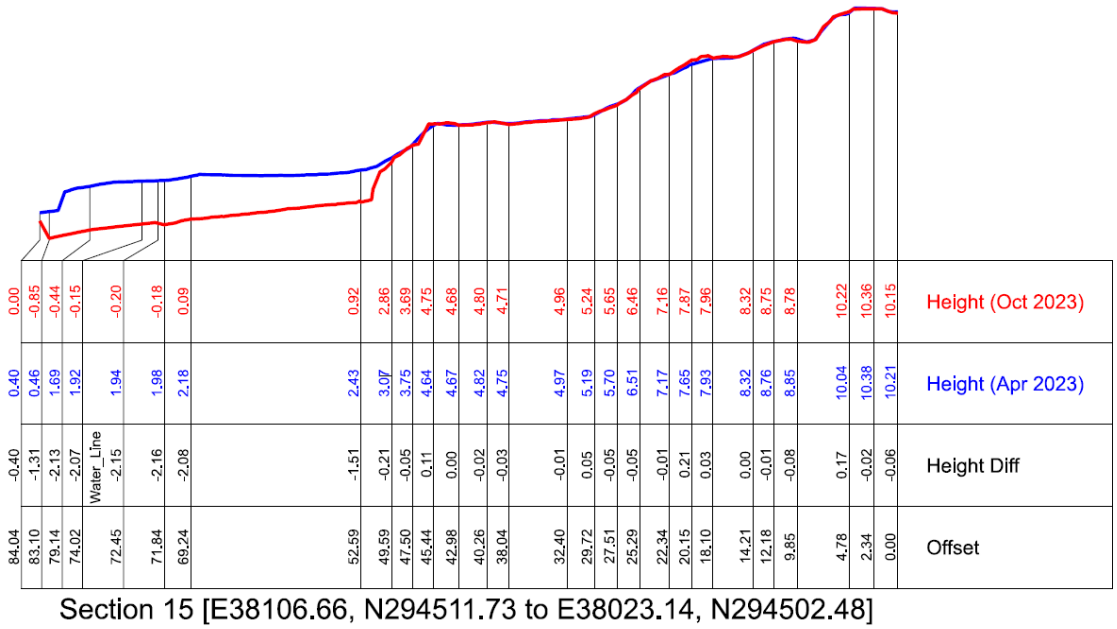
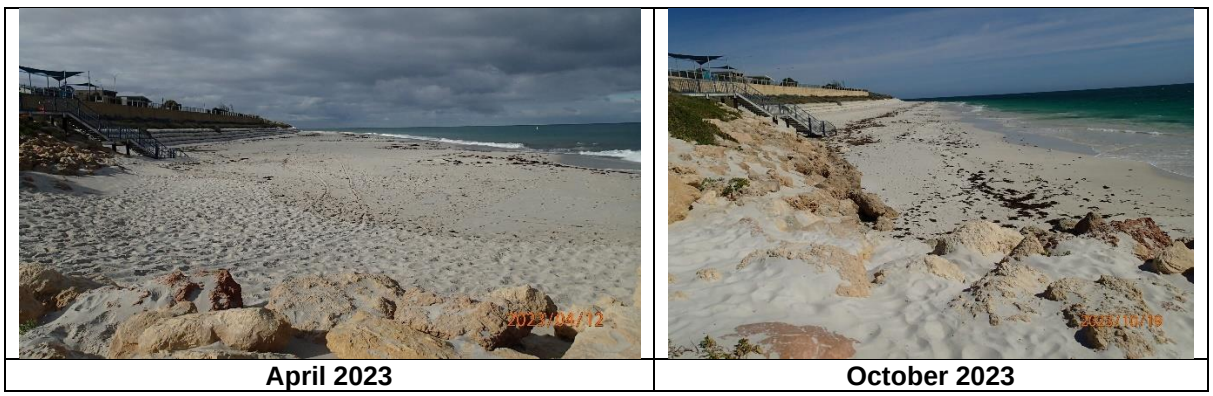


Figure 5-11 *Cross section 15 at Quinns Beach which shows a reduction in beach height of up to 2.15m just below the waterline between April 2023 and October 2023.*

The beach profile comparison for Quinns Beach cross section 15 shows a reduction in beach elevation of up to 2.15m between the April 2023 survey and the October 2023 survey, which represents significant erosion along this section of coastline. Seasonal erosion at this location is common as the site is confined by Quinns Groyne 1 to the north which limits southward transport of sand in the winter months. As the reduction in elevation was mostly limited to the beach area close to the waterline, this site was not identified as having experienced major seasonal erosion in manual imagery analysis.



April 2023	October 2023

Figure 5-12 *Manual imagery taken at Mindarie B02 Down-Coast in April 2023 and October 2023.*

5.3.5.3 Yanchep

Cross Section 1 – Manual Imagery Site B01 Down-Coast

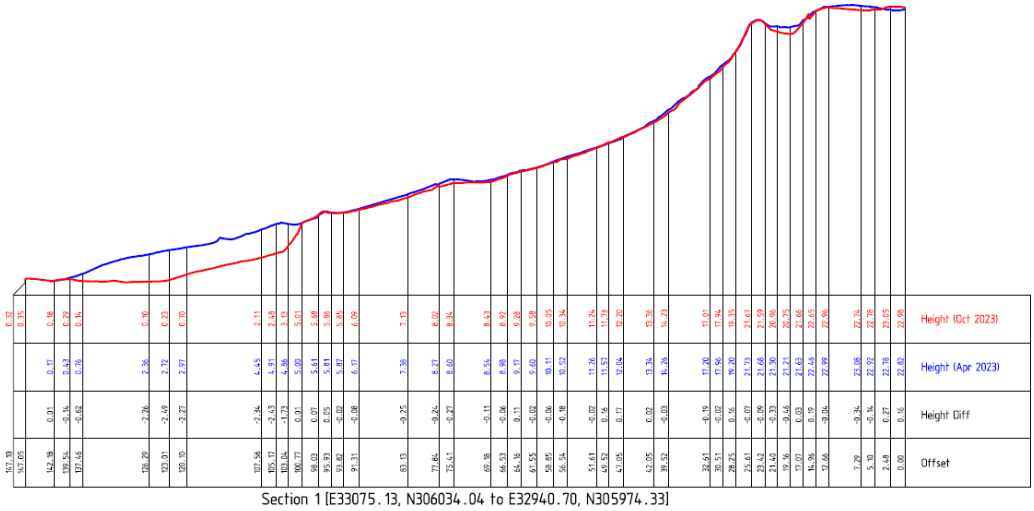


Figure 5-13 *Cross section 1 at Yanchep Beach which shows a reduction in beach height of up to 2.49m between April 2023 and October 2023.*

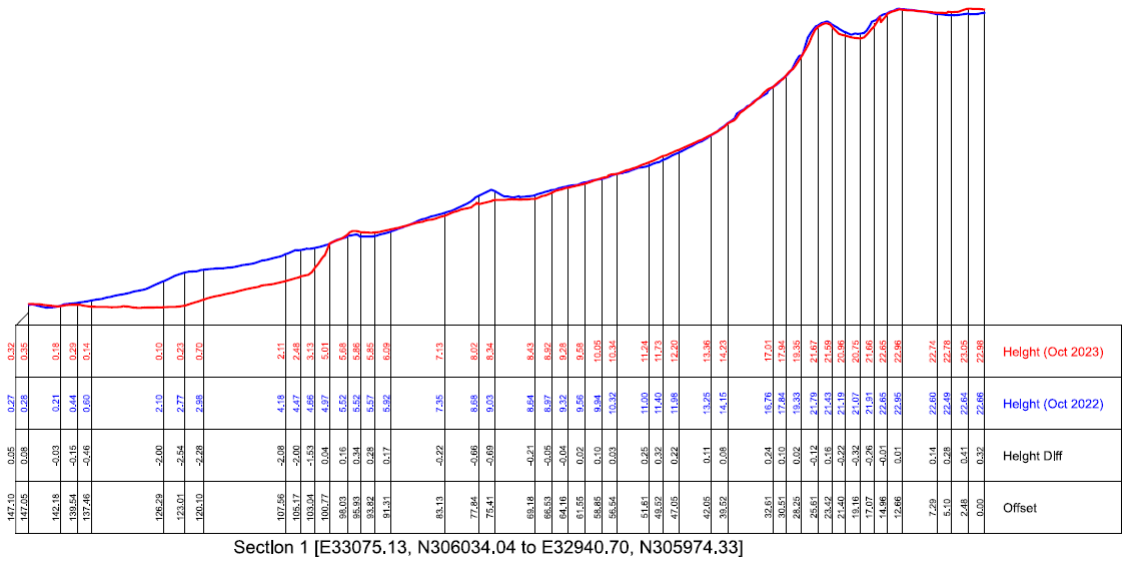


Figure 5-14 *Cross section 1 at Yanchep Beach which shows a reduction in beach height of up to 2.54m between October 2022 and October 2023.*

The results from cross section 1 along Yanchep Beach show a significant drop in elevation of the beach profile between April 2023 and October 2023 as well as between October 2022 and October 2023. This site is located along the southern Yanchep coastline, away from infrastructure. The site is situated 400m south of Yanchep manual imagery site B01 (Figure 5-15) and is likely not captured within the field of view of this site.

Figure 5-15 Manual imagery taken at Yanchep B01 Down-Coast in April 2023 and October 2023.

Cross Section 23 – Manual Imagery Site B07 Up-Coast

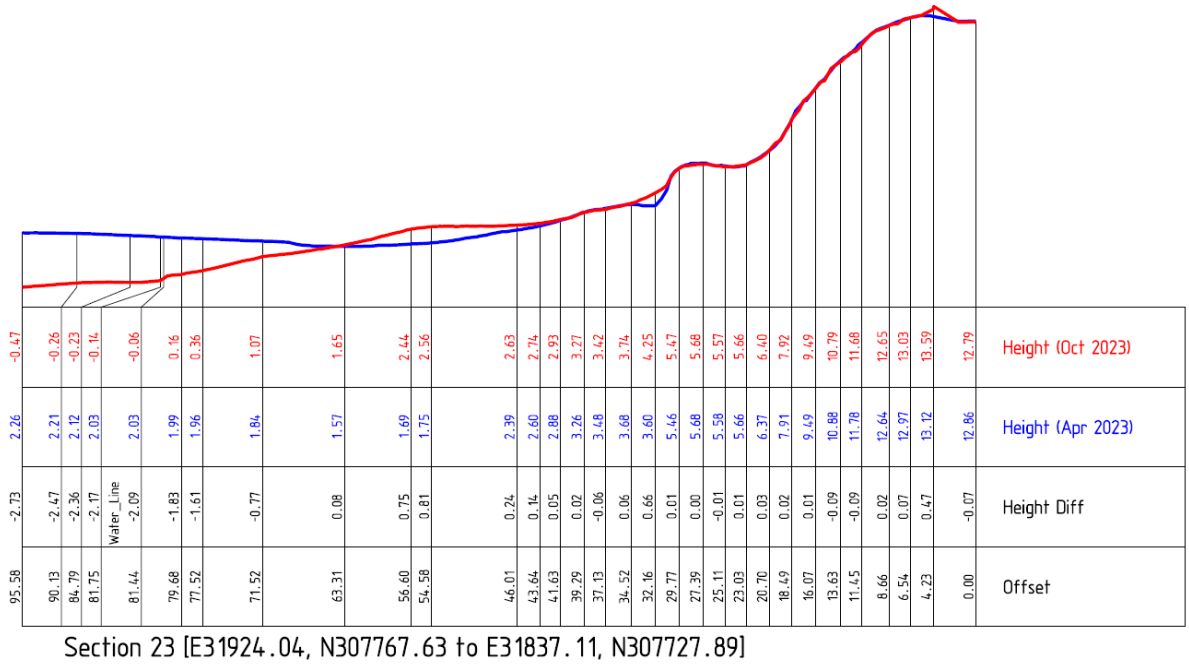


Figure 5-16 Cross section 23 at Yanchep Beach which shows a reduction in beach height of up to 2.73m between April 2023 and October 2023.

Yanchep Cross Section 23 is situated within the field of view of manual imagery site Yanchep B07 Up-Coast (Figure 5-17) and while major seasonal erosion was not identified in manual imagery analysis, beach profile cross section comparisons show a reduction in elevation of 2.73m between April 2023 and October 2023. While minor erosion is noted in the manual imagery observations, the reduction in elevation identified in beach profile cross sections was mostly limited to the beach area close to the waterline, and outside of the field of view, which is why this site was not identified as having experienced major seasonal erosion in manual imagery analysis. Seasonal erosion at this site is common, as the site is confined by two natural rock headlands to the north and south, and sediment is often captured within the site across the summer months as the northern headland interrupts the northward sediment transport.

April 2023	October 2023

Figure 5-17 Manual imagery taken at Yanchep B07 Up-Coast in April 2023 and October 2023.

5.3.5.4 Two Rocks

Cross Section 2 – Manual Imagery Site B07 Down-Coast

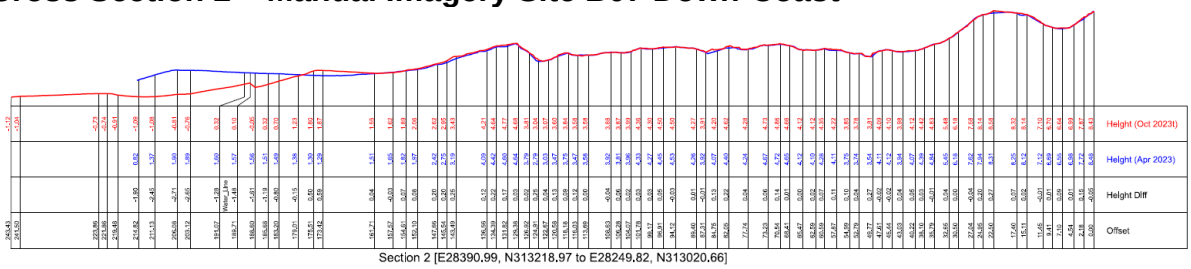


Figure 5-18 Significant reduction in beach elevation below the waterline between April and October 2023 recorded at Two Rocks Cross Section 2.

Two Rocks cross section 2 is within the field of view of Two Rocks manual imagery site B07 (Figure 5-19) and while there was minor erosion oberved at the site with a notable reduction in beach width (Section 4), the extent of erosion below the waterline was not captured.

April 2023	October 2023

Figure 5-19 Manual imagery taken at Two Rocks B07 Down-Coast in April 2023 and October 2023.

6 Remote Monitoring

Five remote monitoring cameras were installed along Quinns and Yanchep Beach in November 2021. The location and field of view of the cameras was selected to monitor vulnerable sections of the City's coastline, these locations are presented below in Figure 6-1 and Figure 6-2. The cameras take photos hourly between the hours of 7:00 and 18:00. Timelapse videos were created for each camera to assess morphological changes to the coastline between October 2022 and October 2023.

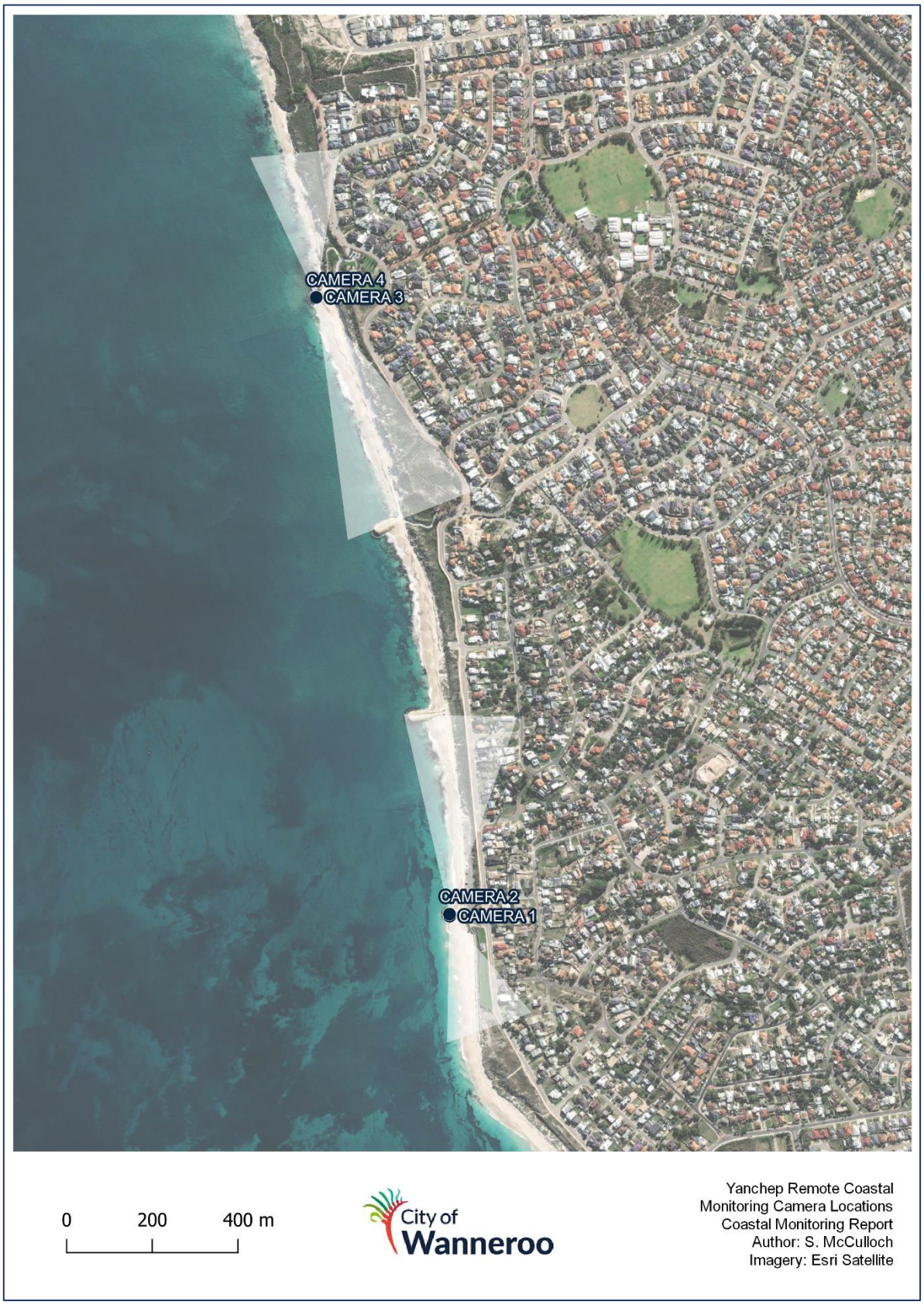


Figure 6-1 *Quinns Rocks Remote Coastal Monitoring Camera Locations.*

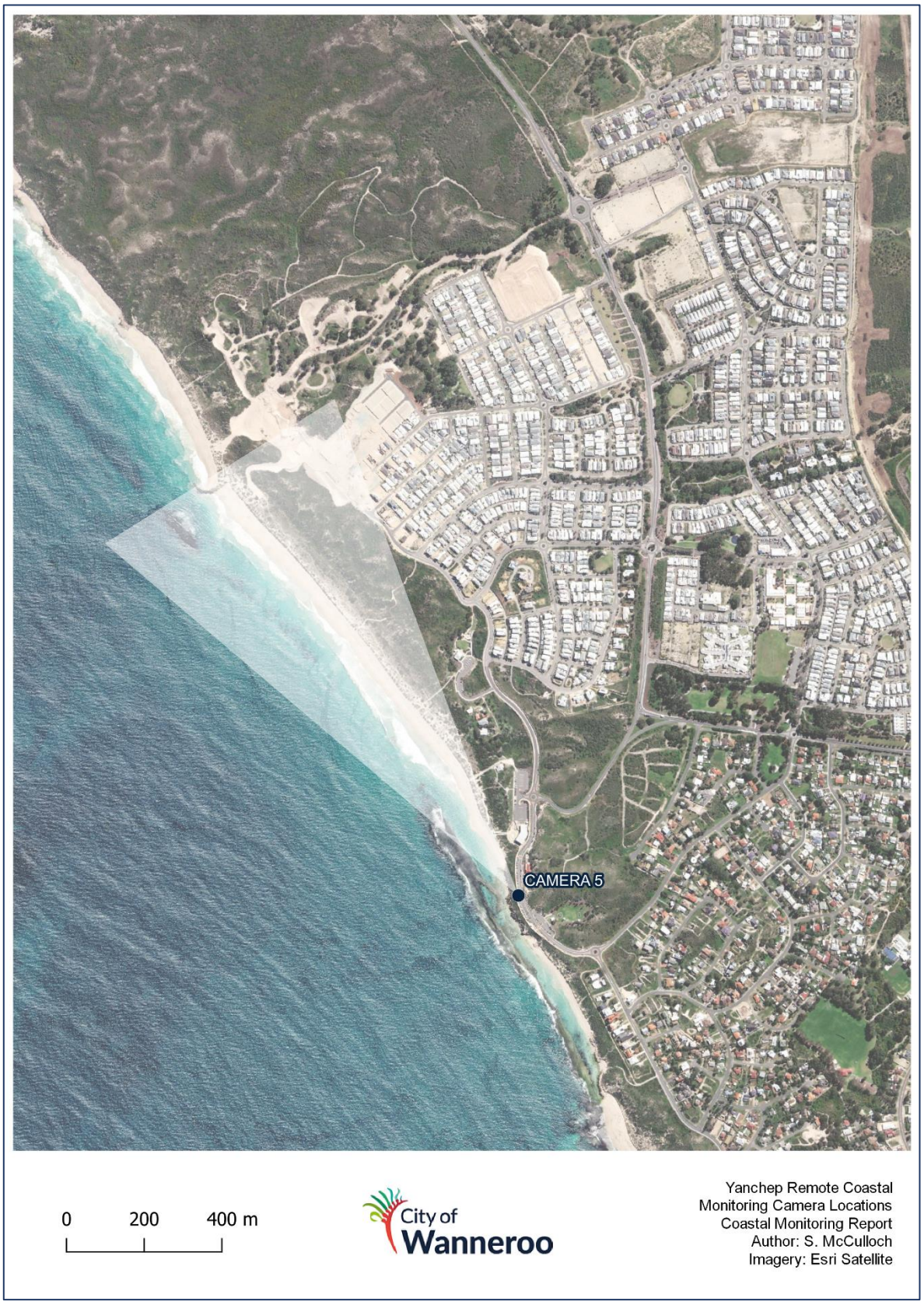
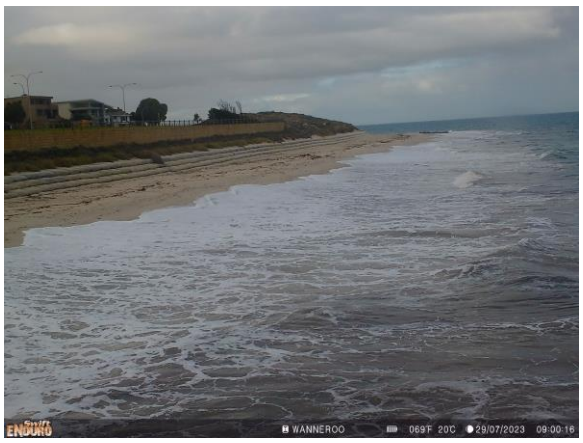


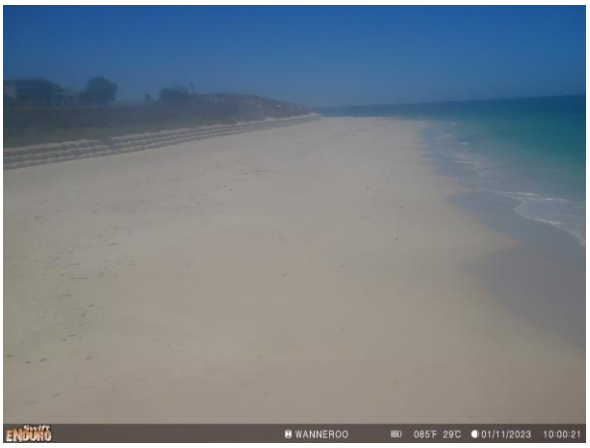
Figure 6-2 Yanchep Remote Coastal Monitoring Location.

6.1 Quinns Camera 1

Quinns Camera 1 captures the beach immediately south of Groyne 1, adjacent to the GSC Revetment. The condition of Camera 1 was impacted in October 2022 and unfortunately was out of action until June 2022. The time series of images taken from Quinns Camera 1 between June 2023 and October 2023 shows a wide beach at the beginning of the monitoring period in June 2023 that is subject to erosion until the end of July 2023. The beach begins to build up from August to the end of the monitoring period in October 2023. This section of coastline is at its most accreted position at the end of the monitoring period, as outlined in Figure 6-3. As outlined in Section 2.2.1 there was a significant increase in southerly winds between September and October 2023 which is likely to have contributed to the build-up of sand to the south of Groyne 1.



Most receded position – 29 July 2023

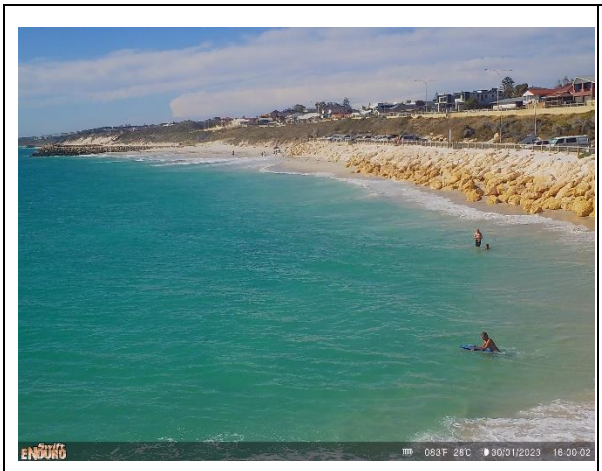


Most accreted position – 1 November 2023

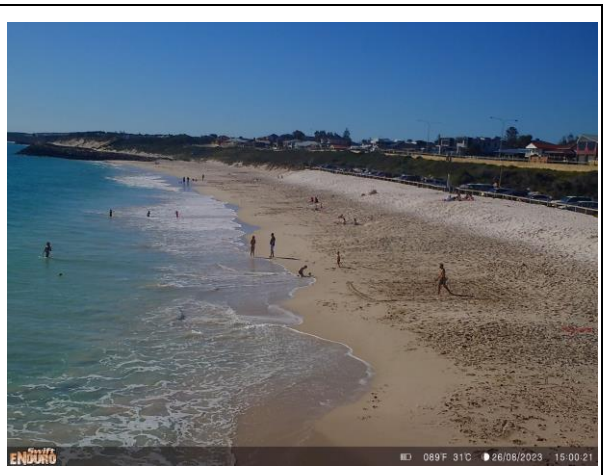
Figure 6-3 Most receded and most accreted shoreline position to the south of Quinns Groyne 1 during the study period.

6.2 Quinns Camera 2

Quinns Camera 2 captures the beach immediately north of Groyne 1, adjacent to the Frederick Stubbs Carpark. Northward longshore drift is particularly evident from the start of the monitoring period, in October 2022, with northward longshore transport depositing sand to the south of Groyne 2. Steady erosion of the beach area immediately adjacent to the Frederick Stubbs Carpark continues until late January 2023 where sediment trapped to the south of Groyne 1 bypasses the Groyne and is deposited on the beach. Nourishment was undertaken at this site in May 2023, where 4,950 tonnes of sand was placed to provide a buffer against the impacts of winter storm events and create a safe and accessible beach. The placement of nourishment sand and additional sand transported south via early August storm events is likely to have led to the beach's most accretion position in August 2023 as identified through automatic imagery.



Most receded position – 30 January 2023



Most accreted position – 26 August 2023

Figure 6-4 Most receded and most accreted shoreline position to the north of Quinns Groyne 1 during the study period.

6.3 Quinns Camera 3

Quinns Camera 3 monitors the beach and dunes to the south of Quinns Groyne 4. Hourly images of the site show slow steady accretion of the beach from the start of the monitoring period until January 2023 where the beach then begins to erode. The most receded shoreline position was observed in July, just following a minor storm event, which resulted in minor erosion at the dune toe site and exposure of limestone bedrock on the beach. Beach scraping was undertaken at this site in early February 2023 where sand that had built up to the south of Groyne 4 was taken from the nearshore and used to create a buffer at the base of the dunes. This buffer limited the impact of winter storm events on the dune system. Throughout August, until the end of the monitoring period, the beach appears to be steadily accreting.

Most receded position – 4 July 2023

Most accreted position – 20 January 2023

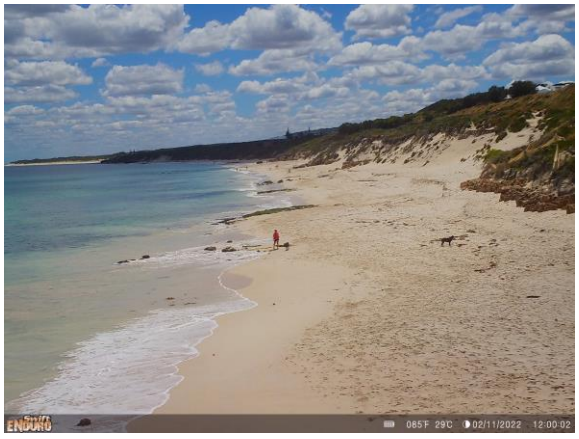
Figure 6-5 Most receded and most accreted shoreline position to the south of Quinns Groyne 4 during the study period.

6.4 Quinns Camera 4

From the beginning of the monitoring period in October 2022, the beach area to the north of Groyne 4 was steadily accreting until the start of November 2022 where the beach continued to erode until the start of seasonal winter period in April 2023. Seasonal erosion over the summer months is expected in

this area as prevailing southerly winds generally transport sand to the north, away from the Groyne. Across the winter months, until the end of the monitoring period, the beach appears to be steadily accreting. Again, this is expected for this site as sand moves south during the winter months, driven by southward-flowing currents generated by north-westerly storms and is captured at the site by Quinns Groyne 4.

Most receded position – 26 April 2023

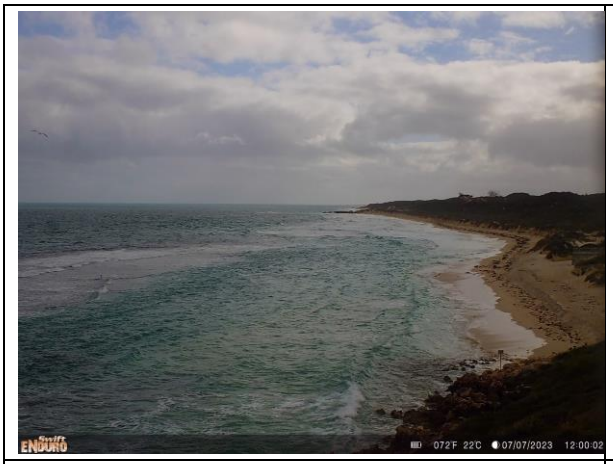


Most accreted position – 2 November 2022

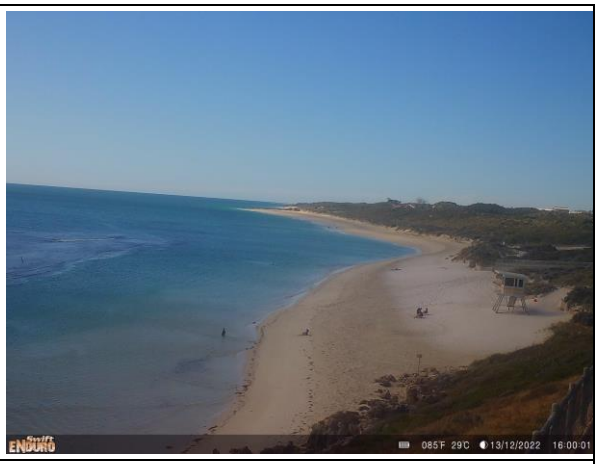
Figure 6-6 Most receded and most accreted shoreline position to the north of Quinns Groyne 4 during the study period.

6.5 Yanchep Camera

The beach area captured within the field of view of the Yanchep Remote Monitoring Camera is bounded by a rocky headland to the south and a small rock groyne to the north. Yanchep Lagoon Beach is at an accreted position at the start of the monitoring period, October 2022. This is expected as southward-flowing currents generated by north-westerly storms move sand to the south which is then captured at Yanchep Lagoon Beach by the headland. The beach then appeared to steadily erode across the summer period, with the beach eroding further following a minor storm even in July 2023.



Most receded position – 7 July 2023



Most accreted position – 13 December 2022

Figure 6-7 Most receded and most accreted shoreline position at Yanchep Lagoon Beach.

7 Aerial Imagery

Aerial imagery obtained from Nearmap and captured during the six-monthly LiDAR Surveys is used to assess changes to the CoW coastline.

The improved temporal resolution of aerial imagery allows us to assess the condition of the coastline throughout the year, unlike manual imagery, where we are limited to only two snapshots in time. Analysis of aerial imagery is limited to the visual assessment of changes to the coastline, which, in this instance, is defined as the shoreline.

During the study period, from October 2022 to October 2023, a total of 11 aerial images of the sites were available.

Table 7-1 Date of Aerial Images

Imagery Date	Imagery Time	Source	Water Level at Time of Monitoring (Fremantle Tide Gauge – mAHD)
1 October 2022	09:33 AM	Nearmap	-0.22 mAHD
3 October 2022	10:30 AM to 4:30 PM	MNG	-0.36 to -0.19 mAHD
4 December 2022	9:20 AM to 10:14 AM	Nearmap	-0.01 to 0.03 mAHD
25 February 2023	9:40 AM to 3:08 PM	Nearmap	0.11 to 0.30 mAHD
23 April 2023	10:20 AM to 3:20 PM	Nearmap	0.36 to 0.71 mAHD
29 April 2023	10:35 AM	Nearmap	0.16 mAHD
1 July 2023	11:36 AM to 12:22 PM	Nearmap	0.05 to 0.17 mAHD
4 October 2023	12:19 PM	Nearmap	-0.40 mAHD
5 October 2023	8:10 AM	Nearmap	-0.25 mAHD
7 October 2023	11:13 AM to 2:30 PM	Nearmap	-0.26 to -0.10 mAHD
17 October 2023	7:00 AM to 3:00PM	MNG	-0.17 to 0.08mAHD

7.1 Assessment Methodology

Similar to the analysis of remote imagery, aerial and satellite imagery is assessed through visual assessment.

Visual assessment allows for the identification of major erosion or accretion periods and is used to determine the most advanced and receded shoreline position during the observation period. Visual assessment also allows for the identification of additional vulnerable coastline areas that may require more detailed assessment into the future. Images obtained throughout the observation period are all loaded into QGIS software, georeferenced and assessed individually.

7.2 Results

For assessment purposes, the coastline has been divided into fourteen discrete areas as outlined in Table 7-2. The most advanced and most receded shoreline position was identified for each discrete area.

Table 7-2 Most advanced and receded shoreline positions as identified through aerial imagery review.

Area	Most Receded Shoreline Position	Most Advanced Shoreline Position
Clayton's Beach	1 October 2022	25 February 2023
Quinns Main Beach	29 April 2023	11 December 2022
Quinns – GSC Revetment	4 October 2023	14 January 2023
Quinns – Groyne 1 to Groyne 2	14 January 2023	4 October 2023
Quinns – Groyne 2 to Groyne 3	4 October 2023	14 January 2023
Quinns – Groyne 3 to Groyne 4	4 October 2023	14 January 2023
Jindalee	4 October 2023	14 January 2023
Eden Beach	1 August 2023	1 October 2022
Shorehaven	23 April 2023	7 October 2023
Eglinton Beach	4 October 2023	25 February 2023
South Yanchep	4 October 2023	25 February 2023
North Yanchep	23 April 2023	4 December 2022
South of Two Rocks Marina	1 October 2022	23 April 2023
North of Two Rocks Marina	1 August 2023	4 December 2022

The most receded shoreline position was observed in October 2023 at a number of sites which is likely due to erosion along these sections of coastlines across the winter months. The most advanced shoreline position was observed in January and February aerial imagery at a number of sites which indicates a significant build-up of sediment along the coastline over the summer months.

Some areas experienced the most receded and advanced shoreline positions outside of the survey periods (April and October). This indicates that while seasonal assessment of beach volume changes as detailed in **Section 5.2.1** are indicative, they do not necessarily capture the total seasonal beach volume change for each area. Further assessment of satellite, aerial and remote imagery allows for the identification of the most appropriate time for surveys to capture the most accurate seasonal changes in beach volumes.

8 Results and Recommendations

8.1 Seasonal Changes

Areas that experienced major seasonal erosion were identified via manual imagery and the analysis of beach cross-sections. These areas are as follows.

1 **Two Rocks Beach North:** Major erosion was identified along Two Rocks Beach North, adjacent to the Sovereign Drive Beach Access Way, between October 2022 and April 2023 via manual imagery. The survey cross-section comparisons show a drop in elevation of 2.64m between the October 2022 and April 2023 surveys. This site is situated within a coastal erosion hotspot and seasonal erosion is experienced at this site each year.

2 **Fisherman's Hollow Beach:** Fisherman's Hollow Beach, south of Yanchep Lagoon, experienced erosion between April 2023 and October 2023, below the waterline a maximum elevation difference of 2.73m was recorded at cross section 23. It is important to note that residential houses and road infrastructure are in close proximity to the site and could, in future, be susceptible to the effects of coastal erosion. There is however, significant seasonal accretion each year at this site and long-term manual imagery results show only minor erosion at the site and minimal erosion at the base of the dunes. It is recommended that this area is closely monitored moving forward.

3 **Yanchep Lagoon Beach North:** Significant seasonal erosion was identified along an area of approximately 200m at Yanchep Lagoon Beach, to the north of the beach access way. Seasonal survey cross-section comparisons show a maximum reduction in elevation of 1.95m between the October 2022 and April 2023 LiDAR surveys. It is possible that erosion at this site, over the summer period, was caused by higher than average wind speeds and sea wave action. Wind data captured at the Ocean Reef Weather Station recorded a higher percentage of winds exceeding 40km/h over the summer 2022/23 period than in previous years.

4 **Quinns Beach North of Groyne 3:** A significant reduction in beach width and major erosion scarp was noted at Quinns Dog Beach, immediately north of Groyne 3, in April 2023 manual imagery. Beach cross-section analysis noted a drop in elevation of 2.17m just below the water line at this location. However, renourishment was undertaken at this location in May 2023, after monitoring, in response to the eroded beach conditions which improved beach usability at the site and provided a buffer for erosion that resulted from the subsequent winter storms.

5 **Quinns Beach GSC Revetment South of Groyne 1:** Significant seasonal erosion is expected at this site each year as the site is confined by Quinns Groyne 1 which limits southward sediment transport. Major erosion at this site was not identified via manual imagery however survey cross section comparisons showed a significant reduction is elevation close to the waterline. While there was still significant erosion at this site across the 2023 winter period, the level of erosion was significantly less than in previous winter periods.

6 **Quinns Beach South:** During the 2022/23 summer period there was significant erosion at Quinns Beach South. Manual imagery shows a wide beach in October 2022 and a very narrow beach in April 2023, with loss of dune vegetation. Analysis of survey cross sections at this site show a reduction in elevation of 2.55m between October 2022 and April 2023. While seasonal erosion is expected at this site as sediment is transported northward, away from the headland immediately south of this site, major seasonal erosion is uncommon. However, it is important to note that long-term survey analysis show a net increase of beach volume at this site between 2018 and 2023 which is likely due to higher than average winter storm activity and subsequent southward transport of sediment.

7 **Clayton's Beach, Mindarie**: Claytons Beach in Mindarie is bound by the Mindarie Breakwater to the north which interrupts longshore transport leading to significant seasonal erosion over the winter months. Seasonal erosion is expected at this site each year, with a total beach volume loss of 52,050m^3 reported for the 2023 winter period. Major erosion was not observed at this site via manual imagery as a there was a significant storm surge during the April 2023 monitoring period which led to high waterlines making it difficult to assess seasonal changes through manual imagery. However, survey cross sections show a reduction of 2.57m between the April and October 2023 surveys.

8.2 Annual Change

Changes in beach volumes between October 2022 and October 2023 were assessed via LiDAR survey elevation difference plots, volume change calculations and cross section transect comparisons undertaken by MNG. Volume change calculations show an overall increase in beach volume across the coastline between October 2022 and October 2023 in all coastal focus areas, aside from Yanchep.

Over the year, there was a net gain of 6,124 m^3 along the Quinns Rocks coastline however it is important to note that approximately 6,700 m^3 of sand was placed at Quinns Rocks in May 2023 as part of the City's ongoing renourishment program. The gain in beach volume across the year was likely a result of the relatively calm winter conditions where there were less frequent significant erosion events.

While there was a gain in beach volume for all monitored suburbs, there was a significant overall decrease in beach volume along the Yanchep coastline. Overall, the Yanchep coastline saw a net reduction of 19,000m^3 in net beach volume between October 2022 and October 2023. The significant seasonal erosion observed within Section 4 of Yanchep Beach following the 2022/23 summer period likely contributed to the overall reduction in beach volume along Yanchep. Yanchep Lagoon Beach is bound by a rock headland to the south which interrupts the longshore transport of sediment during the summer months. By the April 2023 monitoring period sediment had begun to move around the headland and build up at the southern end of Yanchep Lagoon Beach however the major erosion was observed along the northern end of the beach.

The most notable areas of beach volume increase are within Two Rocks and Mindarie where the total estimated net beach volume increase within Two Rocks Section 1 and Claytons Section 1 was 41,901m^3 and 40,744m^3 respectively.

One survey cross section showed significant reduction in beach elevation between October 2022 and October 2023 at one site in Yanchep. The survey results from the Yanchep Dog Beach, to the south of Fisherman's Hollow, show an approximate reduction of 2.5m in the beach between the October 2022 and the October 2023 surveys. This was not within the field of view of any manual imagery sites, this highlights the importance of utilising multiple data sets when undertaking coastal monitoring.

8.3 Long-term Changes

Long-term changes to the shoreline were assessed via manual imagery where, in Quinns Rocks and Two Rocks, October 2023 images were compared to images taken at the same location in October 2014, allowing for an assessment of long-term changes of the coastline from up to eight years prior. At Yanchep, the earliest recorded monitoring images were taken in October 2018 and therefore the long-term changes of the coastline can only be assessed from up to five years prior.

One site in Yanchep was identified through manual imagery as having experienced major long-term erosion. The site is situated to the north of Yanchep Lagoon. Following significant erosion observed at the site over the 2022/23 summer period, a significantly narrow beach is evident in the image taken in October 2023 with notable impact to the dunes.

No other areas were found to have experienced major erosion over the long-term however it is difficult to assess long-term changes to the coastline through manual imagery alone. It is recommended that long-term changes be assessed via the analysis of changes to vegetation lines in aerial imagery in the future.

Long-term trends in erosion and accretion were assessed by analysing historic surveyed net beach volume changes. There has been a notable increase in net beach volume across the Mindarie coastline since October 2021, where strong seabreezes observed throughout the seasonal summer periods likely contributed to increased sand build up at the site. Long-term trends for Quinns Beach show a significant increase in the beach sections north of the Quinns Artificial Headland for this study period relative to other years. Despite the calm winter conditions for 2023 there was a considerable loss in beach volume across Yanchep between October 2022 and October 2023. It is possible that this is a result of strong summer seabreeze conditions transporting sediment further north, away from the Yanchep coastline. There has been a considerable increase in beach volume within Two Rocks Section 1 for the periods assessed between October 2021 and October 2023. This pattern is similar to Mindarie and is likely a result of strong summer seabreeze conditions transporting sand northward.

8.4 Notable Erosion Events

Due to the relatively calm winter conditions, there were no significant acute erosion events across the 2023 winter period. The most notable winter storm events were observed on the 4th of July and 13th of September 2023 which recorded a peak significant wave height of 6.59m and 6.44m respectively. While there was some erosion observed across the study period, these storm events did not significantly impact any of the City's coastal assets or dune systems.

8.5 Renourishment Activities

The location, date and quantity of renourishment activities along the coastline within the past 12 months is outlined in the table below.

Table 8-1 Renourishment locations and quantities within the study period.

Date	Renourishment Location	Renourishment Quantity
May 2023	Quinns Beach, adjacent to Frederick Stubbs Carpark	4,950 tonnes
May 2023	Quinns Beach, north of Groyne 3	3,300 tonnes

8.6 Recommendations

8.6.1 Automatic Tracking of Shorelines

Five remote monitoring cameras were installed at Quinns and Yanchep in November 2021. Remote monitoring cameras allow for the continuous assessment of the coastline, particularly in areas where continued coastal erosion is experienced. It is recommended that the methodology for automatic shoreline tracking be finalised for 2023/24 so that hourly data can be quantified. Automatic shoreline tracking can be used with imagery obtained from remote monitoring cameras to track the shoreline across the study period and estimate changes in beach volume.

8.6.2 Automatic Vegetation Line Tracking in Aerial Imagery

The City is in the process of developing a methodology for the automatic detection of vegetation lines in satellite and aerial imagery It is recommended that this methodology be finalised in 2023/24 as it will facilitate quantitative analysis of satellite and aerial imagery. This will allow for the long term analysis of coastline changes as historic Aerial Imagery of the City's coastline has been captured since 1965.

8.6.3 Yanchep Study to Inform Coastal Management

It is recommended that, similar to the Quinns Beach Long-Term Coastal Management Study, a Yanchep Beach Coastal Management Study be undertaken to inform the future long-term management practices for Yanchep Beach. Yanchep Beach is one of the City's most popular beaches and is subject to significant seasonal and annual erosion. Sections of the Yanchep Coastline have also been identified as vulnerable coastal locations within the City's Coastal Hazard Risk Management and Adaptation Plan (CHRMAP). Additionally, there was significant erosion along the northern portion of Yanchep Lagoon Beach across the 2022/23 summer period. There are a number of residential properties in close proximity to this dune system and it is important to investigate future coastal management actions to address these risks.

8.6.4 Continued Beach Renourishment

It is recommended that beach renourishment continues to be undertaken in vulnerable areas to minimise the impact of erosion on coastal infrastructure and the City's dune systems. It is recommended that the results from this report be utilised to identify areas that require ongoing scheduled renourishment works. As outlined in Section 4.2.1 significant seasonal erosion was experienced at Quinns Dog Beach, to the north of Groyne 3, which impacted beach accessibility and beach amenity. Continued beach renourishment is required along Quinns Beach to address localised erosion issues.

As outlined in Section 5.2.3 there was considerable accretion along the coastline to the south of the Two Rocks Marina Southern Breakwater since October 2021. It is recommended that this location be investigated as a potential future sand source for nourishment although it is important to note that the site is currently inaccessible and major beach access upgrades would be needed in order to implement this option.

8.6.5 Continued Beach Scraping

It is recommended that beach scraping be undertaken annually along Quinns Dog Beach, to the south of Groyne 4, during periods of significant accretion. This will continue to improve the condition of the dune system and provide a buffer against the impact of winter storms. It is also recommended that the City investigate additional sites where beach scraping could be implemented to limit the impacts of erosion.

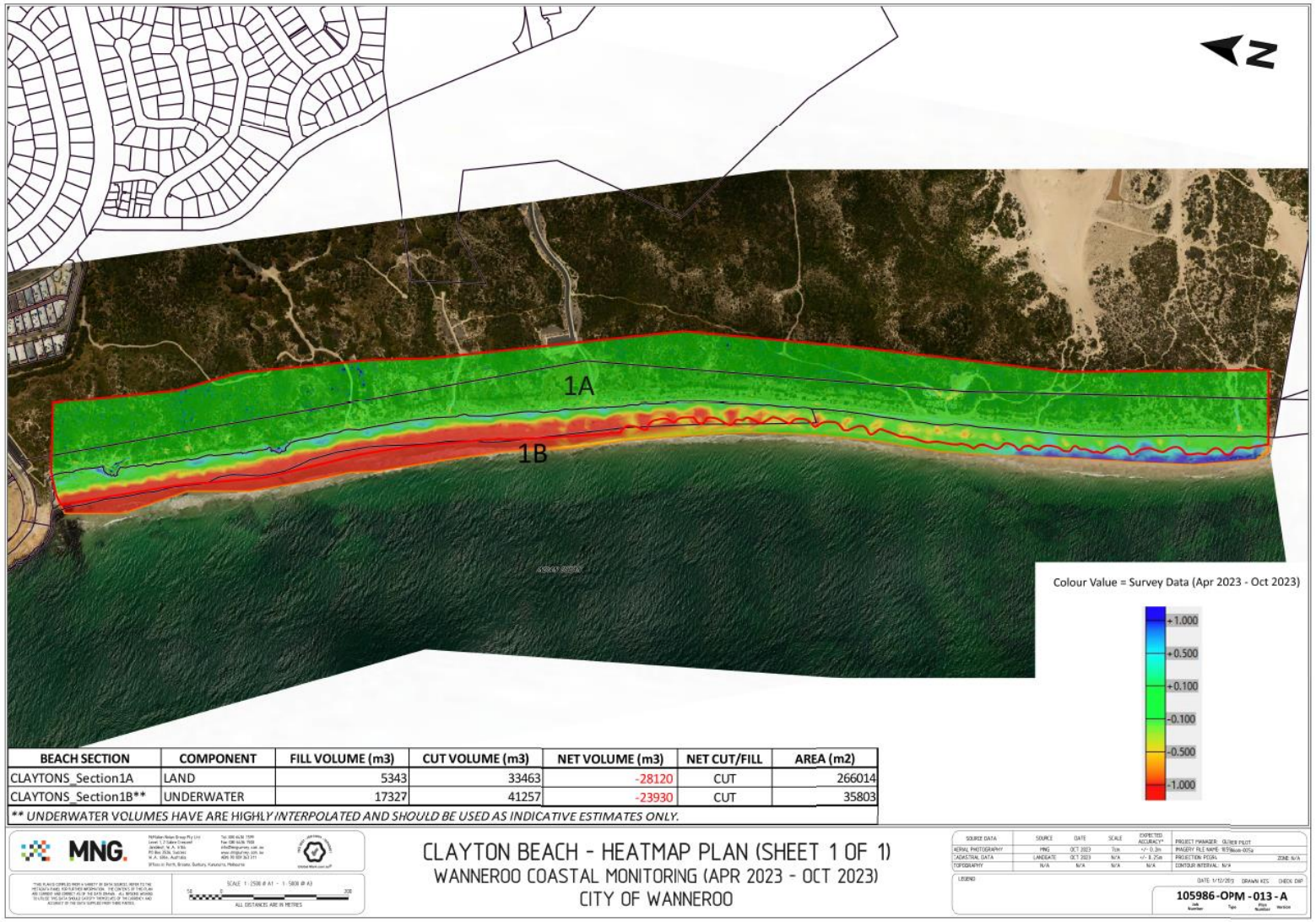
8.6.6 Incorporation of Nearshore Wave Buoy Data

The City recently engaged a contractor to deploy three nearshore Sofar Spotter Wave Buoys offshore of Quinns Rocks and Yanchep. These buoys were deployed in December 2023 and it is recommended that the data captured from by these buoys be incorporated into the City's next Coastal Monitoring Report. The nearshore wave buoys will enable site specific analysis of metocean conditions allowing for an improved understanding of coastal changes.

8.6.7 Renewal of the Two Rocks Marina Northern Breakwater

The dune system immediately north of the Two Rocks Marina Northern Breakwater has been subject to significant ongoing erosion since the construction of the Marina. Over this period, the condition of the Northern Breakwater has deteriorated considerably. It is recommended that the condition of this Breakwater be formally assessed and the structure be renewed/repaired where required. While the structure is under the management of the Department of Transport (DoT), the City will work with the DoT to manage this process.

Appendix A



BEACH SECTION	COMPONENT	FILL VOLUME (m3)	CUT VOLUME (m3)	NET VOLUME (m3)	NET CUT/FILL	AREA (m2)
CLAYTONS_Section1A	LAND	5343	33463	-28120	CUT	266014
CLAYTONS_Section1B**	UNDERWATER	17327	41257	-23930	CUT	35803

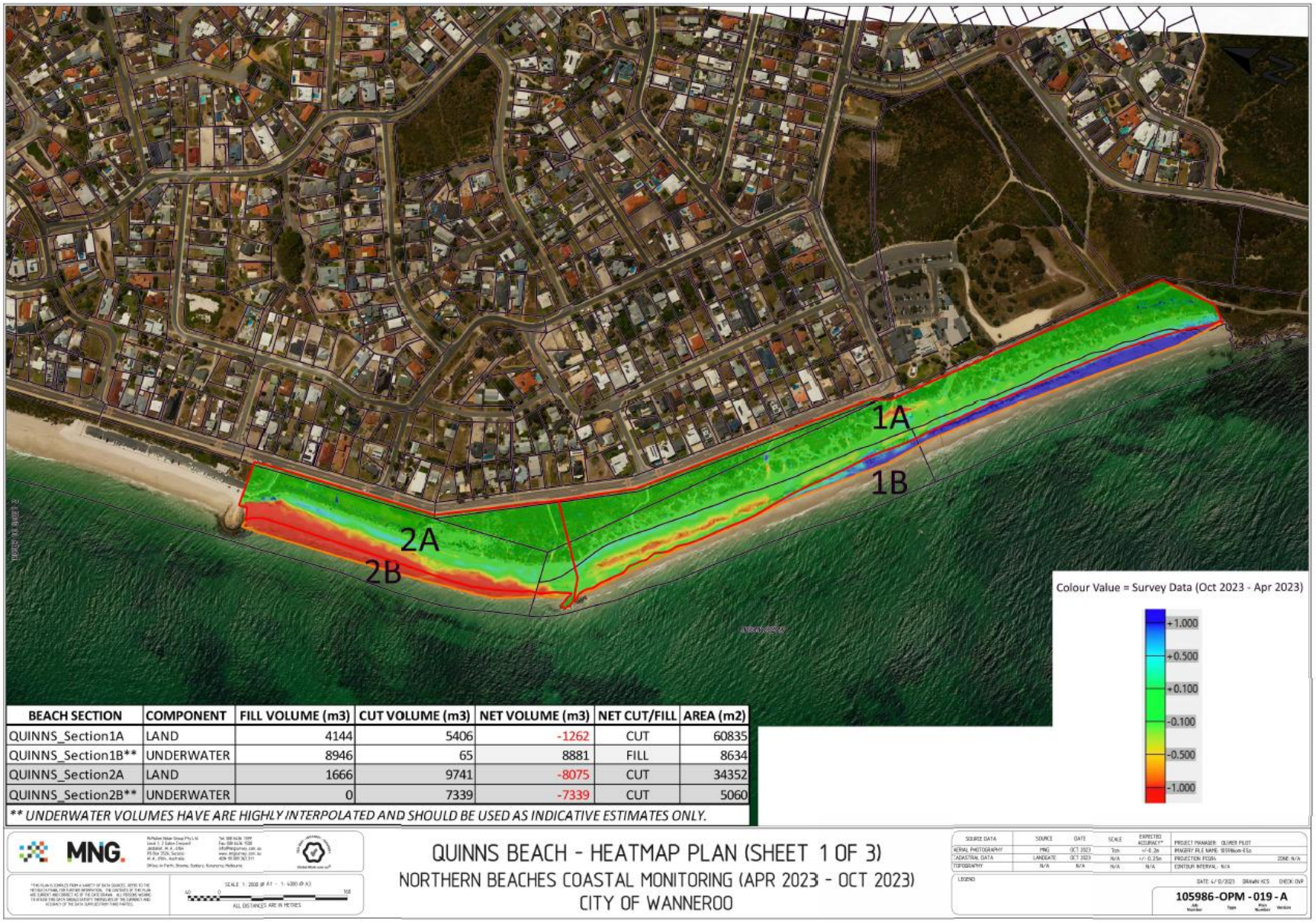
** UNDERWATER VOLUMES HAVE ARE HIGHLY INTERPOLATED AND SHOULD BE USED AS INDICATIVE ESTIMATES ONLY.

MNG.

CLAYTON BEACH - HEATMAP PLAN (SHEET 1 OF 1)
WANNEROO COASTAL MONITORING (APR 2023 - OCT 2023)
CITY OF WANNEROO

105986-OPM-013-A

Figure 0-1 Net seasonal beach volume change plot for Claytons Beach in Mindarie.



BEACH SECTION	COMPONENT	FILL VOLUME (m3)	CUT VOLUME (m3)	NET VOLUME (m3)	NET CUT/FILL	AREA (m2)
QUINNS_Section1A	LAND	4144	5406	-1262	CUT	60835
QUINNS_Section1B**	UNDERWATER	8946	65	8881	FILL	8634
QUINNS_Section2A	LAND	1666	9741	-8075	CUT	34352
QUINNS_Section2B**	UNDERWATER	0	7339	-7339	CUT	5060

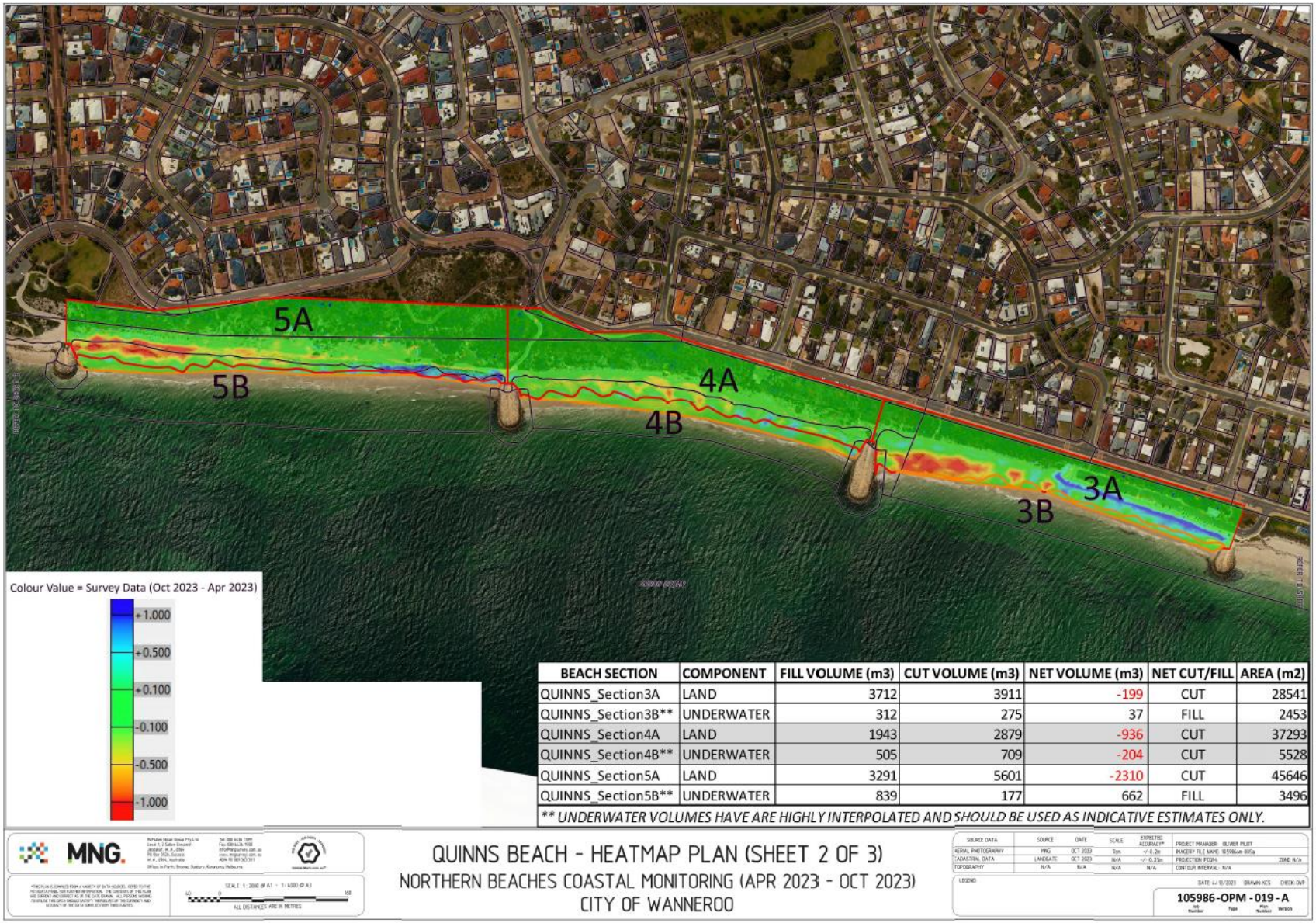
*** UNDERWATER VOLUMES HAVE ARE HIGHLY INTERPOLATED AND SHOULD BE USED AS INDICATIVE ESTIMATES ONLY.*

MNG.

QUINNS BEACH - HEATMAP PLAN (SHEET 1 OF 3)
NORTHERN BEACHES COASTAL MONITORING (APR 2023 - OCT 2023)
CITY OF WANNEROO

105986-OPM-019-A

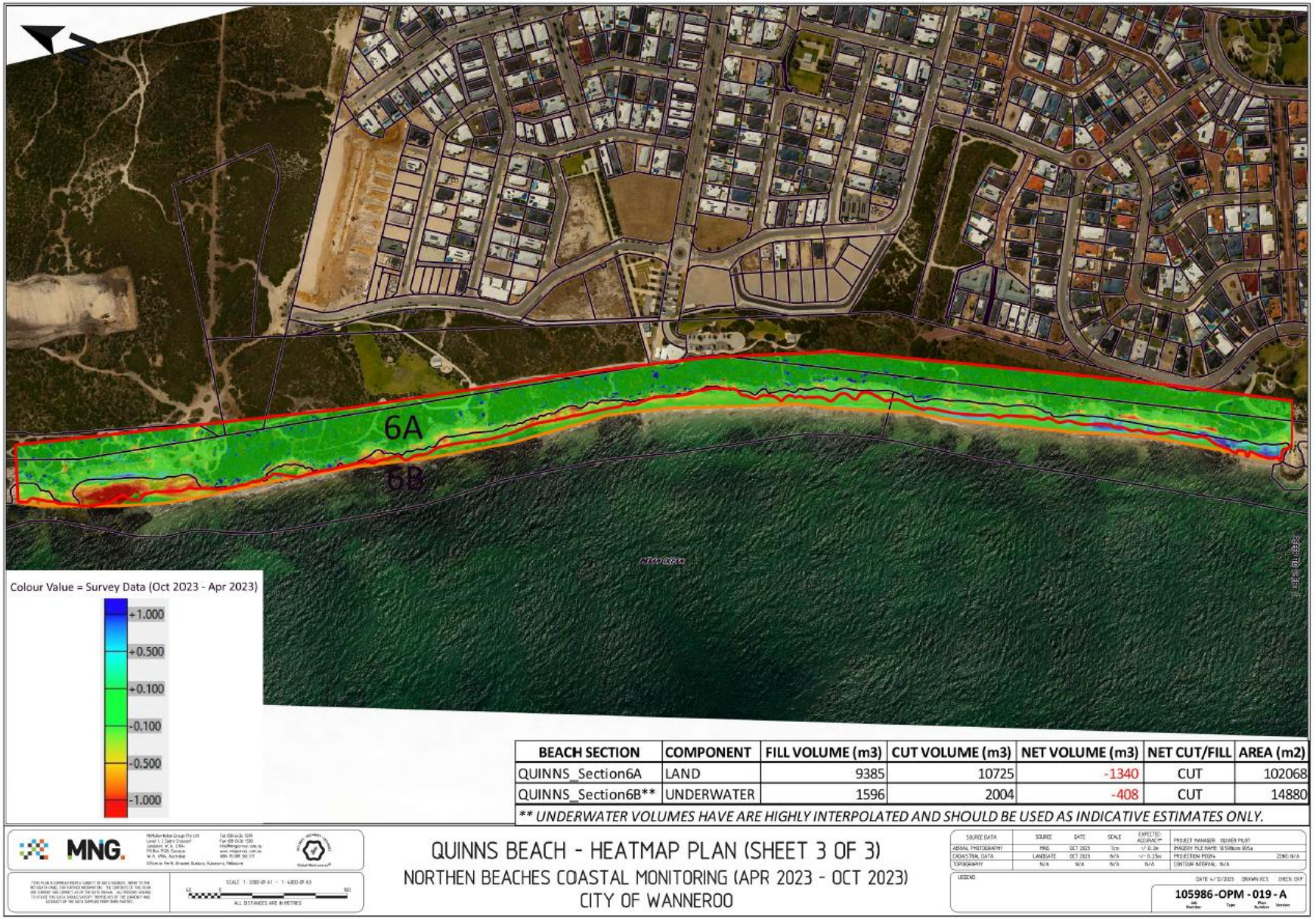
Figure 0-2 Net seasonal beach volume change plot for Quinns Beach sections 1 and 2.



BEACH SECTION	COMPONENT	FILL VOLUME (m3)	CUT VOLUME (m3)	NET VOLUME (m3)	NET CUT/FILL	AREA (m2)
QUINNS_Section3A	LAND	3712	3911	-199	CUT	28541
QUINNS_Section3B**	UNDERWATER	312	275	37	FILL	2453
QUINNS_Section4A	LAND	1943	2879	-936	CUT	37293
QUINNS_Section4B**	UNDERWATER	505	709	-204	CUT	5528
QUINNS_Section5A	LAND	3291	5601	-2310	CUT	45646
QUINNS_Section5B**	UNDERWATER	839	177	662	FILL	3496

*** UNDERWATER VOLUMES HAVE ARE HIGHLY INTERPOLATED AND SHOULD BE USED AS INDICATIVE ESTIMATES ONLY.*

Figure 0-3 Net seasonal beach volume change plot for Quinns Beach sections 3, 4 and 5.



BEACH SECTION	COMPONENT	FILL VOLUME (m3)	CUT VOLUME (m3)	NET VOLUME (m3)	NET CUT/FILL	AREA (m2)
QUINNS_Section6A	LAND	9385	10725	-1340	CUT	102068
QUINNS_Section6B**	UNDERWATER	1596	2004	-408	CUT	14880

*** UNDERWATER VOLUMES HAVE ARE HIGHLY INTERPOLATED AND SHOULD BE USED AS INDICATIVE ESTIMATES ONLY.*

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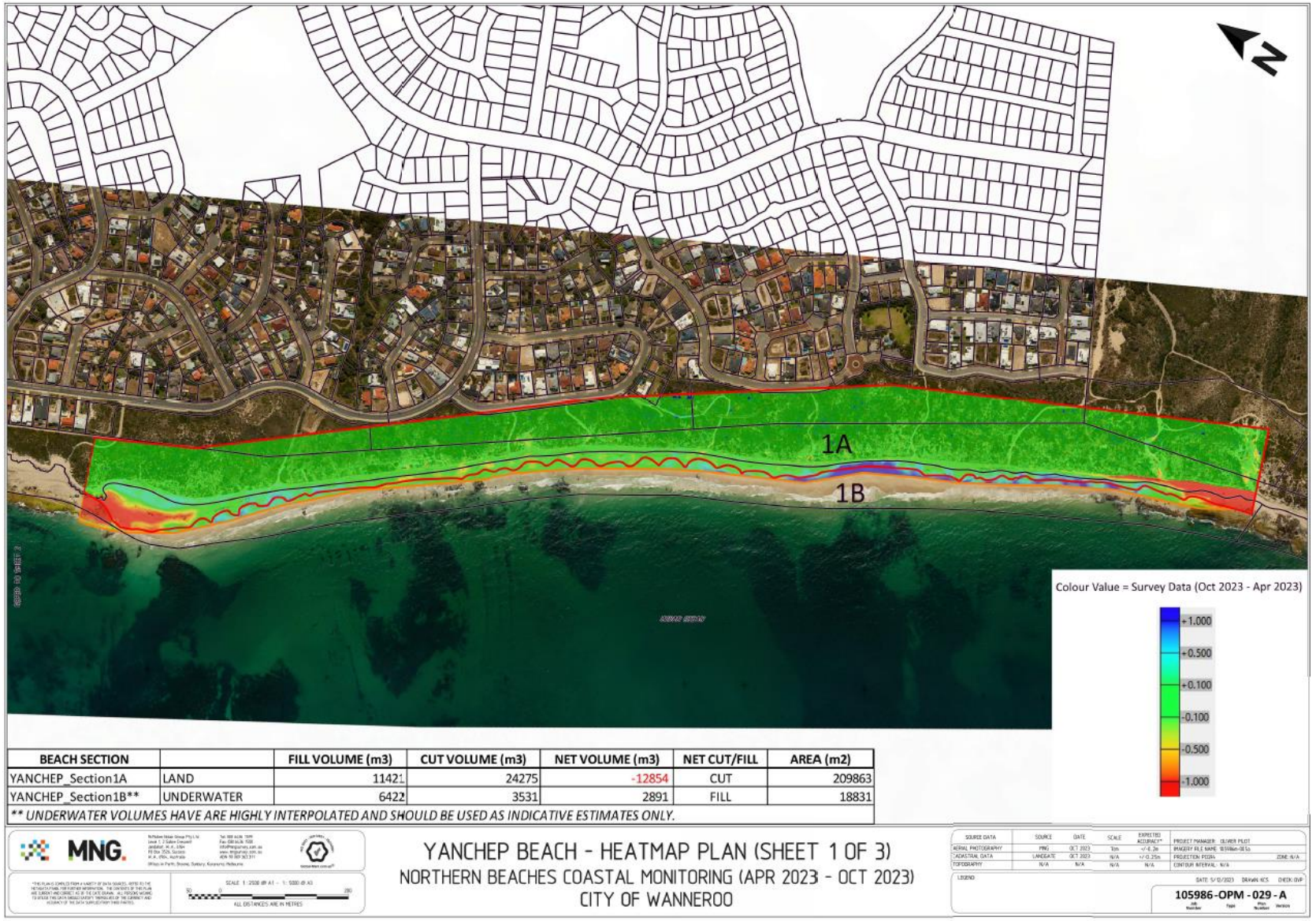
QUINNS BEACH - HEATMAP PLAN (SHEET 3 OF 3)
NORTHEN BEACHES COASTAL MONITORING (APR 2023 - OCT 2023)
CITY OF WANNEROO

105986-OPM-019-A

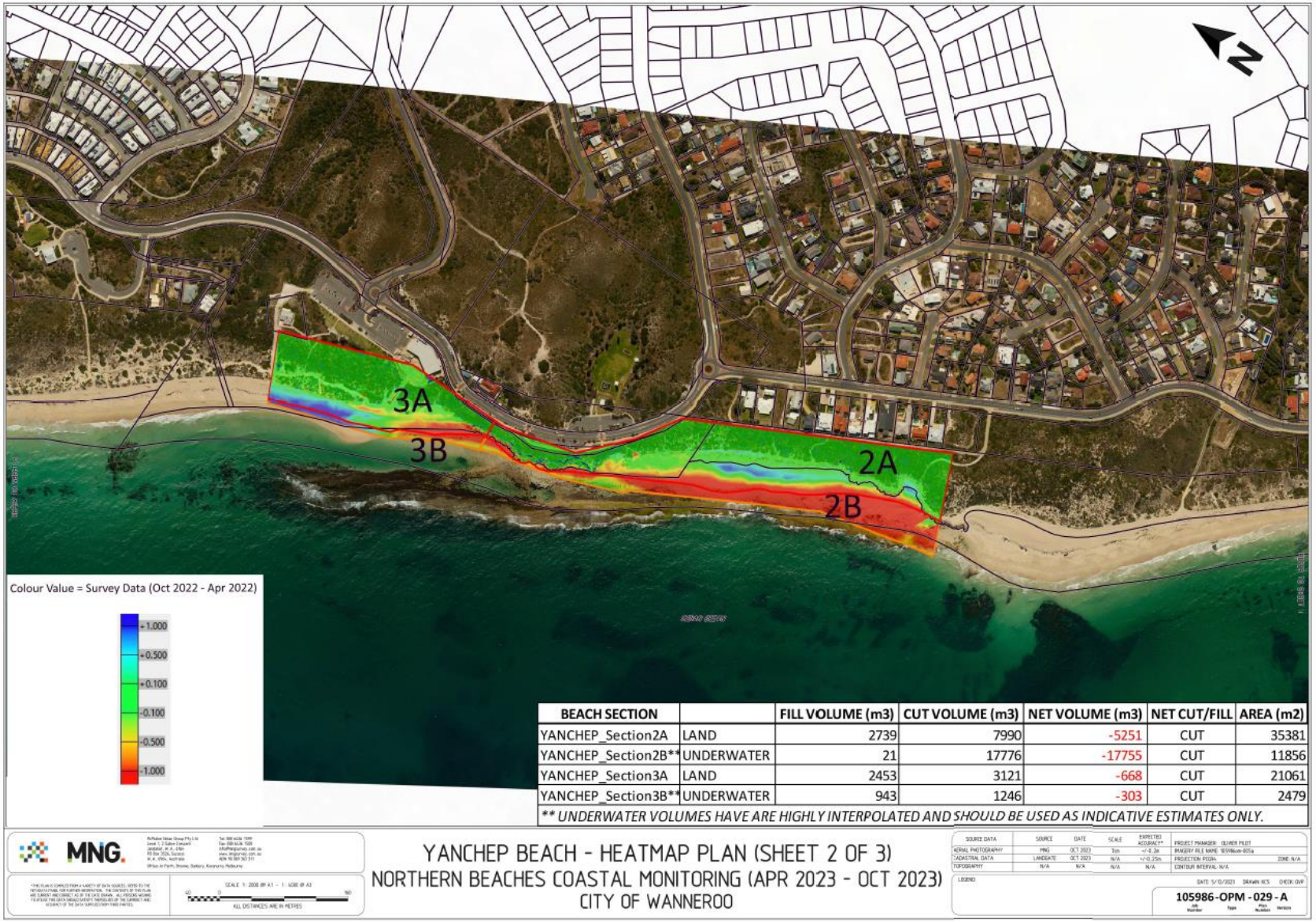
Figure 0-4 Net seasonal beach volume change plot for Quinns Beach section 6.



BEACH SECTION		FILL VOLUME (m3)	CUT VOLUME (m3)	NET VOLUME (m3)	NET CUT/FILL	AREA (m2)
YANCHEP_Section1A	LAND	11421	24275	-12854	CUT	209863
YANCHEP_Section1B**	UNDERWATER	6422	3531	2891	FILL	18831

*** UNDERWATER VOLUMES HAVE ARE HIGHLY INTERPOLATED AND SHOULD BE USED AS INDICATIVE ESTIMATES ONLY.*

Figure 0-5 Net seasonal beach volume change plot for Yanchep Beach section 1.



BEACH SECTION		FILL VOLUME (m3)	CUT VOLUME (m3)	NET VOLUME (m3)	NET CUT/FILL	AREA (m2)
YANCHEP_Section2A	LAND	2739	7990	-5251	CUT	35381
YANCHEP_Section2B**	UNDERWATER	21	17776	-17755	CUT	11856
YANCHEP_Section3A	LAND	2453	3121	-668	CUT	21061
YANCHEP_Section3B**	UNDERWATER	943	1246	-303	CUT	2479

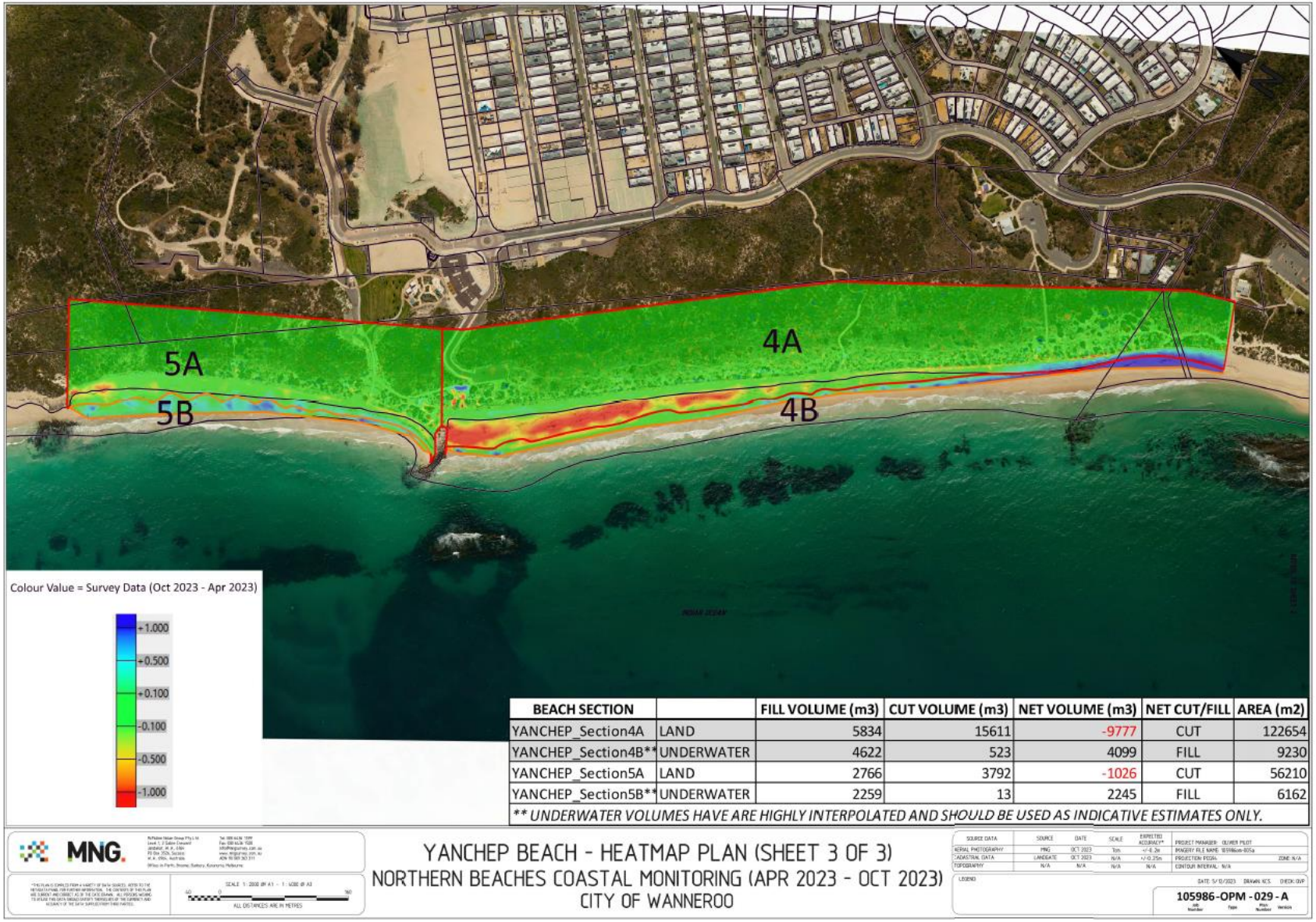
*** UNDERWATER VOLUMES HAVE ARE HIGHLY INTERPOLATED AND SHOULD BE USED AS INDICATIVE ESTIMATES ONLY.*

MNG.

YANCHEP BEACH - HEATMAP PLAN (SHEET 2 OF 3)
NORTHERN BEACHES COASTAL MONITORING (APR 2023 - OCT 2023)
CITY OF WANNEROO

105986-OPM - 029 - A

Figure 0-6 Net seasonal beach volume change plot for Yanchep Beach section 2 and 3.



BEACH SECTION		FILL VOLUME (m3)	CUT VOLUME (m3)	NET VOLUME (m3)	NET CUT/FILL	AREA (m2)
YANCHEP_Section4A	LAND	5834	15611	-9777	CUT	122654
YANCHEP_Section4B**	UNDERWATER	4622	523	4099	FILL	9230
YANCHEP_Section5A	LAND	2766	3792	-1026	CUT	56210
YANCHEP_Section5B**	UNDERWATER	2259	13	2245	FILL	6162

*** UNDERWATER VOLUMES HAVE ARE HIGHLY INTERPOLATED AND SHOULD BE USED AS INDICATIVE ESTIMATES ONLY.*

MNG.

YANCHEP BEACH - HEATMAP PLAN (SHEET 3 OF 3)
NORTHERN BEACHES COASTAL MONITORING (APR 2023 - OCT 2023)
CITY OF WANNEROO

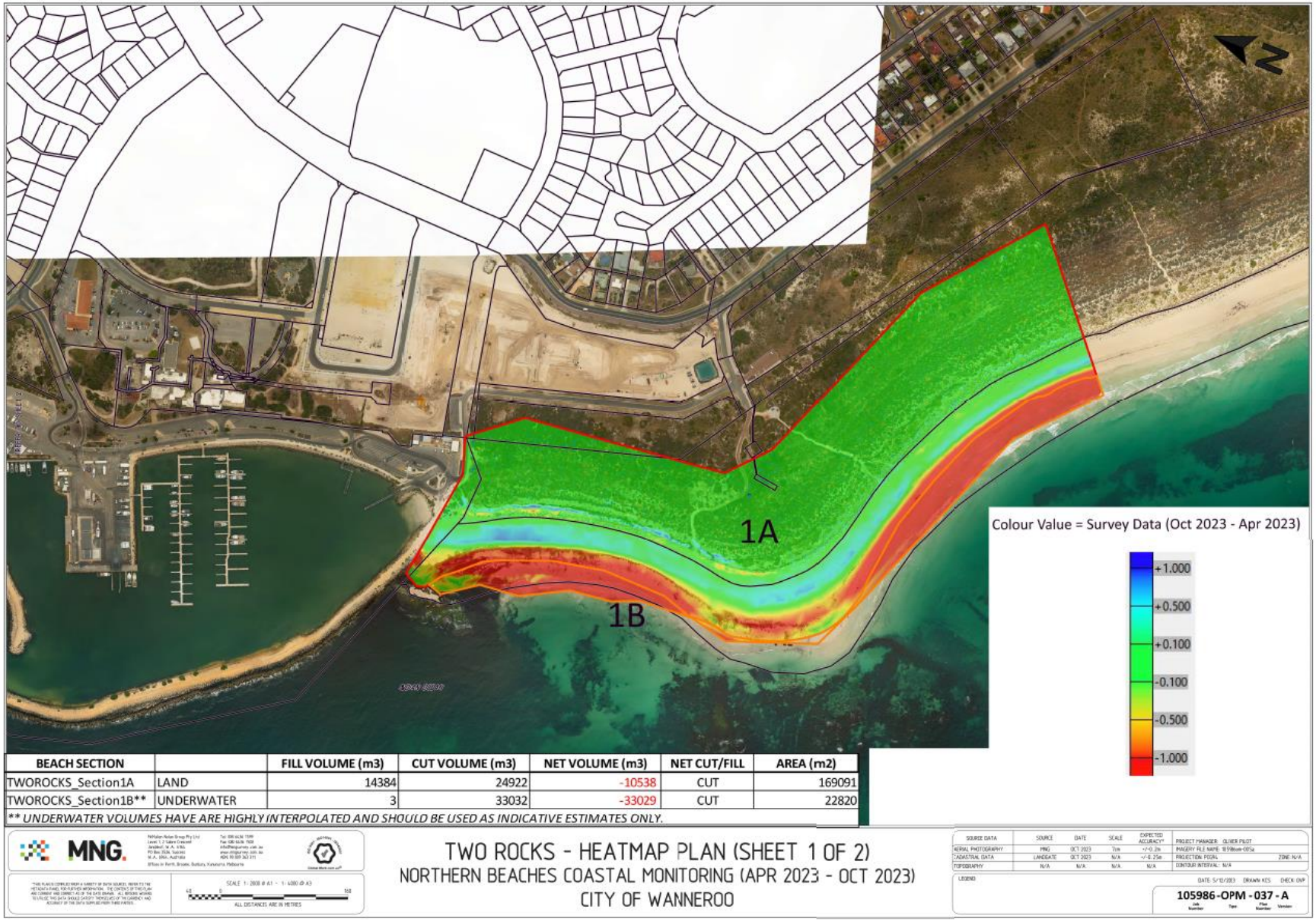
ALL DISTANCES ARE IN METRES

SOURCE DATA	SOURCE	DATE	SCALE	EXPECTED ACCURACY*
AERIAL PHOTOGRAPHY	MNG	OCT 2023	5cm	+/-0.2m
CADASTRAL DATA	LANDGATE	OCT 2023	N/A	+/-0.25m
TOPOGRAPHY	N/A	N/A	N/A	N/A

PROJECT MANAGER: OLIVER PILOT
IMAGERY FILE NAME: 5599bcm-005a
PROJECTION: PCG94- ZONE: N/A
CONTOUR INTERVAL: N/A
LEGEND
DATE: 5/10/2023 DRAWN: KCS CHECK: OVP

105986-OPM - 029 - A

Figure 0-7 Net seasonal beach volume change plot for Yanchep Beach section 4 and 5.



BEACH SECTION		FILL VOLUME (m3)	CUT VOLUME (m3)	NET VOLUME (m3)	NET CUT/FILL	AREA (m2)
TWOROCKS_Section1A	LAND	14384	24922	-10538	CUT	169091
TWOROCKS_Section1B**	UNDERWATER	3	33032	-33029	CUT	22820

*** UNDERWATER VOLUMES HAVE ARE HIGHLY INTERPOLATED AND SHOULD BE USED AS INDICATIVE ESTIMATES ONLY.*

MNG.

TWO ROCKS - HEATMAP PLAN (SHEET 1 OF 2)
NORTHERN BEACHES COASTAL MONITORING (APR 2023 - OCT 2023)
CITY OF WANNEROO

105986-OPM - 037 - A

Figure 0-8 Net seasonal beach volume change plot for Two Rocks beach section 1.

BEACH SECTION		FILL VOLUME (m3)	CUT VOLUME (m3)	NET VOLUME (m3)	NET CUT/FILL	AREA (m2)
TWOROCKS_Section2A	LAND	11200	17995	-6795	CUT	209725
TWOROCKS_Section2B**	UNDERWATER	2251	685	1566	FILL	10448

** UNDERWATER VOLUMES HAVE ARE HIGHLY INTERPOLATED AND SHOULD BE USED AS INDICATIVE ESTIMATES ONLY.

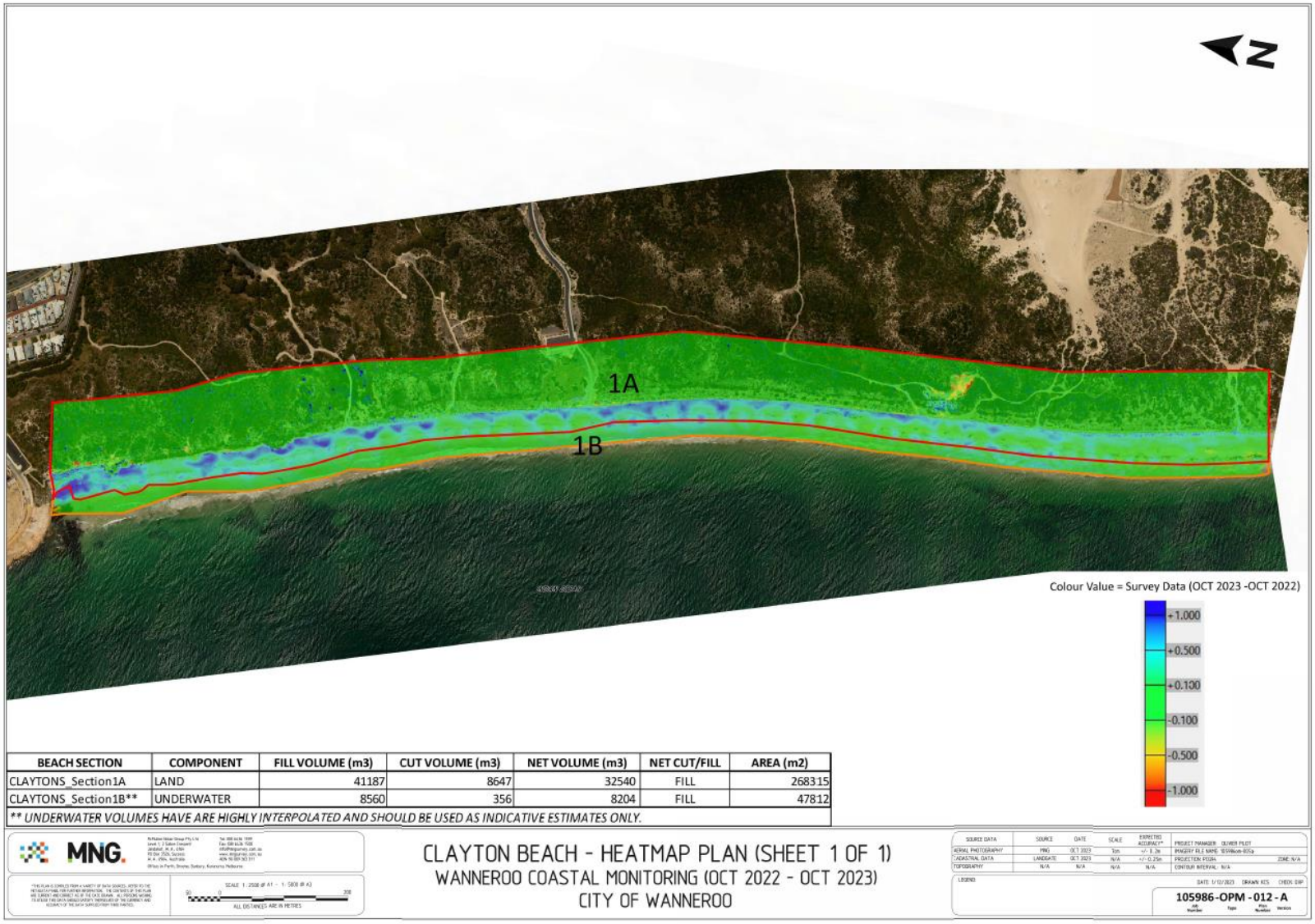
MNG.

TWO ROCKS - HEATMAP PLAN (SHEET 2 OF 2)
NORTHERN BEACHES COASTAL MONITORING (APR 2023 - OCT 2023)
CITY OF WANNEROO

105986-OPM-037-A

Figure 0-9 Net seasonal beach volume change plot for Two Rocks beach section 2.

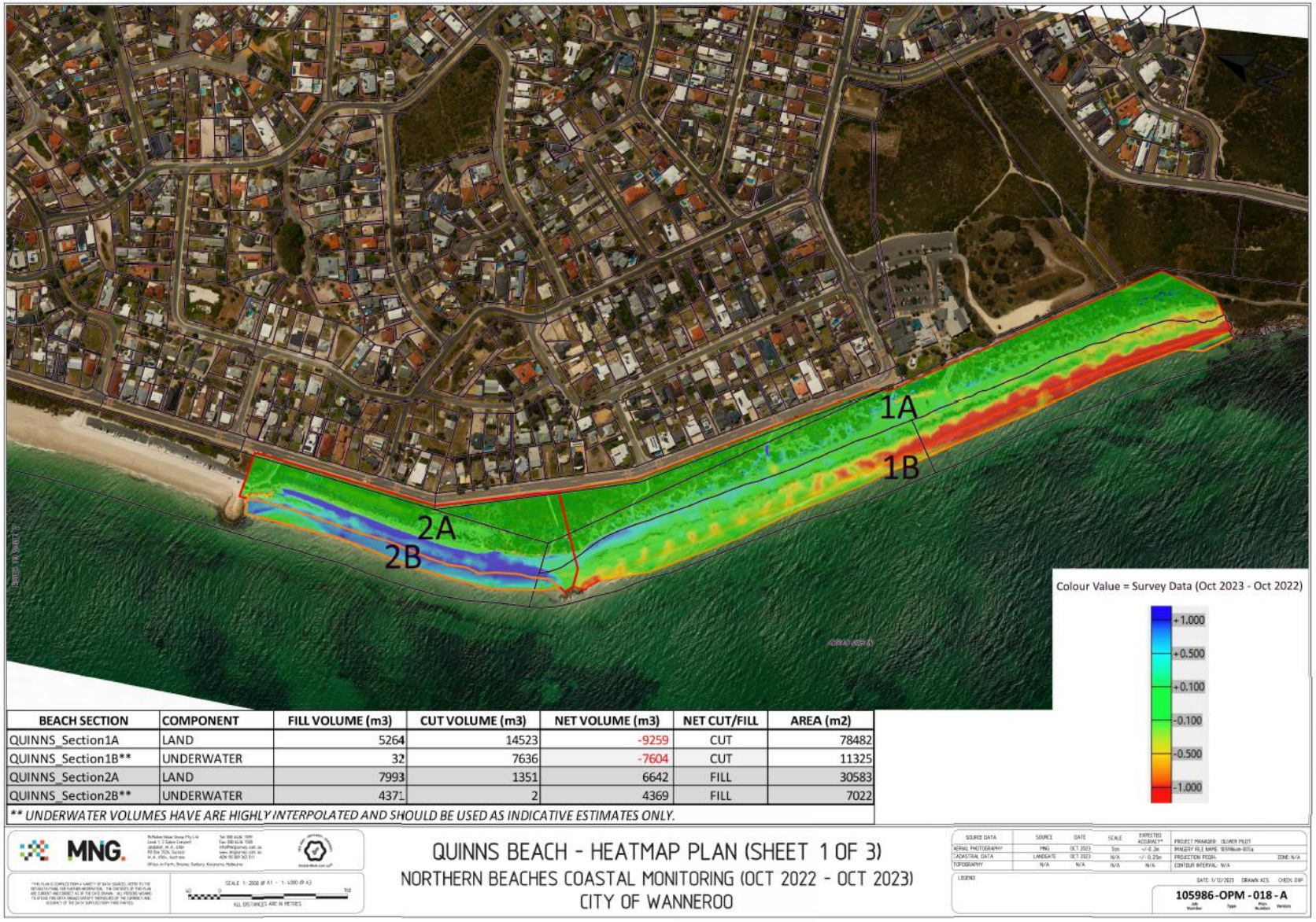
Appendix B



BEACH SECTION	COMPONENT	FILL VOLUME (m3)	CUT VOLUME (m3)	NET VOLUME (m3)	NET CUT/FILL	AREA (m2)
CLAYTONS_Section1A	LAND	41187	8647	32540	FILL	268315
CLAYTONS_Section1B**	UNDERWATER	8560	356	8204	FILL	47812

*** UNDERWATER VOLUMES HAVE ARE HIGHLY INTERPOLATED AND SHOULD BE USED AS INDICATIVE ESTIMATES ONLY.*

Figure 0-1 Net annual beach volume change plot for Claytons Beach in Mindarie



BEACH SECTION	COMPONENT	FILL VOLUME (m3)	CUT VOLUME (m3)	NET VOLUME (m3)	NET CUT/FILL	AREA (m2)
QUINNS_Section1A	LAND	5264	14523	-9259	CUT	78482
QUINNS_Section1B**	UNDERWATER	32	7636	-7604	CUT	11325
QUINNS_Section2A	LAND	7993	1351	6642	FILL	30583
QUINNS_Section2B**	UNDERWATER	4371	2	4369	FILL	7022

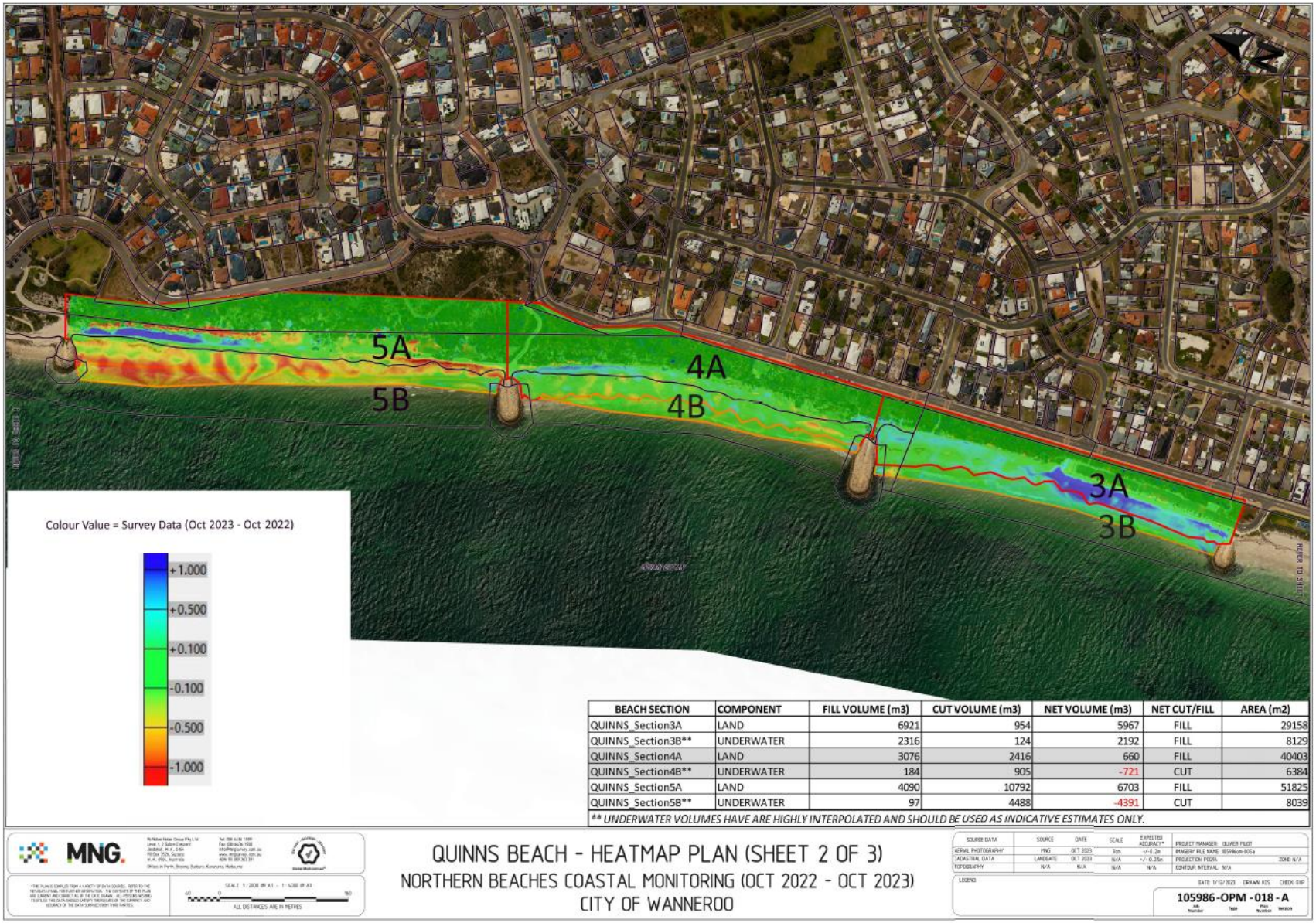
*** UNDERWATER VOLUMES HAVE ARE HIGHLY INTERPOLATED AND SHOULD BE USED AS INDICATIVE ESTIMATES ONLY.*

MNG.

QUINNS BEACH - HEATMAP PLAN (SHEET 1 OF 3)
NORTHERN BEACHES COASTAL MONITORING (OCT 2022 - OCT 2023)
CITY OF WANNEROO

105986-OPM-018-A

Figure 0-2 Net annual beach volume change plot for Quinns Beach sections 1 and 2



BEACH SECTION	COMPONENT	FILL VOLUME (m3)	CUT VOLUME (m3)	NET VOLUME (m3)	NET CUT/FILL	AREA (m2)
QUINNS_Section3A	LAND	6921	954	5967	FILL	29158
QUINNS_Section3B**	UNDERWATER	2316	124	2192	FILL	8129
QUINNS_Section4A	LAND	3076	2416	660	FILL	40403
QUINNS_Section4B**	UNDERWATER	184	905	-721	CUT	6384
QUINNS_Section5A	LAND	4090	10792	6703	FILL	51825
QUINNS_Section5B**	UNDERWATER	97	4488	-4391	CUT	8039

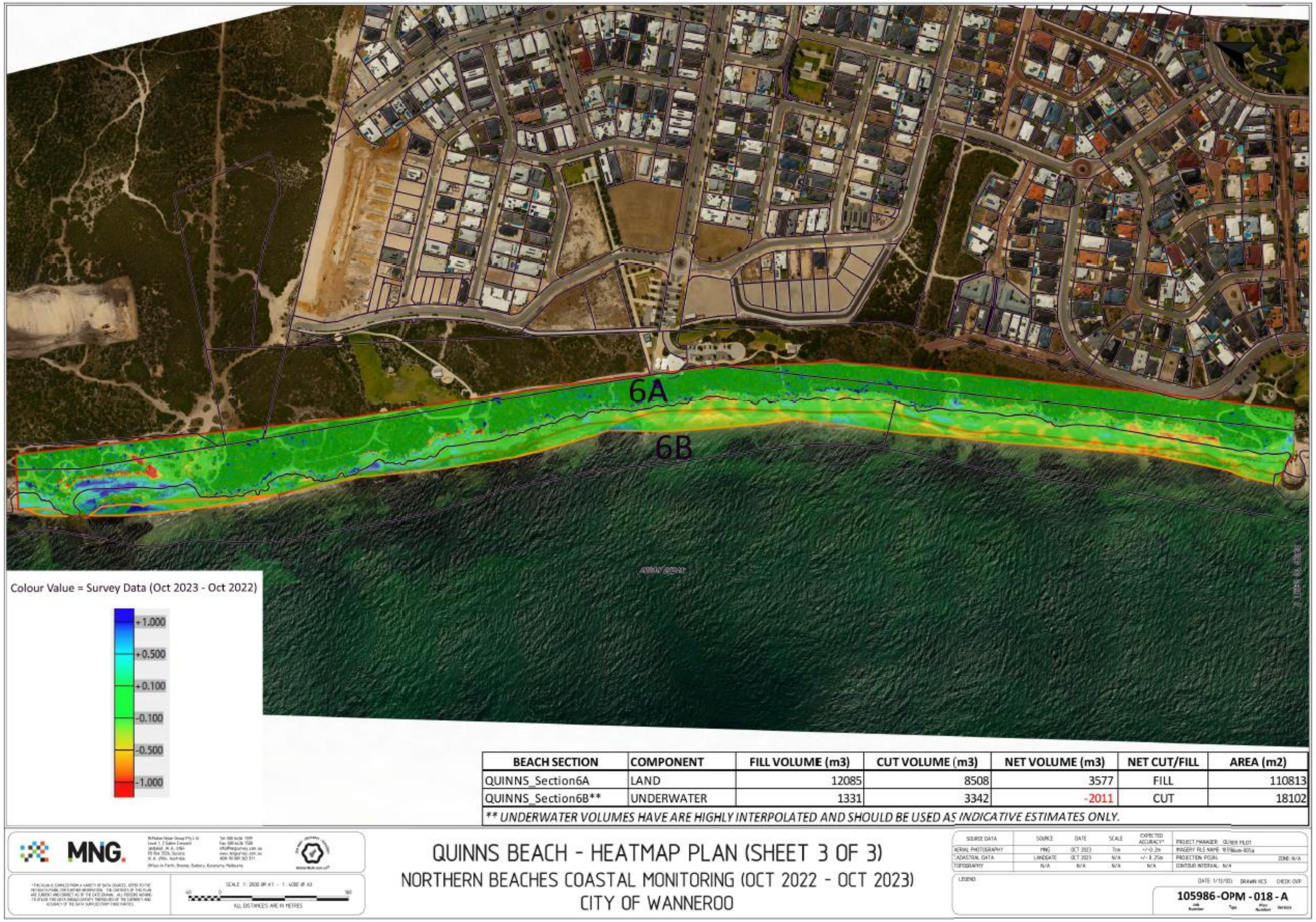
*** UNDERWATER VOLUMES HAVE ARE HIGHLY INTERPOLATED AND SHOULD BE USED AS INDICATIVE ESTIMATES ONLY.*

MNG.

QUINNS BEACH - HEATMAP PLAN (SHEET 2 OF 3)
NORTHERN BEACHES COASTAL MONITORING (OCT 2022 - OCT 2023)
CITY OF WANNEROO

105986-OPM - 018 - A

Figure 0-3 Net annual beach volume change plot for Quinns Beach sections 3, 4 and 5



BEACH SECTION	COMPONENT	FILL VOLUME (m3)	CUT VOLUME (m3)	NET VOLUME (m3)	NET CUT/FILL	AREA (m2)
QUINNS_Section6A	LAND	12085	8508	3577	FILL	110813
QUINNS_Section6B**	UNDERWATER	1331	3342	-2011	CUT	18102

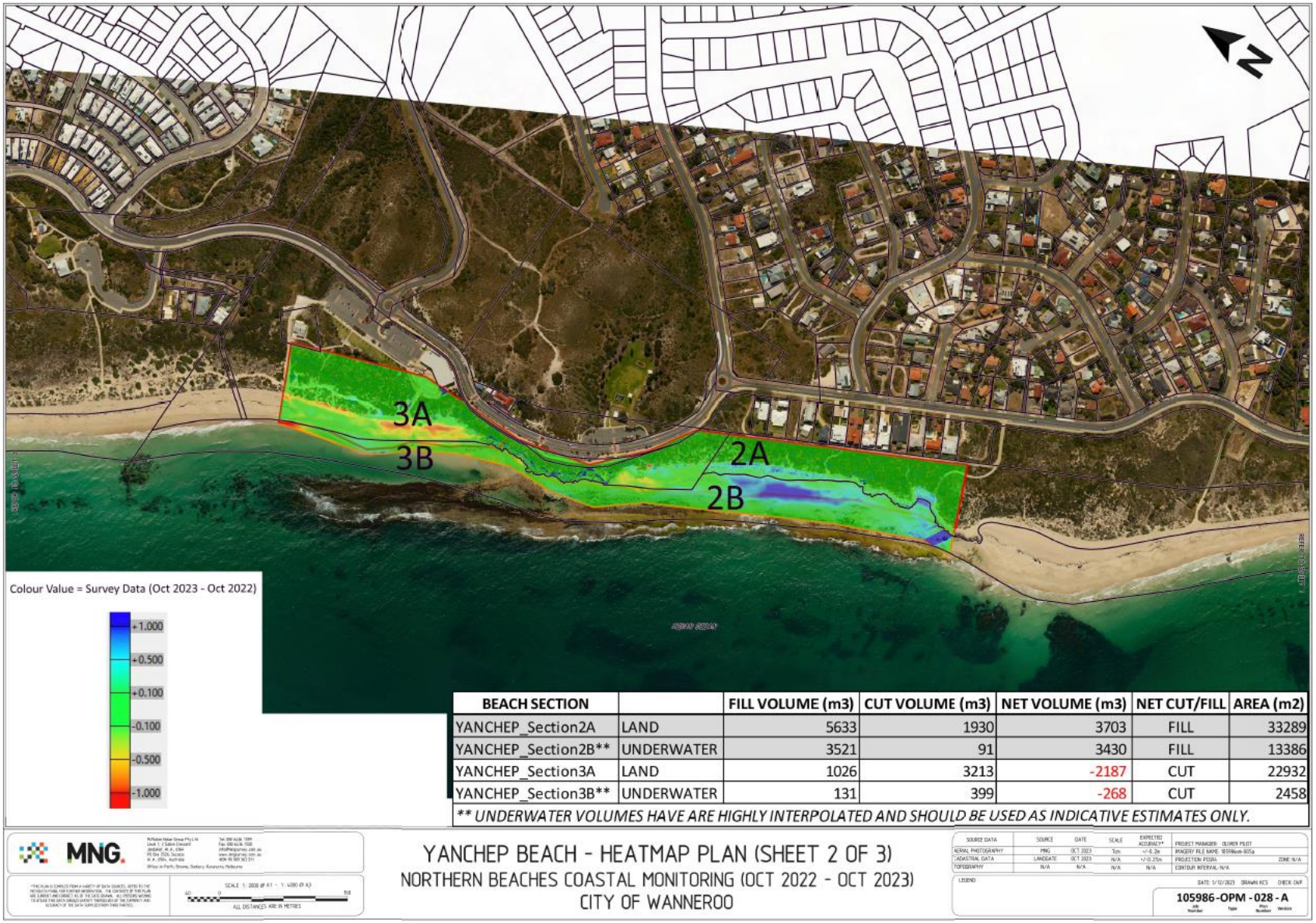
*** UNDERWATER VOLUMES HAVE ARE HIGHLY INTERPOLATED AND SHOULD BE USED AS INDICATIVE ESTIMATES ONLY.*

Figure 0-4 Net annual beach volume change plot for Quinns Beach sections 6

BEACH SECTION		FILL VOLUME (m3)	CUT VOLUME (m3)	NET VOLUME (m3)	NET CUT/FILL	AREA (m2)
YANCHEP_Section1A	LAND	13256	25627	-12371	CUT	224889
YANCHEP_Section1B**	UNDERWATER	3498	1510	1988	FILL	23443

*** UNDERWATER VOLUMES HAVE ARE HIGHLY INTERPOLATED AND SHOULD BE USED AS INDICATIVE ESTIMATES ONLY.*

Figure 0-5 Net annual beach volume change plot for Yanchep Beach section 1.



BEACH SECTION		FILL VOLUME (m3)	CUT VOLUME (m3)	NET VOLUME (m3)	NET CUT/FILL	AREA (m2)
YANCHEP_Section2A	LAND	5633	1930	3703	FILL	33289
YANCHEP_Section2B**	UNDERWATER	3521	91	3430	FILL	13386
YANCHEP_Section3A	LAND	1026	3213	-2187	CUT	22932
YANCHEP_Section3B**	UNDERWATER	131	399	-268	CUT	2458

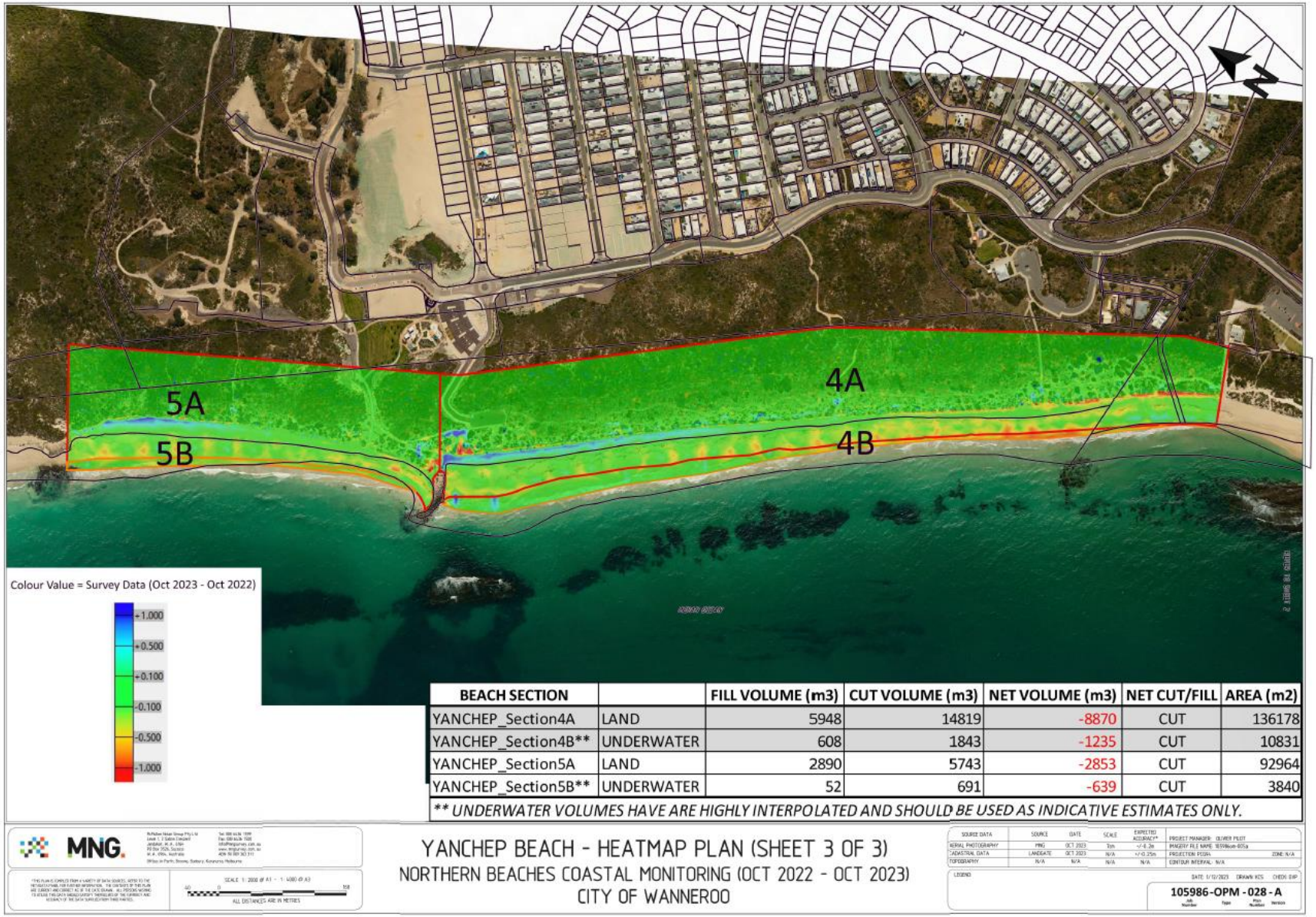
*** UNDERWATER VOLUMES HAVE ARE HIGHLY INTERPOLATED AND SHOULD BE USED AS INDICATIVE ESTIMATES ONLY.*

MNG.

YANCHEP BEACH - HEATMAP PLAN (SHEET 2 OF 3)
NORTHERN BEACHES COASTAL MONITORING (OCT 2022 - OCT 2023)
CITY OF WANNEROO

105986-OPM - 028 - A

Figure 0-6 *Net annual beach volume change plot for Yanchep Beach sections 2 and 3.*



BEACH SECTION		FILL VOLUME (m3)	CUT VOLUME (m3)	NET VOLUME (m3)	NET CUT/FILL	AREA (m2)
YANCHEP_Section4A	LAND	5948	14819	-8870	CUT	136178
YANCHEP_Section4B**	UNDERWATER	608	1843	-1235	CUT	10831
YANCHEP_Section5A	LAND	2890	5743	-2853	CUT	92964
YANCHEP_Section5B**	UNDERWATER	52	691	-639	CUT	3840

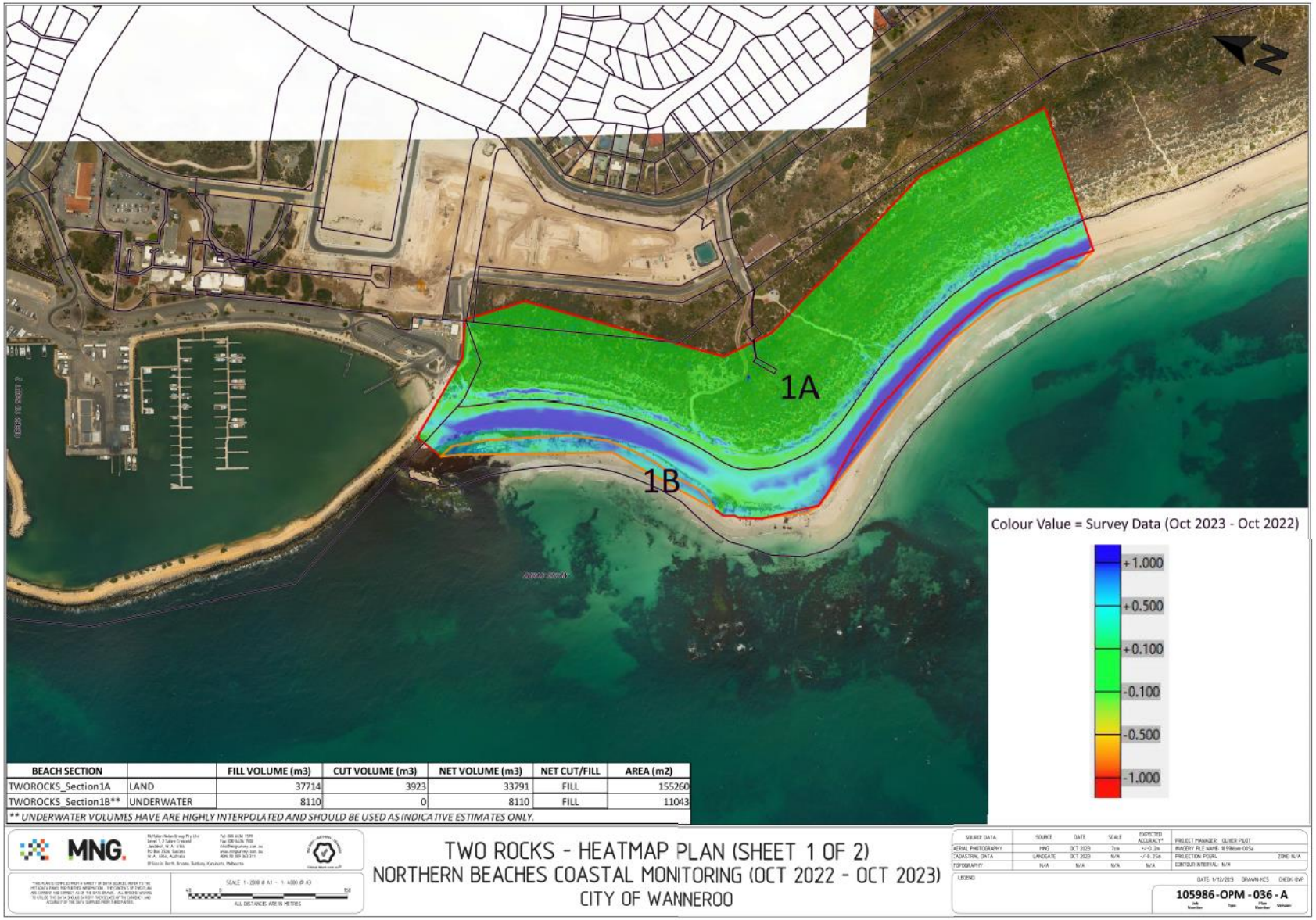
*** UNDERWATER VOLUMES HAVE ARE HIGHLY INTERPOLATED AND SHOULD BE USED AS INDICATIVE ESTIMATES ONLY.*

MNG

YANCHEP BEACH - HEATMAP PLAN (SHEET 3 OF 3)
NORTHERN BEACHES COASTAL MONITORING (OCT 2022 - OCT 2023)
CITY OF WANNEROO

105986-OPM - 028 - A

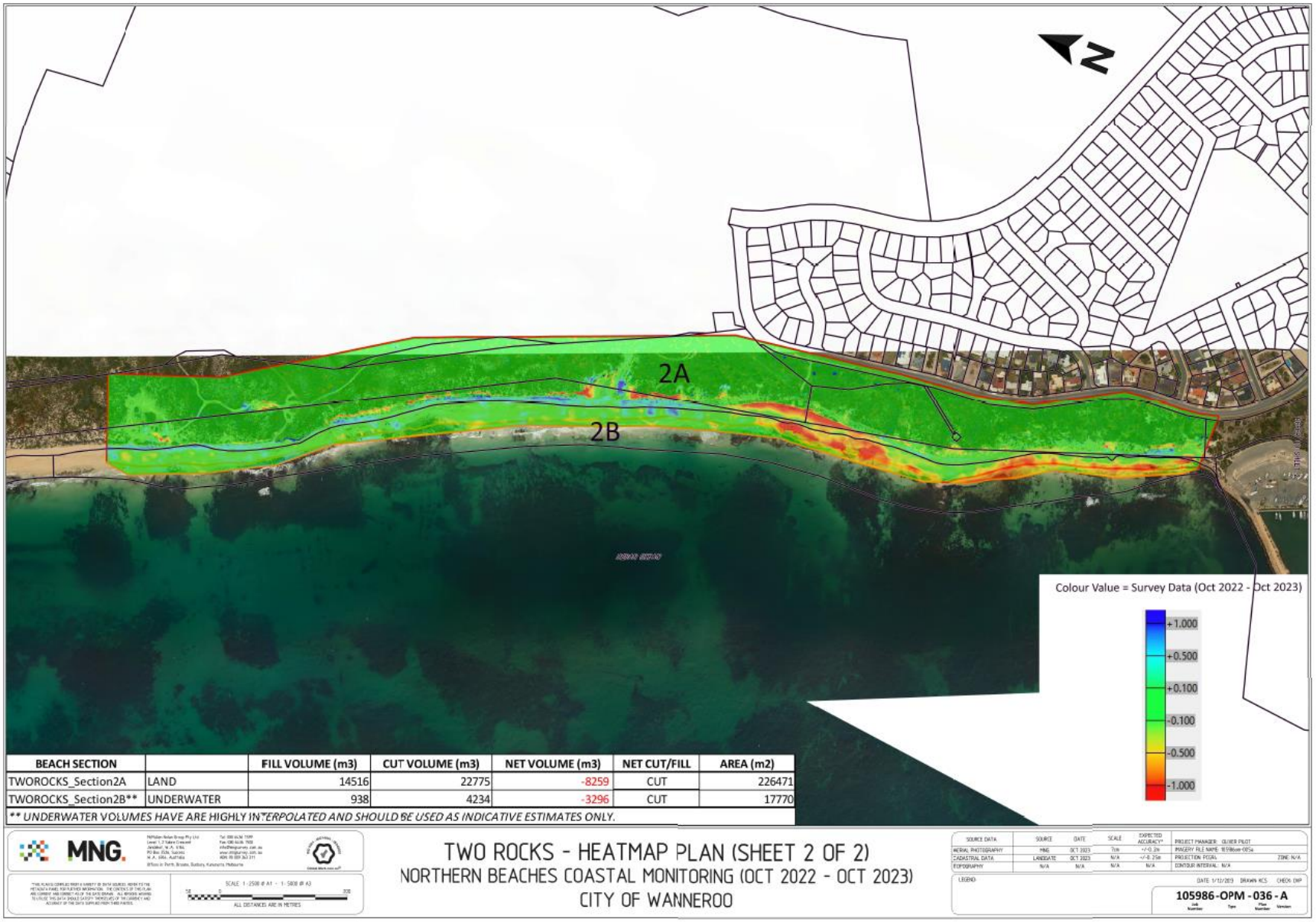
Figure 0-7 Net annual beach volume change plot for Yanchep Beach sections 4 and 5.



BEACH SECTION		FILL VOLUME (m3)	CUT VOLUME (m3)	NET VOLUME (m3)	NET CUT/FILL	AREA (m2)
TWOROCKS_Section1A	LAND	37714	3923	33791	FILL	155260
TWOROCKS_Section1B**	UNDERWATER	8110	0	8110	FILL	11043

** UNDERWATER VOLUMES HAVE ARE HIGHLY INTERPOLATED AND SHOULD BE USED AS INDICATIVE ESTIMATES ONLY.

Figure 0-8 Net annual beach volume change plot for Two Rocks Beach section 1.



BEACH SECTION		FILL VOLUME (m3)	CUT VOLUME (m3)	NET VOLUME (m3)	NET CUT/FILL	AREA (m2)
TWOROCKS_Section2A	LAND	14516	22775	-8259	CUT	226471
TWOROCKS_Section2B**	UNDERWATER	938	4234	-3296	CUT	17770

** UNDERWATER VOLUMES HAVE ARE HIGHLY INTERPOLATED AND SHOULD BE USED AS INDICATIVE ESTIMATES ONLY.

Figure 0-9 Net annual beach volume change plot for Two Rocks Beach section 2.