SOUTH WEST COASTAL MONITORING

making space for sand



Making Space for Sand – Summerleaze Report

Topographic and LiDAR Data Analysis

SWCM TBR39 28/11/2023

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Summary

This report utilises Light Detection and Ranging (LiDAR), topography and aerial imagery data collected by the South West Coastal Monitoring (SWCM) Programme to analyse beach and dune volume at Summerleaze. The aim is to highlight coastal change at Summerleaze using SWCM data since 2007, focusing on beach and dune areas categorised into four zones: Beach, Mobile, Fixed, and Developed. Summerleaze Beach is a west facing sandy beach, just over 0.5 km long and is detailed as the study site. Topographic data collected bi-annually along fixed cross-shore profile lines and are presented to indicate change of the intertidal beach area over time. LiDAR data is compared from each available flight to show difference models of the intertidal area, to compare volumetric data over time and to show change in Mean Seal Level (MSL) and Dune Toe contours over time.

Since 2007, there has been a total of 38 topographic surveys at Summerleaze; 4 full coverage surveys, 30 interim surveys and 4 post storm surveys. Analysis shows an annual accretion rate of 10.7 m² per year. The lowest recorded area was during the 2014 spring interim, however the beach recovered by the following year. The highest recorded area was in 2011 autumn interim. From the 2024 spring interim, both profiles at Summerleaze displayed below-average cross-sectional areas. Profile 7b01463A was heavily impacted from the 2013/2014 winter period, with beach levels still well below pre-2013 levels. Erosion has been observed since the 2007 baseline survey, with up to 1.5 m loss in elevation along the beach face.

Beach volume extracted from 7 LiDAR flights since 2007, within the Mobile Zone, showed an increase from 2008 and peaked in 2014, followed by a decline in volume to the lowest beach volume on record. The Beach Zone was more varied, displaying the lowest beach volume in 2014, as a result of the 2013/2014 winter storms. The most recent LiDAR, captured in 2022, shows a small amount of recovery. The Dune Toe at Summerleaze has retreated by ~24 m since 2007, whilst the MSL contour has varied between 15-50 m.

Overall, analysis of both the Lidar and topographic survey data shows that Summerleaze is eroding over time. Erosions is particularly prevalent in the Mobile Zone and significant Dune toe retreat has been observed.

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1.0 Introduction

The aim of this report is to highlight beach and dune change at Summerleaze using data collected as part of the South West Coastal Monitoring (SWCM) Programme since 2007. Four zones have been identified to define the beach/dune area and are defined as:

- **Beach Zone** – The wet beach area has been defined using Mean Low Water Spring (MLWS) and Mean High Water Spring (MHWS) contours extracted from all LiDAR data captured by SWCM. The Beach Zone will therefore encompass the area between the MHWS and MLWS contours, with volumes for this area extracted from each LiDAR surface.
- **Mobile Zone** – This area is defined as the active dune face and embryo dune[1] from MHWS +1 m to the back of the mobile area, often distinguished by vegetation depth or urban development. The Mobile Zone has been defined using aerial imagery from 2007 to 2021 and historic OS maps and has been verified through site visits.
- **Fixed Zone** – This area is defined by permanent dune vegetation that may also include scrub or invasive species, effectively denoting vegetation atop sandy soil.
- **Developed Zone** – This is defined as urban development areas (i.e., car parks, unnatural grassy areas, roads, houses etc.) which have been built atop previously present dune systems.

1.1 Study Site

Summerleaze is a west facing sandy beach, directly exposed to the swell of the North Atlantic (Fig.1). Summerleaze is mostly backed by a dune system with a car park situated directly behind, cutting into the dune. A river outlet and a historical canal are situated to the southern end of the beach. The beach is separated by a wide hard rock headland to the north which also consists of a tidal lido. The southern end of the unit is protected by a breakwater which extends out by more than 200 m from the southern headland. To the seaward side of the breakwater is Breakwater beach, which is mainly made up of rocks and pebbles on the upper beach, sand along the beach-face, and a rock platform along the low tide terrace.

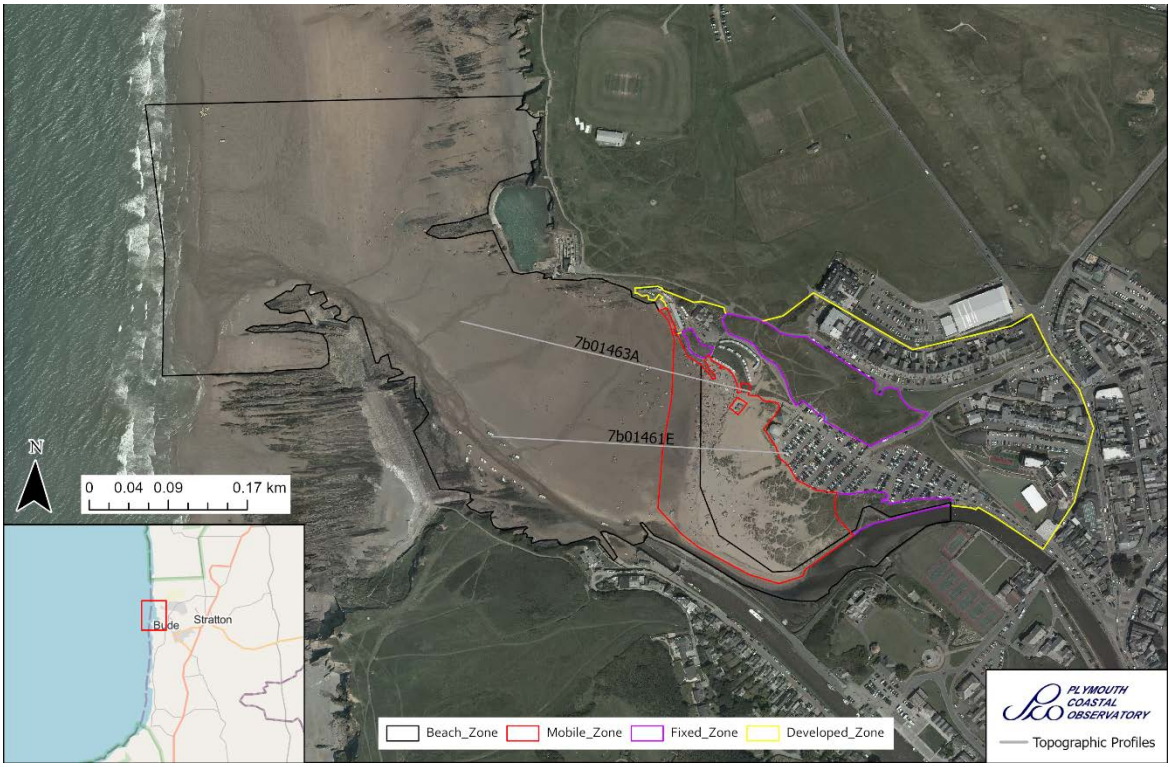


Figure 1 - Location Map of Summerleaze Beach and Dune System, indicating the four defined zones outlined in section 1.0. Interim topographic profiles are also overlain to show their location, as detailed in section 2.1.

[1] An embryo dune, or yellow dune, is the earliest stage of dune growth, usually found along the seaward extent of a dune system or newly formed dune.

2.0 Methods

Data utilised in this report was collected by SWCM between 2007 and 2024. Information on topographic and LiDAR data collection and specifications can be found on the Website for the National Network of Coastal Monitoring Programmes.

2.1 Topographic Data

SWCM have undertaken routine topographic beach surveys at 34 of the 40 MS4S sites since 2006. All surveys are conducted from the MLWS contour to the backshore. On average, each surveyed beach receives two interim surveys a year and one full coverage survey every 5 years:

- Interim - Conducted twice a year in the spring (conducted between January and April), and autumn (conducted between September and December). An interim survey consists of collecting data points at 5m intervals along pre-defined profiles; these are outlined in Figure 1.
- Full coverage – Conducted once per phase (6 years), or annually at more vulnerable sites (conducted between May and September). Full coverage surveys include a full profile survey at 50 m intervals and continuous spot height data collected across a 5 m grid covering the whole beach.

Analysis of the Cross-Sectional Area (CSA) change is conducted for each individual profile between each separate survey. Changes in CSA are measured relative to the fixed master profile which is defined by a pre-determined stable landward position and the MLWS level in reference to Ordnance Datum.

2.1.1 Topographic Data Analysis

Topographic data is presented as the following, where applicable:

Trend Analysis Plot - The combined profile trend in CSA is presented for each survey unit (example shown in Fig.2). The sum of all interim profile CSA is combined for each survey conducted to date to provide a survey unit with a single 'beach area' value, known hence-forth as the Combined Profile Area (CPA). CPA is compared using linear trend analysis over a temporal scale (Fig.2).

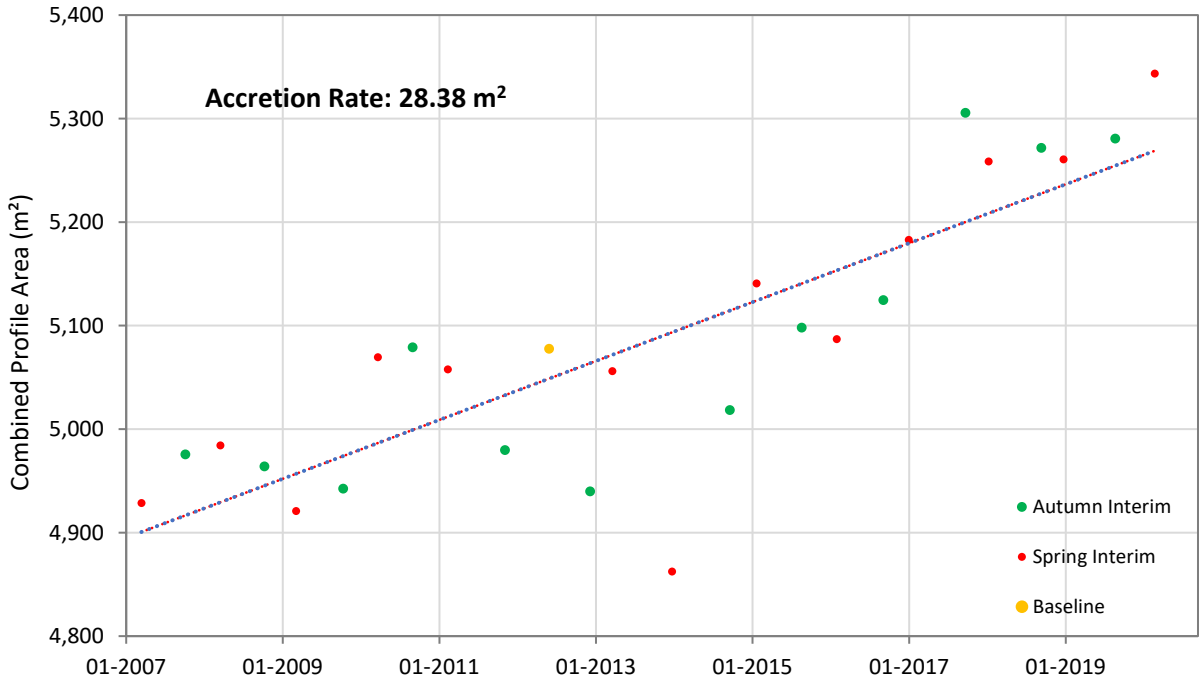


Figure 2 - Example of trend analysis for CPA for each survey with a linear trend rate highlighted at 28.4 m^2 y^{-1} equating to the increase of 0.56% of the average CPA per year.

If a profile has been omitted from a particular survey, for reasons of obstruction or similar, the average CSA of that profile from all available surveys is taken to ensure a consistent 'beach area'; if fewer than 75% of surveys have been conducted for a particular profile, the profile is omitted.

Profile Extremes Analysis - This plot displays the range of CSA values recorded throughout the duration of data collection (2006-2024) for each individual interim profile; the most recent survey is represented as a green dot. An example is given in figure 3. This plot provides the reader with information on how the CSA for each interim profile from the most recent survey corresponds to the entire dataset range.

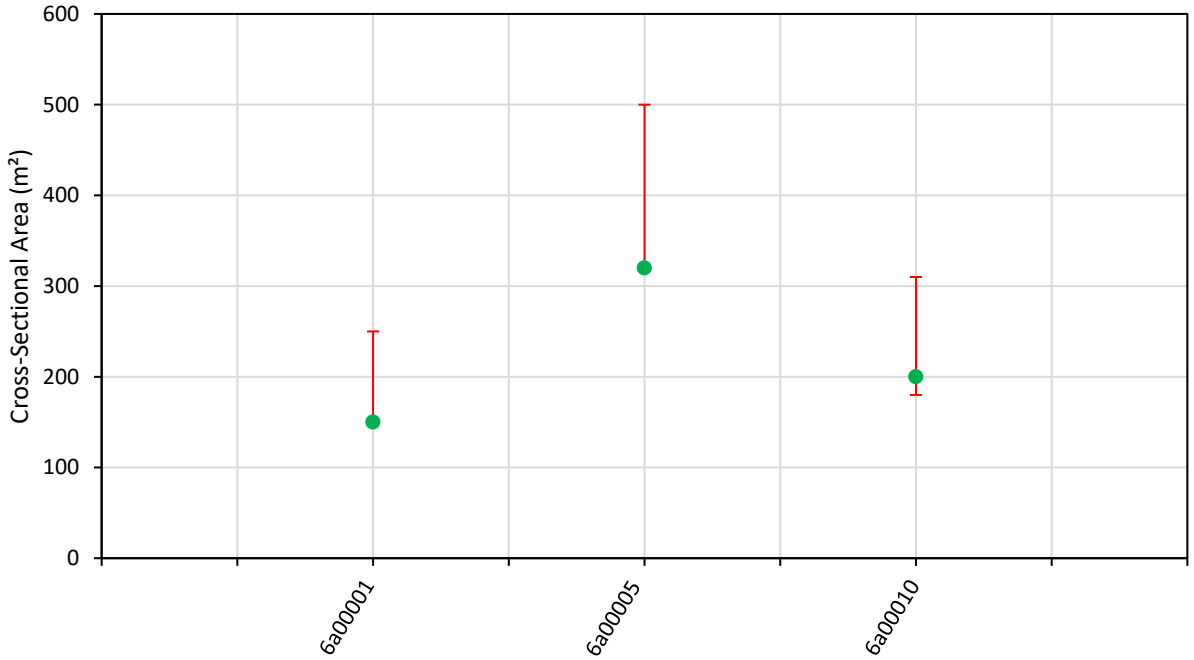


Figure 3 - Example plot showing the most recent CSA value recorded for three separate profile lines (green dots). The error bars represent the range of CSA recorded by each profile throughout the topographic dataset.

CSA Time Series Plot - CSA measurements for each interim profile are displayed on a separate plot representing values from each interim and full coverage survey conducted to date (example shown in Fig.4). This provides the reader with information on each interim profile's CSA evolution through time.

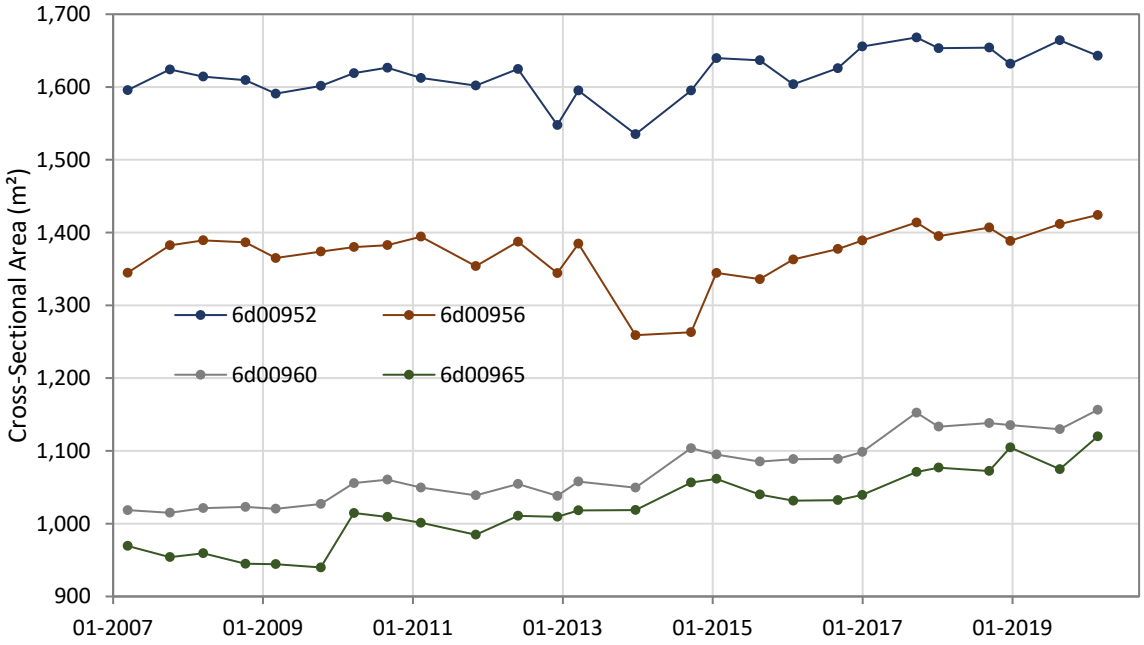


Figure 4 - Example of a cross-sectional area plot showing each of the interim profiles recorded for every survey since the 2007 baseline.

Individual Profile Charts - Each interim profile is portrayed as a cross-sectional profile comparing the most recent spring interim (blue), the previous spring interim (green) and the original full coverage survey (red). Profiles are displayed against the master profile (dotted red line) and are presented in the Appendices.

The 2013/2014 Storms – The winter period between September 2013 and April 2014 was, for many beaches in Cornwall, the most destructive period since SWCM records began in 2007. An abnormal number of significant storms, occurring in quick succession, heavily impacted many beaches, causing the loss of sediment from the intertidal area and dune face. This period is extensively discussed throughout this report and will hereinafter be referred to as the 2013/2014 winter period.

2.2 LiDAR Data

Airborne Light Detection and Ranging (LiDAR) data have been captured as part of the SWCM since 2007. Products include a point clouds, from which filtered and unfiltered 1 m^2 gridded surface models are derived:

- Unfiltered (Digital Elevation Model) representing the earth's surface including natural and artificial features such as trees and buildings.
- Filtered (Digital Terrain Model) representing the bare earth surface, with trees, buildings, cars etc. removed.

LiDAR is captured between September and March to minimise vegetation capture. Data is captured between MLWS and up to approximately 500 m inland. This report utilises "filtered" LiDAR data.

2.2.1 LiDAR Data Analysis

LiDAR data analysis is presented as the following:

Difference Modelling – Separate LiDAR surfaces are compared to produce a difference model of change based on gridded spot height elevations. The raw spot height data is processed into a gridded digital terrain model (DTM) and successive models are subtracted from one another to produce a difference model for the survey unit. Change in elevation is shown for values +/- 0.25 m and is represented by a colour scale bar.

Volume Extraction - Net sediment volume (m^3) is extracted for each LiDAR surface from the Beach Zone above MLWS and Mobile Zone above MHWS for trend comparison over time.

Contour Analysis – Contours are mapped from four LiDAR epochs spanning from 2007 to 2023, representing Mean Sea Level (MSL) and dune toe (calculated using the Stockdon equation by UoP, 2023[2]).

2.3 Accuracy Statement

Topographic Data – All survey points recorded along profiles have a measurement accuracy of +/- 0.03 m RMSE[3] in the horizontal and +/-0.03 m RMSE in the vertical.

LiDAR Data – Each LiDAR point cloud dataset has an average point density of 1.5 points per square metre. The digital terrain surfaces provide a minimum accuracy in elevation data of +/- 0.10 m RMSE with a minimum horizontal standard deviation as < 0.05 m. Please note that while every endeavour has been made to capture LiDAR as far seaward as MLWS, tidal and weather restrictions may in some instances have precluded this and coverage may be slightly reduced.

[2] Please refer to the following for Dune Toe elevation calculation: UoP, 2023. MS4S: Contemporary Dune Evolution and Future Predictions, Report, University of Plymouth, 33 pp.
[3] RMSE – Root-Mean-Square Error

3.0 Results

3.1 Topographic Data Analysis

There has been a total of 38 topographic surveys at Summerleaze since 2007, 4 full coverage surveys, 30 interim surveys and 4 post storm surveys. Exact dates of each survey for Summerleaze are available to view on our survey record. Analysis of the CPA indicates the survey unit has been eroding at 11.5 m^2 y^{-1} equating to 0.32% of the average beach area per year (Fig.5). Summerleaze has been losing material since 2012, but experienced significant impact from the 2013/2014 winter period. The beach has since seen low-level recovery with the most recent 2024 spring interim displaying a similar CPA to 2014.

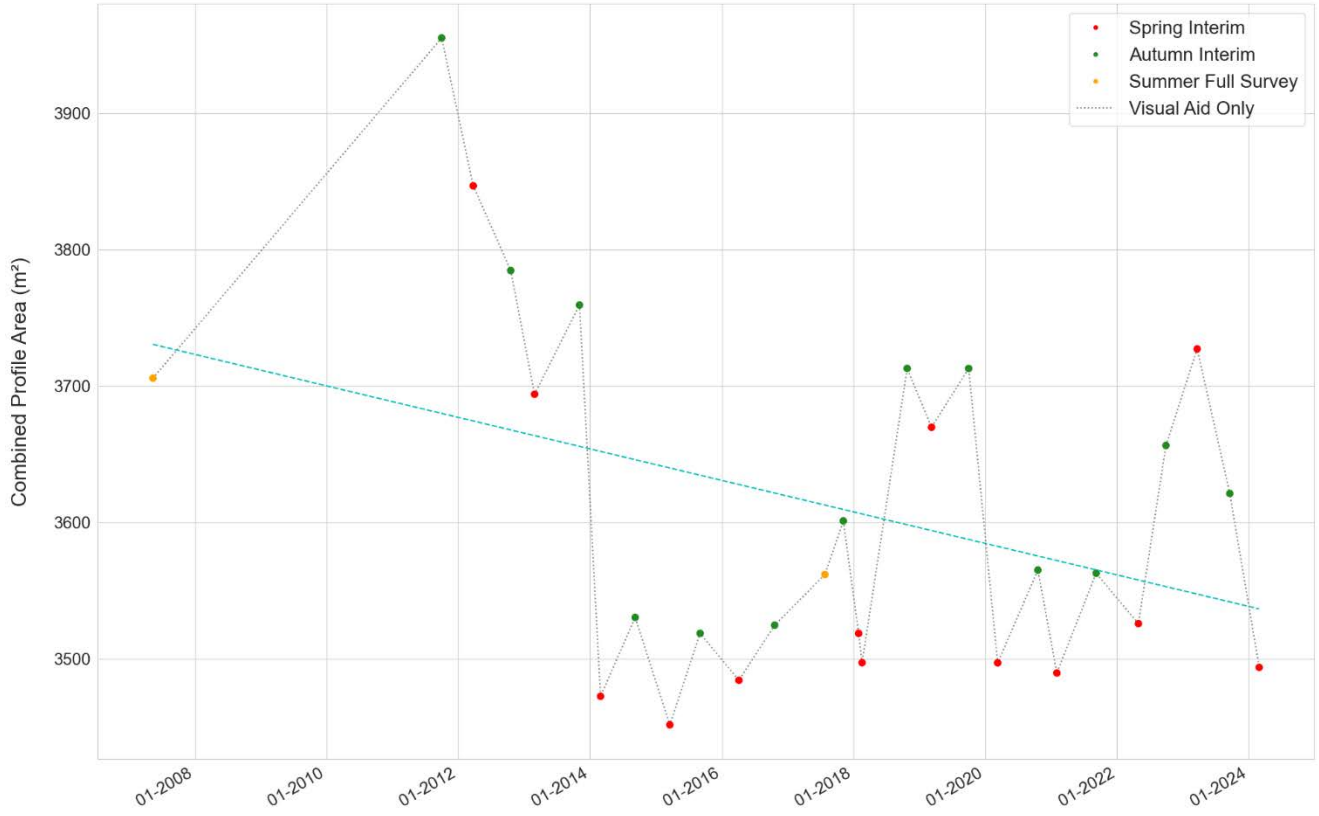


Figure 5 - The Combined Profile Area (CPA) for Summerleaze, including every spring (red), summer (yellow) and autumn (green) survey completed between 2007 and 2024.

When comparing to the entire dataset (Fig.6), during the 2024 spring interim, both profiles at Summerleaze were displaying a below average cross-sectional area.

When comparing profile cross-sectional areas to the entire time series (Fig.7), profile 7b01463A saw a sharp drop in 2014, whilst profile 7b01461E steadily declined between 2011 and 2015. Since then both profiles have remained stable, but neither have recovered to pre-storm beach levels.

Profile Charts for Summerleaze can be found in Appendix 1, these display the cross-sections of each profile for the initial baseline survey conducted in 2007 along with the two most recent interim surveys. Both profiles have shown erosion since the 2007 baseline survey, with up to 1.5 m loss in elevation along the beach face.

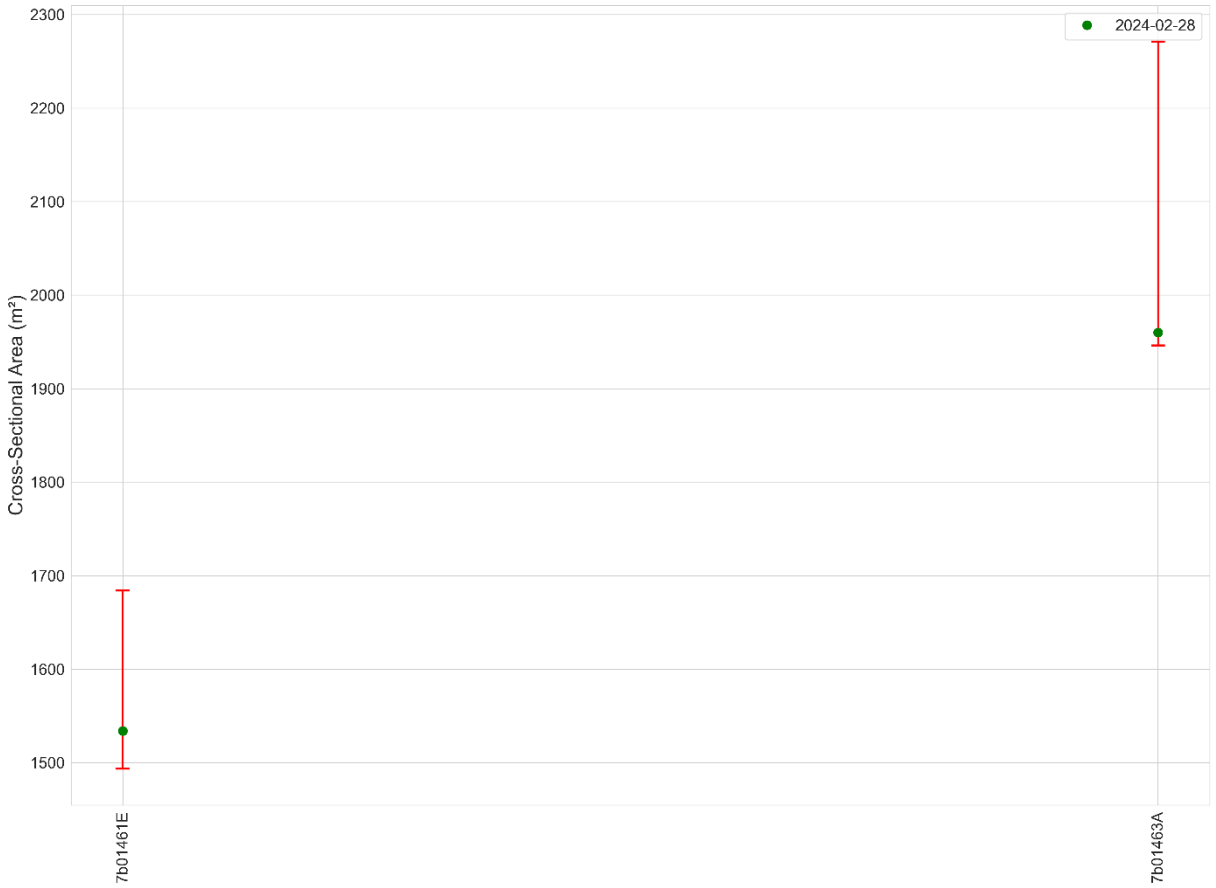


Figure 6 - Cross-sectional area of each interim profile, comparing the current area of the profile (green dot), with the maximum and minimum values (red error bar) recorded between 2007 and 2024.

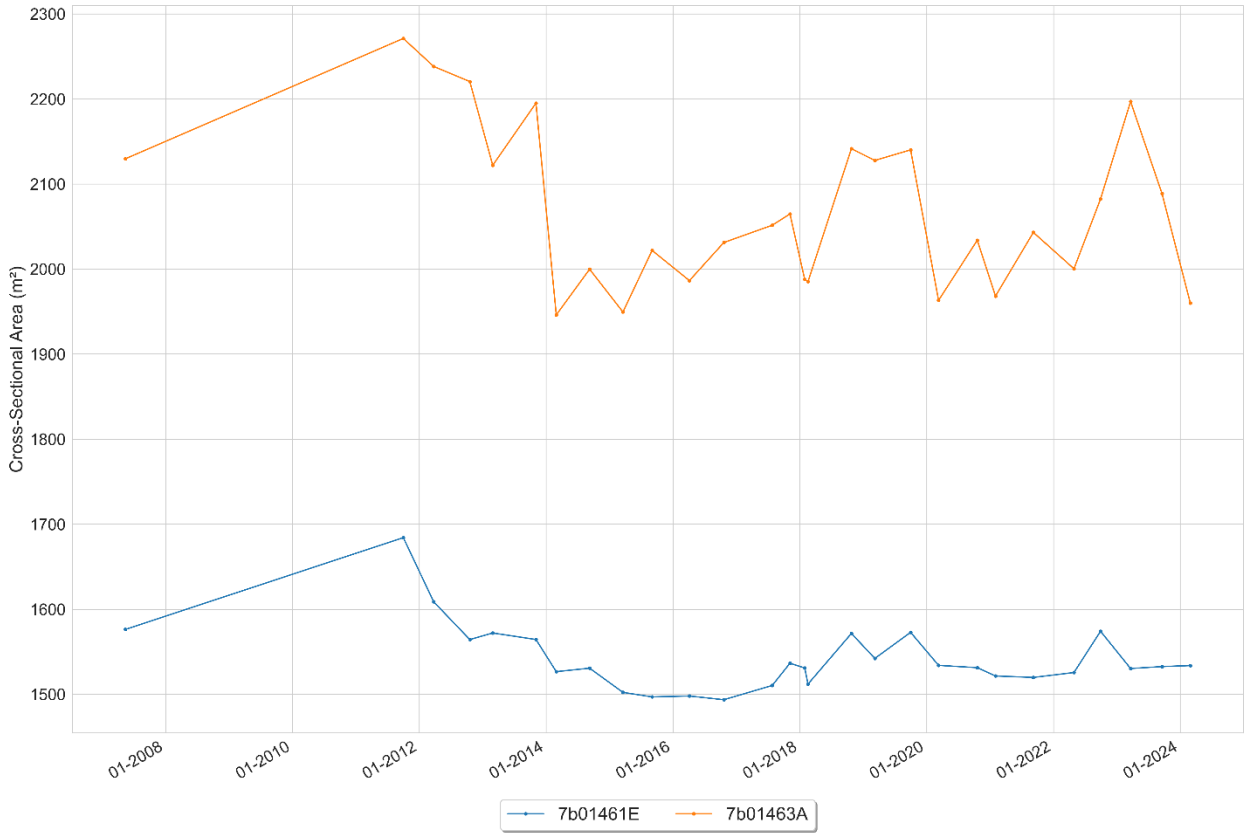


Figure 7 - Cross-sectional area of each interim profile, comparing the values recorded during each interim and baseline survey between 2007 and 2024.

3.2 LiDAR Data Analysis

There has been a total of 7 LiDAR flights captured at Summerleaze since 2007 through SWCM.

3.2.1 Difference Models

Difference models between each epoch of LiDAR data are presented here. Accretion and erosion values observed behind the dune system can be attributable to noise in the filtered LiDAR data or man-made changes in elevation and should be dismissed as such.

Please note that the difference models below (figures 8 - 14) display the analysis for the whole system, encompassing Summerleaze and Crooklets Beach. Analysis specific to Crooklets Beach is available in report TBR40.

Figure 8 shows the difference in elevation between the first filtered LiDAR data from September 2007 compared to the most recent, captured in March 2022. There is considerable accretion observed along the main body of the dune system of >3 m. The upper beach face and mobile dune face suggests erosion of 1-2 m. Areas of erosion are seen across large areas of the beach, whilst a strip of accretion can be seen along the edge of the river.

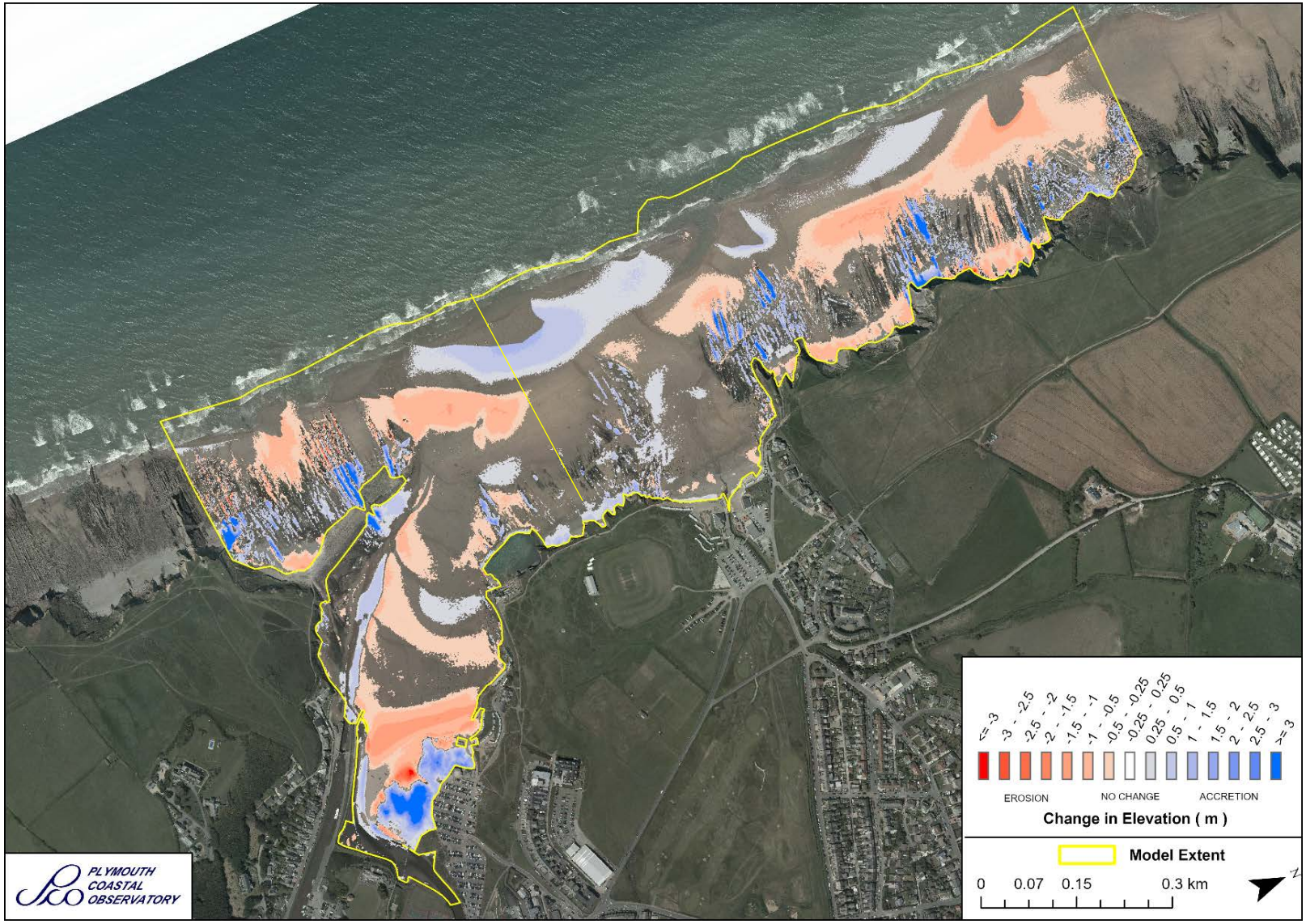


Figure 8 – Difference model indicating the changes in elevation observed between the September 2007 and March 2022 filtered LiDAR datasets within the yellow model extent.

Figure 9 shows differences in elevation between filtered LiDAR data from September 2007 compared to March 2009. Patches of accretion are observed across the main dune system, followed by a bar-trough system across the main beach. A bar has built up along the seaward extent of the beach.

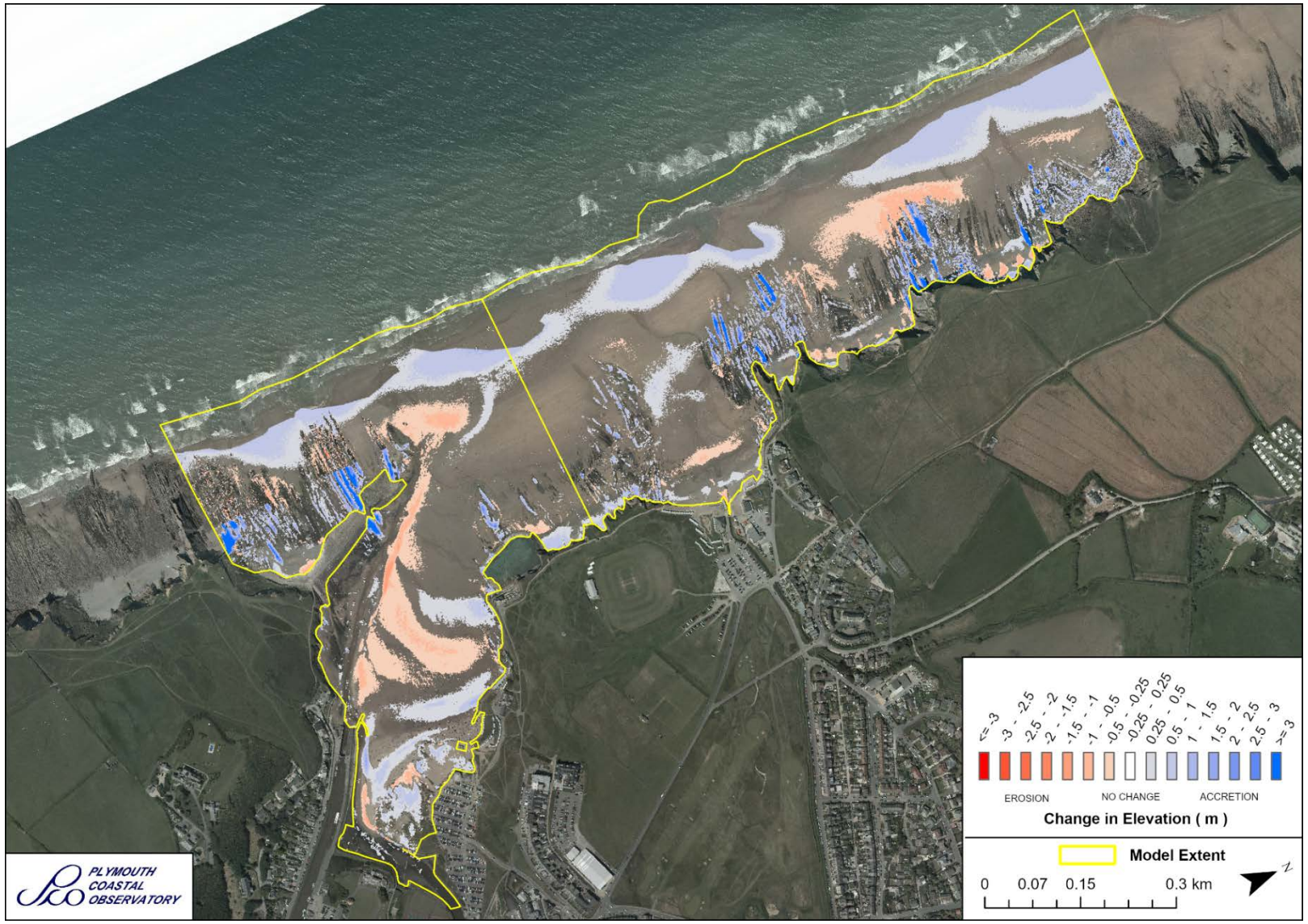


Figure 9 - Difference model indicating the changes in elevation observed between the September 2007 and March 2009 filtered LiDAR datasets within the yellow model extent.

Figure 10 shows differences in elevation between filtered LiDAR data from March 2009 compared to September 2009. Unlike Figure 9, minimal change has been seen on the dune system, but a trough feature has been created at the toe of the beach. A large area of the seaward end of the unit has seen widespread accretion since earlier in the year.

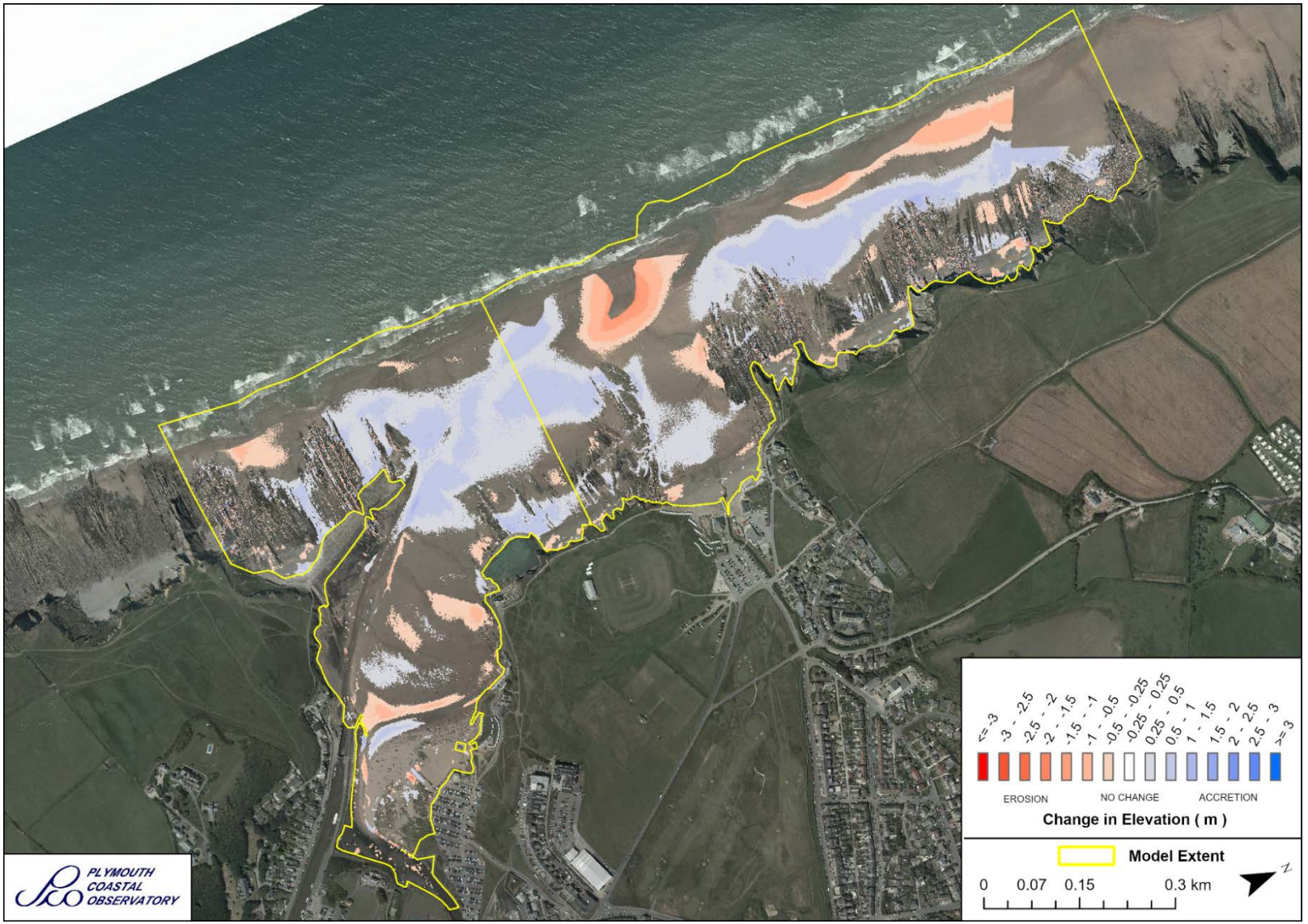


Figure 10 – Difference model indicating the changes in elevation observed between the September 2009 and March 2009 filtered LiDAR datasets within the yellow model extent.

Figure 11 shows differences in elevation between filtered LiDAR data from September 2009 compared to October 2010. This epoch indicates large areas of change, with accretion observed within the main dune system but counteracted by erosion along the dune face. Minimal change is experienced along the beach toe; however, the remaining lower half of the beach has seen widespread accretion of up to 2 m.

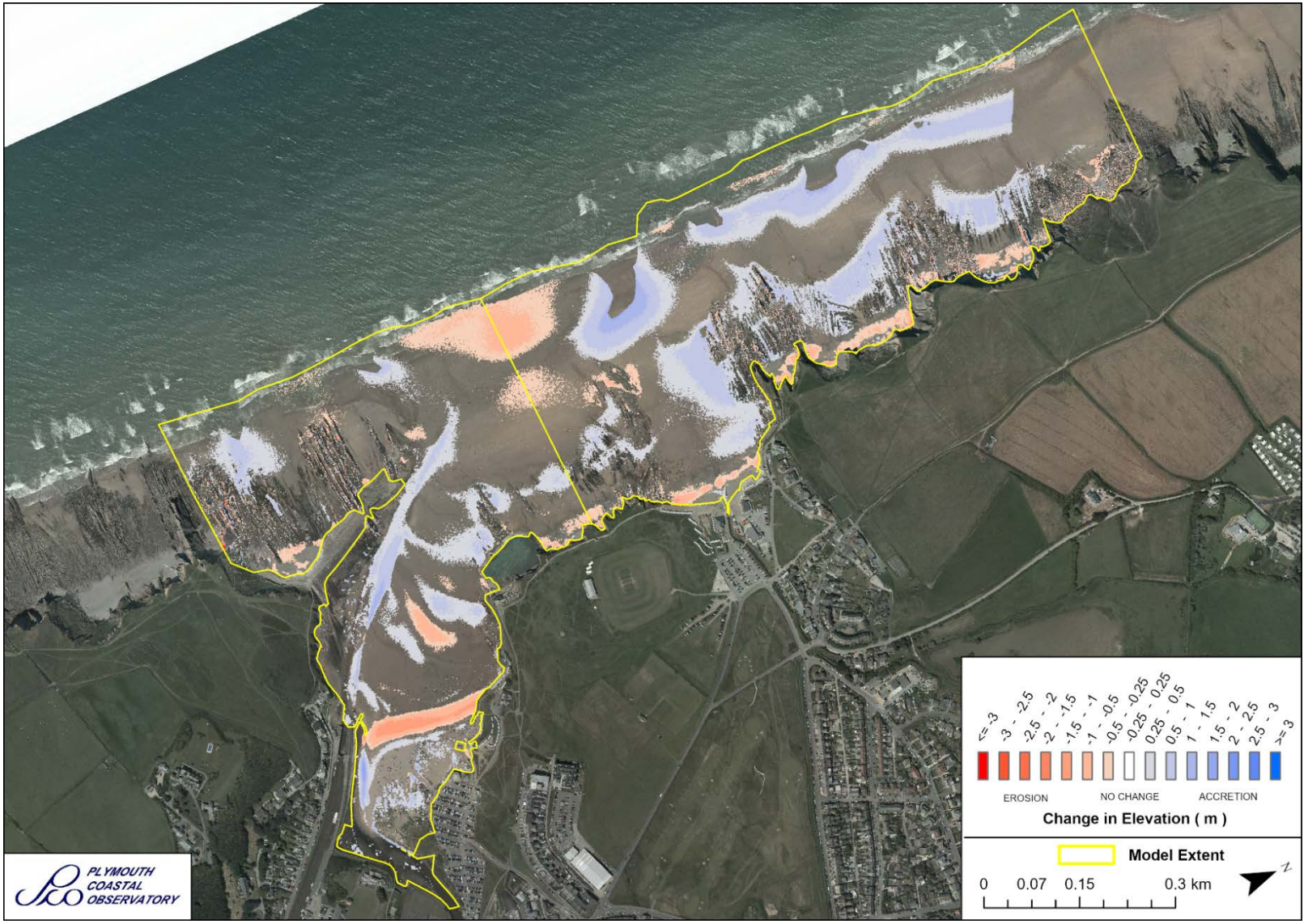


Figure 11 - Difference model indicating the changes in elevation observed between the September 2009 and October 2010 filtered LiDAR datasets within the yellow model extent.

Figure 12 shows differences in elevation between filtered LiDAR data from October 2010 compared to April 2014. The impact of the 2013/14 winter storms is clear, with the entire beach experiencing considerable erosion with some areas to the northeast losing up to 3 m in elevation. Some accretion can be observed within the dune system at Summerleaze, with other pockets of accretion occurring primarily at the upper beach face of the unit.

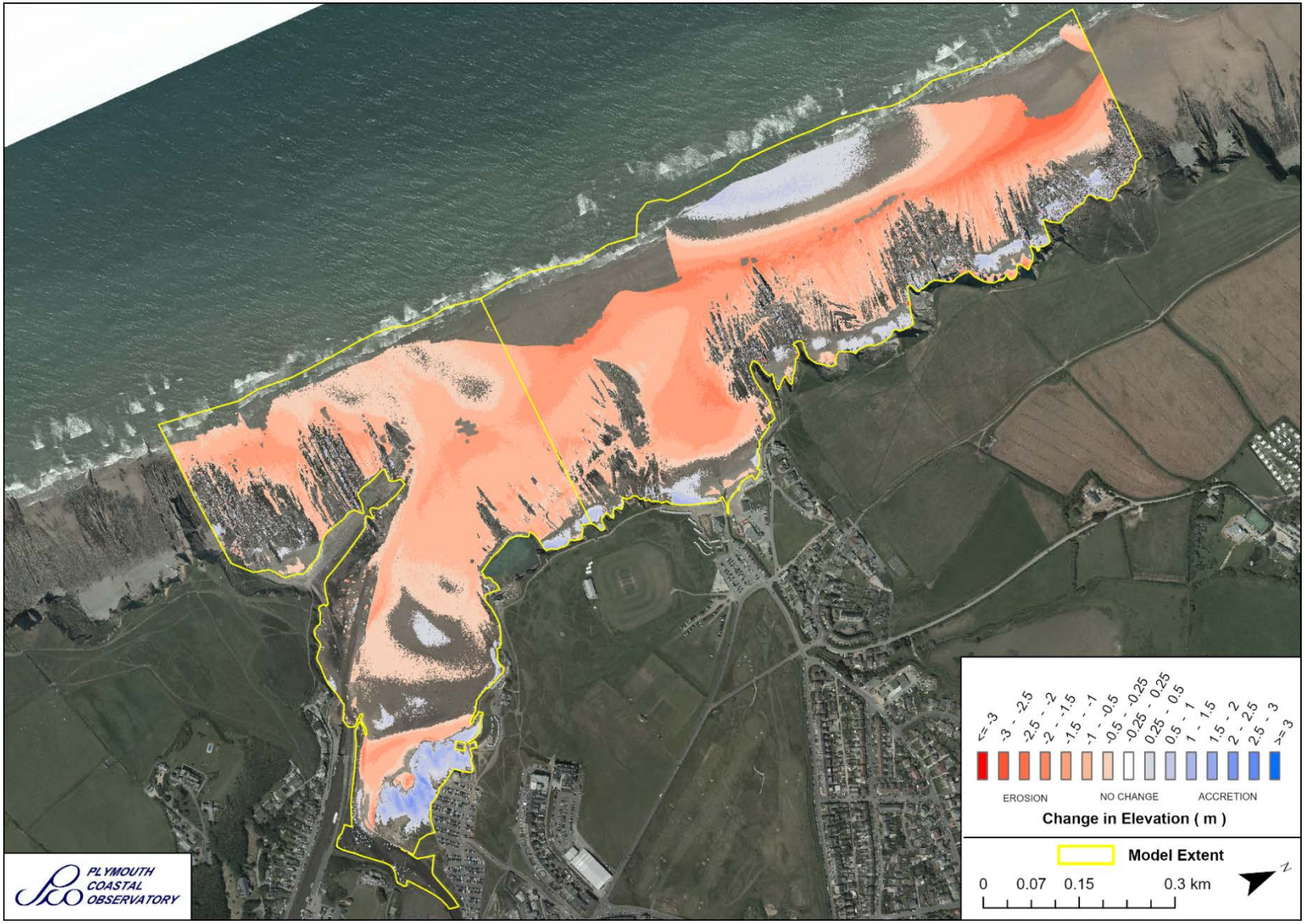


Figure 12 - Difference model indicating the changes in elevation observed between the October 2010 and April 2014 filtered LiDAR datasets within the yellow model extent.

Figure 13 shows differences in elevation between filtered LiDAR data from April 2014 compared to April 2019. The survey area is dominated by large bands of accretion across the lower beach face, indicating the recovery of the system following the 2013/14 winter storms, despite this, considerable erosion is observed along the upper beach face at both Crooklets and Summerleaze beach, with the dune toe at the latter losing up to 1.5 m in elevation.

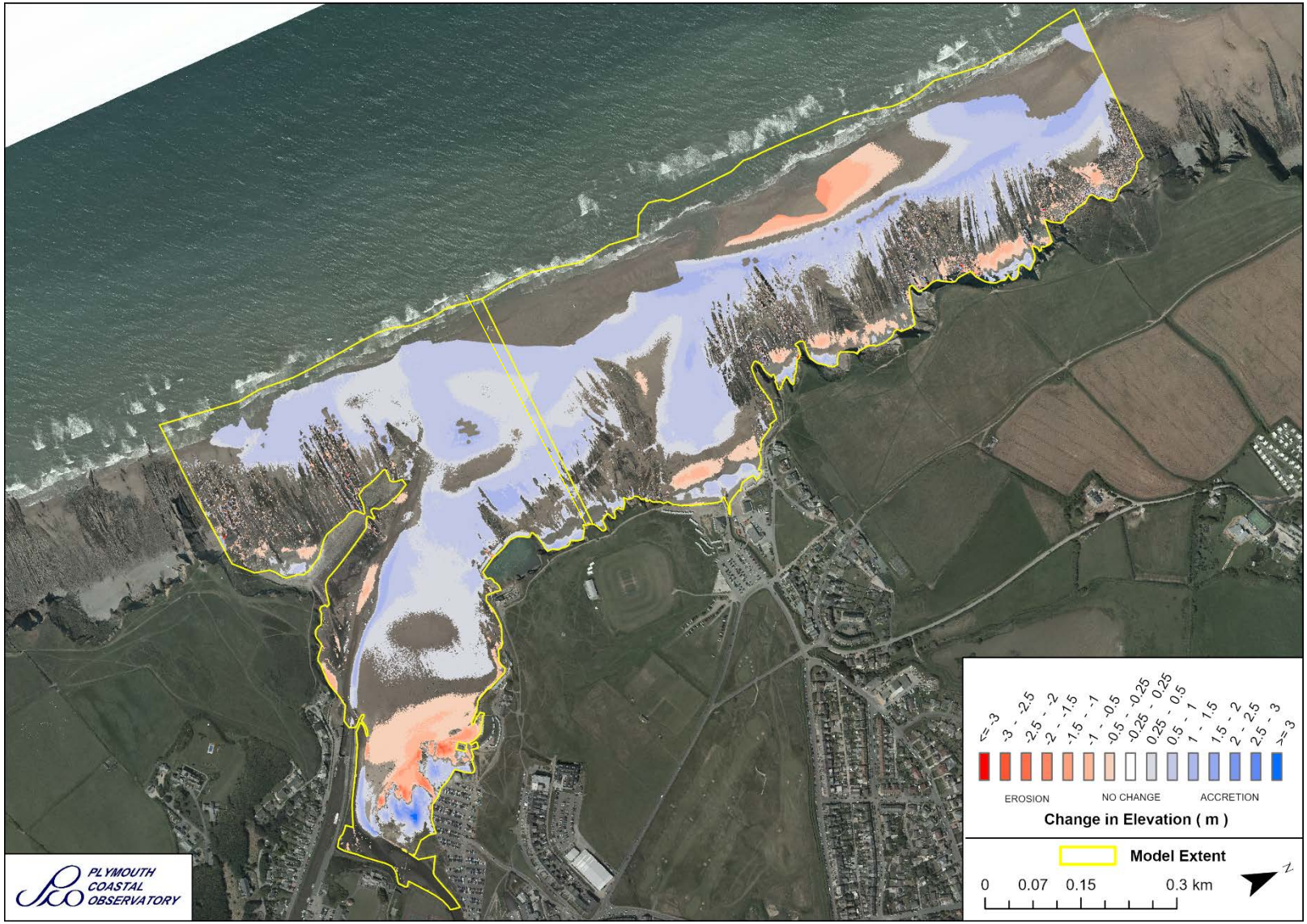


Figure 13 - Difference model indicating the changes in elevation observed between the April 2014 and April 2019 filtered LiDAR datasets within the yellow model extent.

Figure 14 shows differences in elevation between filtered LiDAR data from April 2019 compared to March 2022. There are relatively minimal changes observed in the centre of the beach but accretion on the back dune and some erosion seen along the dune face. The seaward end of the unit has seen widespread of erosion of up to 2 m.

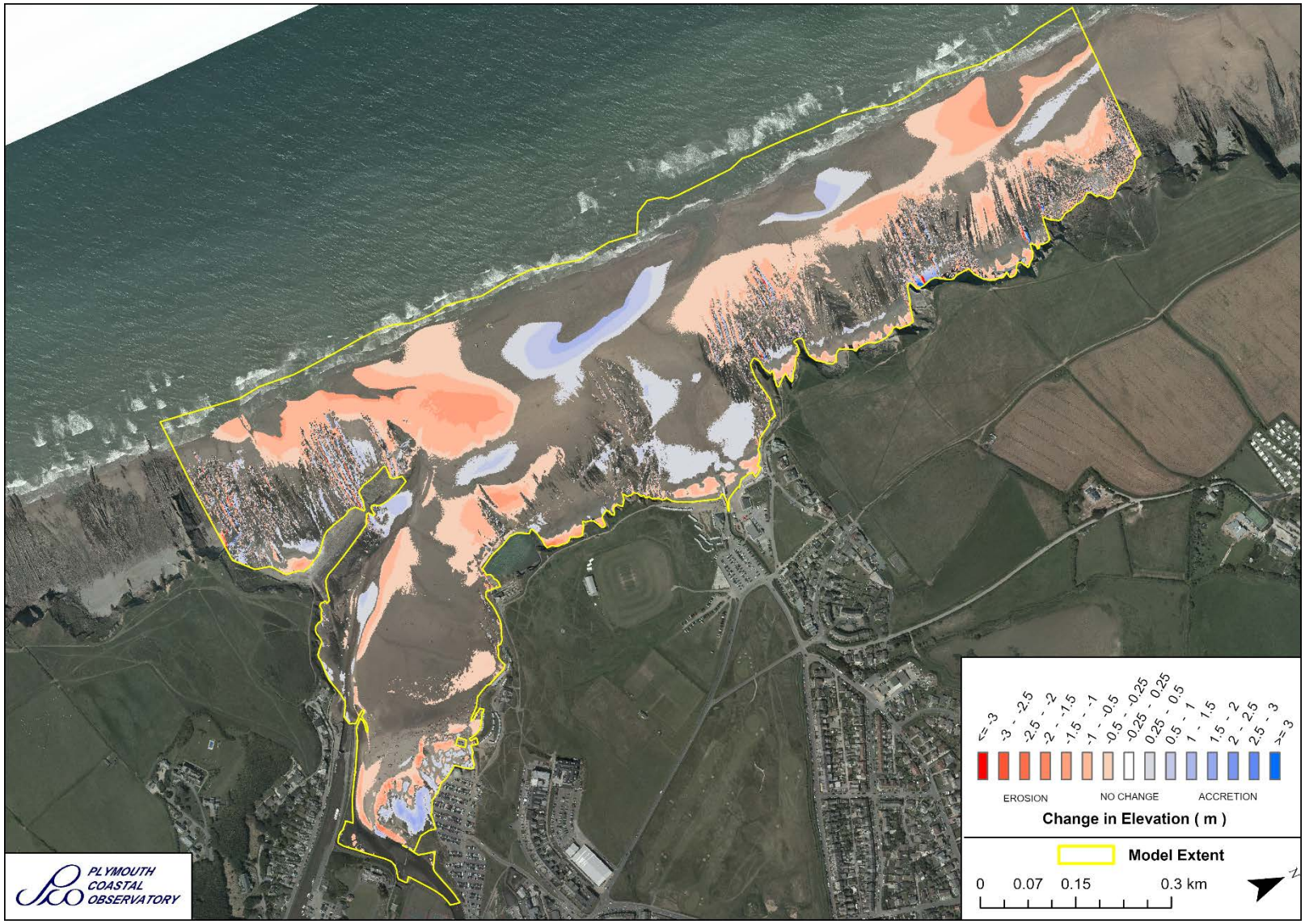


Figure 14 - Difference model indicating the changes in elevation observed between the April 2019 and March 2022 filtered LiDAR datasets within the yellow model extent.

3.2.2 Beach and Dune Volume Extraction

Surface volume extracted from each available LiDAR dataset from the Mobile Zone above the MHWS contour (3.50 m OD) are shown in Table 1. Volumetric data in the Mobile Zone shows a different trend to that of the topographic data with the lowest recorded values from the March 2022 (97,337 m^3) and September 2007 (97,992 m^3) datasets (Fig.15). The highest volume was recorded during the April 2014 survey (108,050 m^3), despite the observed losses from the beach identified in Figure 14, the Mobile Zone gained considerable material between the two surveys.

Surface volume extracted from each LiDAR dataset from the Beach Zone above the MLWS contour (-2.90 m OD) are also shown in Table 1. Distinctly separate from the Mobile Zone trend, steady erosion is visible within the Beach Zone throughout 2007 to 2022, with the lowest volumes recorded in April 2014 (508,040 m^3) and February 2022 (510,968 m^3) y^{-1} (Fig.16). As expected from the more fluctuating Beach Zone, accretion is not as linear as that of the Mobile Zone, with erosive periods observed in the 2009, 2010 and 2019 data.

Table 1 – Surface volume values (m^3) extracted from all available filtered LiDAR datasets for the Mobile Zone above MHWS (3.50 m OD) and for the Beach Zone above MLWS (-2.90 m OD).

Date	Mobile Zone Volume (m^3)	Beach Zone Volume (m^3)
09/2007	97,992	540,383
03/2009	103,266	559,805
09/2009	104,908	578,769
10/2010	104,673	585,316
04/2014	108,050	508,040
04/2019	107,079	558,117
03/2022	97,337	510,968

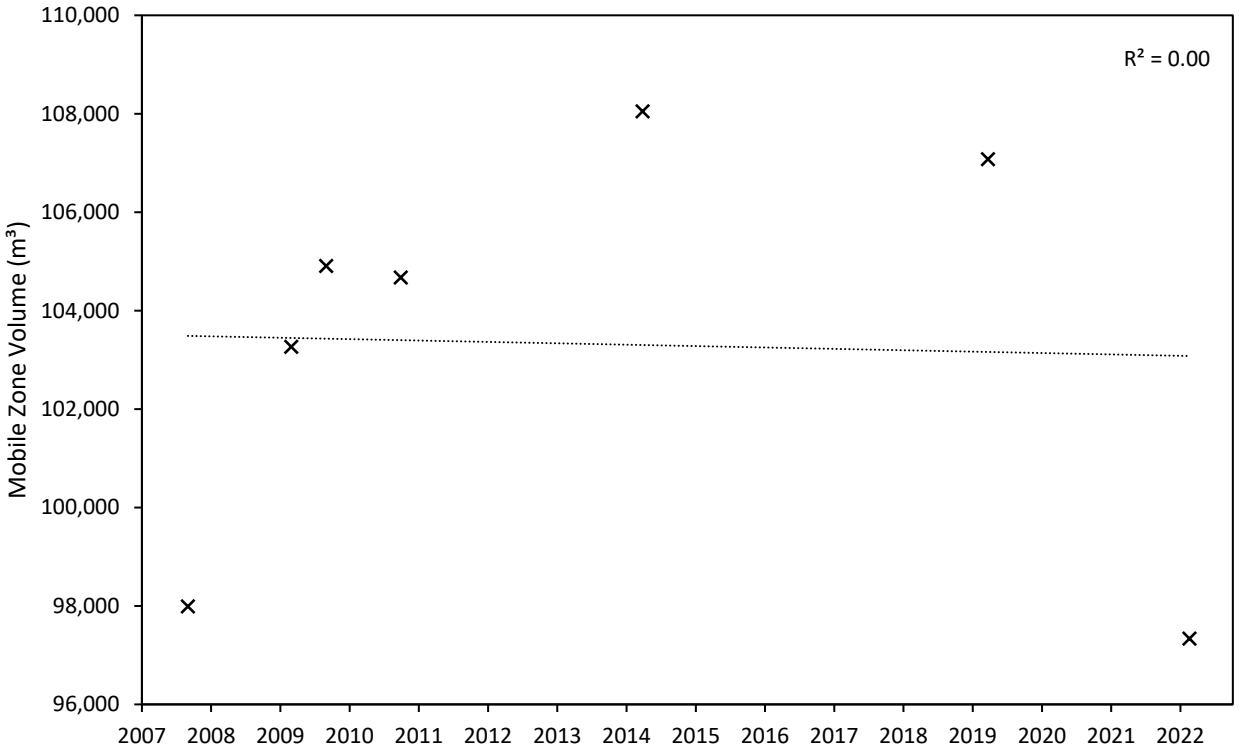


Figure 15 - Plot indicating beach volume (m^3) recorded in the Mobile Zone above MHWS (3.50 m OD) for each filtered LiDAR datasets between 2007 and 2022.

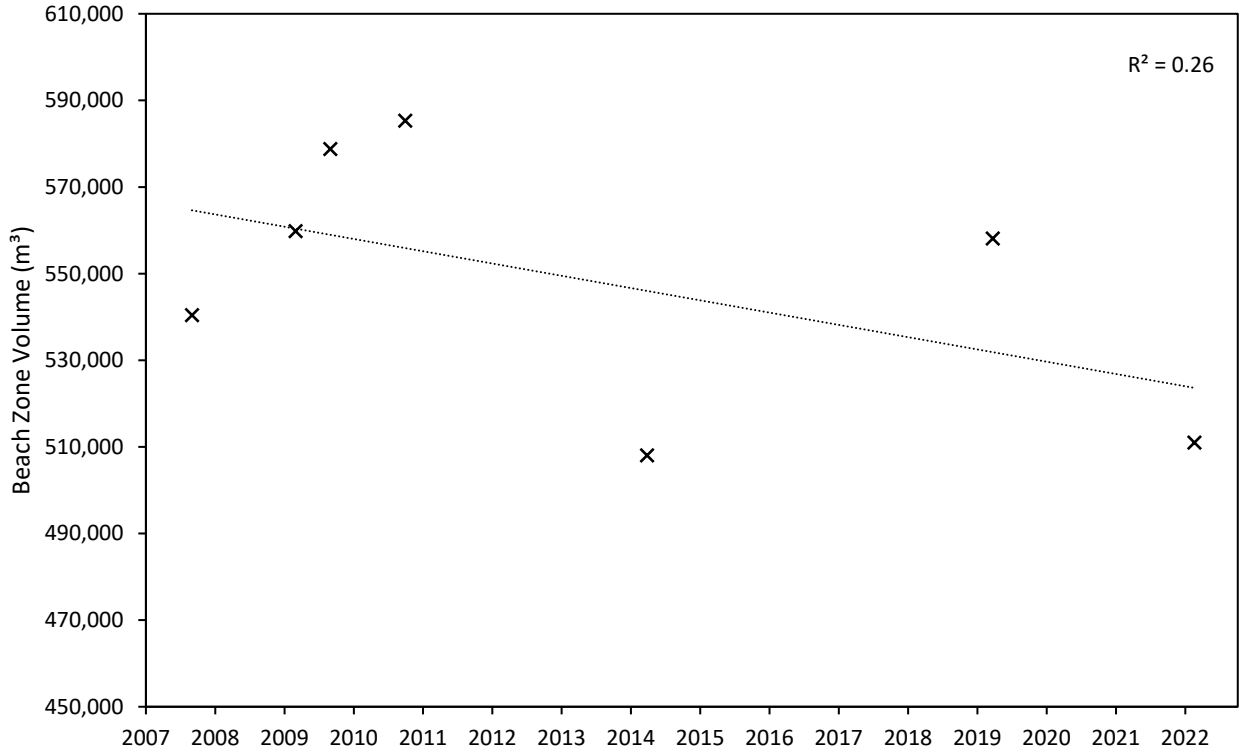


Figure 16 - Plot indicating beach volume (m^3) recorded in the Beach Zone above MLWS (-2.90 m OD) for each filtered LiDAR datasets between 2007 and 2022.

3.2.3 Contour Comparison

Figure 17 indicates the Mean Sea Level (MSL) and Dune Toe contours from the 2008, 2014, 2019 and 2022 LiDAR datasets. MSL contours agree with CPA and volumetric data, indicating a varying width of the beach from 2008 to 2022 by approximately 15-50 m. The Dune Toe contours have retreated by up to 24 m to the northern half of the beach.

3.3 Historic Aerial Maps

Historic aerial photography captured in 1947 by the RAF, in 2001 by the Environment Agency and from 2007 onwards by the SWCM are presented here.

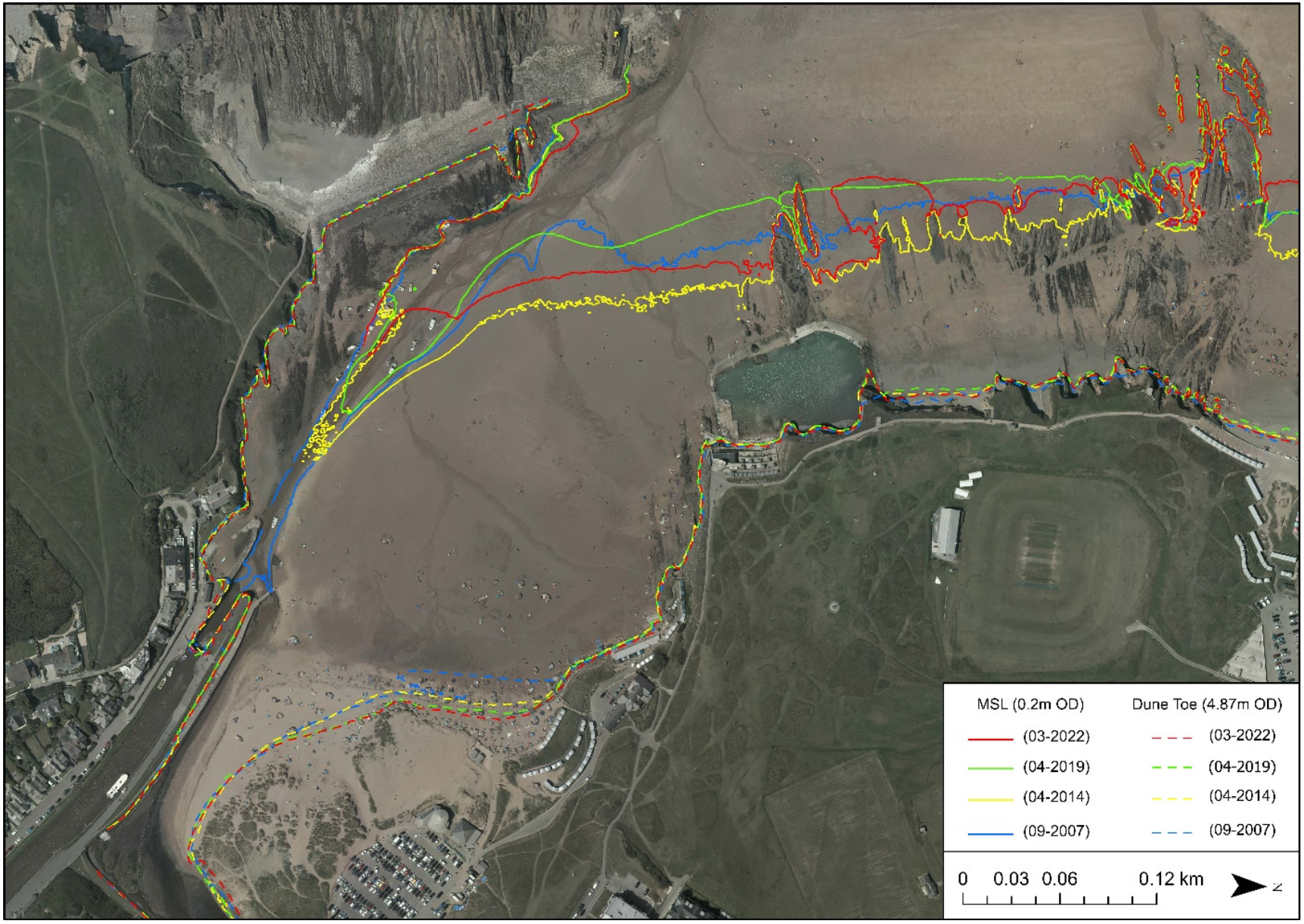


Figure 17 – Contour map indicating Mean Sea Level (solid line) and Dune Toe (dashed line) extracted from 2007, 2014, 2019 and 2022 LiDAR datasets.



Figure 18 – Aerial imagery from 1947.

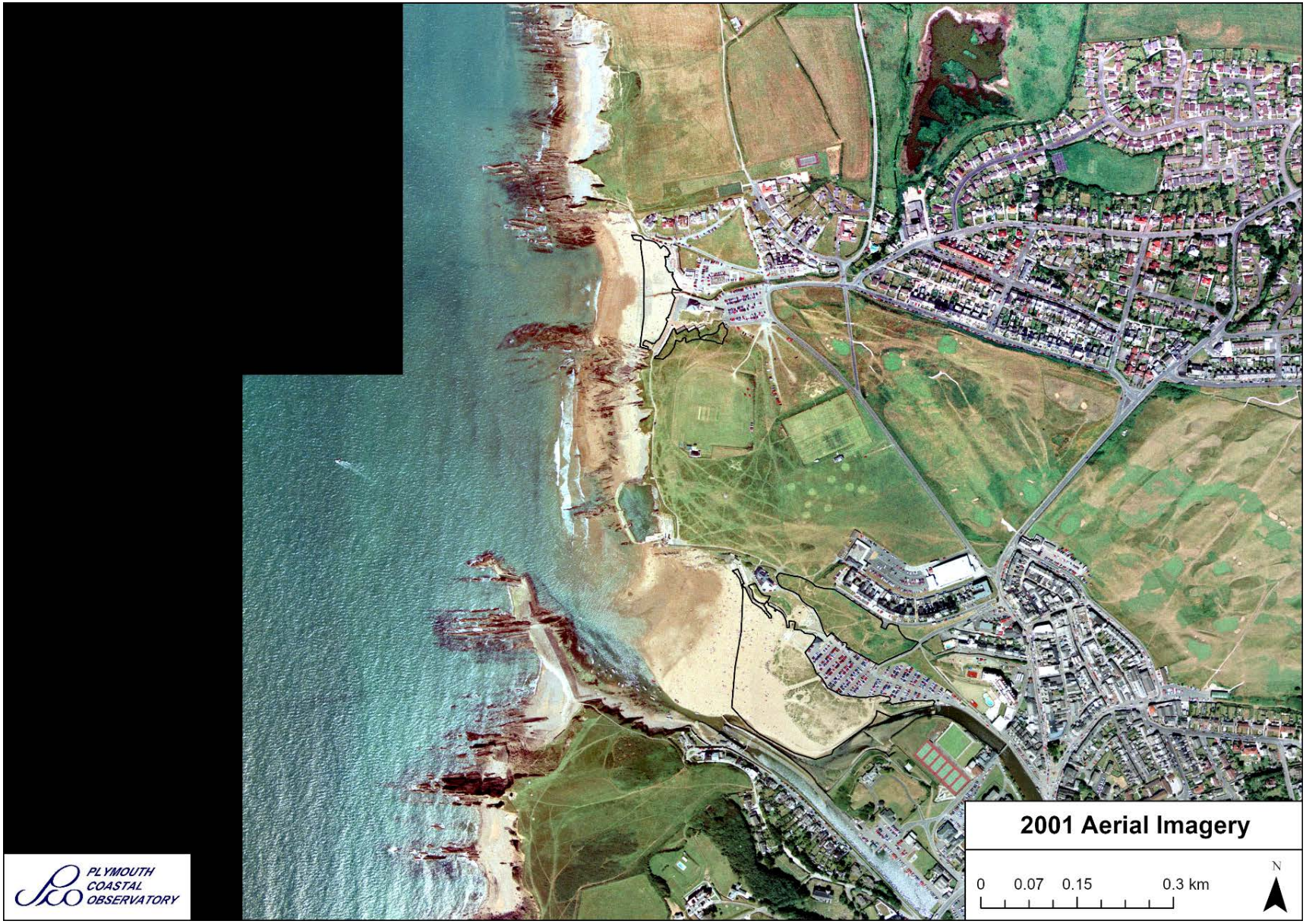


Figure 19 – Aerial imagery from 2001.



Figure 20 – Aerial imagery from 2006.



Figure 21 – Aerial imagery from 2010.



Figure 22 – Aerial imagery from 2014.



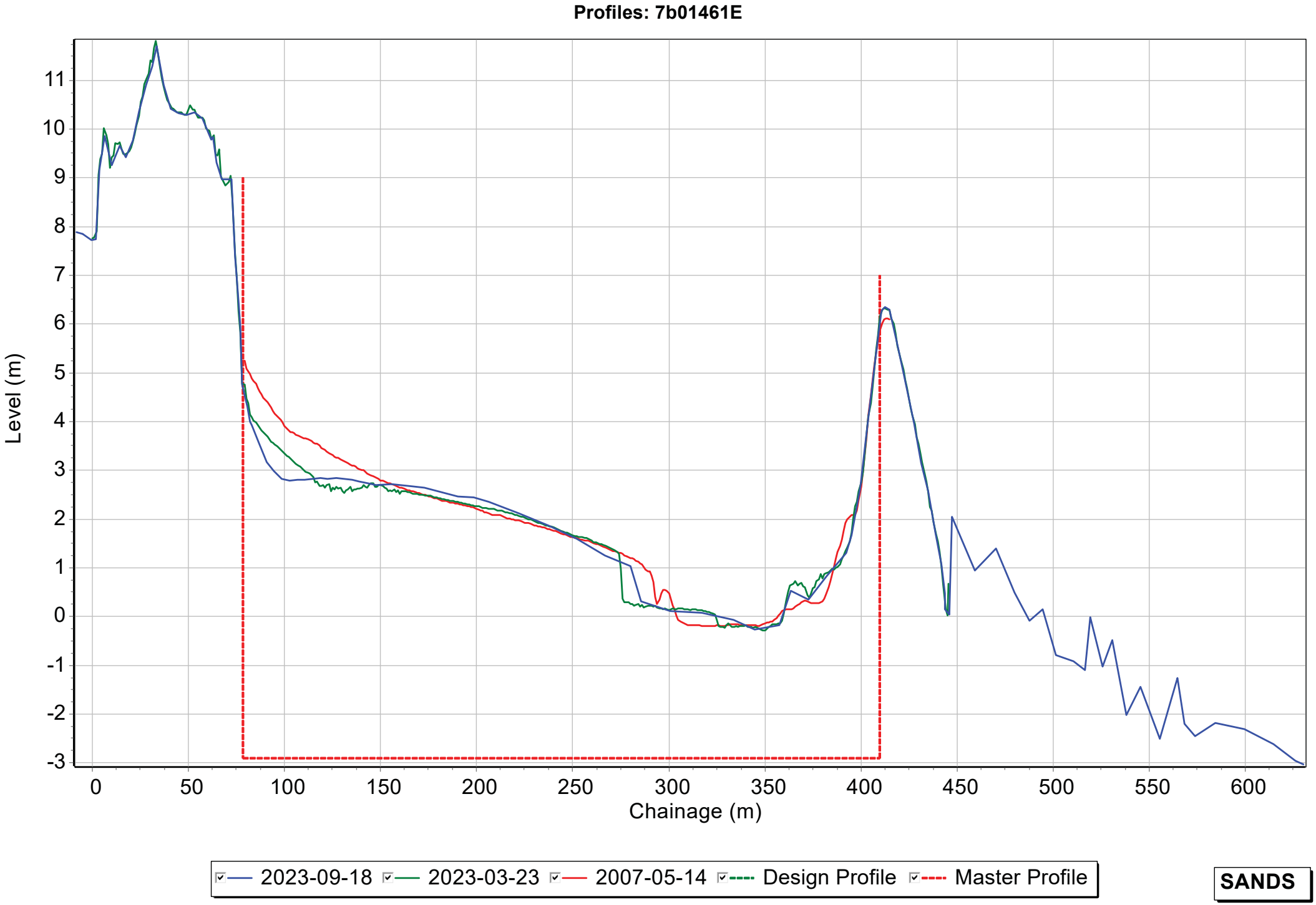
Figure 23 – Aerial imagery from 2017.

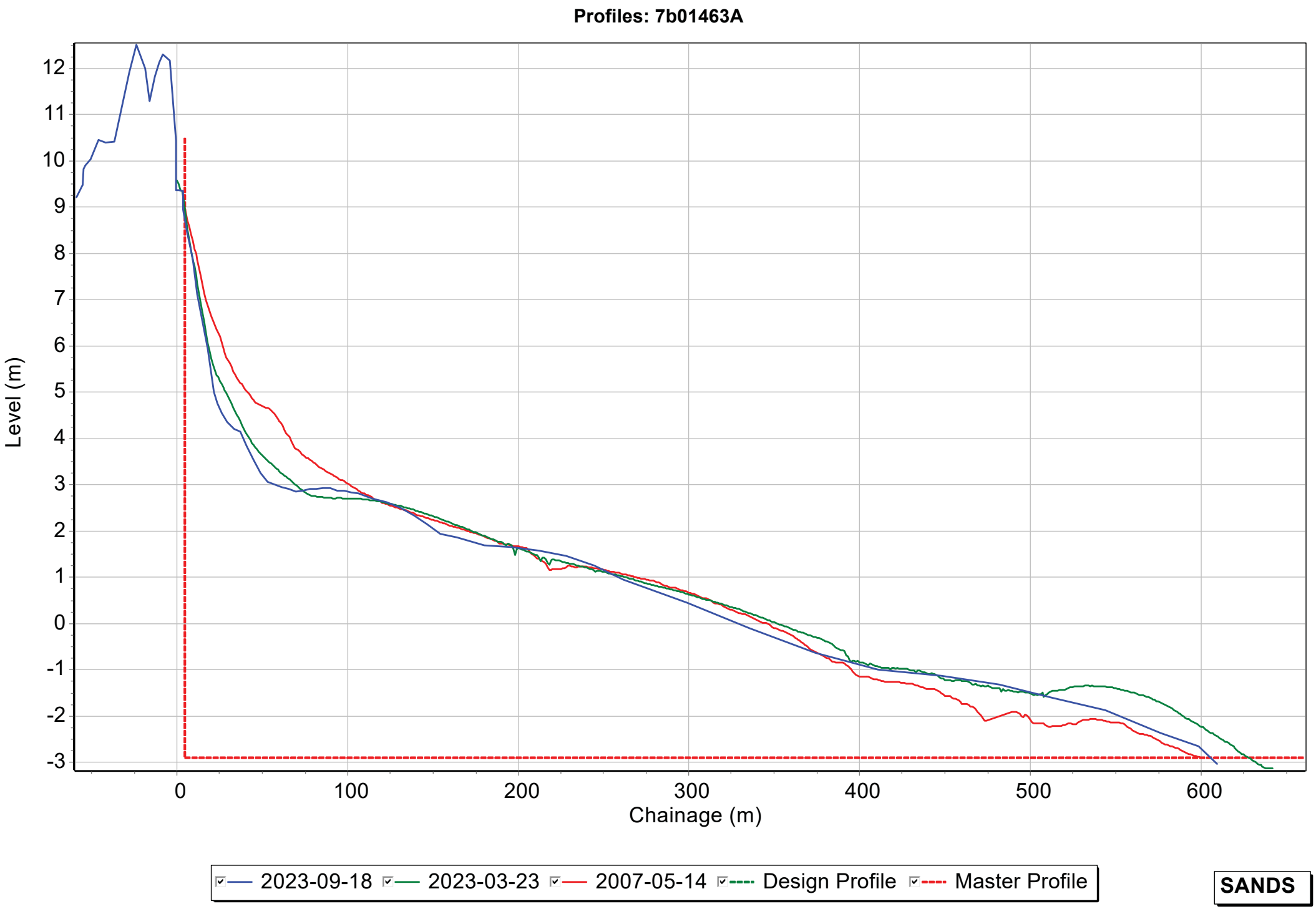
Glossary

1. Accretion: The net accumulation of deposited sediment, deposited by waves, tides or current.
2. Coastal Morphodynamics: The study of changes in coastal landforms and landscapes over time.
3. Contour Analysis: Mapping of contours from LiDAR datasets to represent Mean Sea Level (MSL) and Dune Toe elevations.
4. Cross-Sectional Area (CSA): The area of a two-dimensional cross-section of a cross-shore beach profile, running between Mean Low Water Spring and the back of the beach.
5. Developed Zone: Areas of urban development built atop previously present dune systems.
6. Difference Modelling: Comparison of separate LiDAR surfaces to produce a difference model of change based on gridded spot height elevations.
7. Digital Elevation Model (DEM) and Digital Terrain Model (DTM): DEM represents the Earth's surface with all features, while DTM represents the bare earth surface, excluding vegetation and structures.
8. Embryo Dune: The earliest stage of dune growth, typically found along the seaward extent of a dune system or newly formed dune.
9. Erosion: The process by which local sea level rise, strong wave action, and coastal flooding wear down or carry away rocks, soils, and sands along the coast.
10. Fixed Zone: Area defined by permanent dune vegetation, including scrub or invasive species, denoting vegetation atop sandy soil.
11. Intertidal Bar: A ridge or mound of sand, gravel, or other sediment deposited in the intertidal zone along a shoreline.
12. LiDAR: Light Detection and Ranging, a remote sensing method that uses light in the form of a pulsed laser to measure variable distances to the Earth.
13. Mean High Water Spring (MHWS): The height of mean high-water springs is the average throughout the year of two successive high waters during those periods of 24 hours when the range of the tide is at its greatest.
14. Mean Low Water Spring (MLWS): The height of the mean low-water springs is the average height obtained by the two successive low waters during the same period.
15. Mobile Zone: The area including the active dune face and embryo dune that is in motion due to wind action or other factors.
16. Root-Mean-Square Error (RMSE): A measure of the differences between values predicted by a model and the observed values.
17. Tidal Range: The vertical difference between high tide and low tide during a tidal cycle.

Appendices

Appendix 1 – Profile charts showing the cross-shore area of each interim profile from the most recent survey (blue), second most recent survey (green) and first survey, also known as the baseline (red) at Summerleaze are presented below.


Profiles: 7b01461E
Level (m)
11
10
9
8
7
6
5
4
3
2
1
0
-1
-2
-3
0
50
100
150
200
250
300
350
400
450
500
550
600
Chainage (m)
2023-09-18
2023-03-23
2007-05-14
Design Profile
Master Profile
SANDS


Profiles: 7b01463A
Level (m)
12
11
10
9
8
7
6
5
4
3
2
1
0
-1
-2
-3
0
100
200
300
400
500
600
Chainage (m)
2023-09-18
2023-03-23
2007-05-14
Design Profile
Master Profile
SANDS