2024 Update of the Sand Volume Analysis at West Beach

Report
Project No 43804540

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The expert in **WATER ENVIRONMENTS**

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Prepared for: Department for Environment and Water
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Executive Summary

Since 2018, DHI has been completing estimates of the sand volume for the West Beach sediment cell. This report extends the previous analysis up to 2024, with some improvements in how the profile analyses were conducted compared to earlier reports.

The analysis is conducted using beach profiling data as well as data collected using LIDAR DEM. The analysis now considers 11 profile locations, as compared to 5 profile locations used historically.

The analysis indicates an accumulation of approximately 91,000 m3 from 2023 – 2024 from the profile data. Analysis of the LIDAR DEM gives a similar estimate.

1 Introduction

In August 2018, DHI delivered a comprehensive study for the Department of Environment and Water (DEW) on shoreline recession at West Beach, specifically focusing on Sediment Cell 3, which extends from the West Beach Boat Ramp to the Torrens Outlet (TO). The study utilized nourishment volumes, bathymetry surveys, and cross-shore coastal profiles to describe the evolution of sand volumes within the cell. However, the large intervals between cross-shore profiles made sand volume estimations less accurate, although they did cover extensive areas into deep water, far from the shoreline.

Recognizing the limitations inherent in methodologies based solely on cross-shore coastal profiles, DEW initiated the capture of LIDAR digital elevation models (DEMs) along West Beach. The objective was to provide a secondary volumetric analysis with higher spatial resolution, particularly focusing on the upper part of the beach profile. This approach aimed to better track sand accumulation at the northern extremity of the cell, near the Torrens Outlet, where coastal profiles alone could not provide precise estimates. The high-resolution DEMs proved highly beneficial in understanding and estimating sand evolution in this complex area.

However, DEMs are not accurate enough for wet areas and are primarily applicable to areas near the shoreline and inland. Therefore, both methodologies have advantages and limitations and are seen as complementary in understanding the evolution of sand volumes in the sediment cell.

In this report, we use both methods to determine sand volume changes to provide additional support for management of this important environmental and community resource.

2 Scope and Methodology

The methodologies for analysing both datasets are detailed in this section. The study includes two main activities:

2.1 Activity 1: Analysis of Beach Profiling Data

The first activity involves the regular surveying of Adelaide beaches maintained by DEW in the form of beach profiling to get the total sand volume at the beginning of different years in Cell 3 (West Beach area). To maintain consistency with previous analyses, the profiles captured during Summer 2024 were processed using the same methodology as the one applied during the main coastal processes study from 2018 and subsequent updates.

Several key updates were made in how the profile analyses were conducted compared to earlier reports:

Interpolation of Missing Data: For each profile, any missing year data is now interpolated from available data within that same profile. In previous studies, missing data for one profile was interpolated using data from other profiles in the same year. The old method was less accurate because sand volume variations between profiles are not linear, whereas the variation within a single profile over time is more linear and therefore better suited for interpolation. For example, West Beach Road, which contains much less sand, is located between Rec Reserve and Surf Road, both of which contain significantly more sand. Interpolating West Beach Road's data from these two profiles would unrealistically increase its sand volume.

Adjustment of Start Points: In previous studies, the start points of profiles were positioned within urban areas rather than on the beach, leading to the inclusion of large volumes from structures rather than sand. Additionally, the start points for the same profile were not always consistent across different years. For example, Figure 2-1 shows that the profile at West Beach Road in 2023 is 52 meters longer than in 2024, resulting in an incorrectly larger sand volume for 2023. In this new analysis, the start points have been adjusted using Google Earth images to more accurately reflect the sand and beach areas. Additionally, extra checks were conducted to ensure that all profiles in a cross-section cover the same length across different years.

Changes in Distance and Elevation Criteria: The previous studies set a maximum distance of 3500 meters from the start point and a minimum sand elevation of -5 meters. In the current study, the maximum distance from the adjusted start point is reduced to 500 meters.

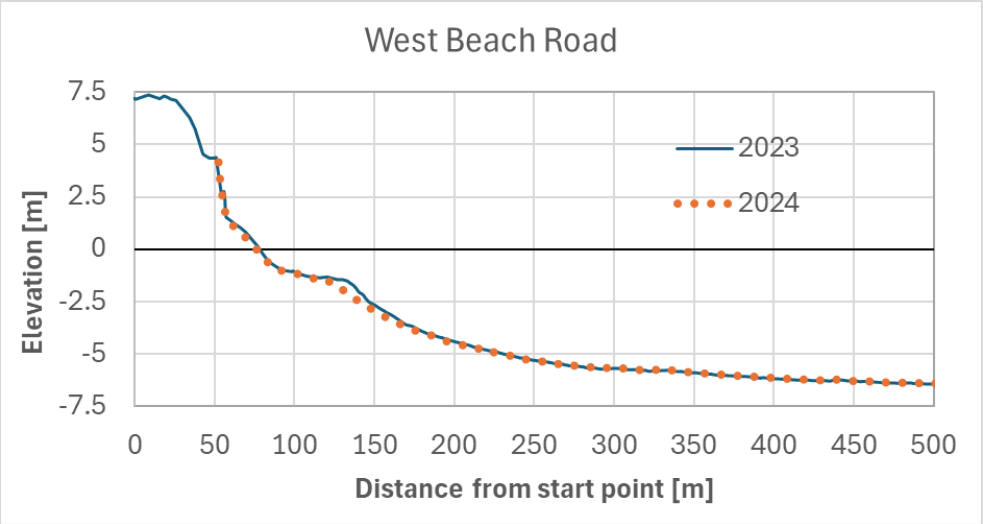


Figure 2-1 Comparison of cross-shore profiles at West Beach Road for the years 2023 and 2024.

The analysis thus consists of the following steps:

1. **Review and Quality Check**: The newly surveyed profiles were reviewed and cleaned where necessary to ensure data quality.
2. **Volume Integration**: The volume of sand per metre was integrated from the back of the dune system up to 500m away from the starting point, or -5m depth, which ever was reached first. Profiles that do not cover a 500 m survey length, do not extend below -5 m AHD, or do not extend above 0 m were excluded from the analysis.
3. **Temporal Interpolation**: To reconcile the different timing of all the surveys throughout the years, the volumes at each profile are interpolated in time to provide an estimated volume on January 1st for each year.
4. **Littoral Volume Calculation**: The total littoral volume is calculated by trapezoidal integration per metre between each surveyed profile.
5. **Profile Sets Analysis**: The study was conducted using two sets of profiles:

- **5 Profiles**: Profiles 3, and 8-11 (as shown in Table 3-1 and Figure 3-1) to maintain consistency with previous studies.
- **11 Profiles**: Profiles 1-11 to enhance the accuracy of sand volume approximations.

The 11 profile set is the preferred approach and is reported herein, however the 5 profile set is reported in a later section for comparison with previous studies.

2.2 Activity 2: Analysis of DEM Surveys

The second activity involves the use of DEM surveys commissioned by DEW to monitor and assess morphological beach change and subsequent volumetric change. The methodology to establish an overall (terrestrial) volume for Cell 3 is as follows:

1. **DEM Review and Cleaning**: The DEM data was reviewed and cleaned to remove any spurious data points.
2. **Data Interpolation**: The data from the years 2022 and 2023 was interpolated into the geometry of 2024.
3. **Elevation Difference Calculation**: The elevation difference from one DEM to another was computed for the entire domain.
4. **Sand Volume Integration**: The sand volume evolution within the assessed area was evaluated by integrating within a defined common polygon (tentatively indicated in yellow in Figure 3-1). This polygon defines the area over which the sand volume change was assessed.

3 Results

3.1 DEW cross-shore profiles

3.1.1 Data analyses

There are 11 cross-shore profile surveys covering Cell 3, extending from Holiday Park in the south to Mellor St in the north (Figure 3-1).

Figure 3-1 Locations and directions of cross-shore profiles surveyed for the West Beach zone (Cell 3).

In previous studies on West Beach, five profiles, surveyed along the orange lines shown in Figure 3-1, were used. In this report, six additional profiles,

shown in cyan in the same figure, are also included, encompassing all years from 1994. The information for these profiles is presented in Table 3-1.

Table 3-1 West Beach cross-shore profiles.

#	File name	Profile name	E [m] MGA54	N [m] MGA54	Direction [deg]	Start [m]
1	200096.DA	Holiday Park	272237.9	6129110.2	247.52	0
2	200093.DA		272230.1	6129231.6	247.52	19
3	200021.DA	Rec Reserve	272174.6	6129407.8	246.19	22
4	200085.DA		272076.7	6129563.9	247.52	10
5	200082.DA		272019.5	6129656.7	247.52	0
6	200078.DA		271952.9	6129765.0	247.52	21
7	200076.DA		271911.1	6129832.7	247.52	23
8	200020.DA	West Beach Rd	271857.2	6130073.9	251.31	54
9	200072.DA	Surf St	271666.7	6130674.2	253.34	23
10	200071.DA	BurBridge Rd	271613.6	6130930.8	250.14	44
11	200019.DA	Mellor St	271620.9	6131207.9	253.38	122

To provide an overview of the long-term variations in beach profiles from 2000 to 2024, all 11 cross-sections are visualized here. Each profile's starting point (where the cross-shore distance is zero) corresponds to the Easting-Northing coordinates provided in the survey files. For example, the start point for Burbridge Rd is (271613.613, 6130930.830). These coordinates and the profile directions are displayed in Figure 3-2.

Since most starting points of the transects fall outside the beach area, we begin the calculations at the back of the dune, where long-term variations are minimal. For instance, red pins in Figure 3-1 represent the start points of the profiles, however the green pins show the starting points of the calculations. The values used for this adjustment are detailed in the 'start' column in Table 3-1.

Figure 3-2 Cross-shore profiles locations and directions used for West Beach (Cell 3) sand volume study.

The profiles are depicted in Figure 3-3 to Figure 3-6. In each frame, cyan lines represent the profiles from 2000 to 2024, while the red lines indicate the average profile over this period. The number of valid profiles used to calculate the average is also noted in the title of each frame.

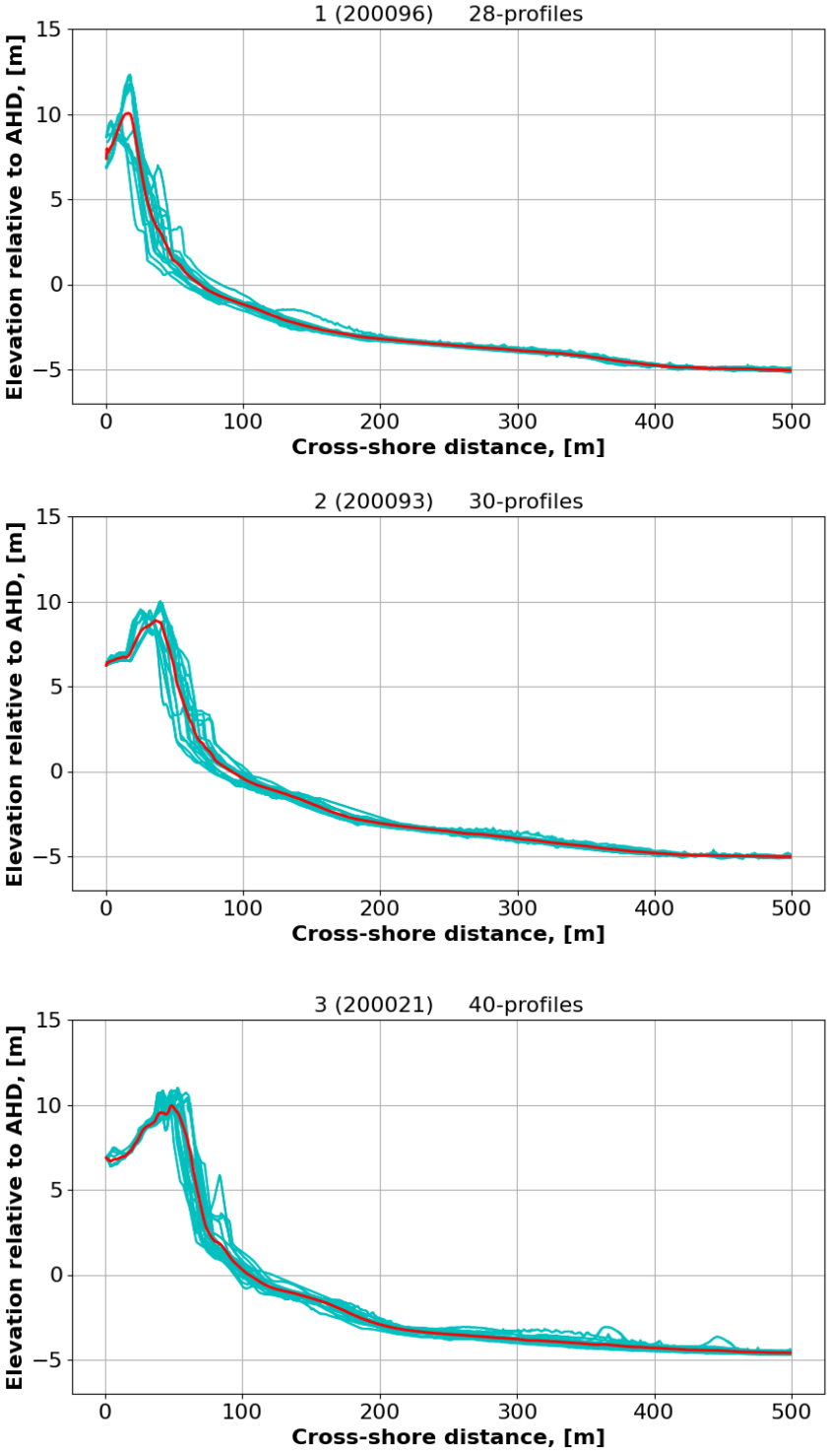
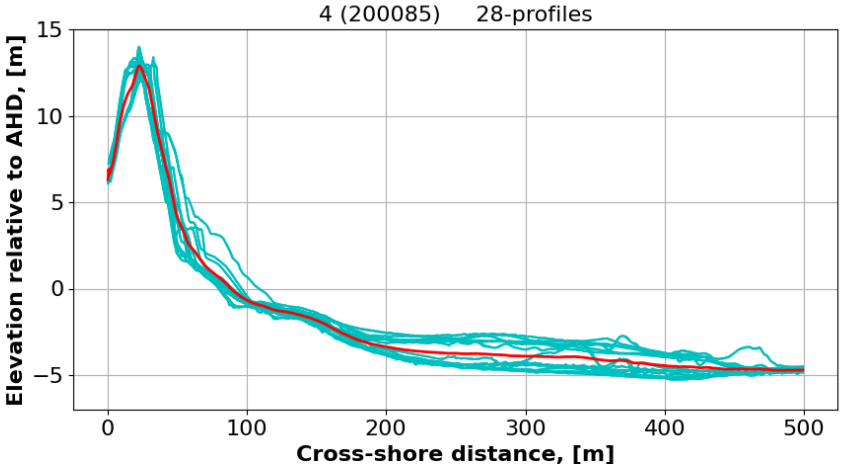
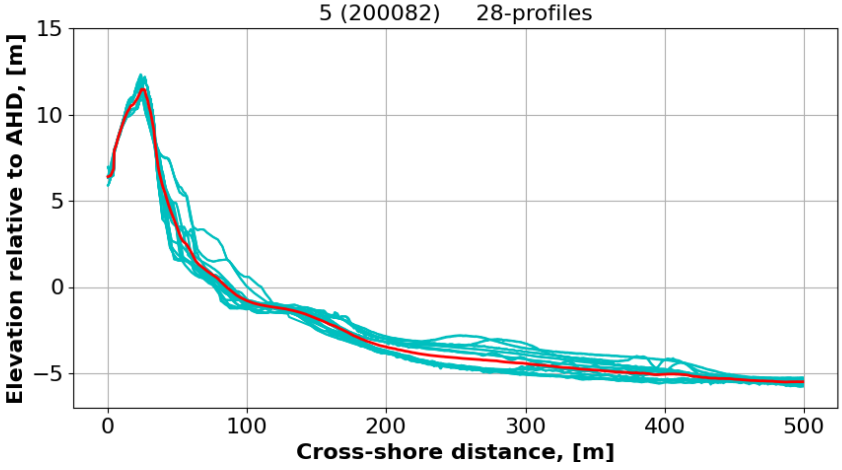


Figure 3-3 Cross-shore profiles for years 2000 to 2024 (cyan lines) and their mean values over years (red line).





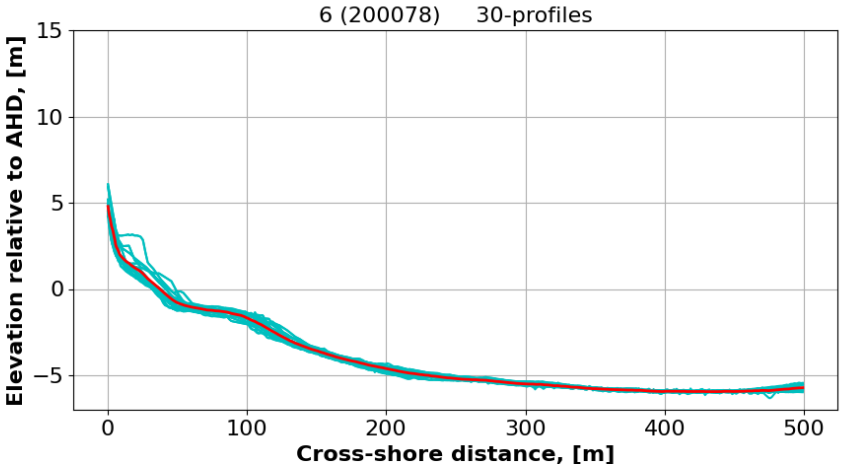
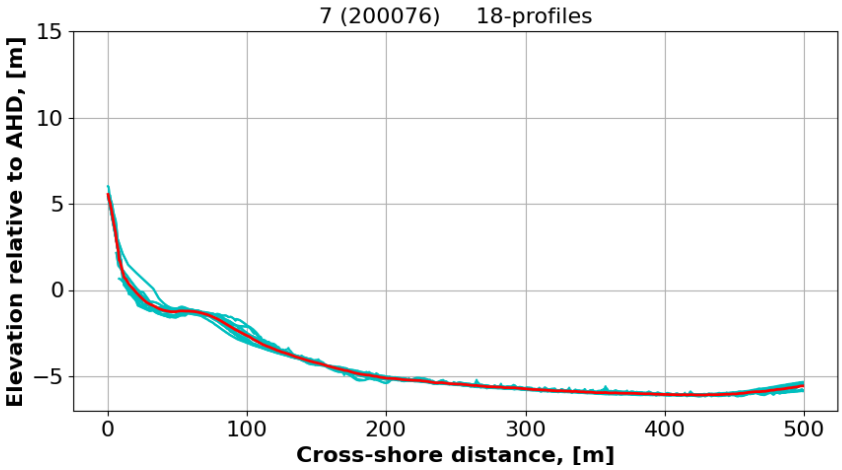
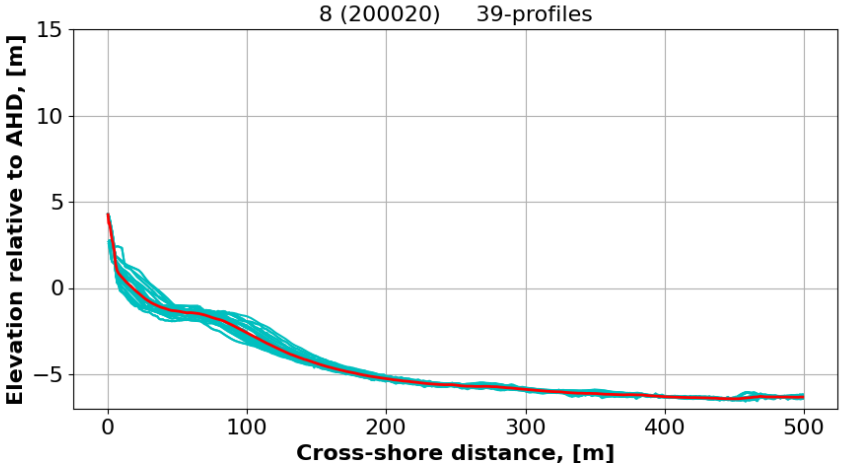


Figure 3-4 Continued.





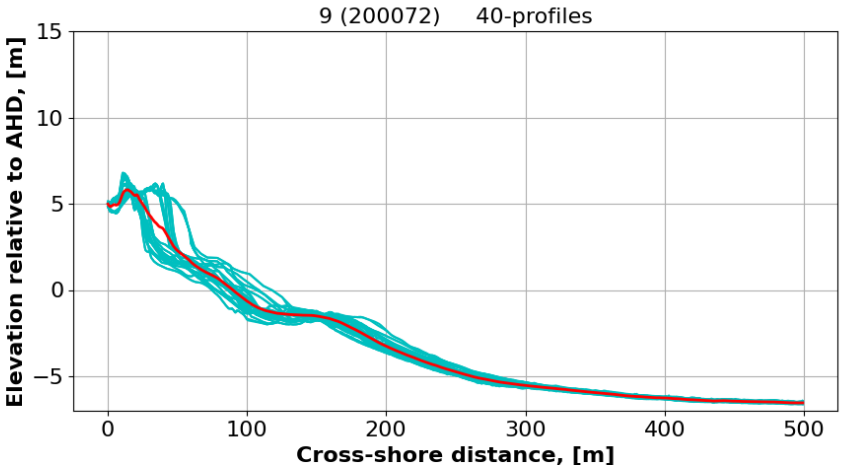


Figure 3-5 Continued.

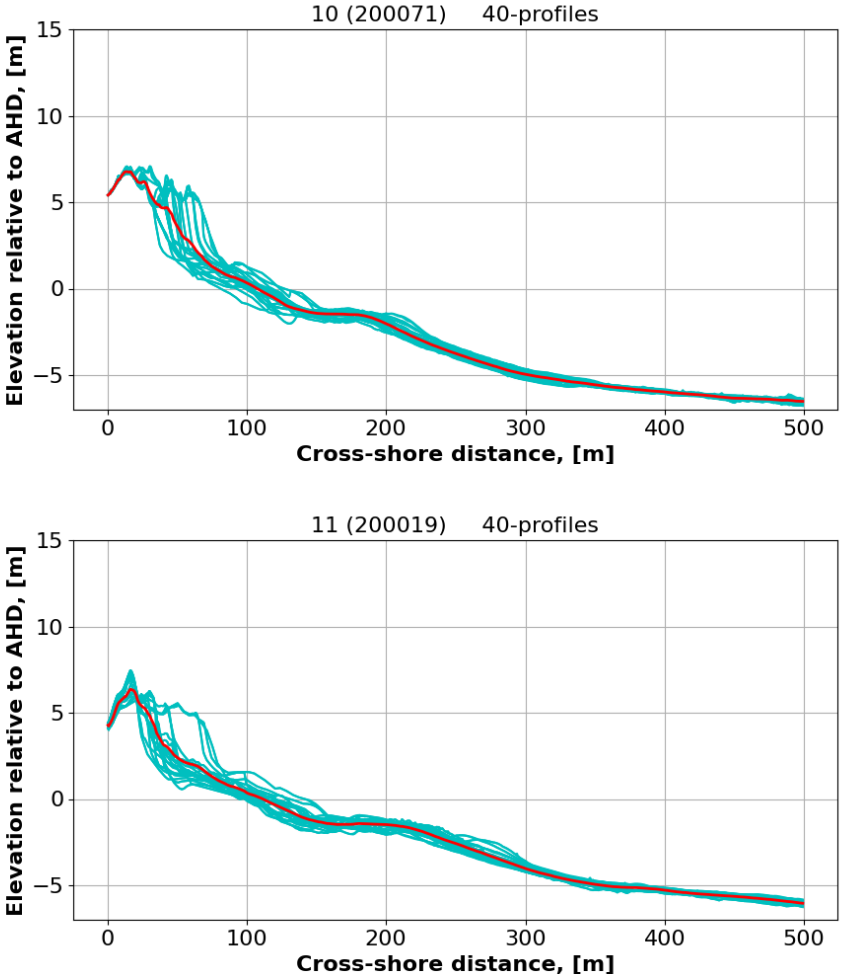


Figure 3-6 Continued.

In this study, only profiles with a length greater than 500 meters were considered for sand volume evaluations. Consequently, some older profiles were excluded. For most profiles, the seabed elevation beyond 400 meters shows minimal variation, with the slope approaching zero.

The average profiles for each cross-shore survey over the 24-year period (depicted as red profiles in Figure 3-3 - Figure 3-6) are presented together in Figure 3-7. These profiles provide reliable information on average beach slopes, which will be valuable for future studies.

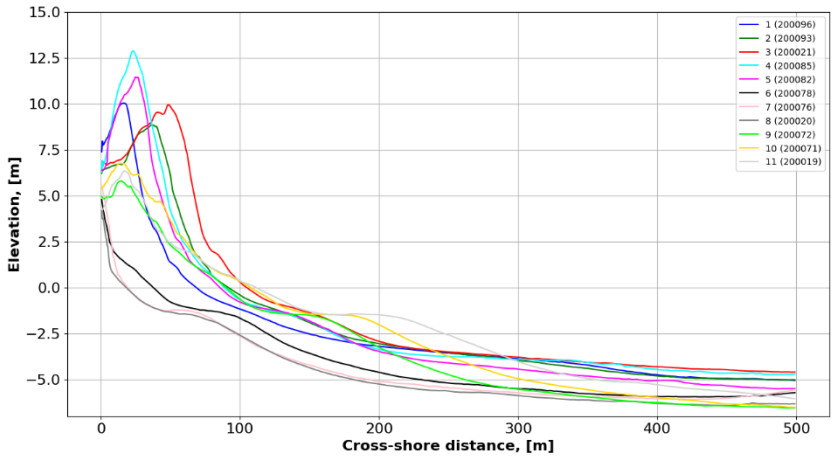


Figure 3-7 Different cross-shore profiles averaged over 25 years (2000 to 2024).

3.1.2 Beach volumes

Figure 3-8 displays the beach volume per metre along the shore for various profiles across different years. The same data is presented relative to 2005 in Figure 3-9.

The increase in volume observed in profiles 4 & 5 (200085 and 200082) from approximately 2002 to present is likely the result of sand placement from West Beach harbour that is pumped to the designated nearshore placement area and which these profiles cross.

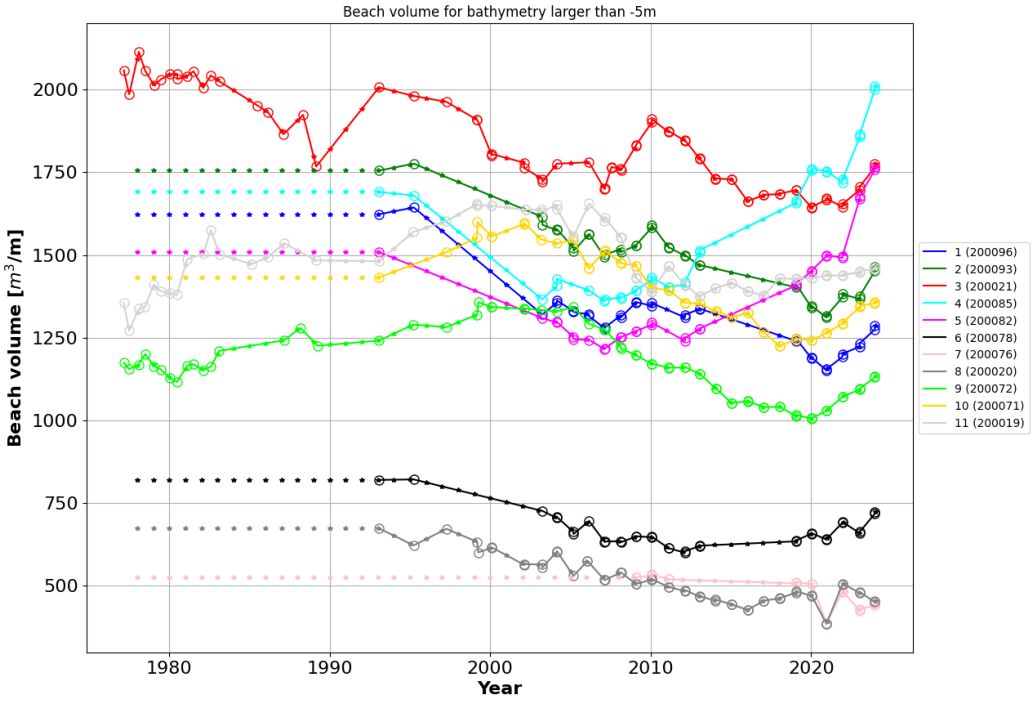


Figure 3-8 **Beach volume per metre alongshore for different profiles over different years. Circles are dates with available data and asterisks are interpolated values. Threshold of -5m AHD were used for sand volume estimation.**

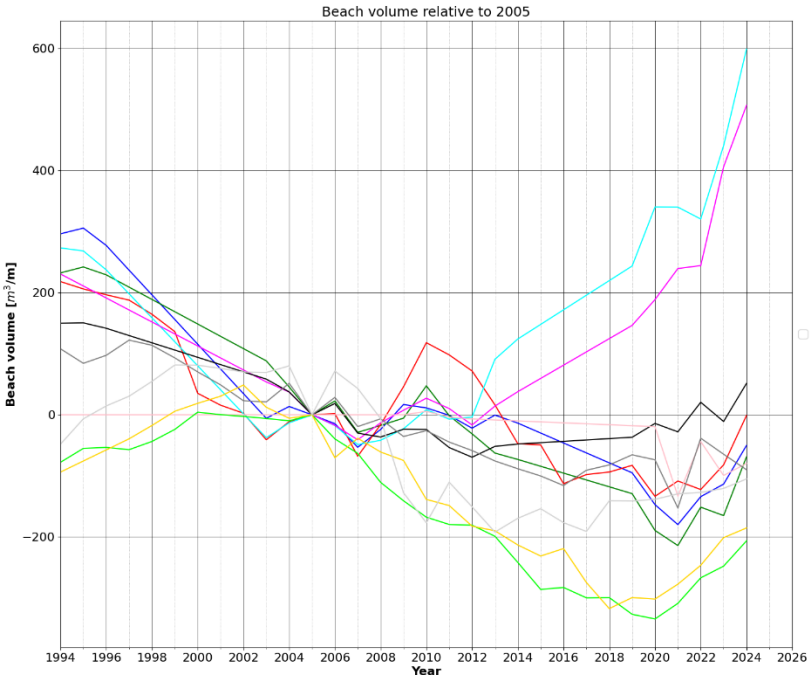


Figure 3-9 **Beach volume per metre alongshore for different profiles over different years relative to the ones of year 2005.**

3.1.3 Total sand volumes in Cell 3

To estimate the total sand volumes, we integrate the beach volumes across all 11 profiles from 1994 to 2024 (Figure 3-12). This shows a gradual decline in total volume to 2020, followed by an uptick in recent years. This trend is shown more clearly when considered relative to 2005 (Figure 3-13). Total sand volume is shown in Table 3-2 with annual accretion / erosion shown in Table 3-3 for the last 7 years.

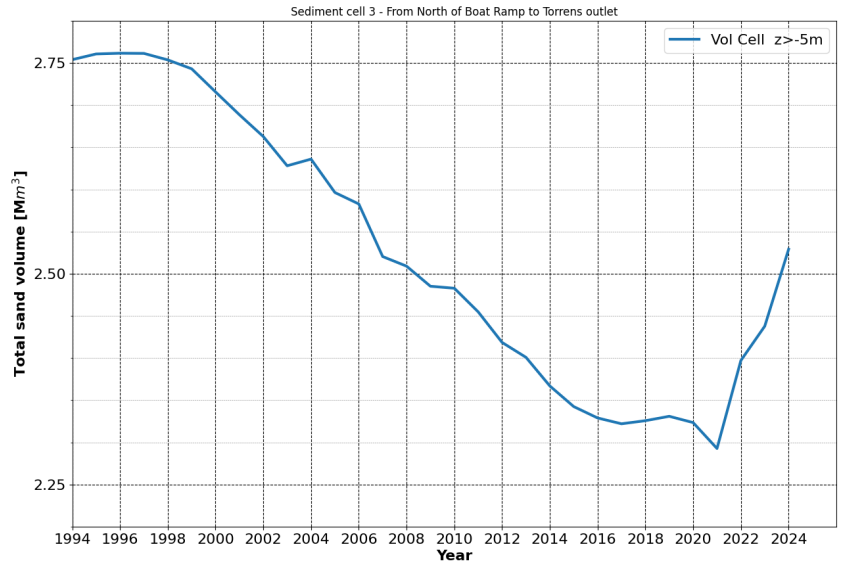


Figure 3-10 Total sand volume in Cell 3 (West Beach).

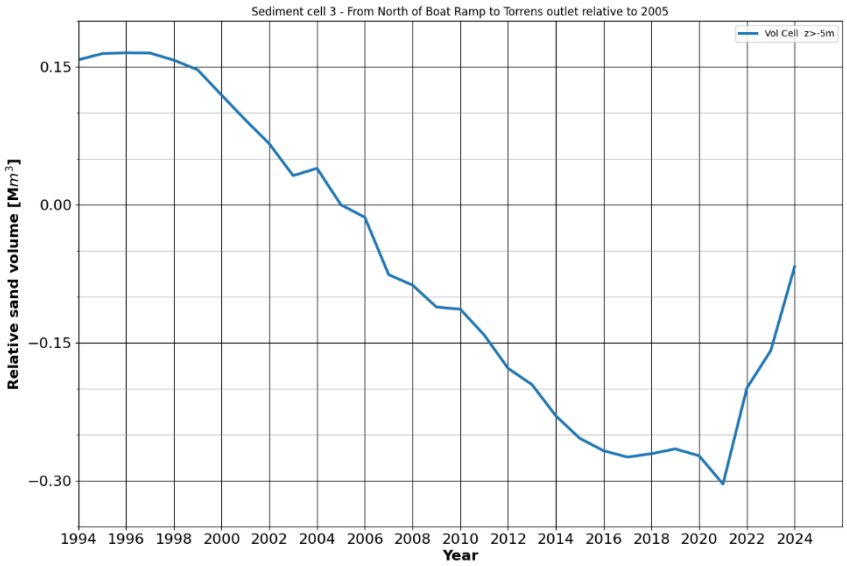


Figure 3-11 Total sand volume in Cell 3 (West Beach) relative to 2005.

Table 3-2 Total sand volume at Cell 3 in million m^3.

Year	Total sand volume
2018	2.3258
2019	2.3310
2020	2.3235
2021	2.2928
2022	2.3972
2023	2.4379
2024	2.5292

Table 3-3 The total annual sand accretion/erosion in Cell 3 in thousand m^3.

Year	Accretion / erosion
2018	3.7
2019	5.2
2020	-7.4
2021	-30.7
2022	104.4
2023	40.7
2024	91.3

3.2 Drone captured LIDAR DEMs

The three TIFF files processed are derived from drone-captured LIDAR DEMs provided by DEW, corresponding to surveys conducted in January 2022, March 2023, and March 2024.

Figure 3-20 to Figure 3-22 display the land surface elevations for these DEMs. It is important to note that the 2022 and 2023 DEMs were provided as continuous surfaces, likely interpolated from scattered data points, while the 2024 DEM exhibits scattered points with some gaps.

To ensure a fair comparison between the DEMs from different years, several methods were tested, including interpolating the 2024 DEM to match the 2023 DEM. However, these approaches did not yield satisfactory results.

Consequently, the focus shifted to identifying the common areas between the 2024 DEM and the other two DEMs. Only these overlapping pixels were used for sand volume analysis, leading to the creation of 'Clipped DEMs'. Table 3-4 provides the minimum and maximum elevations for the original DEM files, after clipping to the 2024 DEM, and further clipping to the yellow polygon outlined in Figure 3-20 which encompasses the area covered by the cross-shore profiles.

Table 3-4 The minimum and maximum elevations of DEM files.

	Original DEMs		DEMs mapped to 2024		Inside polygon		Pixel size [m]
Year	min [m]	max [m]	min [m]	max [m]	min [m]	max [m]	
2022	-1.8	22.0	-1.8	15.8	-1.58	14.12	0.2
2023	-7.1	56.3	-5.2	53.5	-1.66	14.37	0.25
2024	-1.4	16.8	-1.4	16.8	-1.16	14.56	0.25

The table indicates that although there are significant differences in the extreme elevations between the 2023 DEM and those from the other two years, the elevation values within the area of interest - defined by the yellow polygon in the following figures - are relatively consistent.

To compare the 2024 DEM with the 2022 and 2023 DEMs, 2022 and 2023 data were adjusted to align with the 2024 data. Next, locations where both images have data were identified and the differences in these non-empty areas were calculated. Figure 3-23 to Figure 3-25 illustrate these differences, revealing a significant sediment accumulation in front of the Torrens Outlet by the time of the 2024 survey.

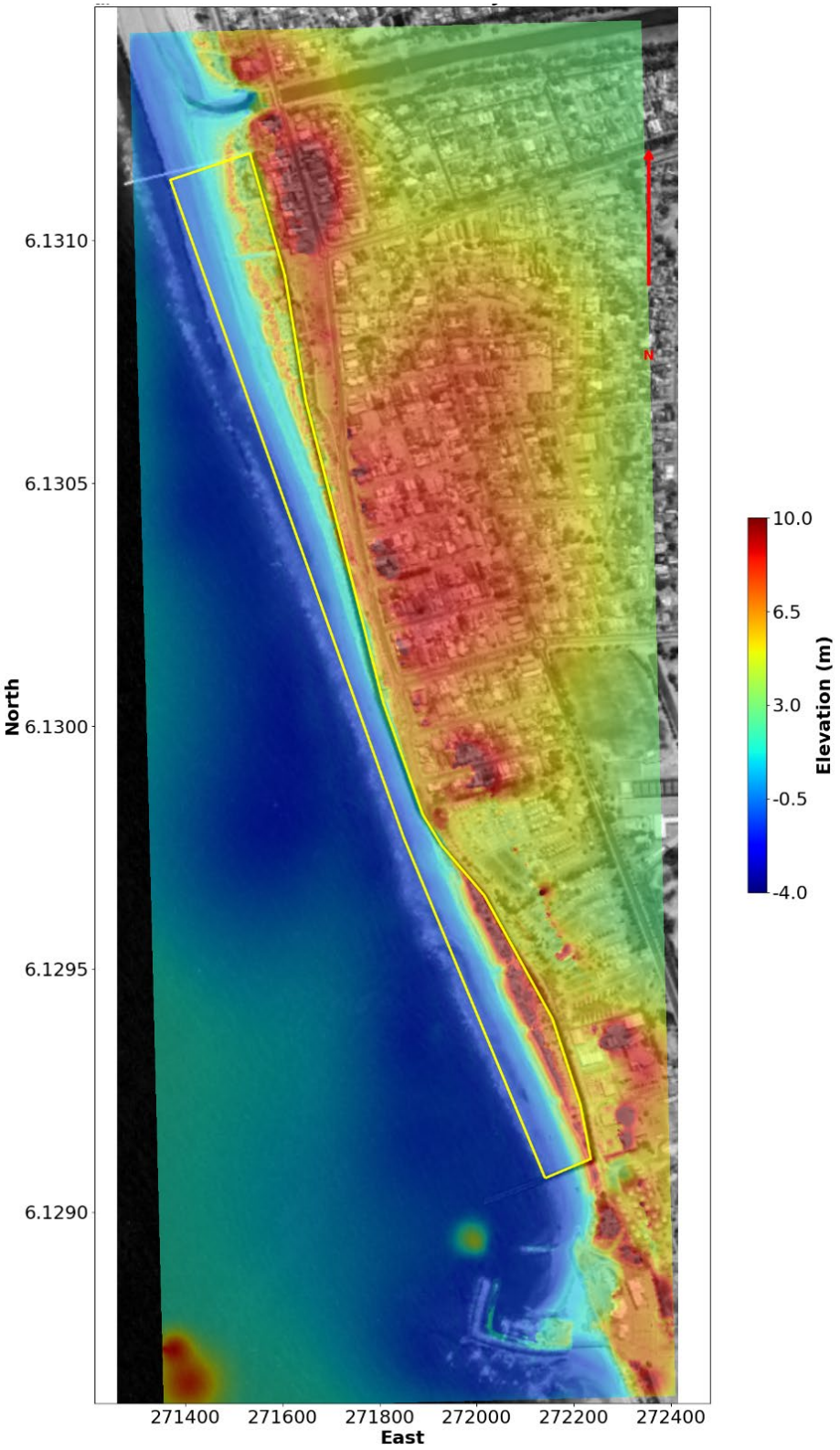


Figure 3-12 LIDAR DEM showing West Beach for January 2022. The background shows satellite image from Google Earth for closest date, 7 Dec 2021.

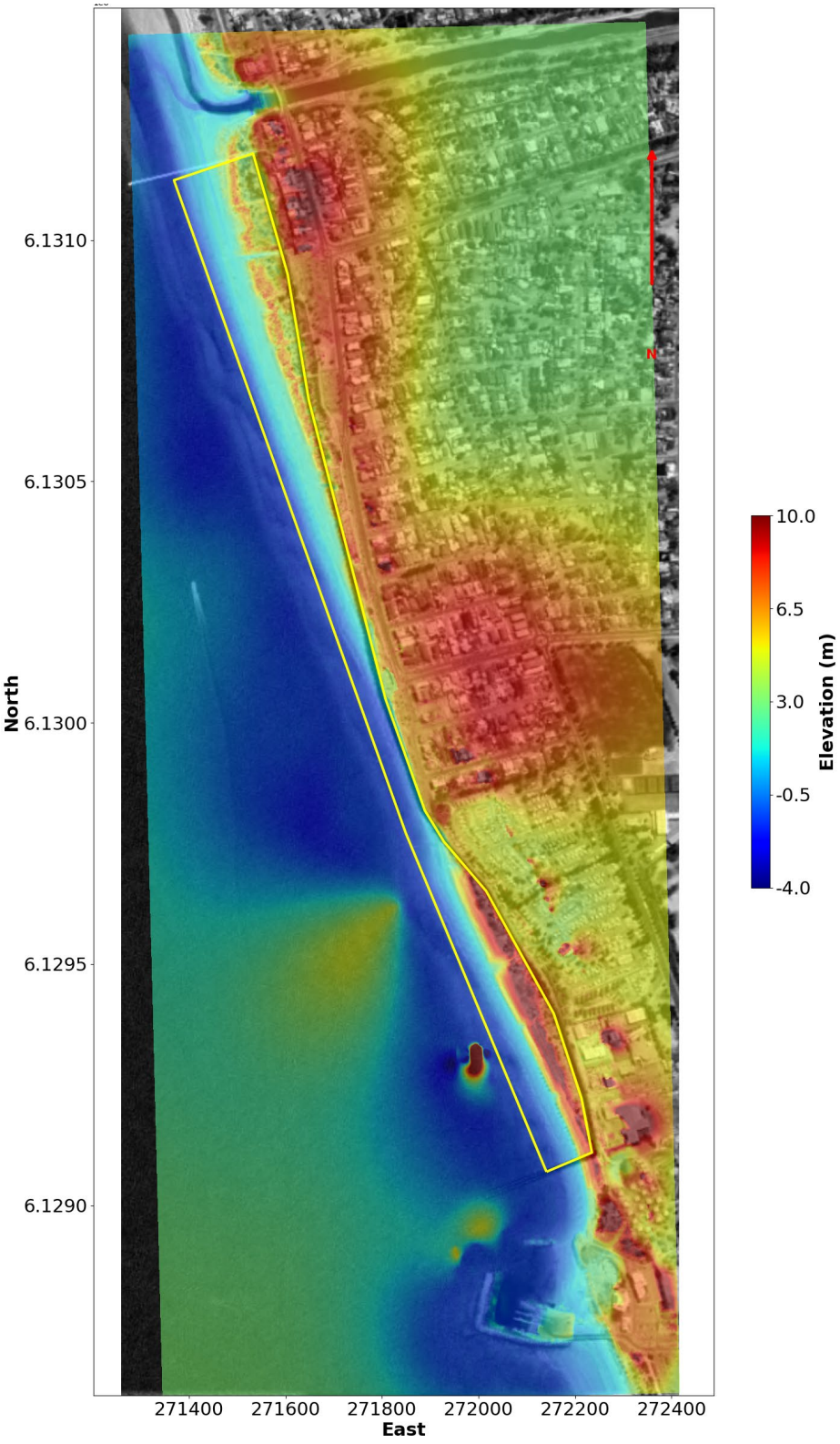


Figure 3-13 LIDAR DEM showing West Beach for March 2023. The background shows satellite image from Google Earth for closest date, 30 Dec 2022.

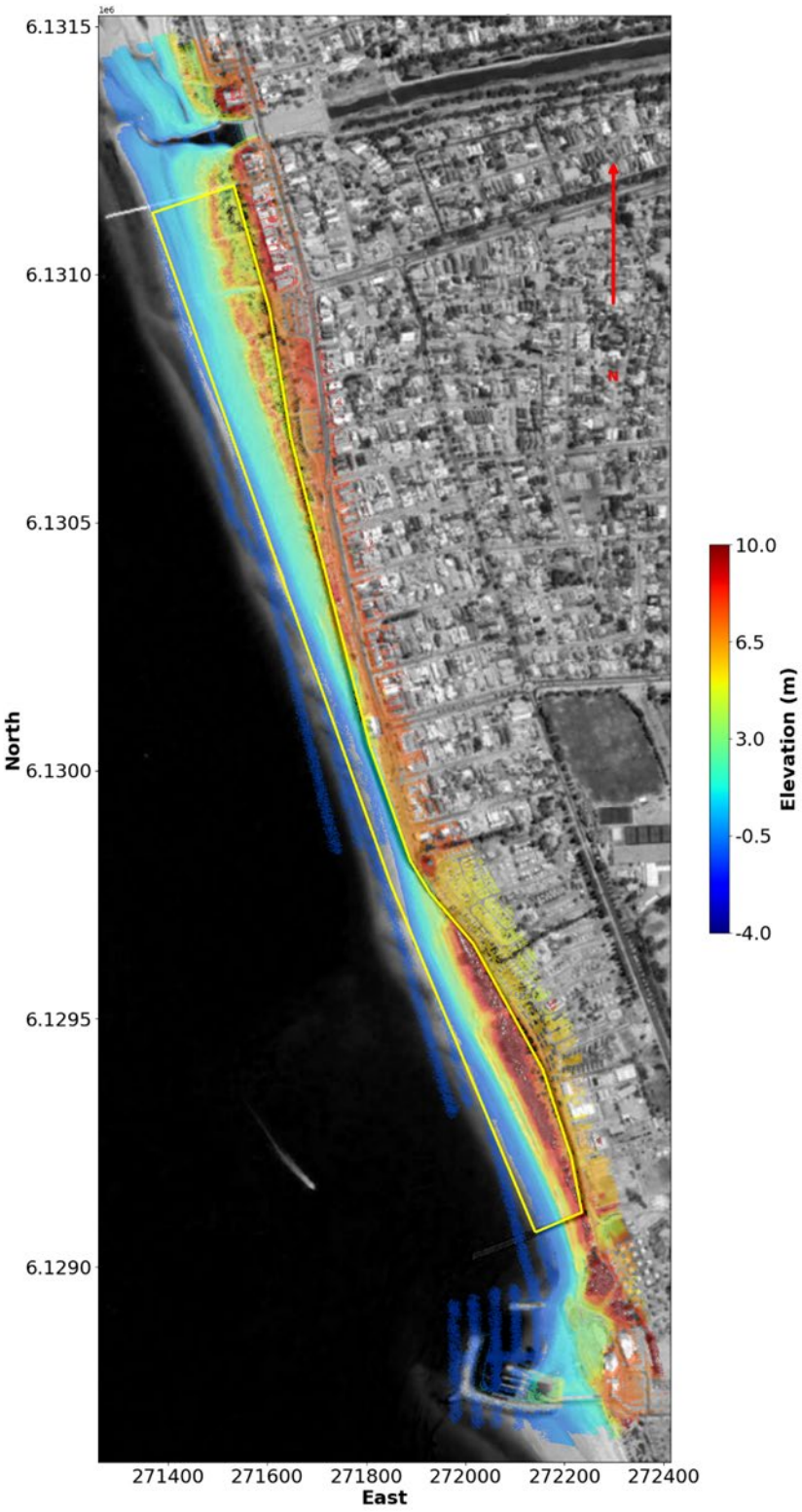


Figure 3-14 LIDAR DEM showing West Beach for March 2024. The background shows satellite image from Google Earth for closest date, 16 Feb 2024.

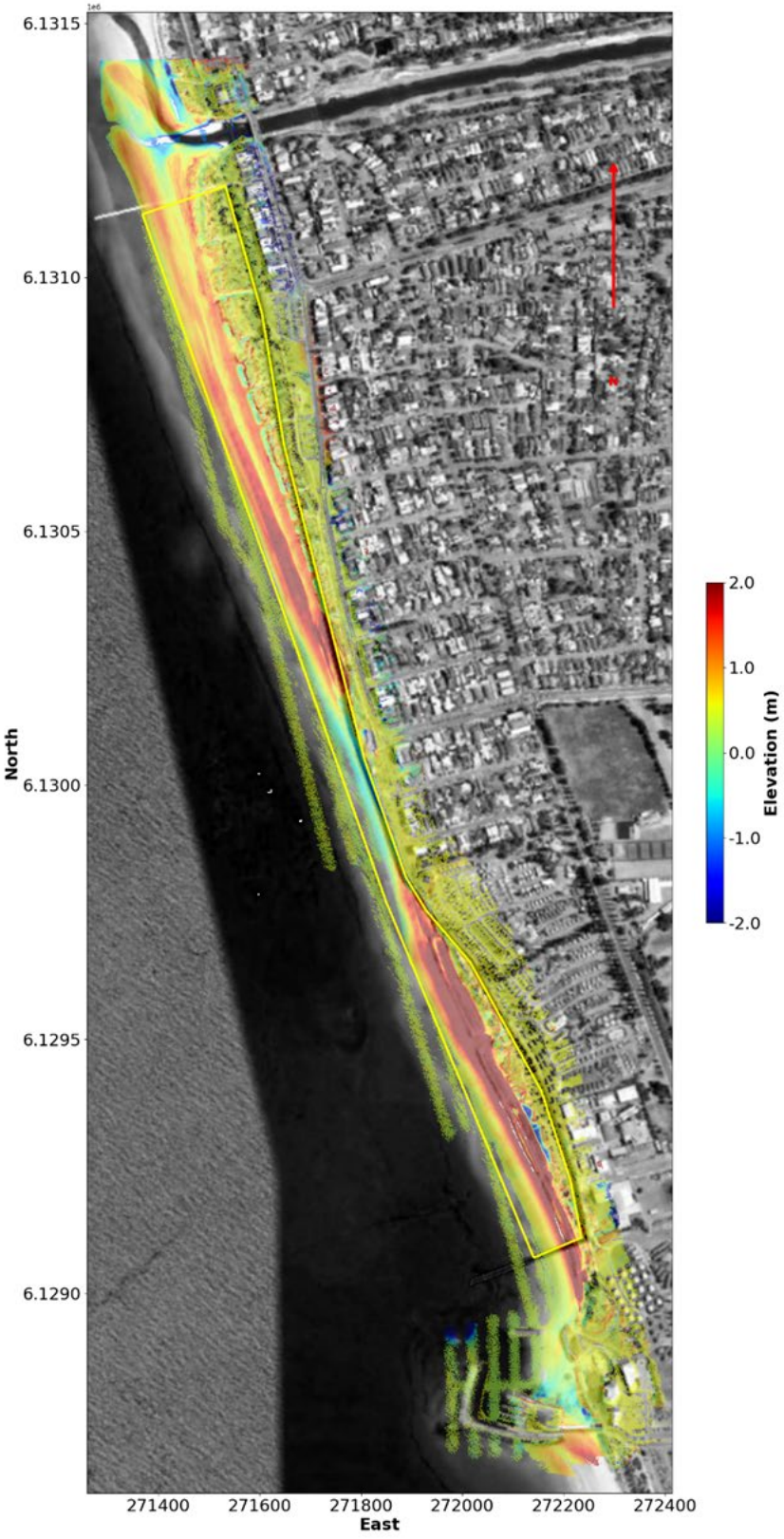


Figure 3-15 Elevation difference between March 2024 and Jan 2022 LIDAR DEMs (diff = E2024 – E2022).

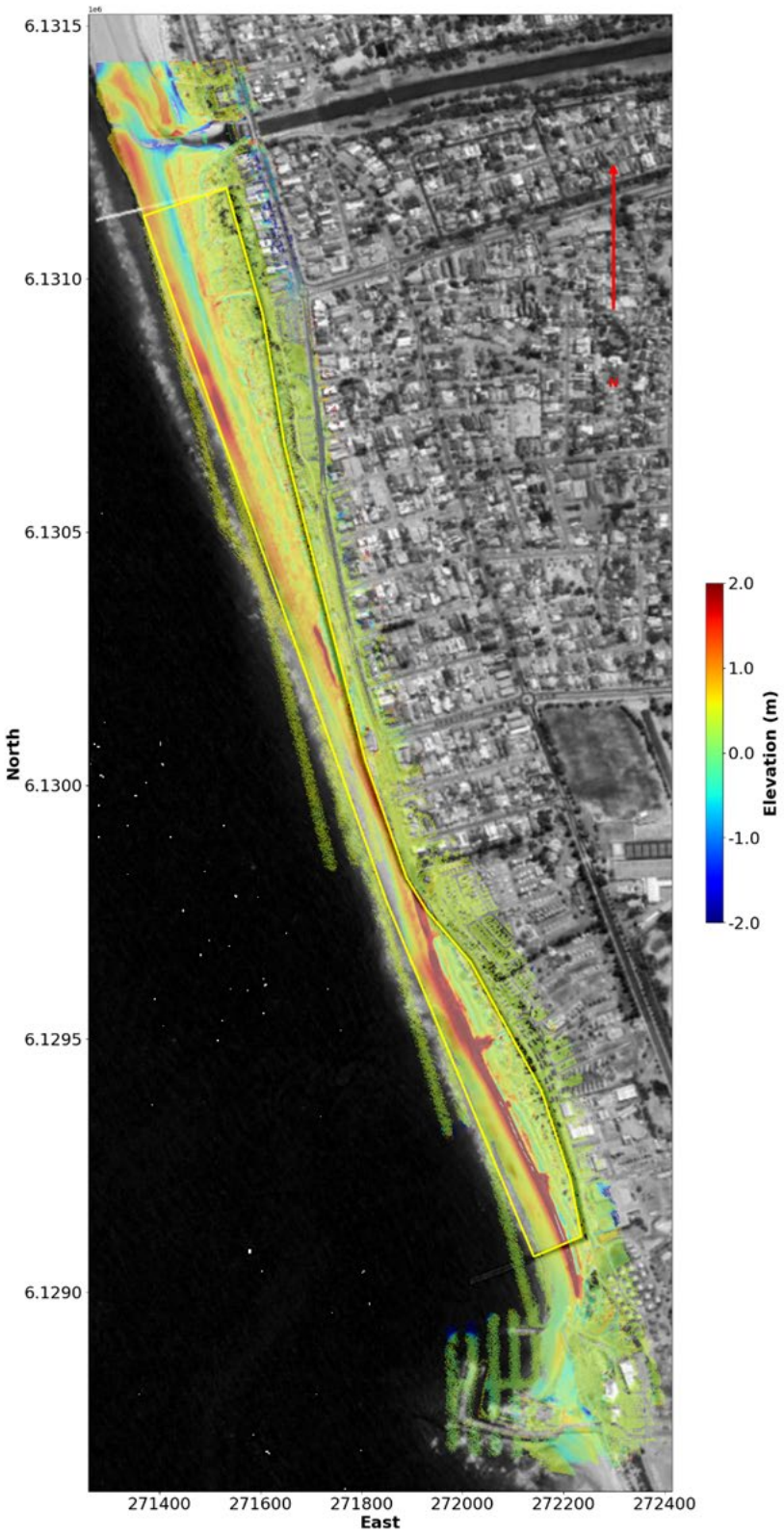


Figure 3-16 Elevation difference between March 2024 and March 2023 LIDAR DEMs (diff = E2024 – E2023).

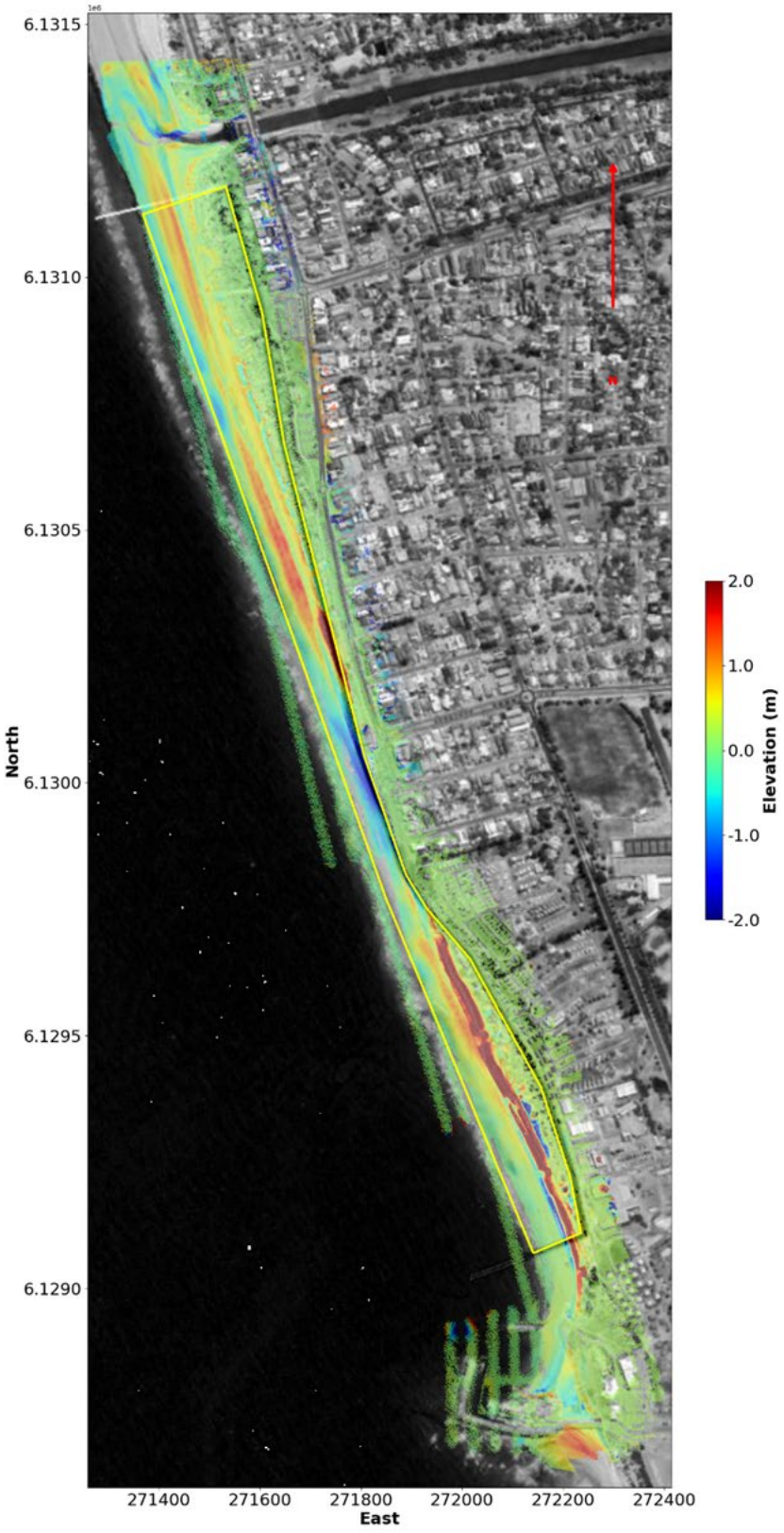


Figure 3-17 Elevation difference between March 2023 and Jan 2022 LIDAR DEMs (diff = E2023 – E2022).

Table 3-5 presents the total sand volumes (in million cubic metres) calculated for years 2022, 2023, and 2024 using two different methods:

- **11 profiles, z > -5**: This column shows the sand volume estimates derived from 11 cross-shore profiles with elevation greater than -5 meters (as presented in Section 3.1.3).
- **DEM_clipped to 2024**: This column presents sand volume estimates based on the 2022 and 2023 DEMs, clipped to match the 2024 DEM. This approach ensures consistency in the spatial extent of the DEMs for comparison, with the volumes being computed for the same area as defined by the 2024 DEM.

Explanation:

Regardless of the method used for DEM analyses, profile-based volumes consistently exceed DEM-based volumes. This is expected because profiles account for a broader area of sand, including underwater regions that are not fully captured by DEMs. Additionally, the area with high-quality DEM data in Cell 3 has a minimum elevation of -1.65m, compared to the -5m used in profile-based sand volume calculations. As a result, profiles cover deeper areas for sand volume calculations.

Despite these absolute differences, what matters for the analysis is the change in volume from one year to the next. We apply a maximum cap on the DEM data of z = 5m, where all data above this height is removed from the analysis. Additionally, we normalise the DEM volume estimates against the area in 2024.

Overall, while sand volume estimates vary depending on the method used, both methods indicate accretion from 2022 to 2024. Estimates for accretion from 2022 to 2023 are larger for the profile data compared to the DEM data (41,000 m^3 compared to 16,000 m^3), whereas estimates for accretion between 2023 and 2024 are similar (90,000 m^3 compared to 91,000 m^3).

Table 3-5 Sand volume (V) or change in sand volume (ΔV) in million m^3 inside yellow polygon. The area (A) covered by all pixels inside the polygon is in hectares (1E4 m^2).

Year	Clipped DEMs 5 > z > -1.65					11 profiles z > -5	
	A	V	V/A	V (2024 area)	ΔV	V	ΔV
2022	17.12	0.99	0.0578	0.884		2.397	
2023	16.30	0.96	0.0589	0.900	0.016	2.438	0.041
2024	15.28	0.99	0.0648	0.990	0.090	2.529	0.091

4 Sensitivity Study

Previous calculations on sand volumes were completed using the five profiles indicated in Figure 3-1, whereas the information provided above updates these estimates to account for the greater resolution provided by the 11 profiles available. We include a brief comparative analysis here for the data from the 5 profile set as compared to the 11 profile set.

The calculated sand volumes for the years 2018 to 2024 are summarized in Table 4-1. The total sand accretion or erosion relative to the previous year is presented in Table 4-2. The results presented in this table indicate which parts of Cell 3 and at what depth are more dynamic from year to year. For instance, the amount of accretion in 2022 is very similar between 5-profiles and 11-profiles, suggesting that the area covered by profiles 1-7 has been more stable than the area between profiles 7-11. Conversely, the accretion in 2024, as calculated from 11 profiles, is double the amount calculated from 5 profiles. This suggests that a significant amount of sand has accumulated between profiles 1-7. This is further confirmed by the formation of a dune from 2023 to 2024, as illustrated by the cyan lines inside the red ovals in Figure 4-1.

Table 4-1 Total sand volume at Cell 3 in million m^3.

Year	5 profiles	11 profiles
2018	1.9178	2.3258
2019	1.9258	2.3310
2020	1.8976	2.3235
2021	1.8716	2.2928
2022	1.9721	2.3972
2023	1.9904	2.4379
2024	2.0275	2.5292

Table 4-2 The total annual sand accretion/erosion in Cell 3 in thousand m^3.

Year	5 profiles	11 profiles
2018	3.2	3.7
2019	8.0	5.2
2020	-28.2	-7.4
2021	-26.0	-30.7
2022	100.5	104.4
2023	18.2	40.7
2024	37.2	91.3

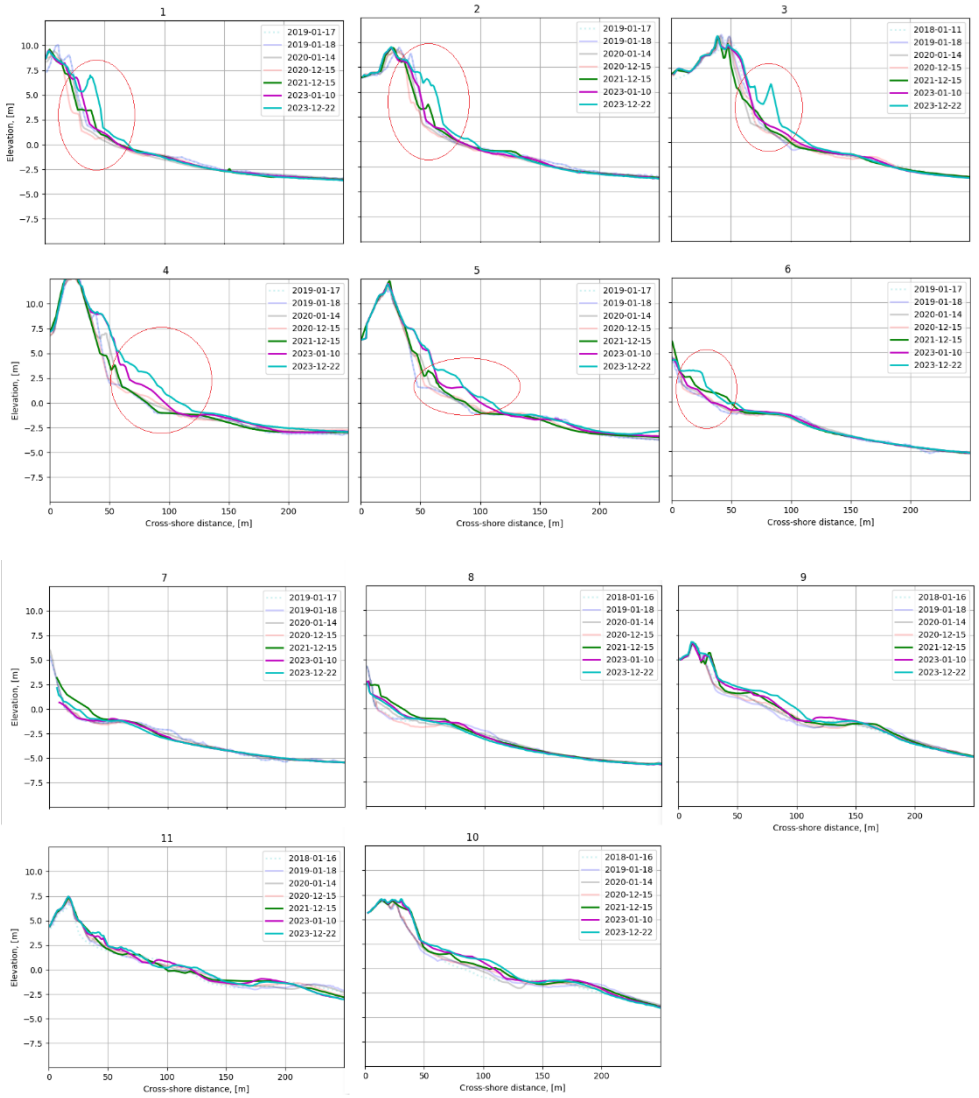


Figure 4-1 Cross-shore profiles from year 2018 to 2024.

5 Conclusion

This study examined the variation in sand volume at West Beach (Cell 3) using two methodologies: cross-shore surveys and Digital Elevation Models (DEMs). Cross-shore surveys, extending from the beach into deeper waters, provide valuable insights into shore dynamics and sand migration, including underwater sand and morphology not captured by drone-based imagery. Conversely, DEMs offer detailed information on the beach's continuous topography and sand distribution.

Both methods involve approximations due to gaps in coverage, but the overall agreement between them is satisfactory and both methods indicate accretion of similar order.

Table 5-1 summarizes the annual changes in sand volume, focusing on erosion and accretion compared to the previous year. The data from all methods, indicate an increase in sand volume from 2022 to 2024, reflecting overall accretion in the beach area. The main reason for the reversal to accretion since 2021 is related to the sand nourishment carried out by DEW.

As referenced in Section 3.1.3, the annual change in Cell 3, calculated using 11 beach profiles, shows an accretion of **91,000 m³** from **2023 to 2024**.

Table 5-1 Annual change of sand volume (in thousand m³) inside yellow polygon.

	Clipped DEMs 5 > z > -1.65	11 profiles z > -5
2022		104.4
2023	16	40.7
2024	90	91.3

6 References

/1/ DHI, August 2018, West Beach Coastal Modelling Processes, Assessment of Coastal Management Options. Technical report prepared for DEW.

/2/ DHI, March 2022, West Beach Fine Sediments and Nourishment Modelling, Report prepared for DEW.