

City of Wanneroo Coastal Monitoring Report October 2022



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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 49 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 CoW coastline.

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).

- 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.

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

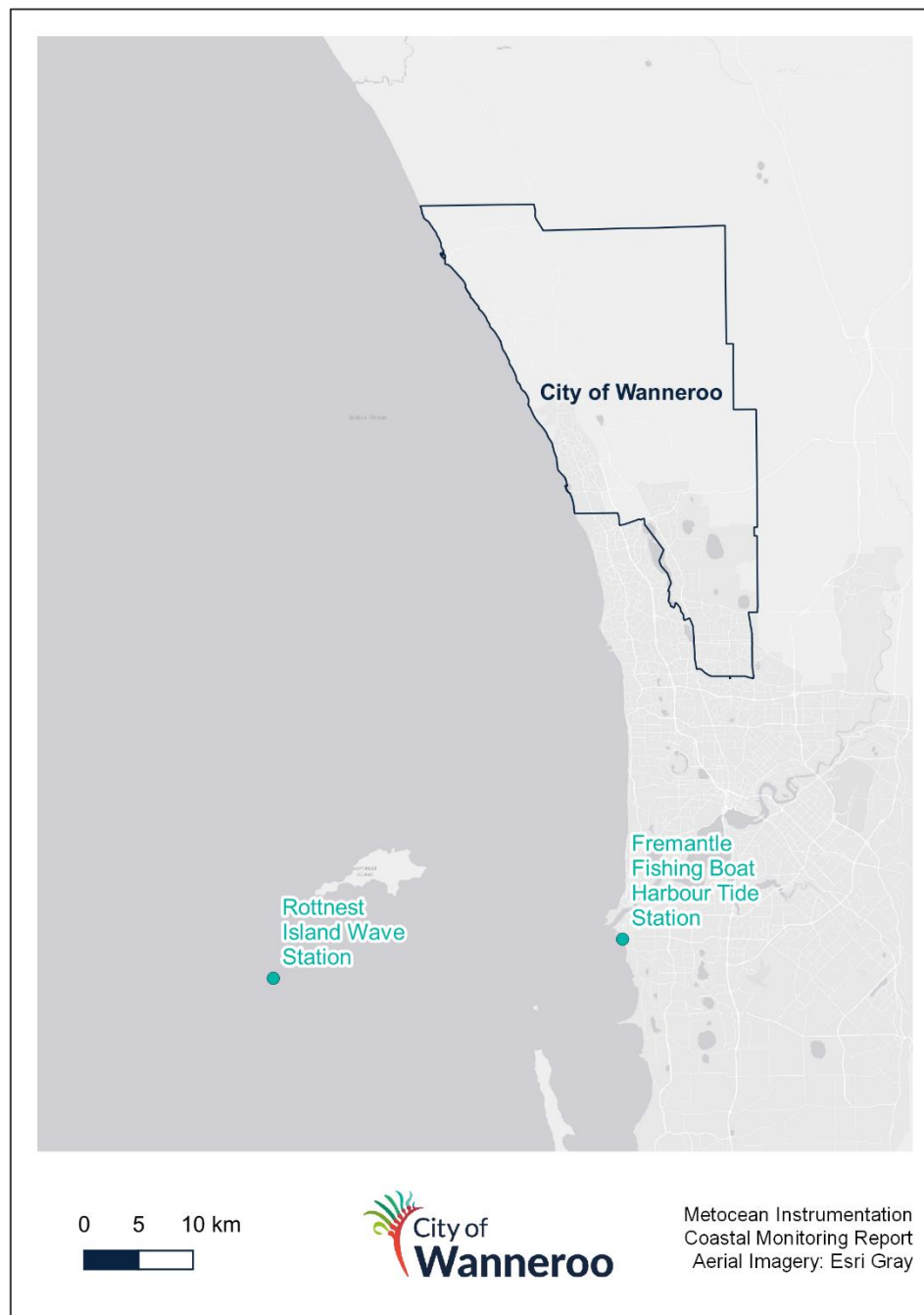


Figure 2-1

Location of Instruments

2.1 Assessment Methodology

The data from these instruments is obtained from the DoT for the annual monitoring period October 2021 to October 2022. The data is assessed using time series and wave 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 2021 to October 2022 is presented below in Figure 2-2.

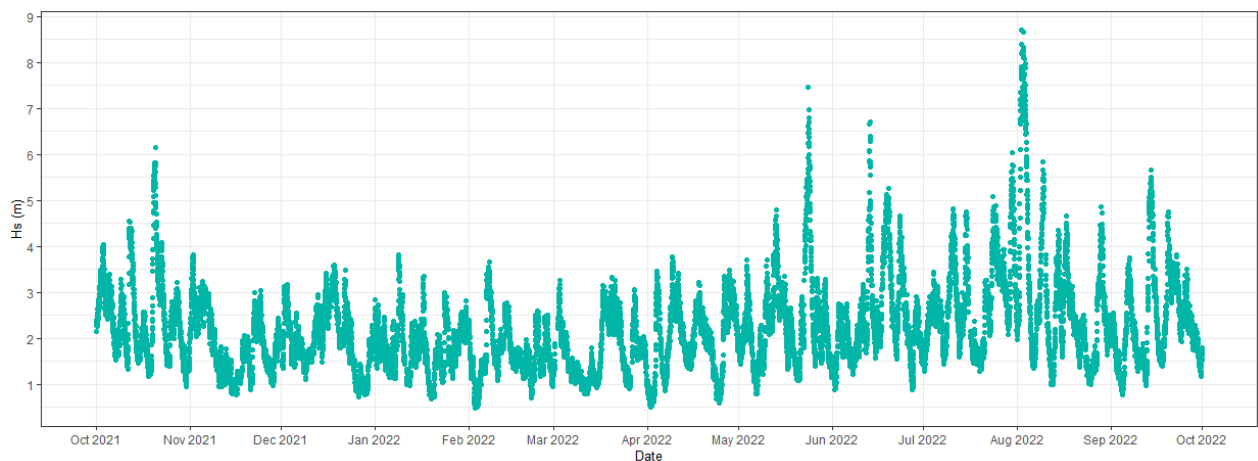


Figure 2-2 Total Significant Wave Height (Hs) recorded at the Rottnest Island Wave Station from October 2022 to October 2022.

The most notable observations from Figure 2-2 are the storm events that were recorded on the 20th of October 2021, 24th of May 2022, 13th of June 2022 and the 3rd of August 2022. The storm that resulted in the most significant infrastructure damage and erosion along the City's coastline occurred on the 3rd of August 2022 which had a peak total significant wave height of 8.67m which was recorded at 2:09 AM on 3rd August 2022.

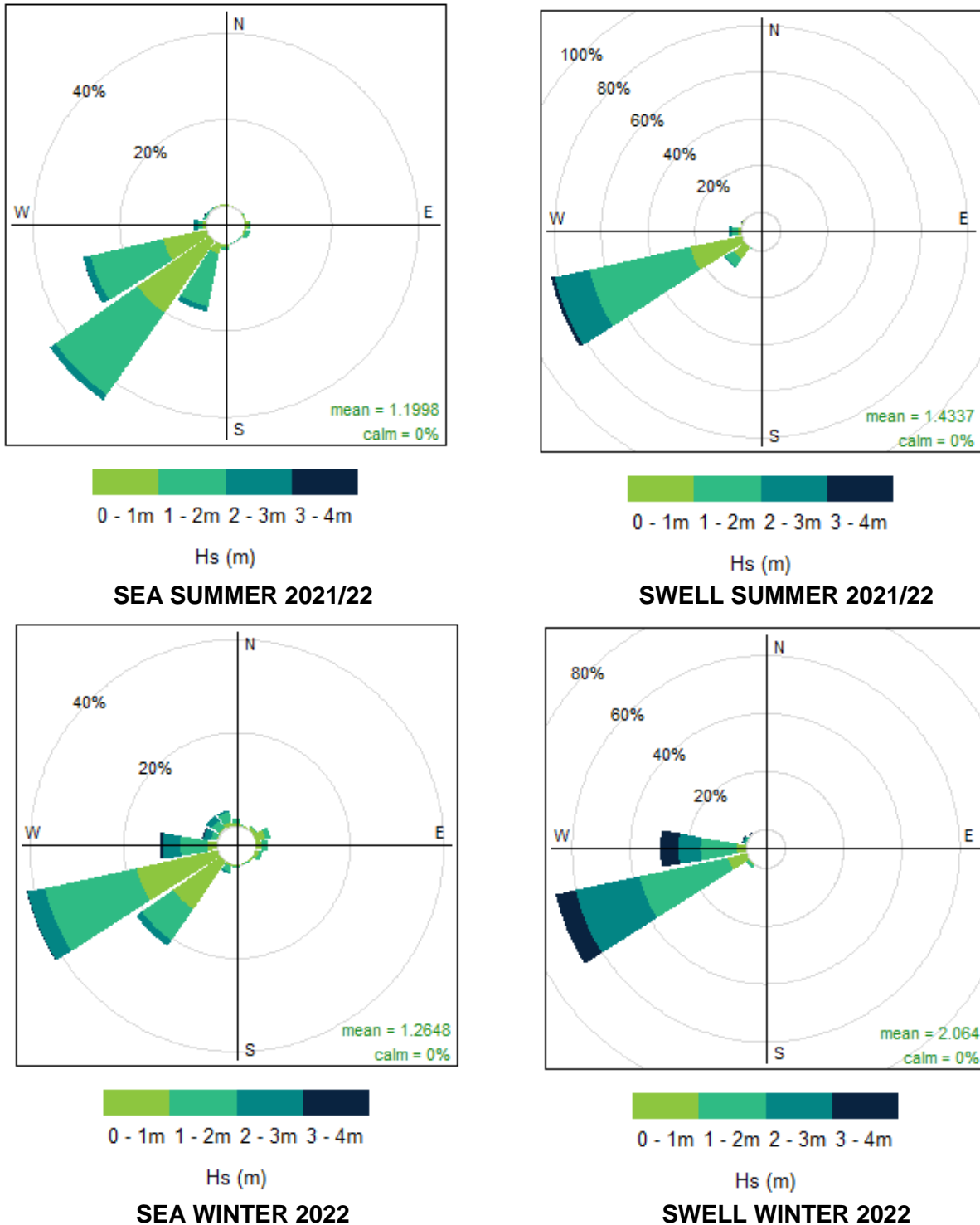


Figure 2-3 Wind rose plots of sea and swell significant wave heights from the summer season (October 2021 to March 2022) and the winter season (April to September 2022)

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. Wave direction across the year was typically recorded from a WSW direction.

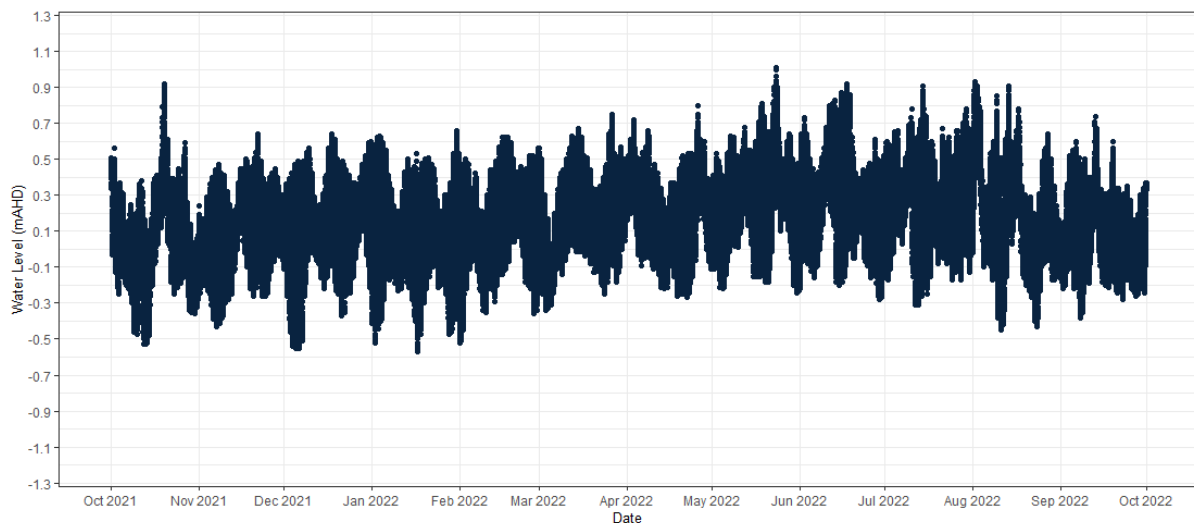


Figure 2-4 Water level (mAHD) recorded at the Fremantle Fishing Harbour Tide Station from October 2021 to October 2022.

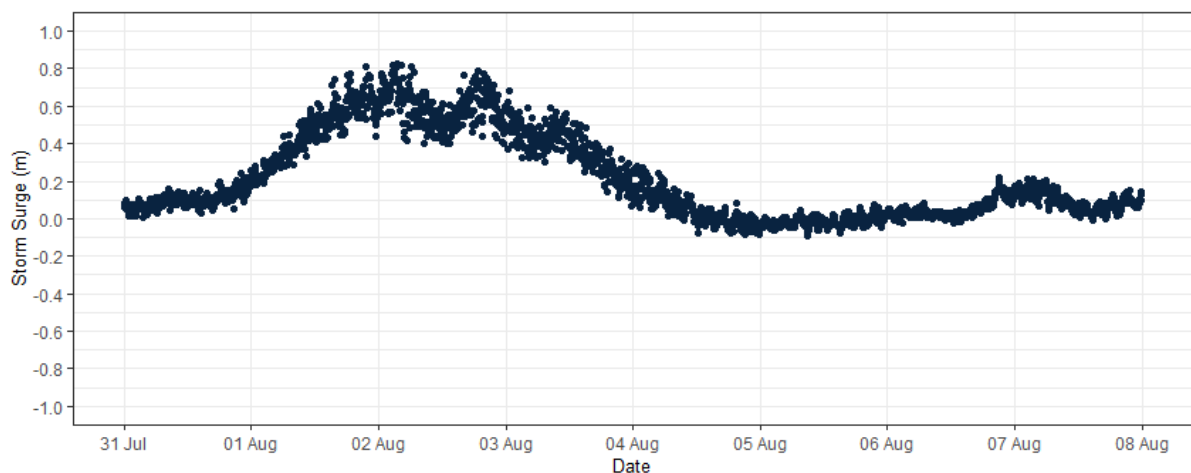


Figure 2-5 Storm surge recorded at the Fremantle Fishing Harbour Tide Station during the August 3rd storm event.

Total recorded water level at the Fremantle Tide Station for October 2021 to October 2022 is presented in Figure 2-4. The highest water level recorded was 1.10 mAHD recorded at 1:15PM on 23rd of May 2022 and the peak storm surge (0.83m) was observed on the 2nd of August at 3:30AM. The winter storm that extended over three days at the beginning of August 2022 was characterised by an extended storm surge and high significant wave heights. This resulted in significant erosion and infrastructure damage to Mindarie Breakwater, Frederick Stubbs Staircase, Queenscliffe Dog Beach Dune System, Jindalee Staircases and Amberton Beach Access Ways. Further details of the storm damage are outlined in Section 3.


2.2.2 During Monitoring




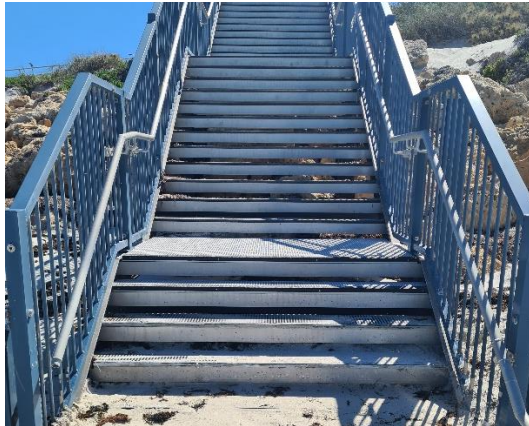
Manual imagery and aerial surveys for this monitoring period were undertaken between 4 October 2022 and 10 October 2022. The water levels during these monitoring periods are presented below in Figure 2-6.

3 Storm Damage




As outlined above in Section **Error! Reference source not found.**, a number of storm events occurred during the 2022 winter period. The most notable of which was the storm event that occurred between the 1st and the 4th of August which resulted in significant infrastructure and dune damage as outlined in Table 3-1.



Table 3-1 Examples of major infrastructure and dune damage caused by winter storms.

Damaged Asset	Damage	Action Taken by the City	Photograph of the asset following actions
Mindarie Breakwater and adjacent road infrastructure		<p>Immediately following the August storm event, the road was cleaned and any debris was removed.</p> <p>Complete asset upgrade/renewal works are planned to begin in February 2023.</p>	

Damaged Asset	Damage	Action Taken by the City	Photograph of the asset following actions
<p>Frederick Stubbs GSC Revetment, Quinns Rocks</p>		<p>Some of the geotextile sand containers (GSCs) were buried shortly after being dislodged from the revetment. The GSCs that could be recovered were removed from the beach. Any additional repair works will be investigated if the structure begins to slump.</p>	
<p>Beach Access Staircase, Quinns Beach</p>		<p>The base of the beach access staircase at Quinns Rocks was damaged following the August storms. A contractor was engaged to repair the decking and fixings.</p>	

Damaged Asset	Damage	Action Taken by the City	Photograph of the asset following actions
<p>Dune and Wind Break Fencing, Quinns Dog Beach</p>		<p>The wind break fencing was repaired and the City continues to undertake annual beach renourishment at this site.</p>	
<p>Amberton Beach Access Pathway</p>		<p>This asset is currently managed and maintained by the Amberton Beach Residential Development. The Developer has undertaken localised renourishment at the site and installed Geotextile Sand Containers (GSCs) at the base of the pathway to limit future scour.</p>	

Damaged Asset	Damage	Action Taken by the City	Photograph of the asset following actions
<p>Fisherman's Hollow Beach Access, Yanchep</p>		<p>The City is currently in the process of obtaining the required approvals to install an extension to the southern arm of the staircase. Due to significant seasonal erosion, this site is only accessible in the months of April and May.</p>	<p>Action is yet to be taken as the City are awaiting heritage approval for the works. Works are scheduled for April 2023.</p>
<p>Southern Fisherman's Hollow Beach Access, Yanchep</p>		<p>The southern staircase at Fisherman's Hollow was undermined following a significant erosion event. The City have backfilled underneath the staircase to ensure safe access. The footings for this staircase are anchored into rock and it remains safe to use.</p>	

Damaged Asset	Damage	Action Taken by the City	Photograph of the asset following actions
<p>Yanchep Lagoon Beach Access, Yanchep</p>	 <p>2022/08/04</p>	<p>The City undertook reactive beach nourishment at Yanchep Lagoon in September 2022 to provide a safe beach for beach users. Further details of the nourishment are outlined in Section 8.5.</p>	 <p>2022/09/30</p>

4 Manual Imagery

There are a total of 49 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 4-4. 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.

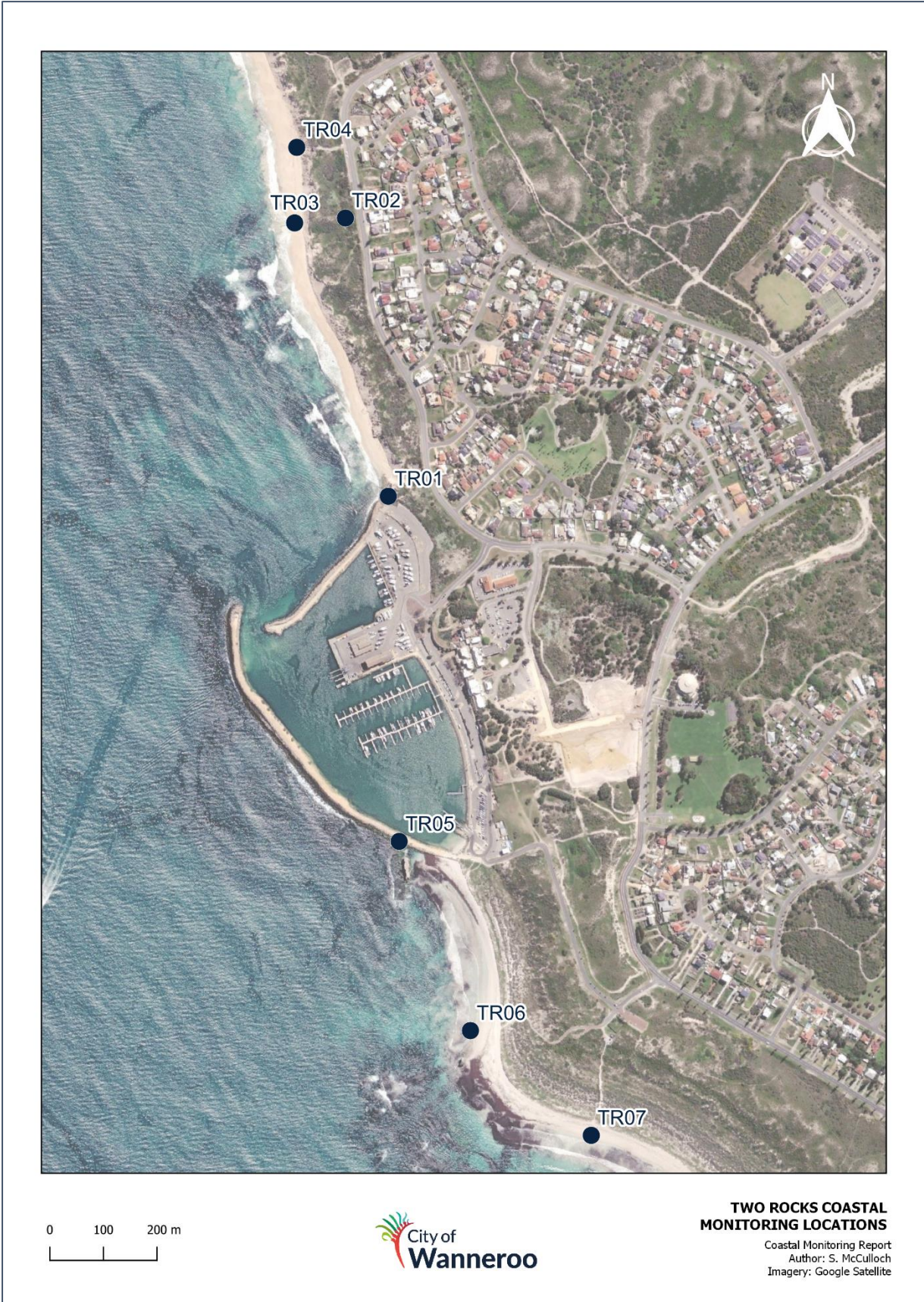


Figure 4-1 Two Rocks Coastal Monitoring Locations

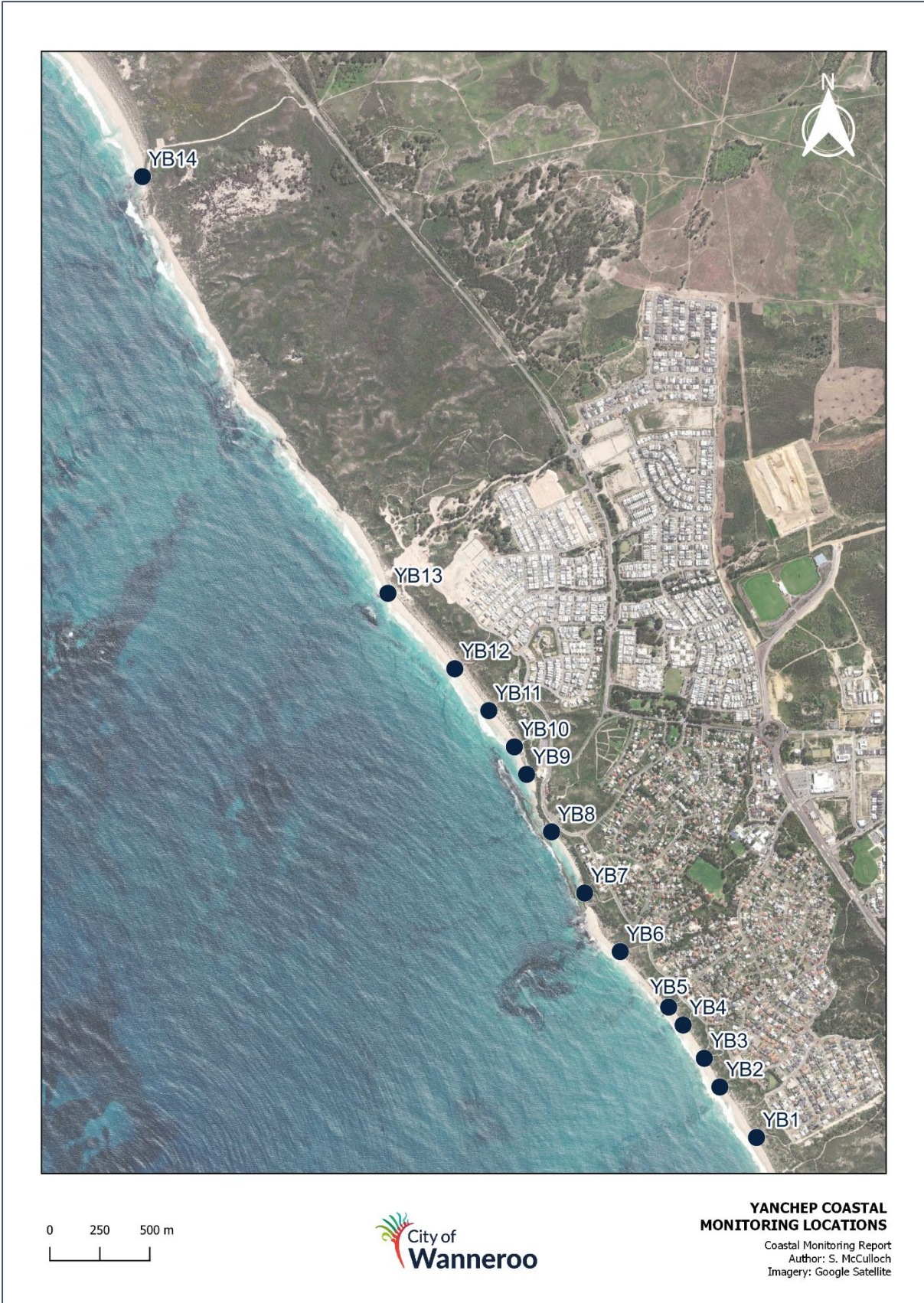


Figure 4-2 Yanchep Coastal Monitoring Locations

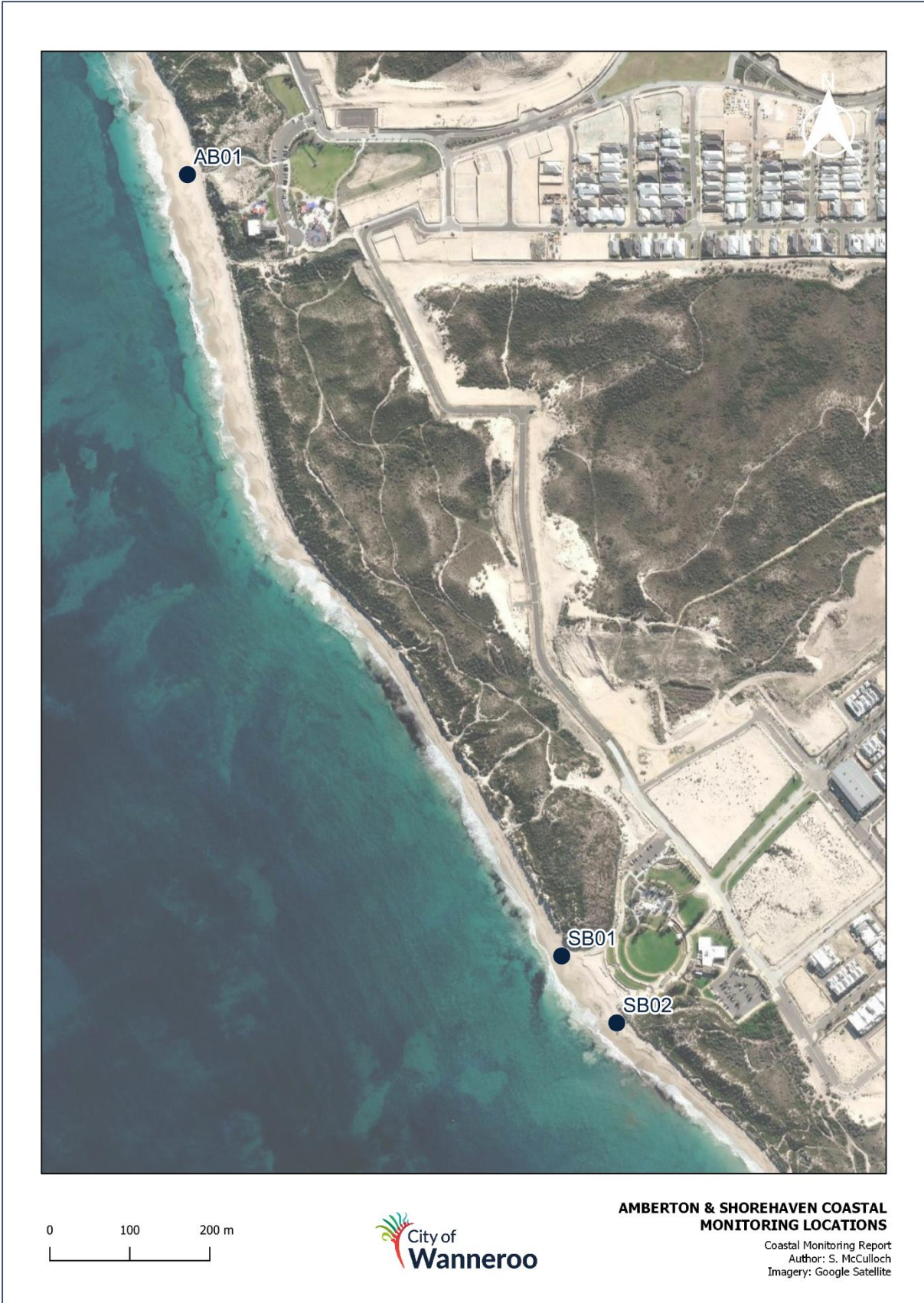


Figure 4-3 *Amberton and Shorehaven Coastal Monitoring Locations*



Figure 4-4 Eden, Jindalee and Quinns Rocks Coastal Monitoring Locations

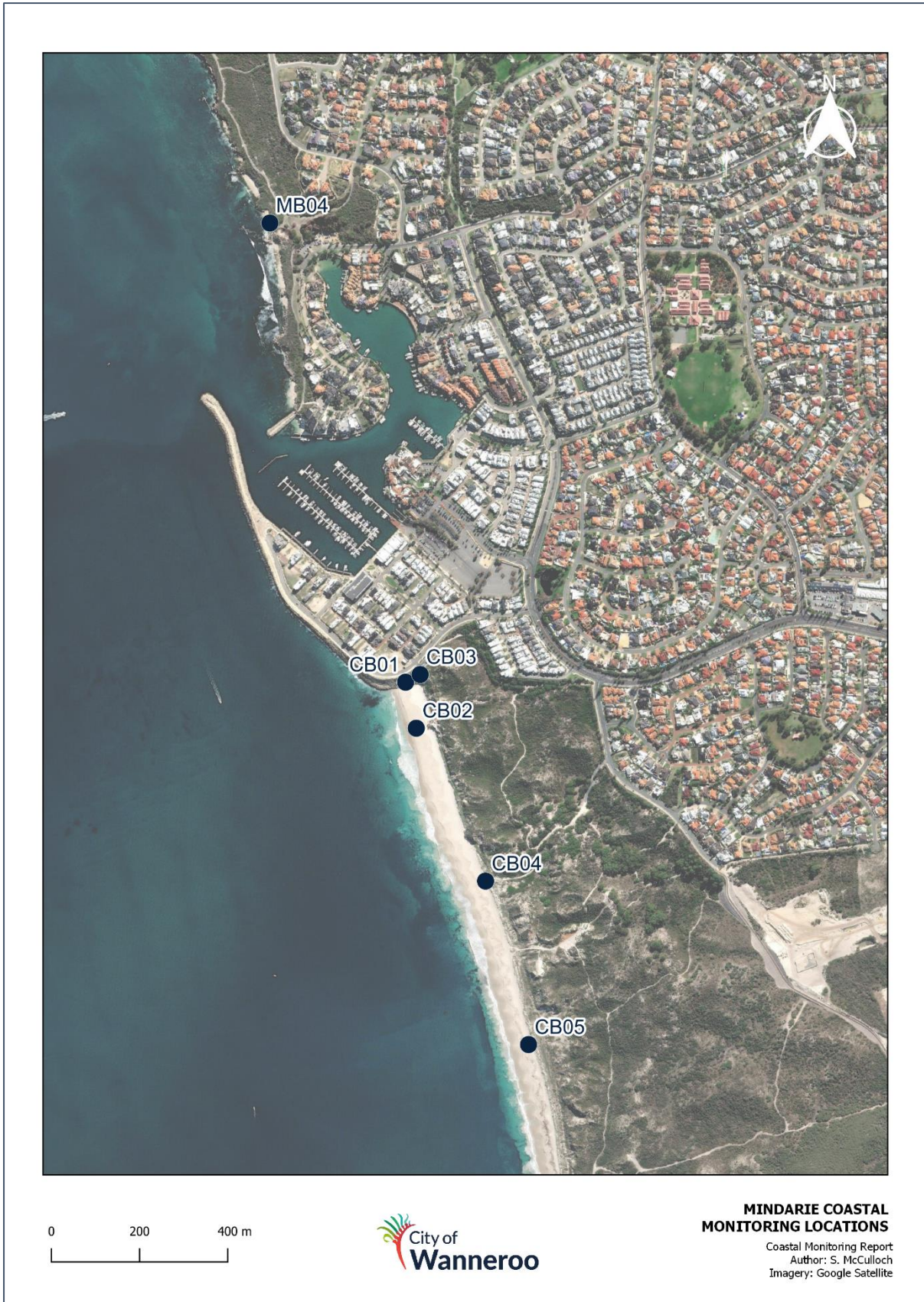


Figure 4-5 Mindarie Coastal Monitoring Locations

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	<ul style="list-style-type: none"> • Increase in beach width; • Notable sand build up; or • Improvement in dune condition.
No change	<ul style="list-style-type: none"> • No identifiable change in beach width, slope or dune condition.
Minor Erosion	<ul style="list-style-type: none"> • 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	<ul style="list-style-type: none"> • 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 4-7 and Table 4-8.

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 2022 to October 2022)		Summer Seasonal Changes (September 2021 to April 2022)		Long-term Changes (October 2014 to October 2022)		Long-term Changes (April 2015 to April 2022)	
	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	Increase in beach width however notable erosion at the base of the dunes.	Minor erosion	Slight reduction in beach width. No notable impact to dunes.	Minor erosion	Erosion at the base of the dunes is evident.	Minor erosion	Decrease in beach width with some improvement to dune condition.
B02 UP-COAST	Accretion	Increase in beach width.	Accretion	Notable increase in beach width.	No change	No notable change in dune condition. Increased beach width.	Minor erosion	Notable decrease in beach width.
B03 UP-COAST	Accretion	Increase in beach width with erosion notable at the base of the dunes.	Accretion	Slight reduction in beach width however there was notable build-up of dune toe.	Minor erosion	Slight erosion at the base of the dunes.	Minor erosion	Notable decrease in beach width.
B03 DOWN-COAST	Accretion	Increase in beach width.	Minor erosion	Slight decrease in beach width.	Minor erosion	Slight erosion at the base of the dunes.	Minor erosion	Slight decrease in beach width.
B04 UP-COAST	Accretion	Increase in beach width with established dune vegetation.	Minor erosion	Very slight decrease in beach width. Build up at the base of the dunes.	Minor erosion	Slight erosion at the base of the dunes.	Minor erosion	Slight decrease in beach width.
B04 DOWN-COAST	Accretion	Significant increase in beach width with established dune vegetation.	Minor erosion	Very slight decrease in beach width. Build up at the base of the dunes.	Accretion	Slight increase in beach width.	Minor erosion	Slight decrease in beach width.
B05	Minor erosion	Reduction in beach width.	Accretion	Significant increase in beach width. No notable changes to dune condition.	<i>Unable to assess - photo monitoring began in 2019.</i>			
B06 UP-COAST	Minor erosion	Slight reduction in beach width with no observed impact on dunes.	Accretion	Significant increase in beach width and build up at the base of the dunes.				
B06 DOWN-COAST	Minor erosion	Slight reduction in beach width with slight impact to the base of dunes.	Accretion	Significant increase in beach width and build up at the base of the dunes.				
B07 UP-COAST	Minor erosion	Slight reduction in beach width with no observed impact on dunes.	Accretion	Increase in beach width and establishment of new dune vegetation.				
B07 DOWN-COAST	Minor erosion	Slight reduction in beach width with no observed impact on dunes.	Accretion	Increase in beach width.				

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

Photo Monitoring Site	Seasonal Changes (April 2022 to October 2022)		Seasonal Changes (October 2021 to April 2022)		Mid-term Changes (October 2018 to October 2022)		Mid-term Changes (April 2019 to April 2022)	
	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	Slight increase in beach width.	Minor erosion	Slight reduction in beach width, however there was build up at the base of the dunes.	No change	No notable change in beach width or dune condition.	Minor erosion	Slight apparent reduction in beach height.
B01 DOWN-COAST	Accretion	Notable increase in beach width.	Minor erosion	Significant erosion scarp. Slight reduction in beach width. Not notable impact to dunes.	No change	No notable change in beach width or dune condition.	Minor erosion	Notable reduction in beach width and apparent beach height.
B02 UP-COAST	Accretion	Slight increase in beach width.	Minor erosion	Slight reduction in beach width however a notable build up at the base of the dunes.	Minor erosion	Notable erosion at the base of the dunes.	Minor erosion	Significant decrease in beach height, notable erosion at the base of the dunes.
B02 DOWN-COAST	Accretion	Significant increase in beach width.	Minor erosion	Slight reduction in beach width.	Minor erosion	Notable erosion at the base of the dunes.	Minor erosion	Significant decrease in beach height, notable erosion at the base of the dunes.
B03 UP-COAST	Accretion	Slight increase in beach width.	No change	No notable change in beach width or dune condition.	Minor erosion	Notable erosion at the base of the dunes.	Minor erosion	Slight decrease in beach height.
B03 DOWN-COAST	Minor erosion	Notable erosion at the base of the dunes.	Minor erosion	Slight reduction in beach width. Improvement in dune condition.	Minor erosion	Notable erosion at the base of the dunes.	Minor erosion	Erosion at the base of the dunes is evident, representing a reduction in beach height.
B05 UP-COAST	Minor erosion	Very minor reduction in beach width.	Accretion	Build up at the base of the dunes. No notable changes to beach width.	No change	No notable change in beach width or dune condition.	No change	No notable change in beach width or dune condition.
B05 DOWN-COAST	Accretion	Slight increase in beach width.	Accretion	Build up at the base of the dunes and increase in beach width.	Minor erosion	Notable erosion at the base of the dunes.	No change	No notable change in beach width or dune condition.
B06 UP-COAST	Accretion	Slight increase in beach width.	Accretion	Slight increase in beach width and improvement to dune condition.	Minor erosion	Notable erosion at the base of the dunes.	Minor erosion	Significant drop in beach height. Notable erosion at the base of the dunes.
B06 DOWN-COAST	Accretion	Slight increase in beach width.	No change	No notable change in beach width or dune condition.	Minor erosion	Notable erosion at the base of the dunes.	Minor erosion	Significant drop in beach height. Notable erosion at the base of the dunes.
B07 UP-COAST	Major erosion	Significant reduction in beach width and erosion at the base of the dunes.	Accretion	Significant increase in beach width.	Minor erosion	Notable erosion at the base of the dunes.	Minor erosion	Slight decrease in beach width.
B07 DOWN-COAST	Major erosion	Significant reduction in beach width.	Accretion	Significant increase in beach width.	Minor erosion	Notable reduction in beach height and erosion at the base of the dunes.	Minor erosion	Slight decrease in beach width.
B08 UP-COAST	Minor erosion	Reduction in beach width with erosion at the base of the dunes.	Accretion	Notable increase in beach width.	No change	No notable change in beach width or dune condition.	Accretion	Notable increase in beach width.
B08 DOWN-COAST	Minor erosion	Reduction in beach width.	Accretion	Significant increase in beach width and improvement in dune condition.	Minor erosion	Notable erosion at the base of the dunes.	Accretion	Notable increase in beach width.
B09 UP-COAST	Accretion	Significant increase in beach width	Accretion	Build-up in beach volume as a result of nourishment.	No change	No notable change in beach width or dune condition. Both images were taken following renourishment.	Minor erosion	Significant reduction in beach width with notable erosion scarp.
B09 DOWN-COAST	Accretion	Slight increase in beach width.	Accretion	Build-up in beach volume as a result of nourishment.	No change	No notable change in beach width or dune condition. Both images were taken following renourishment.	Minor erosion	Slight reduction in beach width with notable erosion scarp.

Photo Monitoring Site	Seasonal Changes (April 2022 to October 2022)		Seasonal Changes (October 2021 to April 2022)		Mid-term Changes (October 2018 to October 2022)		Mid-term Changes (April 2019 to April 2022)	
	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								
B10 UP-COAST	Accretion	Notable increase in beach width.	Minor erosion	Notable decrease in beach width and some dune erosion evident.	No change	No notable change in beach width or dune condition. Both images were taken following renourishment.	Minor erosion	Notable erosion at the base of the dunes.
B10 DOWN-COAST	Accretion	Significant increase in beach width as a result of nourishment	Accretion	Slight reduction in beach width but improvement in dune condition.	No change	No notable change in beach width or dune condition. Both images were taken following renourishment.	No change	No notable change in beach width or dune condition. Both images were taken following renourishment.
B11 UP-COAST	Accretion	Increase in beach width and improvement of dune condition.	Minor erosion	Slight reduction in beach width.	Minor erosion	Notable erosion at the base of the dunes.	Minor erosion	Notable reduction in beach height.
B11 DOWN-COAST	Accretion	Increase in beach width and improvement of dune condition.	Minor erosion	Slight reduction in beach width.	Minor erosion	Notable erosion at the base of the dunes.	Minor erosion	Slight reduction in beach height with erosion evident at the base of the dunes.
B12 UP-COAST	Accretion	Increase in beach width and improvement of dune condition.	Minor erosion	Slight reduction in beach width and notable erosion scarp.	Accretion	Increase in beach width and build up at the base of the dunes.	Minor erosion	Notable erosion scarp and reduction in beach width.
B12 DOWN-COAST	Accretion	Increase in beach width and improvement of dune condition.	Minor erosion	Slight reduction in beach width, no notable changes to the dune condition.	Accretion	Increase in beach width and build up at the base of the dunes.	Accretion	Slight increase in beach width and build up at the toe of the dune.
B13 UP-COAST	Accretion	Increase in beach width and improvement of dune condition.	Minor erosion	Slight reduction in beach width, no notable changes to the dune condition.	No change	No notable change in beach width or dune condition.	Accretion	Slight increase in beach width and build up at the toe of the dune.
B13 DOWN-COAST	Accretion	Increase in beach width and improvement of dune condition.	Accretion	Significant increase in beach width and improvement in dune condition.	Minor erosion	Erosion is evident at the base of the dunes.	Accretion	Slight increase in beach width and build up at the toe of the dune.

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

Photo Monitoring Site	Seasonal Changes (April 2022 to October 2022)		Seasonal Changes (October 2021 to April 2022)		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	Reduction in beach width and erosion evident at the base of the dunes.	Accretion	Increase in beach width and improvement in dune condition.	Unable to assess – photo monitoring began in 2021.			
B01 DOWN-COAST	Minor erosion	Reduction in beach width and significant erosion at the base of the dunes.	Accretion	Significant increase in beach width and 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 2022 to October 2022)		Seasonal Changes (October 2021 to April 2022)		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	Notable increase in beach width.	Minor erosion	Slight decrease in beach width, no changes to dune condition.	Unable to assess – monitoring began in 2020.			
B01 DOWN-COAST	Accretion	Notable increase in beach width.	No change	No change in beach width and no notable erosion.				
B02 UP-COAST	Accretion	Notable increase in beach width.	Minor erosion	Slight decrease in beach width, no changes to dune condition.				
B02 DOWN-COAST	Accretion	Notable increase in beach width.	Minor erosion	Slight decrease in beach width.				

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

Photo Monitoring Site	Seasonal Changes (April 2022 to October 2022)		Seasonal Changes (October 2021 to April 2022)		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	Slight decrease in beach width.	Unable to assess – photo monitoring began in October 2021.			
B01 DOWN-COAST	Accretion	Increase in beach width.	Minor erosion	Slight decrease in beach width.				

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

Photo Monitoring Site	Seasonal Changes (April 2022 to October 2022)		Seasonal Changes (October 2021 to April 2022)		Long-term Changes (November 2013 to October 2022)		Long-term Changes (April 2014 to April 2022)	
	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	Notable increase in beach width.	Minor erosion	Slight reduction in beach width. No notable changes to beach condition.	Accretion	Slight increase in beach width and improvement of dune condition.	Accretion	Significant increase in beach width.
B03 UP-COAST	Accretion	Increase in beach width.	Minor erosion	Notable reduction in beach width.	Minor erosion	Slight reduction in beach width dunes in similar condition.	Accretion	Slight increase in beach width. No notable changes to dune condition.
B03 DOWN-COAST	Accretion	Notable increase in beach width.	Minor erosion	Notable reduction in beach width, no notable impacts to dune condition.	Minor erosion	Slight reduction in beach width dunes in similar condition.	No change	No notable change in beach width. Dunes remain in similar condition.
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	Slight reduction in beach width dunes in similar condition.	No change	No notable change in beach width. Dunes remain in similar condition.
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.	Minor erosion	Slight reduction in beach width dunes in similar condition.	Minor erosion	Slight reduction in beach width.
B06 UP-COAST	Major erosion	Significant reduction in beach width.	Accretion	Significant increase in beach width and beach height.	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.	Accretion	Slight increase in beach width however as there was no GSC revetment in 2014 it makes it difficult to assess the extent of the erosion.
B06 DOWN-COAST	Major erosion	Significant reduction in beach width.	Accretion	Significant increase in beach width and beach height.	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.	Accretion	Slight increase in beach width however as there was no GSC revetment in 2014 it makes it difficult to assess the extent of the erosion.
B07 UP-COAST	Accretion	Notable increase in beach width noting that sand nourishment was undertaken in April following manual imagery.	Major Erosion	Significant decrease in beach width and drop in beach height.	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.	Minor erosion	Reduction in beach width is notable. It is important to note that nourishment is undertaken annually at this site.
B07 DOWN-COAST	Major erosion	Significant reduction in beach width.	Accretion	Significant increase in beach width and beach height.	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.	No change	Unable to determine any changes. Installation of the GSC Revetment was ongoing in 2014 and this could affect the long-term assessment.
B09 UP-COAST	Accretion	Notable increase in beach width.	Minor erosion	Slight reduction in beach width.	Accretion	Notable improvement in dune condition.	Minor erosion	Slight reduction in beach width however there is a notable improvement in dune condition.
B09 DOWN-COAST	Minor erosion	Slight reduction in beach width and notable erosion at the base of the dunes.	Accretion	Slight increase in beach width, improvements in dune condition.	Minor erosion	Notable erosion at the base of the dunes.	Minor erosion	Slight reduction in beach width however there is a notable improvement in dune condition.
B11 UP-COAST	Minor erosion	Slight reduction in beach width to the south of the groyne.	No change	No notable change in beach width or dune condition.	Minor erosion	Notable erosion at the base of the dunes.	Accretion	Slight increase in beach width and improvement in dune condition.
B11 DOWN-COAST	Accretion	Slight increase in beach width.	Minor erosion	Slight decrease in beach width. Dune condition remains unchanged.	No change	Dunes are in a similar condition.	Accretion	Slight increase in beach width and improvement in dune condition.
B13 UP-COAST	Accretion	Significant increase in beach width.	Major erosion	Major reduction in beach width and significant erosion scarp. Limited beach width protecting the base of the dunes.	Minor erosion	Notable reduction in beach width and minor erosion at the base of the dunes.	Major erosion	Significant erosion scarp and reduction in beach width.
B13 DOWN-COAST	Minor erosion	Decrease in beach width and notable erosion at the base of the dunes.	Accretion	Increase in beach width and build up at the base of the dunes.	Minor erosion	Notable erosion at the base of the dunes. Nourishment was undertaken in April 2022.	Minor erosion	Slight reduction in beach width and notable erosion at the base of the dunes.

Photo Monitoring Site	Seasonal Changes (April 2022 to October 2022)		Seasonal Changes (October 2021 to April 2022)		Long-term Changes (November 2013 to October 2022)		Long-term Changes (April 2014 to April 2022)	
	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								
B14 UP-COAST	Accretion	Notable accretion with increase in beach width.	Minor erosion	Major reduction in beach width and significant erosion scarp. Limited beach width protecting the base of the dunes.	Minor erosion	Notable erosion at the base of the dunes.	Minor erosion	Significant reduction in beach width and notable erosion scarp.
B14 DOWN-COAST	Minor erosion	Notable reduction in beach width with erosion notable at the base of the dunes.	Accretion	Slight increase in beach width.	Minor erosion	Notable erosion at the base of the dunes.	Minor erosion	Significant reduction in beach width.
B15 UP-COAST	Accretion	Slight increase in beach width.	Minor erosion	Slight erosion scarp.	Minor erosion**	Some notable erosion at the base of the dunes.	Minor erosion*	Reduction in beach height and beach width evident.
B15 DOWN-COAST	Accretion	Notable increase in beach width.	Minor erosion	Slight reduction in beach width and erosion scarp is notable.	Accretion**	Notable accretion at the base of the dunes.	Minor erosion*	Significant reduction in beach width with notable erosion scarp.
B16 UP-COAST	Minor erosion	Slight reduction in beach width.	Accretion	Slight increase in beach width.	Accretion**	Increase in beach width.	Minor erosion*	Significant reduction in beach width.
B16 DOWN-COAST	Minor erosion	Notable decrease in beach width.	Accretion	Slight increase in beach width.	Accretion**	Increase in beach width.	Minor erosion*	Significant reduction in beach width.
B17 UP-COAST	Minor erosion	Notable reduction in beach width and erosion at the base of the dunes.	Accretion	Increase in beach width and build up at the base of the dunes.	<i>Unable to assess – Monitoring began in 2021.</i>			
B17 DOWN-COAST	Minor erosion	Notable reduction in beach width and erosion at the base of the dunes.	Accretion	Notable build up at the base of the dunes.				

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

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

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

Photo Monitoring Site	Seasonal Changes (April 2022 to October 2022)		Seasonal Changes (October 2021 to April 2022)		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	Major erosion	Significant reduction in beach width with notable erosion at the base of the dunes.	Accretion	Significant increase in beach width.	<i>Unable to assess – monitoring began in 2020.</i>			
B02 UP-COAST	Major erosion	Significant reduction in beach width with notable erosion at the base of the dunes.	Accretion	Significant increase in beach width and improvement to the condition of the dunes.				
B02 DOWN-COAST	Major erosion	Significant reduction in beach width with notable erosion at the base of the dunes.	Accretion	Significant increase in beach width and improvement to the condition of the dunes.				
B03	Major erosion	Significant reduction in beach width with notable erosion at the base of the dunes.	Accretion	Significant increase in beach width and improvement to the condition of the dunes.				
B04	Accretion	Slight increase in beach width.	Minor erosion	Slight decrease in beach width.				

4.2.1 Areas Experiencing Major Seasonal Erosion

While assessing seasonal changes, one area was identified as having experienced major erosion over the summer period (October 2021 to April 2022) and three areas were identified as having experienced major erosion over the winter months (April 2022 to October 2022). Images of the identified areas experiencing major seasonal erosion are shown below.

Quinns Rocks B07 Up-Coast – Major Erosion, Summer 2021/22



Figure 4-6 Major erosion over summer 2021/22 at Quinns B07 Up-Coast.

Major erosion was identified through manual imagery in the area immediately north of Quinns Groyne 1. Major seasonal erosion is experienced at this site each year and in response, the City undertakes planned re-nourishment at the site prior to each winter period. Following the April 2022 monitoring round, approximately 4000 tonnes of sand was placed at this site. The additional sand that is placed following renourishment creates a buffer against the impacts of winter storm events and limits the damage to coastal assets.

Yanchep B07 Up-Coast and Down-Coast – Major Erosion, Winter 2022



Figure 4-7 Major erosion over winter 2021 at Yanchep B07 Up-Coast and Down-Coast.

The beach captured in the photographs taken up-coast and down-coast at the Yanchep monitoring location B07 is bounded by a headland to the north and south. There was a significant reduction in beach width over the 2022 winter period with the transport of sediment southward over the winter months, bypassing the southern headland and feeding the southern beach, resulting in erosion at the site. Northward movement of sediment during the summer months resulted in significant accretion at the site which provided a substantial buffer against early winter storms. While there is major seasonal changes at the site, the long term manual imagery assessment suggests that the site has experienced very minor erosion since the start of monitoring in 2019. It is important to note, however, 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. It is therefore recommended that the site be monitored closely.

Quinns B06 and B07 Down-Coast – Major Erosion, Winter 2022



Figure 4-8 Major erosion over winter 2021 at Quinns B06 Up-Coast, Down-Coast and Quinns B07 Down-Coast.

Major seasonal erosion is experienced adjacent to the GSC and Rock Revetment at Quinns Rocks each year. The area is bound by Quinns Groyne 1 to the north and the Artificial Headland to the south. As presented in Figure 4-8 significant erosion was experienced over the 2022 winter period with very little beach remaining adjacent to the GSC Revetment. While seasonal erosion happens in the area each year, the GSC Revetment provides sufficient protection to adjacent assets and park land. The area will continue to be monitored and the GSC Revetment will continue to be assessed to ensure that it continues to function adequately as a coastal protection structure.

Mindarie B01, B02 and B03 – Major Erosion, Winter 2022



Figure 4-9 Major erosion over winter 2021 at Mindarie B01, B02 and B03.

Significant erosion was observed at Clayton's Beach in Mindarie over the 2022 winter period. While the images show some beach remaining in October 2022, images taken at site B01 and B02 show significant impact to the base of the dunes at Clayton's Beach. Clayton's Beach experiences

significant seasonal erosion and accretion each year however, there was significant dune erosion in 2021 which left the area vulnerable to further erosion in 2022. While there is little infrastructure landward of Claytons Beach it is recommended that the area be closely monitored in future coastal monitoring reports and if significant erosion continues, coastal management measures should be investigated for the area.

Dune volume loss is significant in some areas which is often not captured effectively through manual imagery. Dune volume loss is more effectively assessed through survey results as outlined in **Section 5.3**.

4.2.2 Areas Experiencing Major Long-Term Erosion

One site in Quinns Rocks was identified through manual imagery as having experienced major long-term erosion. The site, which is outlined below in Figure 4-10, is situated immediately north of Quinns Groyne 3 along Quinns Dog Beach. Despite the significant nourishment that has been undertaken at the site since 2004 (80,000 m³), a narrow beach is evident in the image taken in April 2022 with notable impact to the base of the dunes. It is recommended that this site continue to be monitored closely.

Quinns Rocks B13 Up-Coast – Long-Term Major Erosion

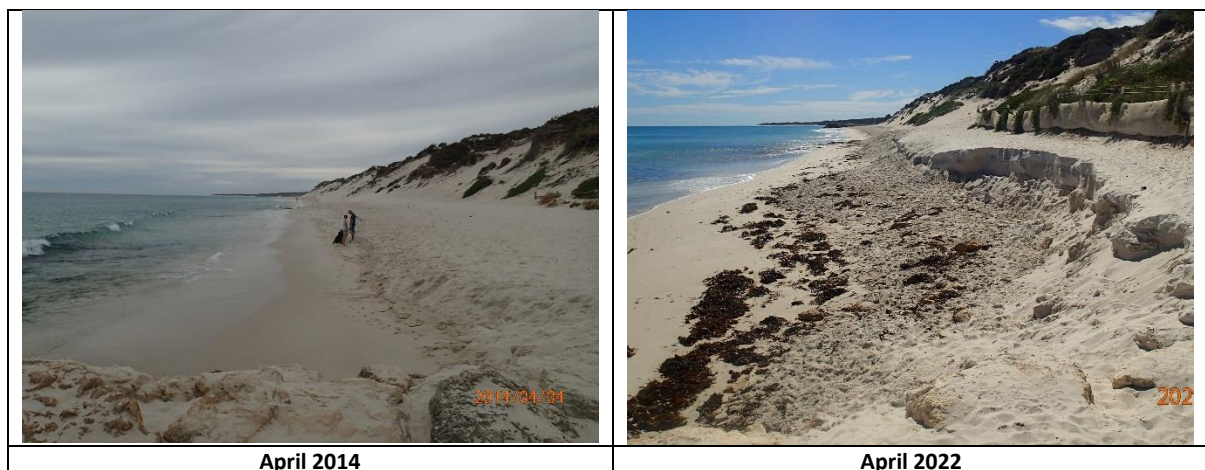


Figure 4-10 Significant long term erosion at Quinns Dog Beach, north of Quinns Groyne 3.

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 and in between the following areas:

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

129 nearshore ground based transect surveys are undertaken around the same time as the LiDAR aerial surveys. These surveys extend into the nearshore area, to a maximum depth of one meter, to collect the data within the nearshore area that is otherwise missed in LiDAR surveys due to constraints. LiDAR Aerial Surveys can only capture areas above the waterline and when the shoreline has receded, the area of analysis is limited. This is the first monitoring round where nearshore surveys have been undertaken which will allow for a better understanding of the morphological changes to the nearshore area.

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 then assessed for changes in beach volume. Note that for this survey technique, this assessment is limited to dry areas landward of the waterline. Seasonal changes (April 2022 to October 2022) and annual changes (October 2021 to October 2022) to beach volume is assessed for each discrete area via difference plots of the two survey surfaces.

The data from ground based survey transects have been interpolated to estimate the changes in beach volume in areas 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 aerial survey profiles 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 evaluate the extent of seasonal and long term erosion or accretion at the location.

5.2 Elevation Difference Plots

5.2.1 Seasonal Changes

The change in beach volume between April 2022 and October 2022 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 2022 – October 2021	Winter Net Volume Change October 2022 – April 2022
Claytons Section 1A	Clayton's Beach, Mindarie above the waterline	+33,694 m ³	-36,220 m ³
Claytons Section 1B*	Clayton's Beach, Mindarie below the waterline	+38,188 m ³	-52,828 m ³
Quinns Section 1A	Quinns Main Beach – South of Artificial Headland above the waterline	+5,804 m ³	+371 m ³
Quinns Section 1B*	Quinns Main Beach – South of Artificial Headland below the waterline	-4,423 m ³	+8,653 m ³
Quinns Section 2A	Frederick Stubbs Park and GSC Revetment above the waterline	+5,794 m ³	-8,807 m ³
Quinns Section 2B*	Frederick Stubbs Park and GSC Revetment below the waterline	+14,522 m ³	-13,182 m ³
Quinns Section 3A	Frederick Stubbs Carpark, South of Groyne 2 above the waterline	+1,436 m ³	-1,599 m ³
Quinns Section 3B*	Frederick Stubbs Carpark, South of Groyne 2 below the waterline	+8,980 m ³	-2,977 m ³
Quinns Section 4A	North of Groyne 2, South of Groyne 3 above the waterline	+2,682 m ³	-1,265 m ³
Quinns Section 4B*	North of Groyne 2, South of Groyne 3 below the waterline	+3,692 m ³	-930 m ³
Quinns Section 5A	North of Groyne 3, South of Groyne 4 above the waterline	+1,371 m ³	-3,896 m ³
Quinns Section 5B*	North of Groyne 3, South of Groyne 4 below the waterline	+168 m ³	+4,533 m ³
Quinns Section 6A	North of Groyne 4, Jindalee above the waterline	+7,666 m ³	-8,710 m ³
Quinns Section 6B*	North of Groyne 4, Jindalee below the waterline	+7,833 m ³	-2,914 m ³
Yanchep Section 1A	South of Fisherman's Hollow Beach Access above the waterline	+11,217 m ³	+2,906 m ³
Yanchep Section 1B*	South of Fisherman's Hollow Beach Access above the waterline	+8,203 m ³	+3,170 m ³
Yanchep Section 2A	South of Headland, North of Fisherman's Hollow Beach Access above the waterline	+1,768 m ³	+41 m ³
Yanchep Section 2B*	South of Headland, North of Fisherman's Hollow Beach Access below the waterline	+16,203 m ³	-19,248 m ³
Yanchep Section 3A	Yanchep Lagoon above the waterline	-54 m ³	+2,439 m ³
Yanchep Section 3B*	Yanchep Lagoon below the waterline	-2,653 m ³	+3,571 m ³
Yanchep Section 4	South of Capricorn Groyne above the waterline	+7,965 m ³	-7,382 m ³
Yanchep Section 4B*	South of Capricorn Groyne below the waterline	+9,510 m ³	+2,930 m ³
Yanchep Section 5A	North of Capricorn Groyne above the waterline	+3,611 m ³	+911 m ³
Yanchep Section 5B*	North of Capricorn Groyne below the waterline	+2,122 m ³	-928 m ³

Beach Section	Section Description	Summer Net Volume Change April 2022 – October 2021	Winter Net Volume Change October 2022 – April 2022
Two Rocks Section 1A	South of Two Rocks Marina above the waterline	+13,227 m ²	-15,764 m ³
Two Rocks Section 1B*	South of Two Rocks Marina below the waterline	+38,654 m ²	-14,555 m ³
Two Rocks Section 2A	North of Two Rocks Marina above the waterline	+9,275 m ²	-7,225 m ³
Two Rocks Section 2B*	North of Two Rocks Marina below the waterline	+2,276 m ²	+5,910 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 whereas volume changes of areas below the waterline are calculated from ground based transects that are taken approximately 100m apart.*

Overall, there was a decrease in beach volume across the 2022 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 89,048 m³ between April 2022 and October 2022;
- The six beach sections along the Quinns foreshore area had an estimated combined net beach volume loss of 30,723 m³ between April 2022 and October 2022;
- The five beach sections along the Yanchep foreshore area had an estimated combined net beach volume loss of 11,590 m³ between April 2022 and October 2022; and
- The two beach sections along the Two Rocks foreshore area had an estimated combined net beach volume loss of 31,634 m³ between October and April 2021.

While these results represent a significant loss in beach volume over the 2022 winter period, particularly along Clayton's Beach, there was a significant increase in beach volume across the summer of 2021/22 where considerably more beach volume was gained in Quinns, Yanchep and Two Rocks than was lost over the 2022 winter period. In previous years, Quinns Section 1 has been steadily accreting and it is possible that the storage of sand at the southern portion of the Quinns coastline has fed a build-up of sand along the Quinns northern coastline as sand moves northward over the summer period.

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 however the data does provide an improved understanding of how sediment is transported locally within these beach segments.

5.2.2 Annual Changes – October 2021 to October 2022

Heat maps depicting the difference in surface elevation between the October 2022 surveys and October 2021 surveys are output by MNG.

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 2022 –October 2021.

Beach Section	Section Description	Net Volume Change October 2022 – October 2021
Clayton Section 1A	Clayton's Beach above the waterline	+24,233 m ³
Clayton Section 1B*	Clayton's Beach below the waterline	+15,341 m ³
Quinns Section 1A	Quinns Main Beach – South of Artificial Headland above the waterline	+9,803 m ³

Beach Section	Section Description	Net Volume Change October 2022 – October 2021
Quinns Section 1B*	Quinns Main Beach – South of Artificial Headland below the waterline	+888 m ³
Quinns Section 2A	Frederick Stubbs Park and GSC Revetment above the waterline	+1,694 m ³
Quinns Section 2B*	Frederick Stubbs Park and GSC Revetment below the waterline	-31 m ³
Quinns Section 3A	Frederick Stubbs Carpark, South of Groyne 2 above the waterline	+3,086 m ³
Quinns Section 3B*	Frederick Stubbs Carpark, South of Groyne 2 below the waterline	+3,436 m ³
Quinns Section 4A	North of Groyne 2, South of Groyne 3 above the waterline	+2,024 m ³
Quinns Section 4B*	North of Groyne 2, South of Groyne 3 below the waterline	+1,765 m ³
Quinns Section 5A	North of Groyne 3, South of Groyne 4 above the waterline	-1,297 m ³
Quinns Section 5B*	North of Groyne 3, South of Groyne 4 below the waterline	+2,168 m ³
Quinns Section 6A	North of Groyne 4, Jindalee above the waterline	+3,154 m ³
Quinns Section 6B*	North of Groyne 4, Jindalee below the waterline	+1,751 m ³
Yanchep Section 1A	South of Fisherman's Hollow Beach Access above the waterline	+18,862 m ³
Yanchep Section 1B*	South of Fisherman's Hollow Beach Access below the waterline	+14,032 m ³
Yanchep Section 2A	South of Headland, North of Fisherman's Hollow Beach Access above the waterline	+3,004 m ³
Yanchep Section 2B*	South of Headland, North of Fisherman's Hollow Beach Access below the waterline	+7,312 m ³
Yanchep Section 3A	Yanchep Lagoon above the waterline	+2,816 m ³
Yanchep Section 3B*	Yanchep Lagoon below the waterline	-187 m ³
Yanchep Section 4A	South of Capricorn Groyne above the waterline	+7,281 m ³
Yanchep Section 4B*	South of Capricorn Groyne below the waterline	+8,469 m ³
Yanchep Section 5A	North of Capricorn Groyne above the waterline	+6,076 m ³
Yanchep Section 5B*	North of Capricorn Groyne below the waterline	+4,824 m ³
Two Rocks Section 1A	South of Two Rocks Marina above the waterline	+14,586 m ³
Two Rocks Section 1B*	South of Two Rocks Marina below the waterline	+6,736 m ³
Two Rocks Section 2A	North of Two Rocks Marina above the waterline	+6,539 m ³
Two Rocks Section 2B*	North of Two Rocks Marina below the waterline	+6,187 m ³

It is apparent that there was a significant gain in beach volume across the year. It is important to note that as part of the annual beach renourishment program, 8,000 tonnes (~6,500 m³) of sand was used in April 2022 for renourishment at Quinns Sections 3A and 5A. Additionally, in response to the erosion caused by the 2022 winter storms, reactive beach renourishment works were also undertaken at Yanchep Section 3, where 2,693 tonnes (~1,750 m³) was placed in September 2022.

The beach volume change maps developed by MNG show that in Quinns, while there was considerable erosion of the dry beach area above the waterline, sand remains trapped by the groynes in the nearshore area. This has likely contributed to the net gain of beach volume in Quinns across the year and is an indication that the groynes are acting as intended by retaining sand within Quinns Sections 2, 3 and 4.

5.2.3 Long Term Trends

Seasonal changes in beach volumes have been assessed by the City since the summer of 2018/19. To identify any long term trends in seasonal beach volume change, net beach volume change per season was plotted for each beach section. These plots are presented in Figure 5-1, Figure 5-2, Figure 5-3 and Figure 5-4 below.

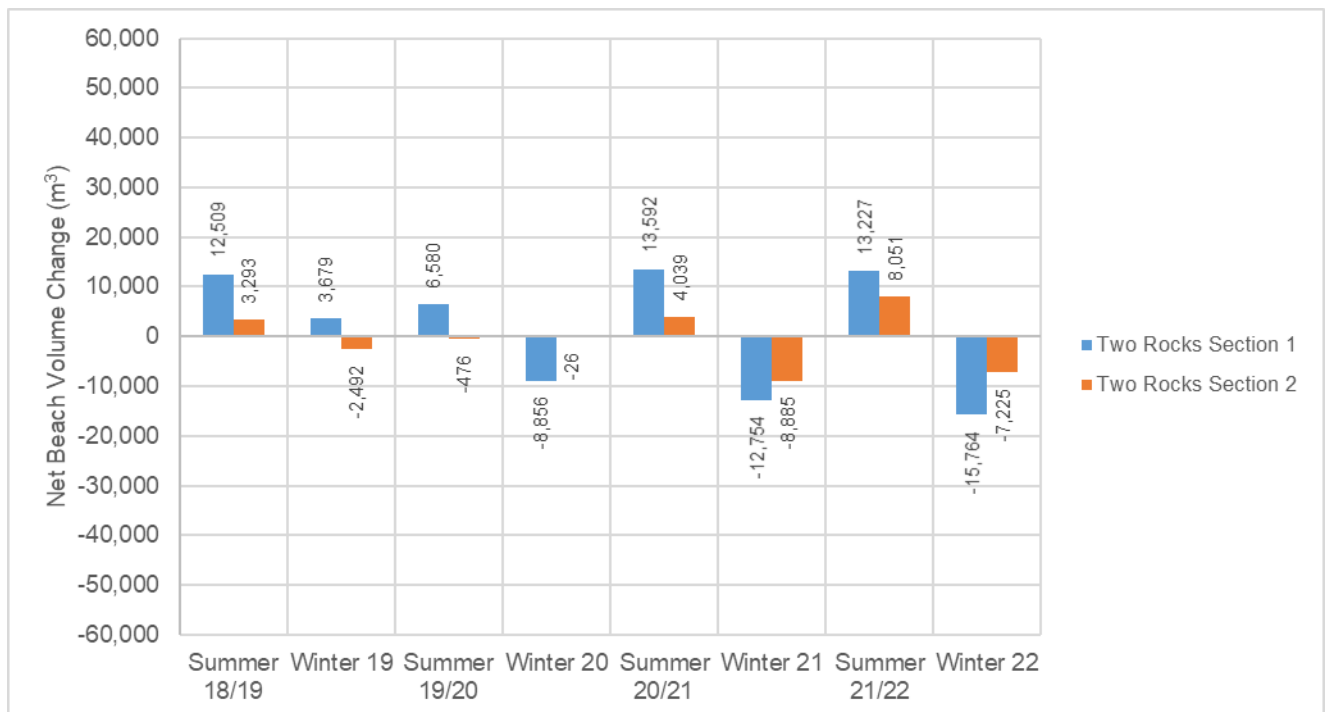


Figure 5-1 Seasonal net beach volume changes for Two Rocks Section 1 and 2.

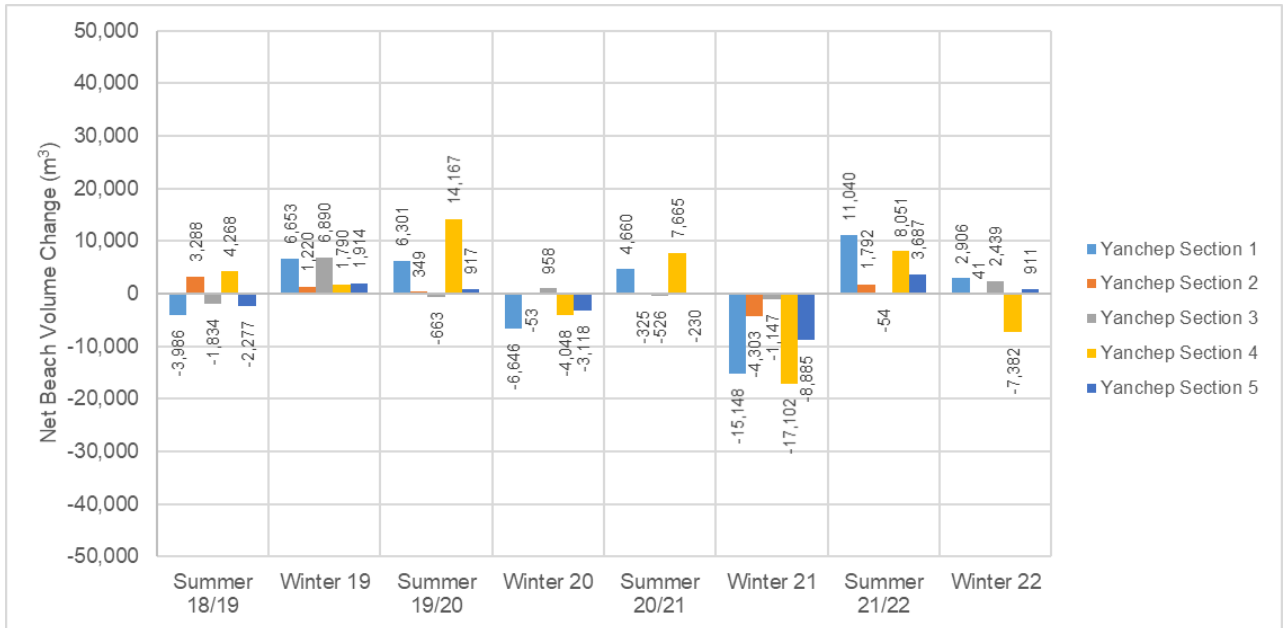


Figure 5-2 Seasonal net beach volume changes for Yanchep Section 1, 2, 3, 4 and 5.

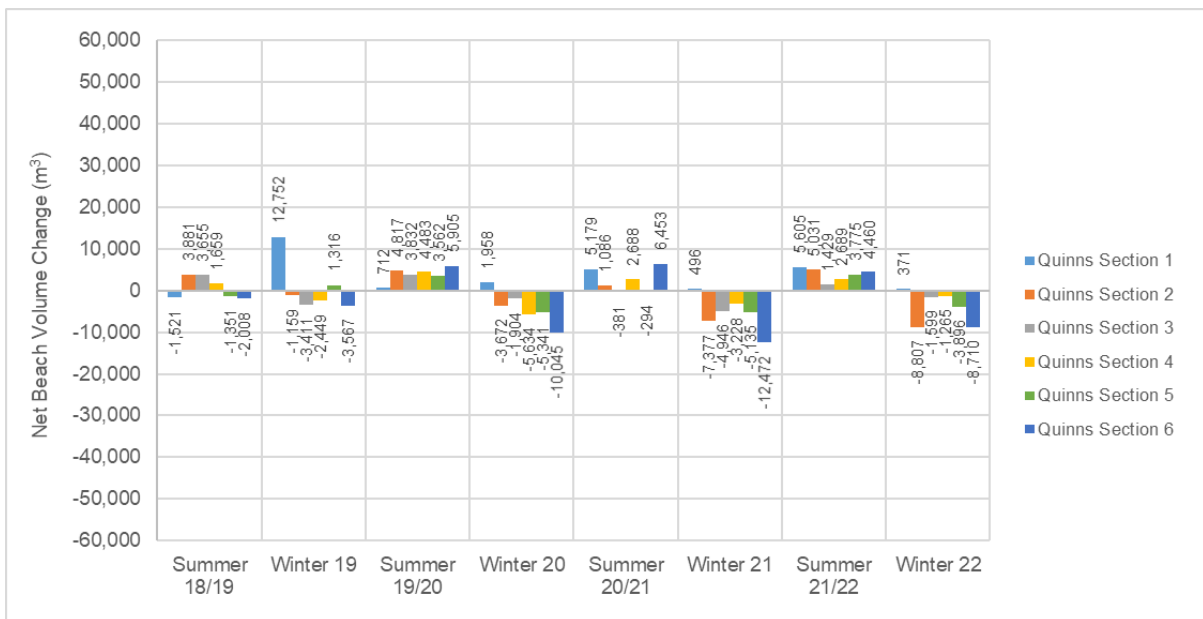


Figure 5-3 Seasonal net beach volume changes for Quinns Section 1, 2, 3, 4, 5 and 6.

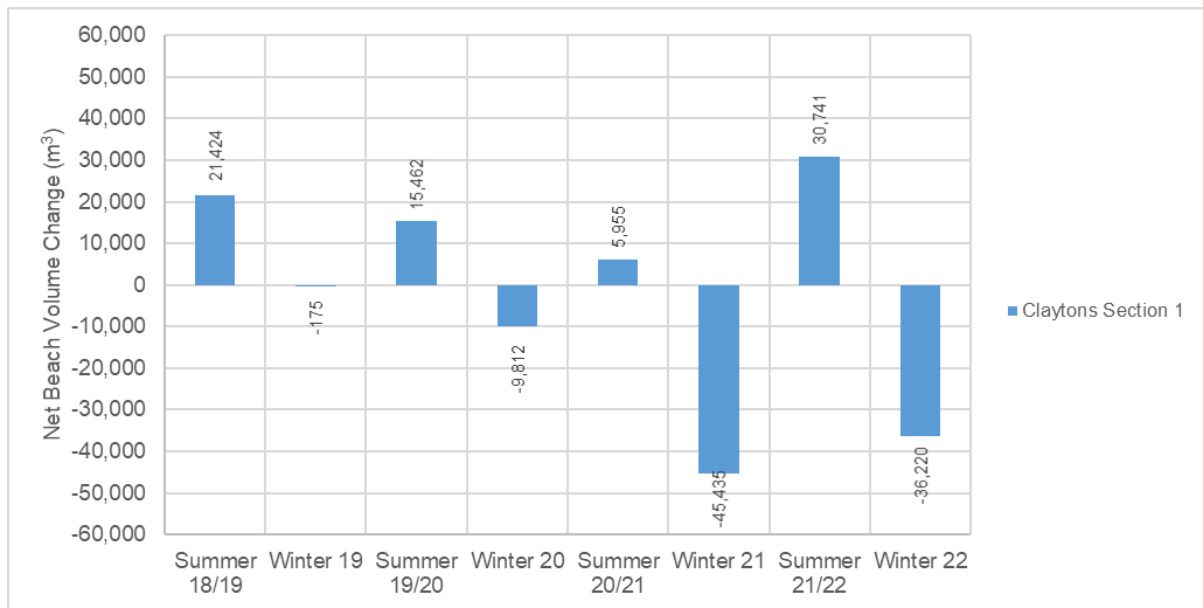


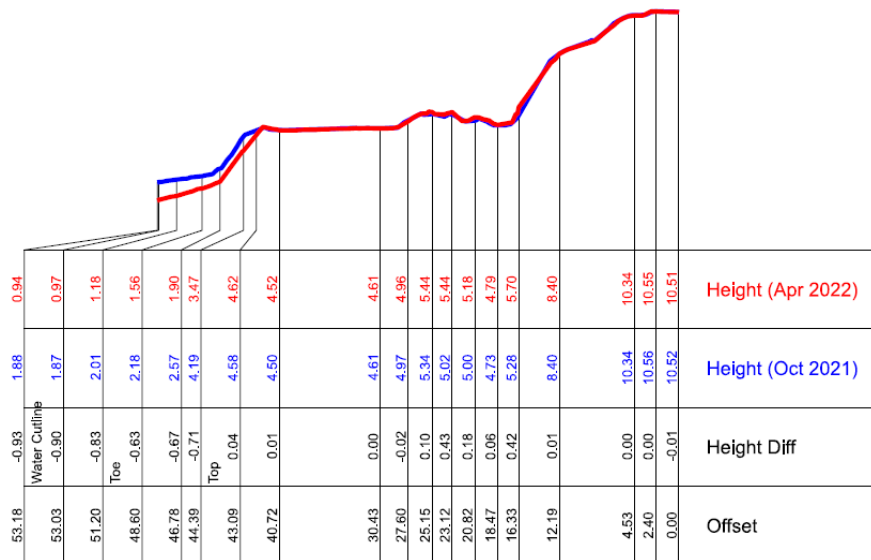
Figure 5-4 Seasonal net beach volume changes for Claytons Section 1.

Most areas present clear seasonal trends, often with a net beach volume loss recorded following the winter months and a net beach volume gain after the summer months however some sites within Yanchep do not necessarily follow this trend. It is recommended that further investigation be undertaken within Yanchep to investigate the drivers of sediment transport within the area.

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 Quinns Rocks B07 Up-Coast – Major Erosion, Summer 2021/22



Section 16 [E38103.88, N294544.73 to E38051.03, N294538.88]

Figure 5-5 Quinns cross section 16 elevation comparison between April 2022 and October 2021 surveys.

Quinns Rocks beach cross-section 16 is situated within the field of view of manual imagery point 'Quinns Rocks B04 Up-Coast'. There is minimal elevation difference apparent between the April 2022 and October 2021 surveys aside from just prior to the water line where there was maximum reduction in elevation of 0.93m between the surveys. In this instance it is difficult to assess the total reduction in elevation as the assessment is limited to the 'safe wading depth' past the waterline. However, the cross-section indicates that erosion did occur over the summer period seaward of the dune toe which is consistent with manual imagery observations.

5.3.2 Quinns Rocks B13 Up-Coast – Major Erosion, Summer 2021/22

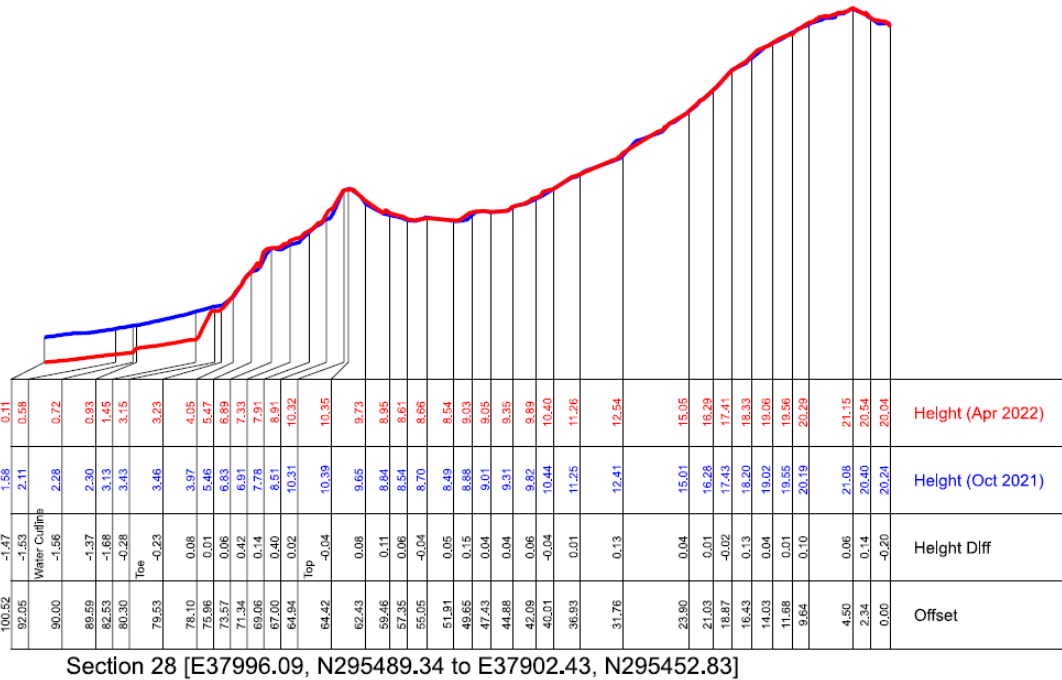
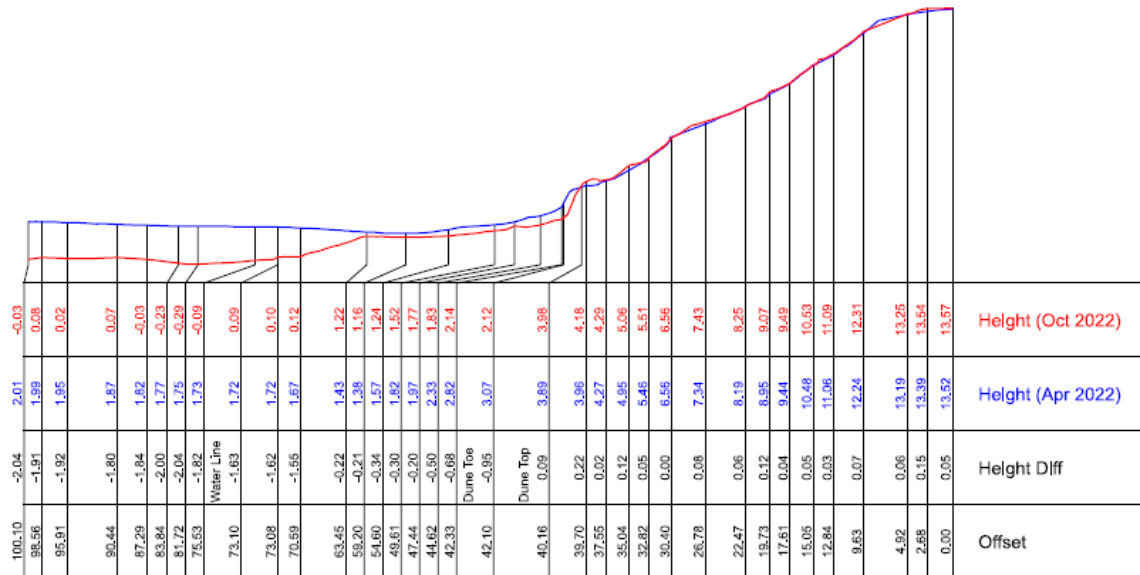


Figure 5-6 Quinns beach cross section 28 elevation comparison between October 2021 and April 2022 surveys.

Quinns beach cross-section 29 is situated within the field of view of manual imagery point 'Quinns Rocks B13 Up-Coast'. Figure 5-6 shows a significant reduction in elevation (1.68m) between the October 2021 and April 2022 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.

5.3.3 Yanchep B07 Up-Coast and Down-Coast – Major Erosion, Winter 2022

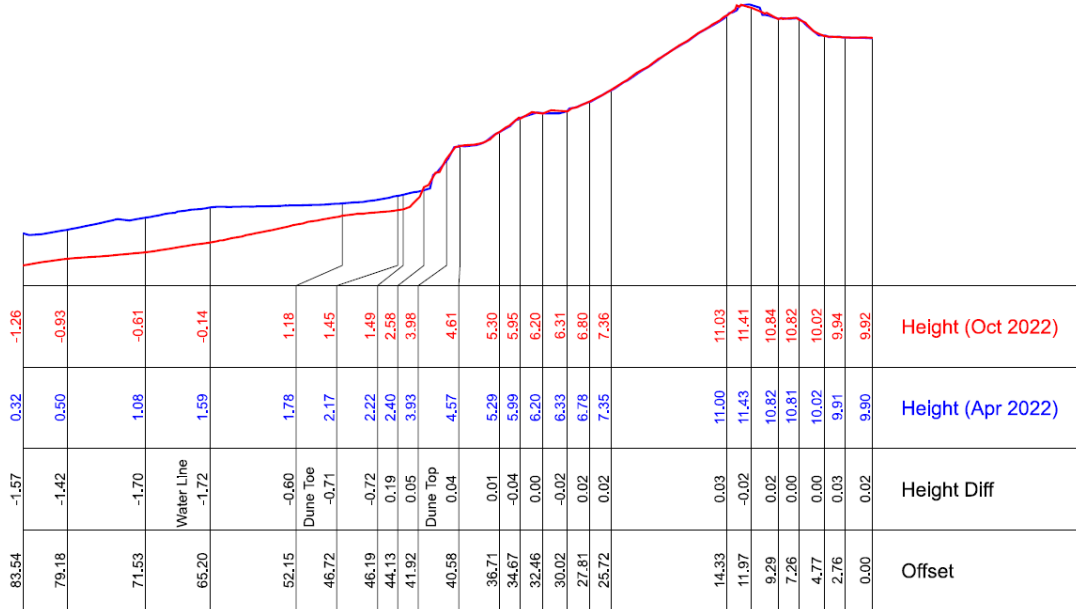


Section 21 [E32020.00, N307577.30 to E31928.96, N307535.69]

Figure 5-7 Yanchep Beach cross section 21 elevation comparison between April 2022 and October 2022 surveys.

Yanchep Beach cross section 21 is situated within the field of view of manual imagery point 'Yanchep B07 Up-Coast' where significant erosion was observed between April and October 2022 in manual imagery. While levels above the water line show only a minor drop in elevation, levels below the water line show quite a significant reduction in elevation, with the maximum height difference between the April and October 2022 survey was 2.04m. These results outline the benefits of undertaking additional ground based nearshore survey transects as the results from these surveys can capture areas of significant erosion that is otherwise not captured through LiDAR Aerial Surveys. The results from this cross section are consistent with manual imagery observations.

5.3.4 Quinns B06 Down-Coast – Major Erosion Winter 2022

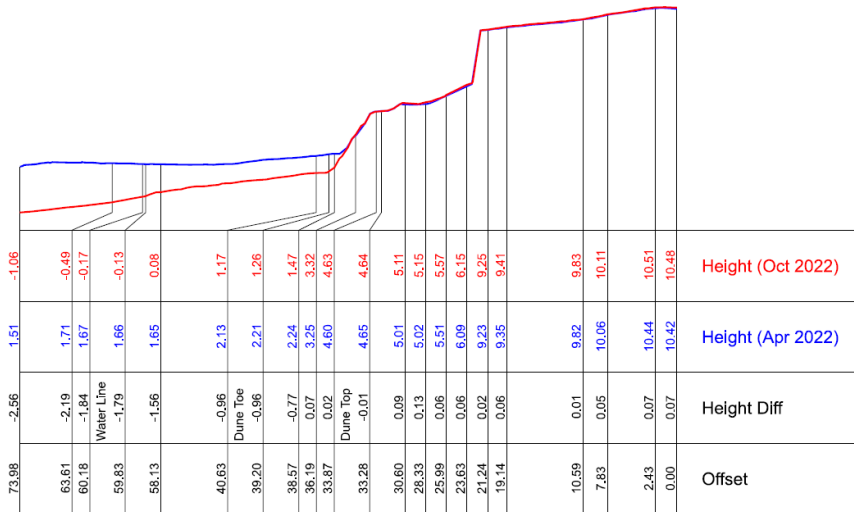


Section 13 [E38125.29, N294290.91 to E38042.26, N294281.72]

Figure 5-8 Quinns Beach cross section 13 elevation comparison between April 2022 and October 2022 surveys.

Quinns Beach cross section 13 is situated within the field of view of manual monitoring point 'Quinns B06 Down-Coast'. The elevation difference presented in Figure 5-8 shows significant erosion at the site over the winter period, between April and October 2022, which is consistent with manual imagery observations. The most significant drop in elevation (1.72m) was recorded at the waterline. This area experiences significant seasonal erosion each year, as sediment builds up southward of Quinns Groyne 1 in the summer months and erodes in the winter months as sand moves southward.

5.3.5 Quinns B07 Down-Coast and B06 Up-Coast – Major Erosion Winter 2022

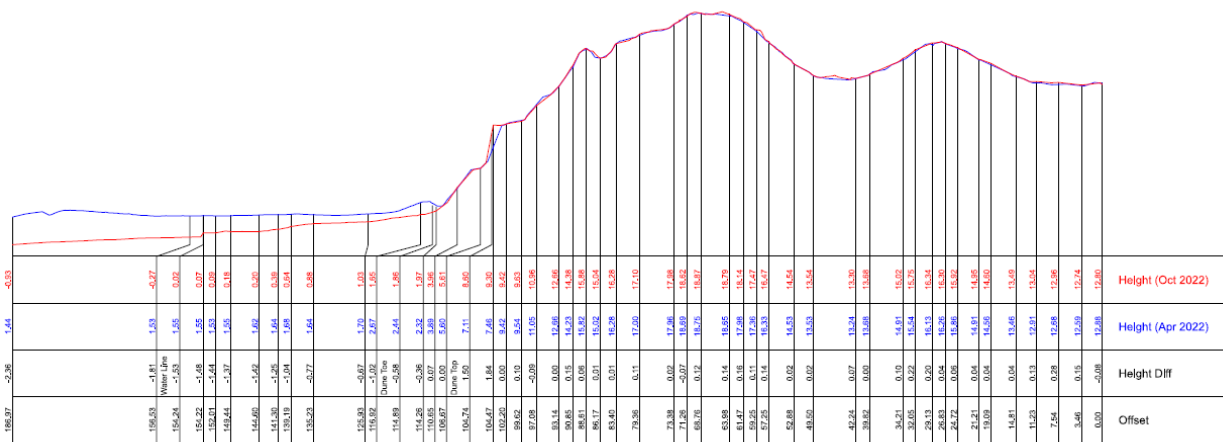


Section 14 [E38116.88, N294390.59 to E38043.36, N294382.45]

Figure 5-9 Quinns Beach cross section 14 elevation comparison between April 2022 and October 2022 surveys.

Quinns Beach cross section 14 is situated within the field of view of both Quinns manual imagery sites 'B07 Down-Coast' and 'B06 Up-Coast'. The cross section shows a significant drop in elevation between April and October 2022, where the maximum recorded elevation difference was 2.56m. Similarly to Yanchep cross-section 21, the highest elevation differences were recorded below the water line. The significant elevation difference recorded between April and October 2022 is consistent with manual imagery observations at the site (**Section 4.2**).

5.3.6 Mindarie B01, B02 Up-Coast & B03 - Major Erosion Winter 2022



Section 20 [E39332.11, N291894.21 to E39152.31, N291842.92]

Figure 5-10 Mindarie cross section 20 elevation comparison between April 2022 and October 2022 surveys.



Figure 5-12 Manual images taken at Quinns B14 Down-Coast.

The cross section presented in Figure 5-11 indicates a significant recession of the dune face between the October 2021 survey and the October 2022 survey. This was not identified in manual imagery (Figure 5-12) as the dune face is not a main focus of the manual imagery field of view and recession in the dune face is difficult to interpret using manual imagery alone.

5.3.7.2 Yanchep

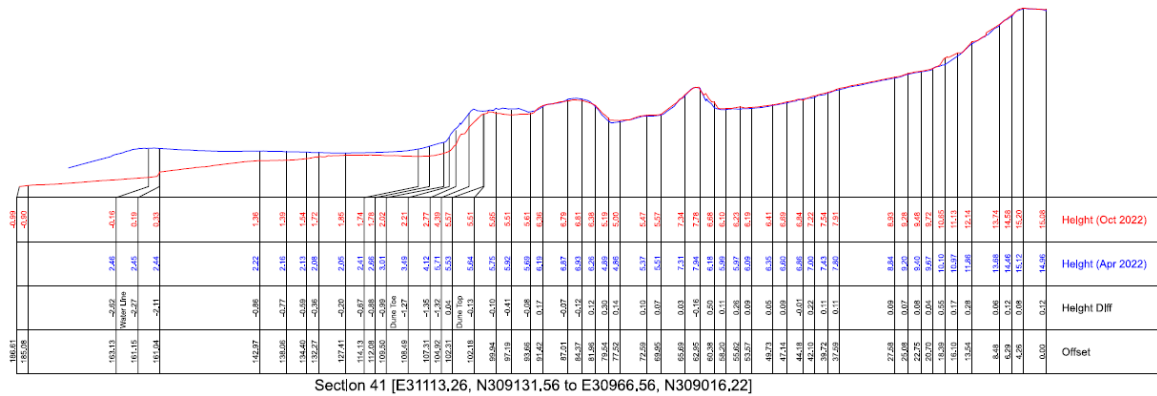


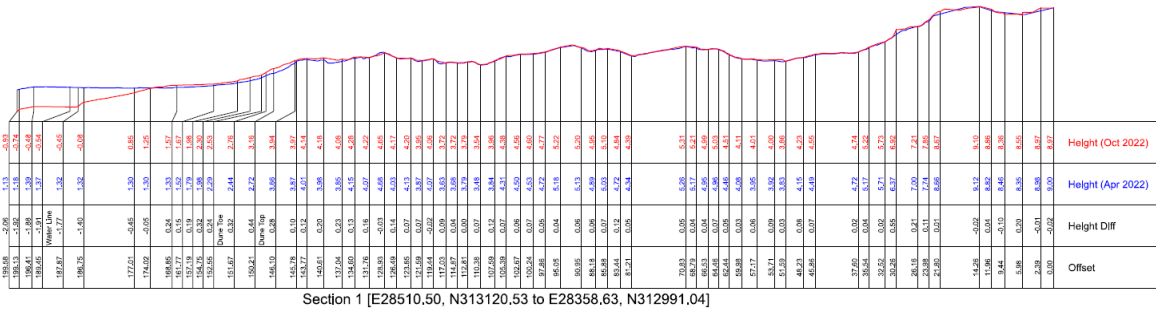
Figure 5-13 Additional Yanchep cross sections that experienced major erosion between April 2022 and October 2022 surveys.

The results from cross section 41 along Yanchep Beach show a significant drop in elevation of the beach profile between April 2022 and October 2022. This site is located immediately south of Capricorn Groyne and is not within the field of view of formal manual imagery sites. The area was noted as having experienced major erosion while on site where considerable dune erosion had exposed a historical beach access staircase.

5.3.7.3 Two Rocks

Two Rocks cross section 1 is within the field of view of Two Rocks manual imagery site B07 and while there was minor erosion observed at the site with a notable reduction in beach width (Section 4), the

extent of erosion below the waterline was not captured.



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 coastline, these locations are presented below in Figure 6-1 and Figure 6-2. These 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 November 2021 and the beginning of October 2022.

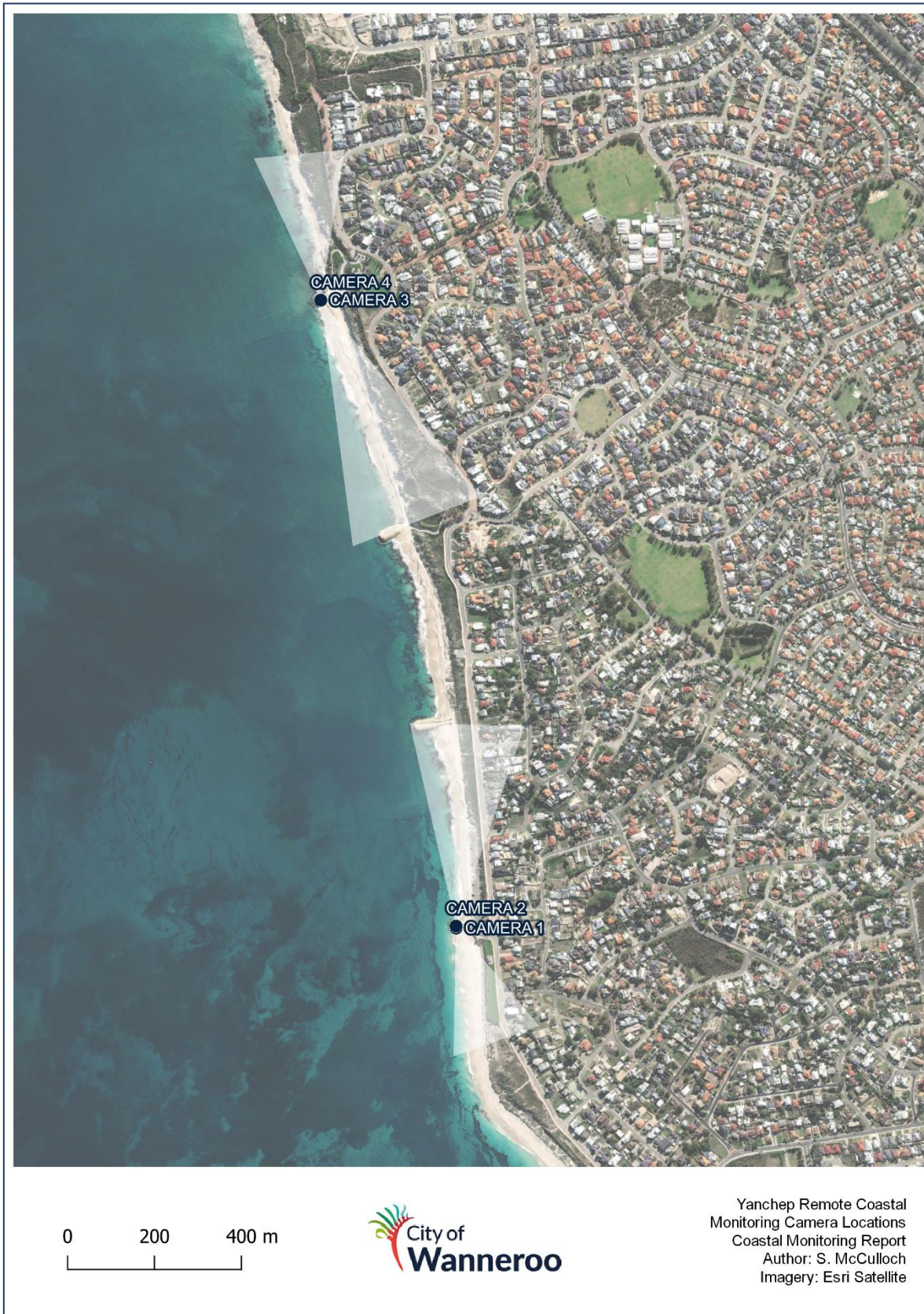


Figure 6-1

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 to the south of Groyne 1, adjacent to the GSC Revetment. The time series of images taken from Quinns Camera 1 between November 2021 and October 2022 show the beach accreting up until the beginning of March 2022. After March the beach begins to erode and continues to erode until the end of the dataset in August 2022. The August 3rd storm event impacted the condition of Camera 1 and there was no additional data captured following the storm event at this site. Significant seasonal erosion is experienced at this site each year and manual imagery monitoring suggests that following the early August storm event, there was minor accretion at the site between August and October.



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. Hourly images from the camera show the beach eroding significantly over November 2021 through to January at which point the beach begins accreting up until August 2022. While accretion at this site is expected during the winter period, accretion of the beach in the summer period is not expected, as prevailing southerly winds generally transport sand north where it is deposited to the south of the Groyne 2. However, it is believed that the significant build up to the south of Groyne 1 has resulted in bypassing of sand around the Groyne and onto the beach, adjacent to the carpark. Beach renourishment was also undertaken at this site in April 2022 which contributed to the accretion at the site.



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 early February where the beach then begins to erode. The most receded shoreline position was observed just after the August storm event, which resulted in significant dune erosion at the site and exposure of limestone bedrock on the beach. There was considerable erosion at this site prior to the August storm event which left the beach and dunes vulnerable to impacts of the storm. Throughout September until the end of the monitoring period the beach appears to be steadily accreting.

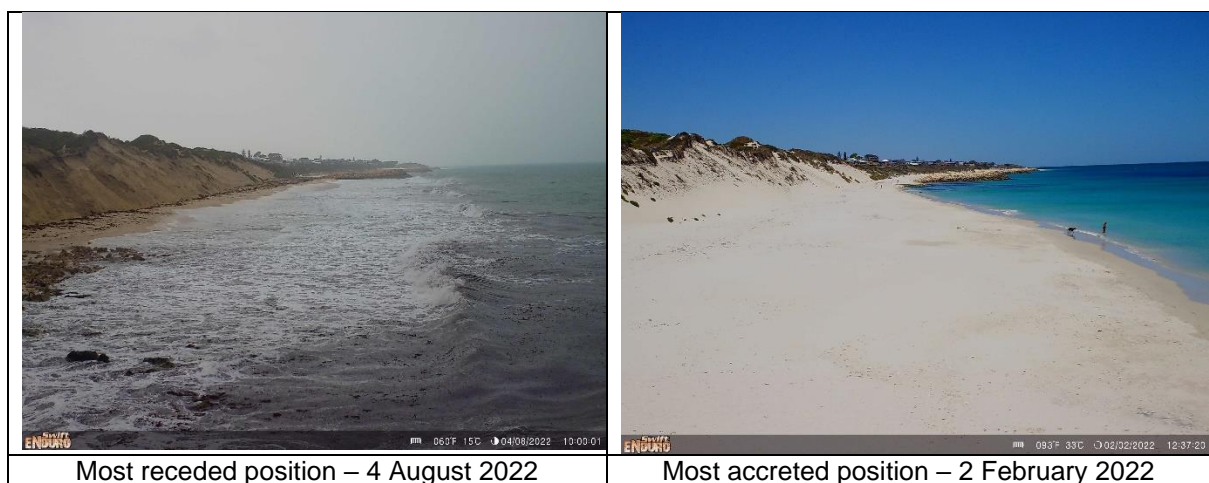


Figure 6-5 Most receded and most accreted shoreline position to the south of Quinns Groyne 4 during the study period.

6.4 Quinns Camera 4

From the beginning of the monitoring period in November 2021, the beach area to the north of Groyne 4 was eroding until the end of May 2022. Seasonal erosion over the summer period is expected in this area as prevailing southerly winds generally transport sand to the north, away from the Groyne. There

was notable accretion at the site following the winter period, particularly in September and October where considerable accretion was observed at the site.

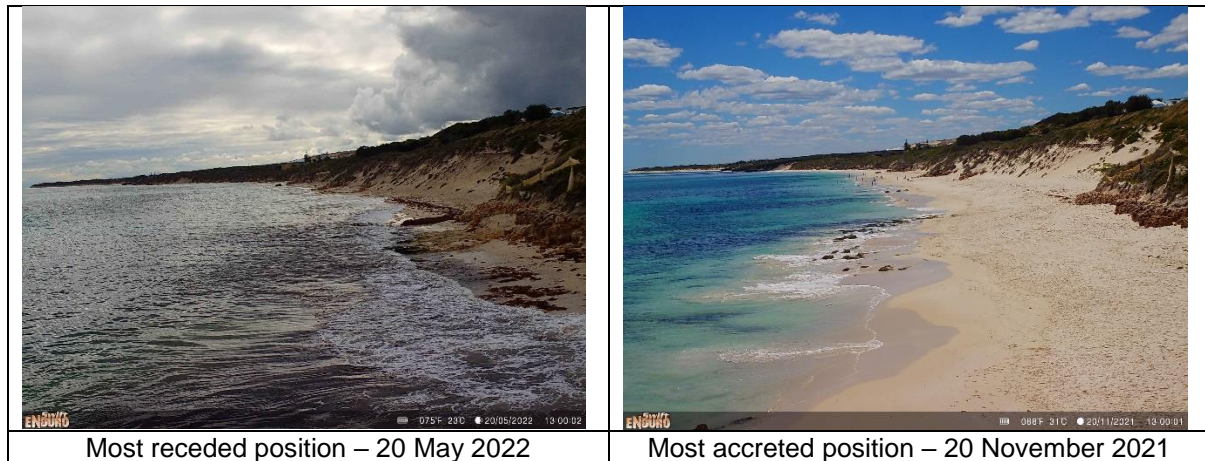


Figure 6-6 Most receded and most accreted shoreline position to the north of Quinns Groyne 4 during the study period.

6.5 Yanchep Camera

There was considerable erosion at Yanchep Lagoon during the summer period, which is expected in this area as longshore sediment transport, which is driven by the prevailing southerly winds, drives the sediment to the north. By the end of March, the beach began to steadily accrete, with a wide beach evident by early June 2022. This is likely to have resulted from sand moving northward from Fisherman's Hollow, bypassing the southern headland and feeding the beach adjacent to Yanchep Lagoon.

Following steady accretion in summer there was significant erosion of the beach in June and July which resulted in a narrow beach with a steep beach slope in August 2022 (Figure 6-7). In response, the City undertook reactive beach renourishment at the site in September 2022 to create a safe and accessible beach at Yanchep Lagoon prior to the 2022/23 summer period.



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

7 Aerial Imagery

Aerial imagery obtained from Nearmap and taken during the 6 monthly LiDAR Surveys is used to assess changes of 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. However, analysis of aerial imagery is limited to assessing the changes to the coastline, which in this instance, is defined as the coastal vegetation line.

During the study period, from October 2021 to October 2022, a total of ten aerial images of the sites were available.

Table 7-1 *Date of Aerial Images*

Monitoring Date	Monitoring Time	Source	Water Level at Time of Monitoring (Fremantle Tide Gauge – mAHD)
22 October 2021	09:59 AM to 12:27 PM	MNG	-0.07 to 0.07 mAHD
14 November 2021	8:16 AM	Nearmap	0.04 mAHD
19 December 2021	3:00 PM	Nearmap	0.06 mAHD
2 January 2022	8:43 AM	Nearmap	-0.28 mAHD
29 January 2022	8:51 AM	Nearmap	-0.13 mAHD
4 April 2022	12:29 PM to 4:01 PM	MNG	0.12 to 0.47 mAHD
15 April 2022	9:53 AM	Nearmap	0.17 mAHD
28 May 2022	Unknown	Nearmap	-0.05 to 0.64 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

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 depicted in Table 7-2. The most advanced and most receded shoreline position was identified for each discrete area. For the purposes of this analysis the shoreline has been classified as the vegetation line.

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	22 October 2021	15 April 2022
Quinns Main Beach	28 May 2022	13 November 2021
Quinns – GSC Revetment	01 October 2022	15 April 2022
Quinns – Groyne 1 to Groyne 2	29 January 2022	22 October 2021
Quinns – Groyne 2 to Groyne 3	28 May 2022	13 November 2021
Quinns – Groyne 3 to Groyne 4	28 May 2022	13 November 2021
Jindalee	28 May 2022	13 November 2021
Eden Beach	28 May 2022	13 November 2021
Shorehaven	15 April 2022	13 November 2021
Eglinton Beach	01 October 2022	14 November 2021
South Yanchep	01 October 2022	15 April 2022
North Yanchep	28 May 2022	14 November 2021
South of Two Rocks Marina	01 October 2022	10 April 2022
North of Two Rocks Marina	28 May 2022	2 January 2022

The most receded shoreline position was observed in May 2022 at a number of sites which is likely due to significant erosion caused by the 24 May storm event. Conversely, the most advanced shoreline position was observed in November and October 2021 aerial imagery at a number of sites which indicates a significant build-up of sediment along the coastline over the winter 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 of 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. However, what is most appropriate for some areas will not necessarily be most appropriate for other areas of the coast and it is important to understand that these results simply allow us to assess whether the volume changes calculated are accurate or are an underestimation of the actual seasonal volume changes.

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. **Fisherman's Hollow Beach:** Fisherman's Hollow Beach, south of Yanchep Lagoon, experienced major erosion between April 2022 and October 2022, below the waterline a maximum elevation difference of 2.04m was recorded at cross section 21. 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.
2. **Quinns Beach North of Groyne 1:** Manual imagery results show significant erosion of the beach area to the north of Quinns Groyne 1, adjacent to the Frederick Stubbs Carpark, over the 2021/22 summer period. Significant erosion in this area over the summer period is common with planned renourishment occurring at this site each year to improve beach accessibility and protect coastal infrastructure. While manual imagery results show significant erosion at the site, survey cross sections only show a reduction in elevation of 0.93 just landward of the waterline.
3. **Quinns Beach GSC Revetment South of Groyne 1:** A major reduction in beach width over winter 2022 was noted in the manual imagery review of the beach immediately south of Quinns Groyne 1. There was very little remaining beach in October 2022 and there was wave impact to the GSC revetment over winter causing some damage to the structure. Similar to the beach in front of Frederick Stubbs Carpark, this is an area that is known to experience significant erosion annually and has caused major maintenance issues in the past. The GSC Revetment was constructed in 2014 and despite the minor damage sustained from the 2021 and 2022 storm events, the structure works effectively in protecting adjacent coastal infrastructure.
4. **Clayton's Beach, Mindarie:** Claytons Beach in Mindarie is bound by the Mindarie Breakwater to the north which interrupts longshore transport along the beach leading to significant seasonal erosion over the winter months. While seasonal erosion is expected at this site, the extent of erosion has been considerably greater in winter 2021 and 2022 than in previously recorded years. The estimated net beach volume change over winter 2022 for this site was 89,048 m³ and manual imagery and survey results show significant impact to the dune condition.

8.2 Annual Change

Changes in beach volumes between October 2021 and October 2022 were assessed via LiDAR survey elevation difference plots, volume change calculations and cross section transect comparisons undertaken by MNG. Overall, volume change calculations show an increase in beach volume across the coastline between October 2021 and October 2022. The most notable areas of beach volume gain are within Yanchep where the total estimated net beach volume increase across the area was 67,655m³. While it is important to note that this volume is inclusive of 1,750 m³ of renourishment that was undertaken in September 2022, this increase is significant and particularly following the significant net loss of beach volume experienced across 2021.

Survey cross section results outline additional areas that experienced significant erosion between October 2022 and October 2021. The survey results from Quinns Dog Beach to the south of Groyne 4 show a 3m recession of the dune toe between the October 2021 and the October 2022 surveys. This was not identified in the manual imagery (site Quinns B14 Down-Coast) as the dune face is not the main focus of the image and recession in the dune face is difficult to interpret using manual imagery alone. 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 2022 images were compared to images taken at the same location at the same time of the year but were taken as late as 2014, allowing for an assessment of long-term changes of the coastline from up to seven 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 four years prior. This will be investigated further as part of the Yanchep Coastal Management Study which is scheduled to commence in 2023/24.

One site in Quinns Rocks was identified through manual imagery as having experienced major long-term erosion. The site is situated immediately north of Quinns Groyne 3 along Quinns Dog Beach. Despite the significant nourishment that has been undertaken at the site (~80,000 m³) since 2004, a significantly narrow beach is evident in the image taken in April 2022 with notable impact to the base of the dunes.

No other areas were found to have experienced major erosion over the long-term period. Of all 51 manual imagery sites, 31 sites appeared to experience minor erosion, 8 appeared to experience accretion and the beach condition in the 12 remaining areas appeared to remain largely unchanged.

8.4 Notable Erosion Events

A number of notable erosion events occurred during the study period between May and August 2022 which resulted in damage to coastal infrastructure. The most notable of which was the storm that occurred on the 3rd of August 2022 which resulted in significant erosion at Clayton's Beach, Quinns Dog Beach, Amberton and Yanchep Beach and also impacted a number of coastal infrastructure assets with damage to the Mindarie Breakwater, Frederick Stubbs GSC Revetment, Jindalee Staircase, Amberton Beach Access Ramp and Staircase. Most areas that experienced significant erosion in August 2022 had an already receded shoreline which was exacerbated by the August storm event.

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
April 2022	Quinns Beach, adjacent to Frederick Stubbs Carpark	4,000 tonnes
April 2022	Quinns Beach, north of Groyne 3	4,000 tonnes
September 2022	Yanchep Lagoon	2,693 tonnes

8.6 Recommendations

8.6.1 Additional Survey Analysis

Long-term coastline changes are currently assessed via manual imagery alone. As LiDAR surveys have been undertaken since October 2018 it is recommended that beach volume change calculations are developed to assess longer-term beach volume changes once sufficient historical data is captured. This will allow for a quantitative assessment of long-term changes of the coastline which will help to inform future long term coastal management strategies.

8.6.2 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 problem areas. It is recommended that suitable computational capacity be acquired by the City so that automatic shoreline tracking can be undertaken to analyse the hourly data. 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.

8.6.3 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, particularly Yanchep Lagoon, is one of the most popular beaches within the City and is subject to both seasonal and annual erosion. Sections of the Yanchep Coastline have also been identified as vulnerable coastal locations from the City's Coastal Hazard Risk Management and Adaptation Plan (CHRMAP). Additionally, Fisherman's Hollow Beach, just south of Yanchep Lagoon, experienced major erosion over the winter 2022 period and while the dunes appear to be in good condition, residential houses and road infrastructure are in close proximity to the site and could, in future, be susceptible to the effects of coastal erosion.

8.6.4 Continued Beach Renourishment

It is recommended that beach renourishment continues to be undertaken in vulnerable areas to minimise the effects of erosion on coastal infrastructure. It is recommended that the results from this report be utilised to identify areas that require ongoing scheduled renourishment works.