Lincolnshire Coastal Change Report 2012 – 2018: Zone A and C

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www.coastalmonitoring.org/

Email: ACM@environment-agency.gov.uk

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Introduction

This technical note presents coastal survey data that has been collected in Zone's A and C of the Lincolnshire Interim Beach Management scheme (2018-2021) – formally Lincshore. This assessment of geomorphological change builds upon the Environment Agency's previous trends report for the 2008 – 2013 period, by extending the spatial analysis to 2018.

This report has been written and prepared by the Environment Agency's Anglian Coastal Monitoring Programme (ACMP), all coastal survey data mentioned has been collected by the ACMP and is available via the coastal monitoring website (coastalmonitoring.org).

In 1994 the Environment Agency commissioned an integrated project team to design and manage the Lincshore renourishment works. Since then, following the main beach reestablishment in 1996 to 1998, yearly recharge campaigns have been delivered.

Every year contractors survey the beach, compare its existing condition to the target profile and plan the year's replenishment work accordingly. For the past four years, an average of 500,000 m3 of sand has been placed each year at an annual cost of approximately £8 million (Royal Haskoning DHV, 2020).

Previous investigations in this area have predominantly focussed on Zone B, the Nourishment area. The trends observed in this area indicate hot-spots of erosion and the formation of alongshore ridges, behind which pools of standing water can form. Additionally, erosion of nourished material from the seaward edge of the beach is identified, while material is more easily retained on the berm.

The Saltfleet to Gibraltar Point Strategy Option Appraisal establishes trends for Zone A and Zone C. In general, Zone A has remained stable since the start of nourishment with some accretion occurring at points. It is deemed unlikely that a widespread northwards movement of sediment exists, moving material from the nourished beaches into Zone A. Aerial photographs and individual topographic transects provide evidence that material from Mablethorpe may have moved north in isolated incidents. It is assumed that the material accreting in Zone A is from further north or offshore. Severe storm conditions in December 2013 caused significant erosion of the dunes in Zone A with a loss of approximately 50,000m^3 (Environment Agency, 2019). The nourishment campaign was adjusted to replace this material through emergency action the following spring and the dunes have remained stable here since.

Zone C exhibits a similar trend of accretion to Zone A, with a spit and dune system present here since at least the mid-1700s. Zone C appears to be more dynamic than Zone A, being impacted by changes in the nourishment zone to the north and in The Wash to the south. The spit south of Skegness, and a ness feature, have been growing with the ness moving northwards, benefitting from a steady supply of sediment from the beaches to the north. It is suggested that up to 12% of the sediment added to the beaches in the nourishment zone has moved south into Zone C. Without this sediment, it is likely that the dunes would quickly become exposed to rapid erosion and would increase the risk of coastal flooding (Environment Agency, 2019). The annual recharge scheme is therefore benefiting the natural coastal protection assets in Zone C also, which increases the value of the scheme. Detailed modelling would be able to inform how much the of the sediment budget of Zone c is derived from Zone B.

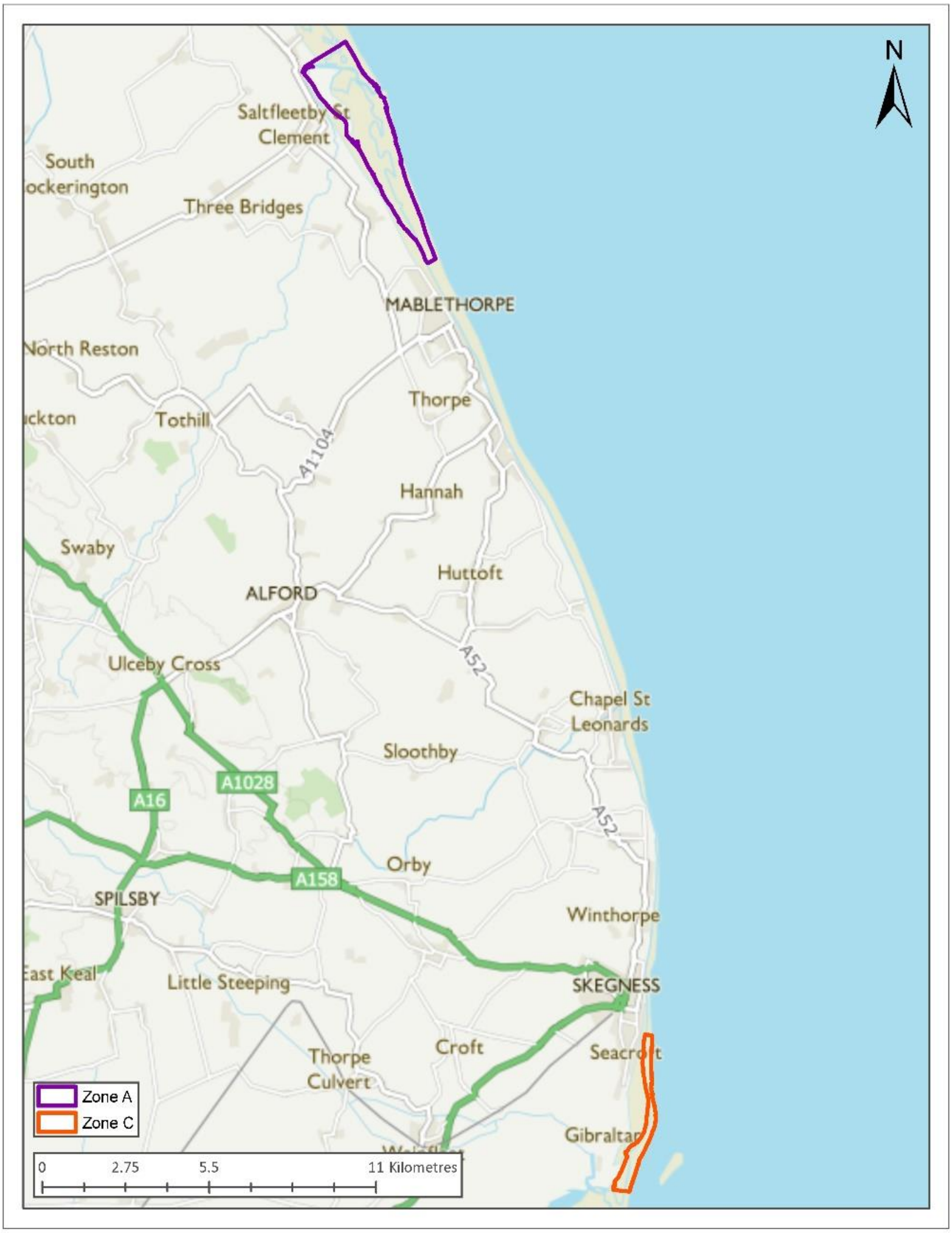


Figure 1: The extent of the analysis zones: Zone A and Zone C. Base map by Ordnance Survey. © Crown copyright and database rights 2020 Ordnance Survey 100024198.

Methodology

This study makes use of six airborne LiDAR surveys (3 per zone) from three years: 2012, 2016 and 2018. The surveys were captured on the dates shown in Table 1: All LiDAR surveys were captured with a spatial resolution of 1m with datasets adjusted to reduce systematic vertical error, which was found to be under 5cm in all datasets. The 2019 annual wavebuoy report for Chapel Point is included to provide additional context to the patterns of change highlighted in this technical note.

	2012	2016	2018
Zone A	13/12/2012	29/09/2016	07/10/2018
Zone C	15/12/2012	02/11/2016	11/10/2018

Table 1. Lidar Acquisition dates

Volume change analysis

Volume change analysis has been completed for both sites across three time periods using image differencing. These consisted of two intermediate periods of 2012 – 2016 and 2016 – 2018 and overall change from 2012 – 2018. Due to the spatial resolution of the LiDAR data (1 m), changes in elevation are herein assumed directly proportional to changes in volume (i.e. a decrease in height of 1 m is equal to 1 m^3 material eroded).

To ensure reliable results, an area of interest was defined between:

- The furthest seaward position of the mean low water neap (MLWN) line
- The furthest landward position of the highest astronomical tide (HAT) line – If accretion has caused the HAT to move seaward between two dates this ensures the change is included in analysis.

In addition, only pixels with valid data values across both LIDAR datasets were included. For example, if the first dataset had a No Data value and the second has a value of 5 then a reading of +5 m^3 would be falsely reported as change. Similarly, permanently vegetated areas, were not included in analysis as changes in vegetation height or vegetation would be incorrectly identified as erosion or accretion.

Following image differencing, the area was split by the locations used by ACM for topographic surveying, allowing analysis of spatial trends along the sites. Results of this are presented as percentages to enable meaningful comparisons between sites.

MLWN change analysis

Changes in the position of the MLWN are a useful indicator of change at the seaward edge of the beach. MLWN positional change was calculated using the ArcMap extension Digital Shoreline Analysis System (DSAS) (Himmelstoss *et al.,* 2018).

DSAS computes rate-of-change statistics across user generated transects for a time series of shoreline vector data. The MLWN lines – generated to define the area of interest – for each year were input into DSAS. Transects were cast with a 25-metre spacing – along an artificial onshore baseline, not the MLWN lines. DSAS generates a range of statistics including Linear Regression Rate (LRR) which fits a least squares regression line to the MLWN lines for each transect in the analysis. The slope of this line shows the rate of change which is reported in metres change per year. Transects were created digitally for the analysis herein, and should not be confused with the ground-based topographic surveys carried out biannually by ACM.

Results and Interpretation

Zone A

Volume Change

Figure 2 (below) shows change in beach volume for Zone A, between 2012 and 2018. A complex pattern of change emerges, and the most intense changes appear to the north of Zone A in the area surrounding Saltfleet Haven (distributary of River Eau which joins the sea here). There are areas of high accretion surrounding the banks of the northern channel while the main channel area shows pronounced erosion due to a slight change of the channel's direction. Further south, the stripes of red and blue in the figure indicate the onshore movement of sandbars over the 5 year period. Looking broadly over the whole of Zone A, the upper beach shows little change over the 5-year period. This suggests the dune system, identified in the preparation of the Saltfleet to Gibraltar Point strategy, remains stable and that the restorative work done following the 2013/14 winter storms has been effective (Environment Agency, 2019).

Figure 3 shows the percentage change in beach volume, between 2012 and 2018, from topographic survey data. This visualisation highlights the trend of sediment movement in Zone A; a dispersal of material from around the mouth of the River Eau towards Donna Nook in the north, and Theddlethorpe beach to the south. The southern portion of Zone A, being closest to the annually replenished Zone B, has benefitted from any northerly sediment drift, hence the increase in beach volumes closer to Mablethorpe.

Table 2 provides the statistics corresponding to Figure 3. Across the 21 profile zones there was an average increase in volume by 2.1 %. The maximum increase in volume was 21.7 % in zone 21 – second from the bottom.

The two figures showing volume change for the interim periods in Zone A (Figures 4 and 5), show a similar pattern to that seen in the overall change analysis described above. Erosion is more concentrated towards the north of the zone with most change occurring in the area surrounding Saltfleet haven. The ridges and gulley's in the south of Zone A are more clearly visible in the 2016-2018 period than the 2012-2016 period which may be as a result of the 2013 winter season, where the cluster of high-energy storms provided the conditions for additional sediment transport (Environment Agency, 2019).

Where is the equivalent table in Zone C?

Volume change metric	**Percentage change (%)**
Minimum	-10.2
Maximum	21.7
Average	2.1
Standard deviation	7.5
Count	21

Table 2: Zone A volume change statistics derived from zonal data

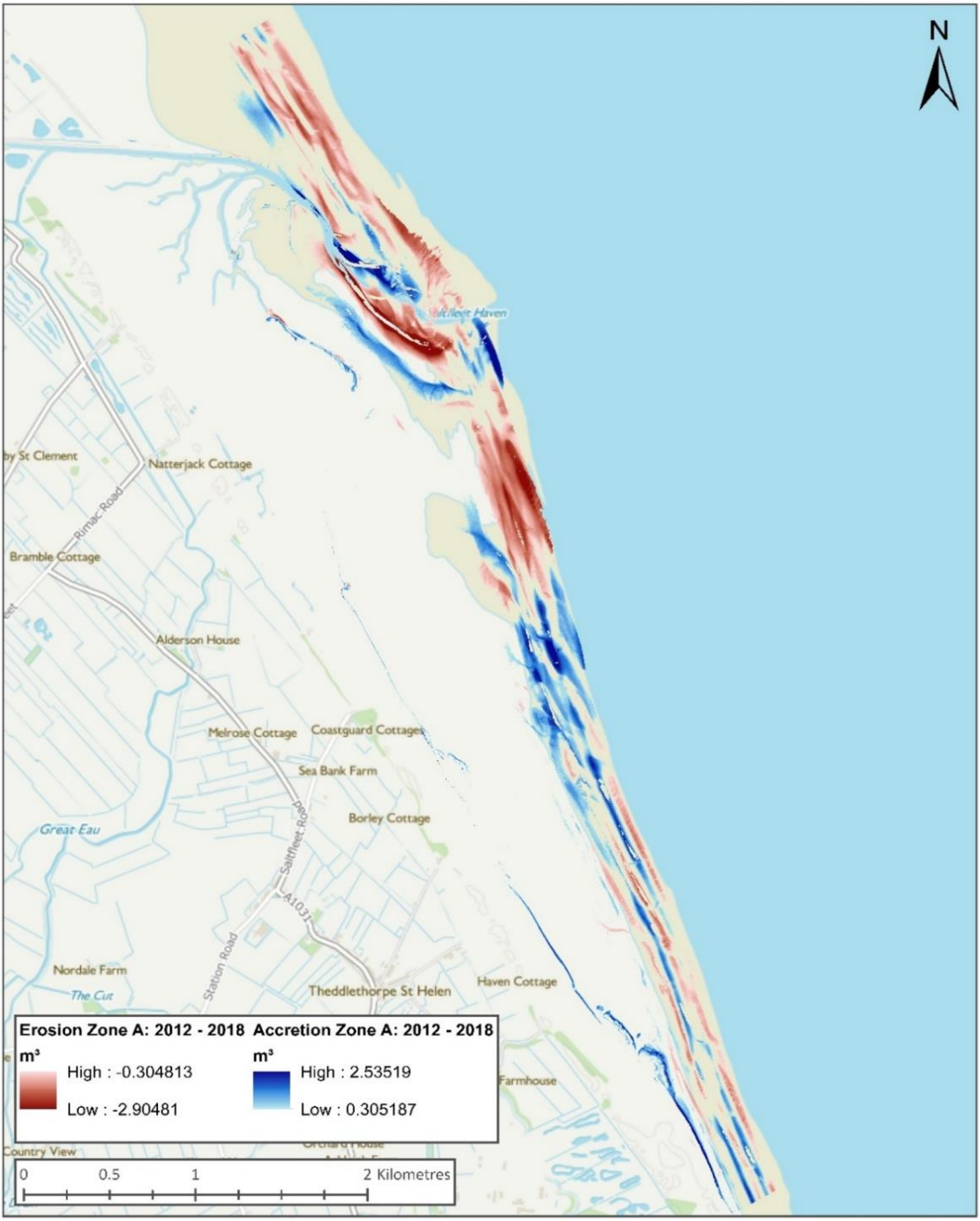


Figure 2: Zone A Change in volume 2012 - 2018

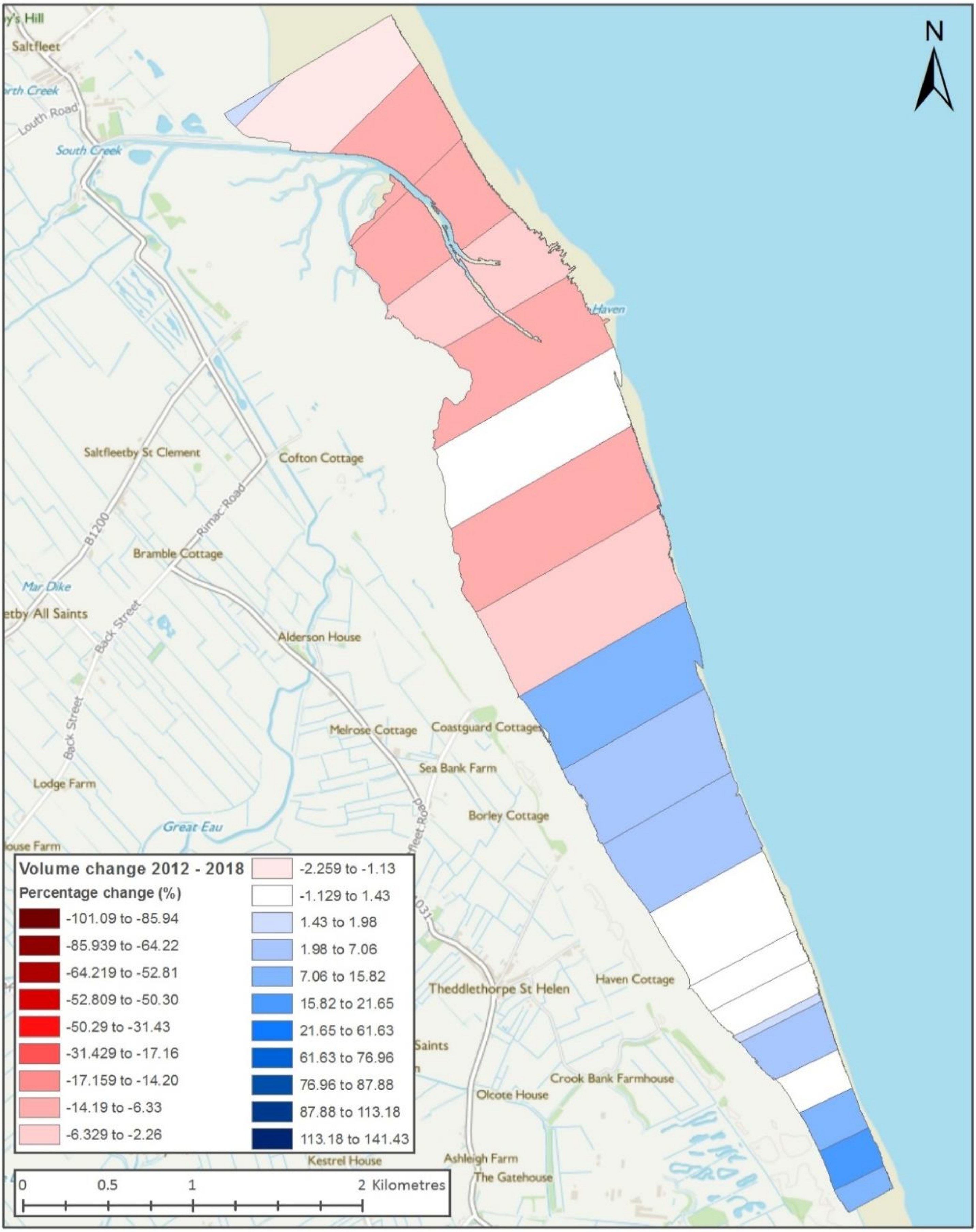


Figure 3: Percentage volume change by beach analysis zone from 2012 – 2018. Red zones depict zones of overall erosion, blue zones show zones of accretion, and white show zones of no significant change.

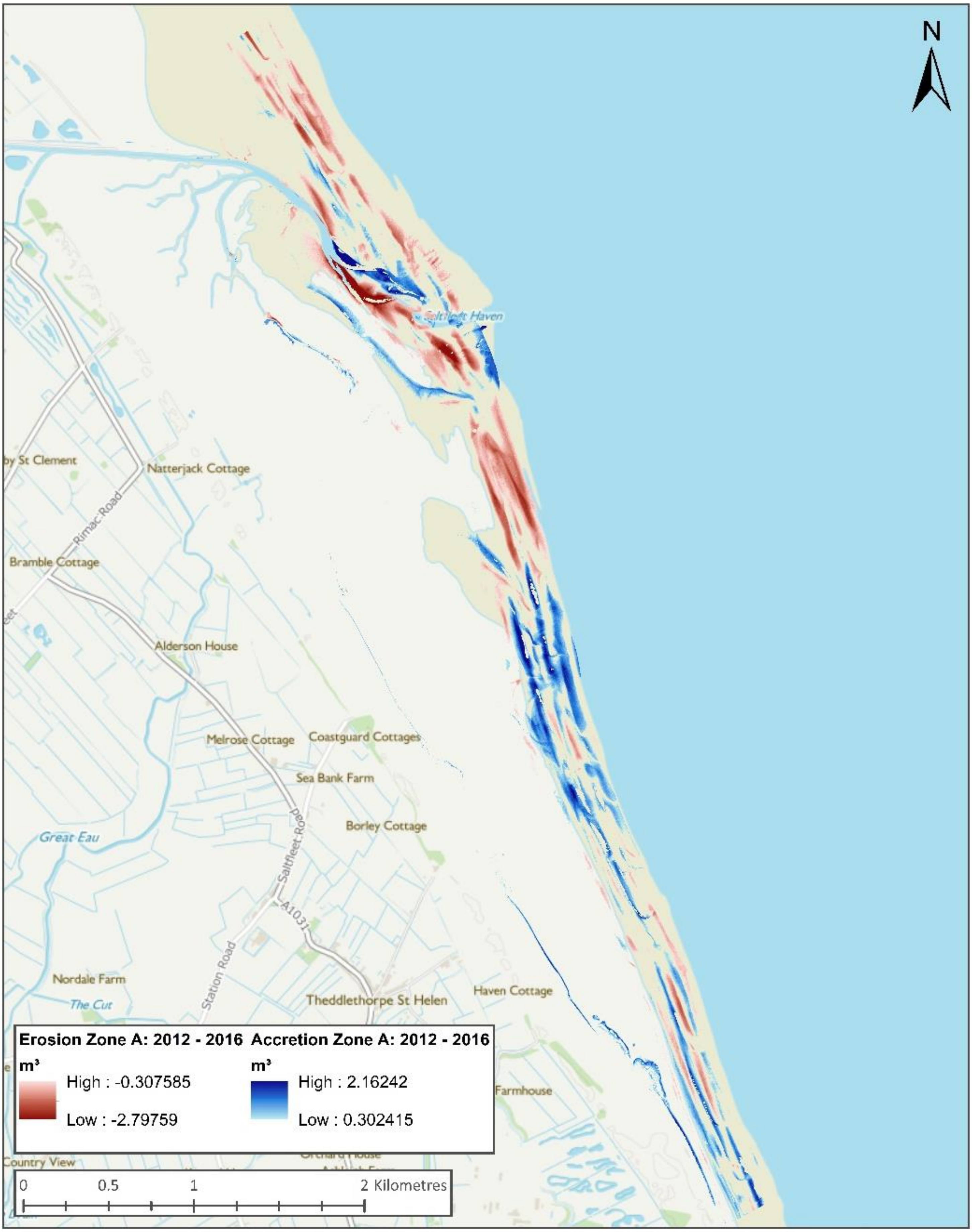


Figure 4: Zone A Change in volume 2012 - 2016

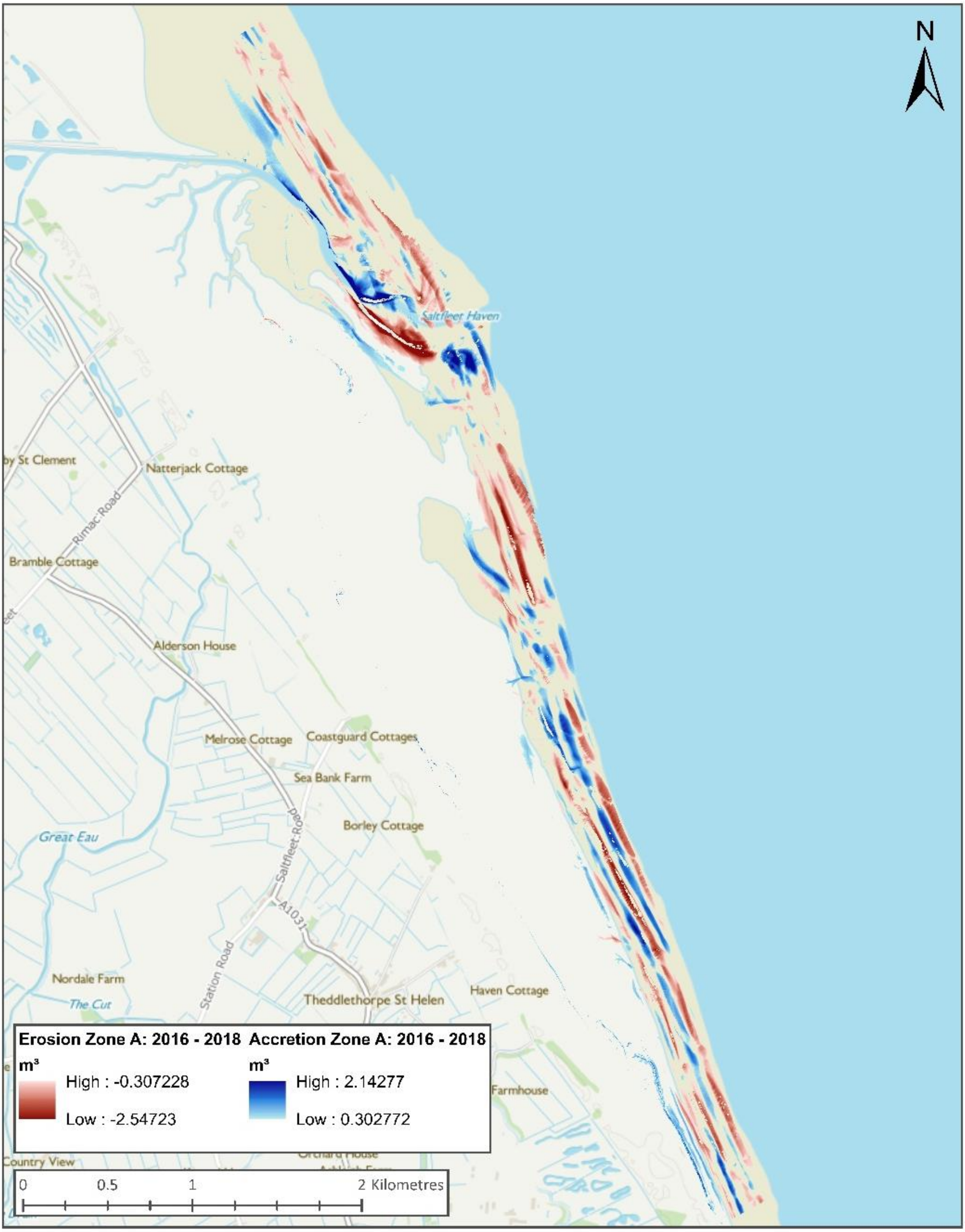


Figure 5: Zone A Change in volume 2016 - 2018

Mean Low Water Neap (MLWN) Change Analysis

Figure 6 (below) shows the results of the MLWN change analysis for the period between 2012 and 2018, in Zone A. The results align with the volume change analysis visualised in Figure 5, where large losses (i.e. landward movement of MLWN line) are around the main channel of the River Eau at Saltfleet Haven. The gains (seaward movement of MLWN contour) are found south of the river channel, with a large area of accretion stretching approximately 1.75 km south of the channel towards Theddlethorpe.

Figure 7 shows the Linear Regression Rate (LRR) values for each transect, equivalent to the average rate of change over time (in meters per year), the positive numbers (blue lines) represent accretion, and the negative numbers (red lines) represent erosion. Table 3 provides descriptive statistics of the MLWN analysis in Zone A. The greatest loss was found in transect 78 at a rate of -28.3 m/yr whereas the biggest gain was found in transect 94 at a rate of 18.6 m/yr. The overall average across 325 transects, a distance of 8125 m, was -4.1 m/yr, with 271 transects incurring losses of material. This result may appear in contrast with the overall volume change analysis (in Table 2) which found a net gain in volume over Zone A, because this analysis focuses purely on the intertidal foreshore.

LRR metric	change (m/year)
Minimum	-28.3
Maximum	18.6
Average	-4.1
Standard deviation	7.3
Count	325

Table 3: Descriptive statistics for the MLWN change analysis covering the years 2012, 2016, and 2018.

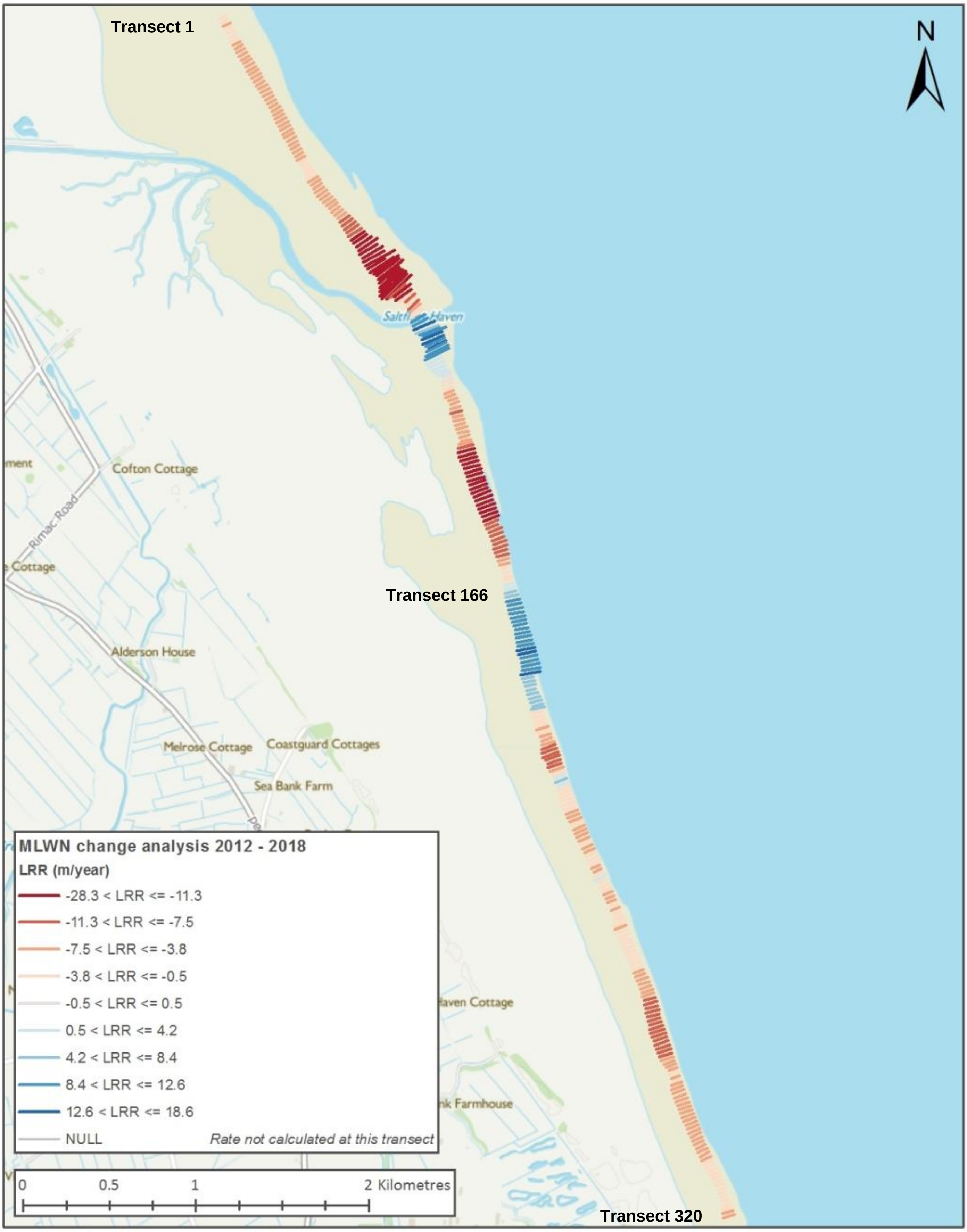


Figure 6: MLWN change analysis for zone A from 2012 to 2018. Values are presented as metres per year. The transect lines have been clipped to the seaward boundary and the baseline, therefore the length of these transects do not represent exact physical change.

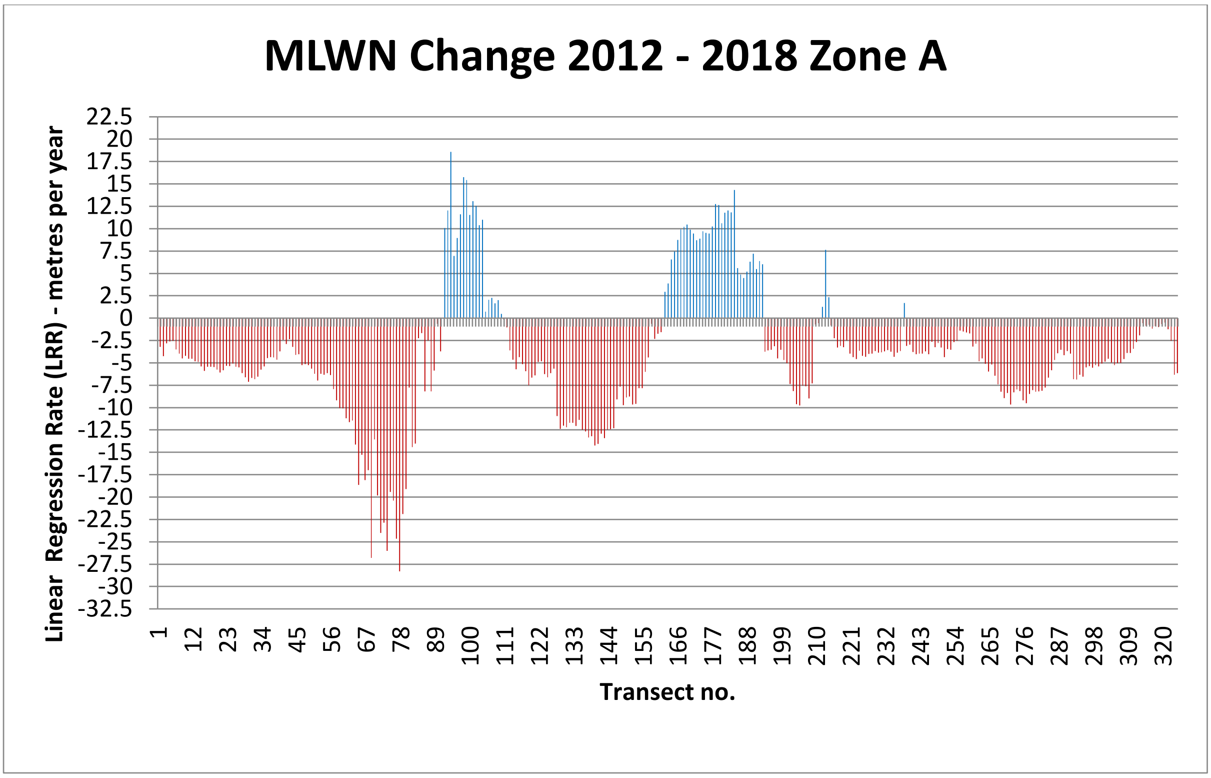


Figure 7: MLWN change from 2012 to 2018 for zone A. The transects run north to south (refer to Figure 6) and have a spacing of 25 m. Change is represented as metres per year, positive numbers (blue lines) represent accretion and negative numbers (red lines) represent erosion.

Zone C

Volume Change

The overall change in beach volume for Zone C between 2012 and 2018 is illustrated in Figure 8 (below). A loss of beach material from the upper beach has occurred between Seacroft and the Ness. It is likely that this material has been transported southwards, with the prevailing drift direction, and added to the significant area of accretion around the Gibraltar Point nature reserve in the centre of Zone C. Material may also be moving into this zone from the nourished area of the coastline in Zone B. This supports the findings of the research completed in preparation of the Saltfleet to Gibraltar Point strategy (Environment Agency 2019).E The southern area of Zone C shows erosion of the upper beach with a distinct deepening of a river channel that runs south past the visitor's centre It is possible that the accretion seen in the centre of the zone is being fed by material from further north where widespread erosion is visible.

Figure 9 shows the percentage change for each cell that Zone C has been divided in to for this analysis. When compared to Figure 3 - the equivalent visualisation for Zone A, much greater volumes of material are moving along the frontage, and therefore it is a more dynamic, than Zone A. The sediment budget is nearly balanced, as the figures convey both erosion and depositional processes are active in this Zone.

The volume change between 2012 and 2016 (Figure 10) shows similar patterns of erosion and accretion to the overall volume change analysis. However, the majority of accretion is slightly further south than in Figure 11 suggesting that the ness feature is still growing and/or migrating north.

The northern end of Zone C, near Seacroft, shows a similar striped pattern of erosion and accretion as seen in the south of Zone A (Figure 4). This pattern is reversed in the 2016 to 2018 image (Figure 6) and not present in the 2012 to 2018 image which indicates the sediment flux in this area is variable, but suggests a balance between losses and gains over the medium to long term.

Volume change analysis between 2016 and 2018 shows similar trends to those described for the longer 2012-2016 period. However, there is less widespread accretion and slightly greater erosion, particularly on the northern edge of the accreting feature. This is likely to be due to the shorter time period, which included the cluster of high magnitude storms in Winter 2013/14, allowing less time for any episodically derived changes to balance out.

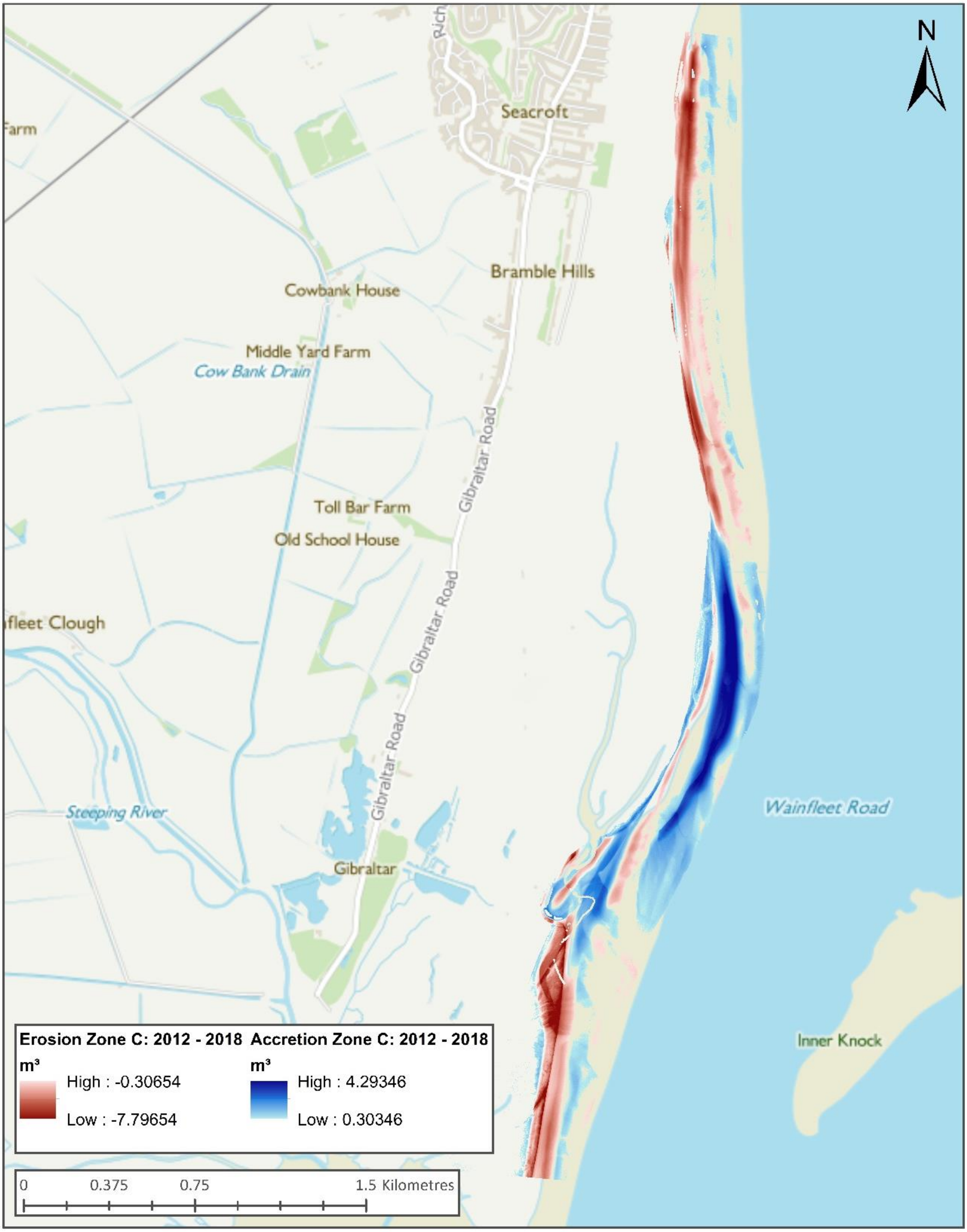


Figure 8: Zone C Change in volume 2012 - 2018

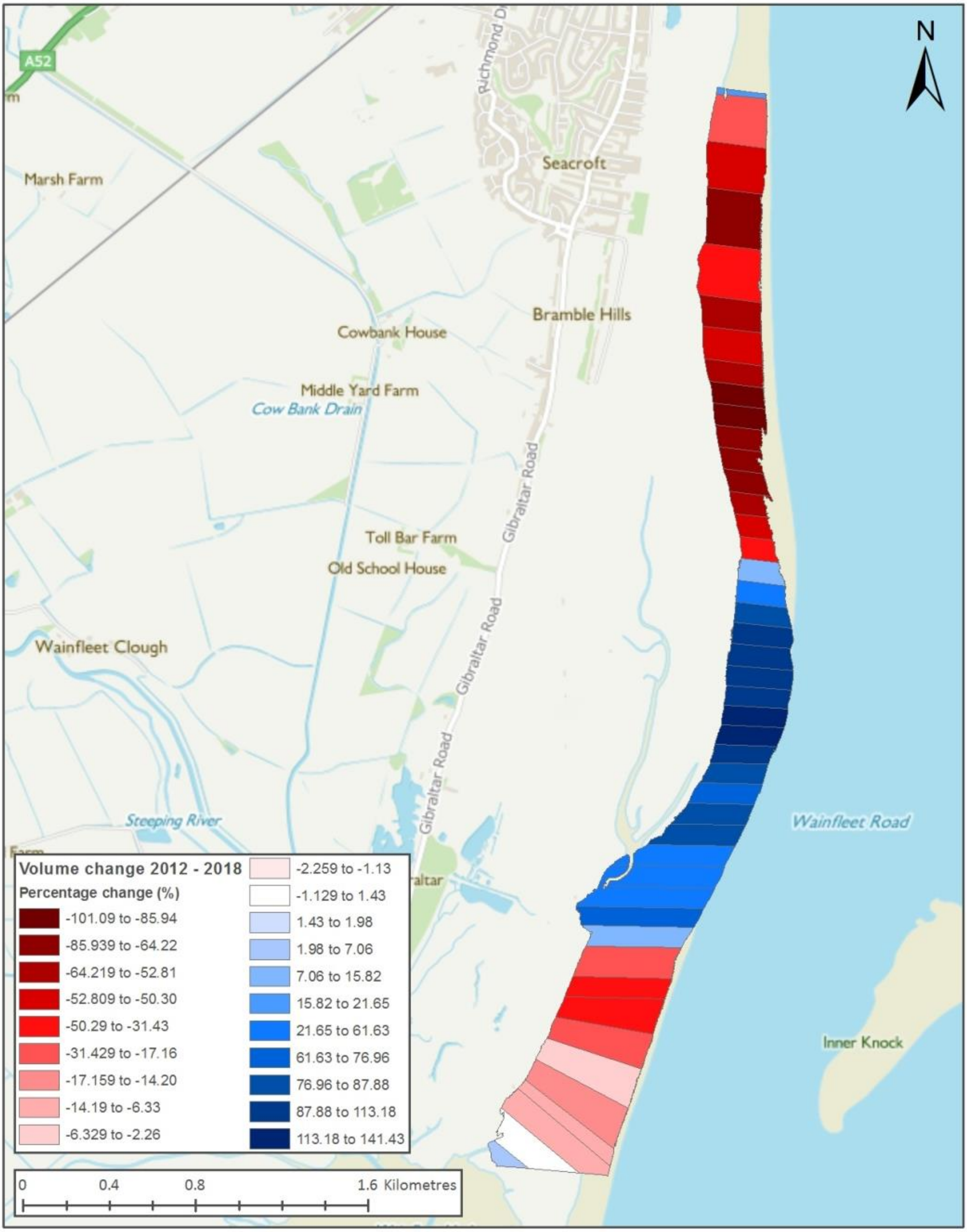


Figure 9: Percentage volume change by beach analysis zones from 2012 – 2018. Red zones depict zones of overall erosion, blue zones show zones of accretion, and white show zones of no significant change.

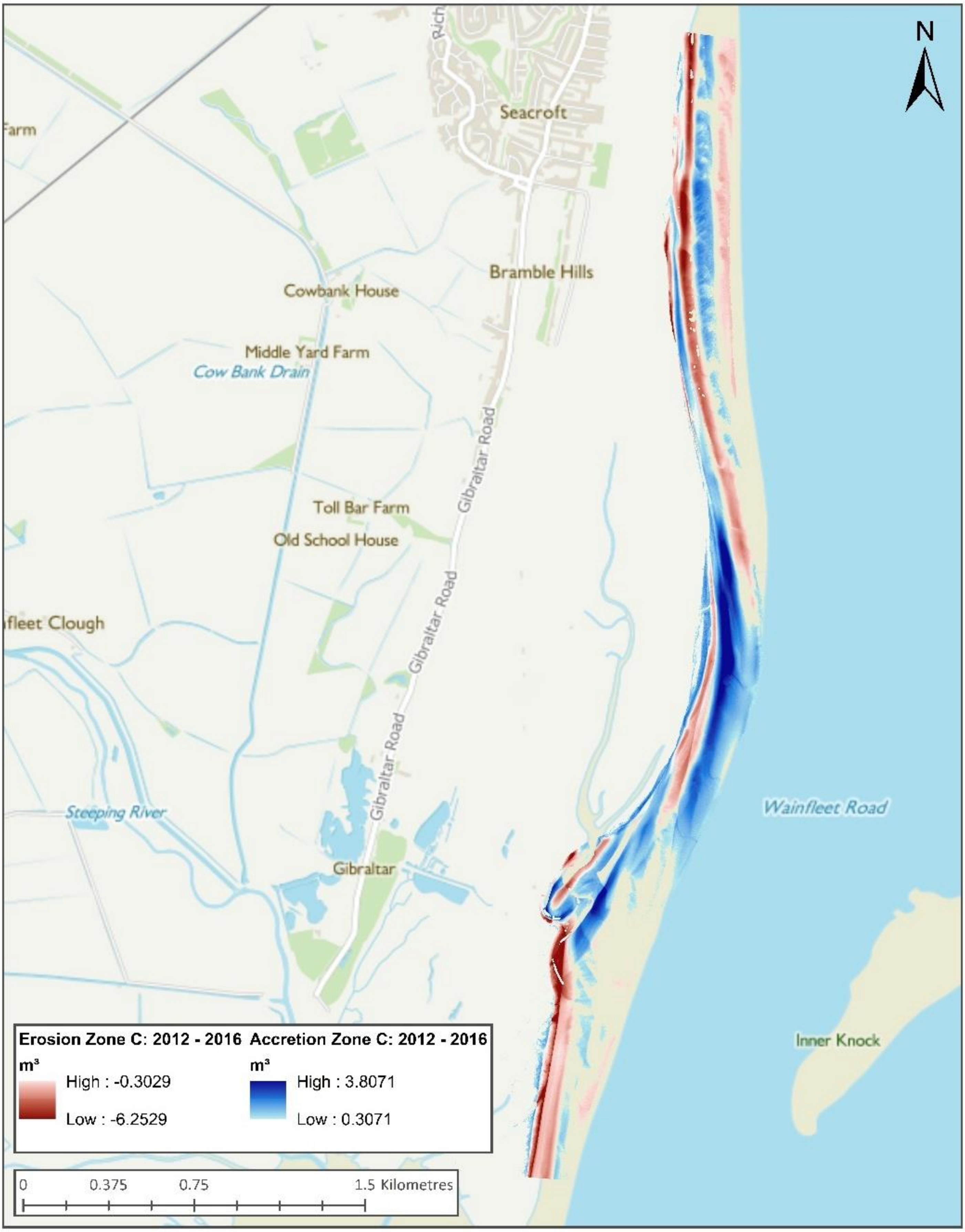


Figure 10: Zone C Change in volume 2012 - 2016

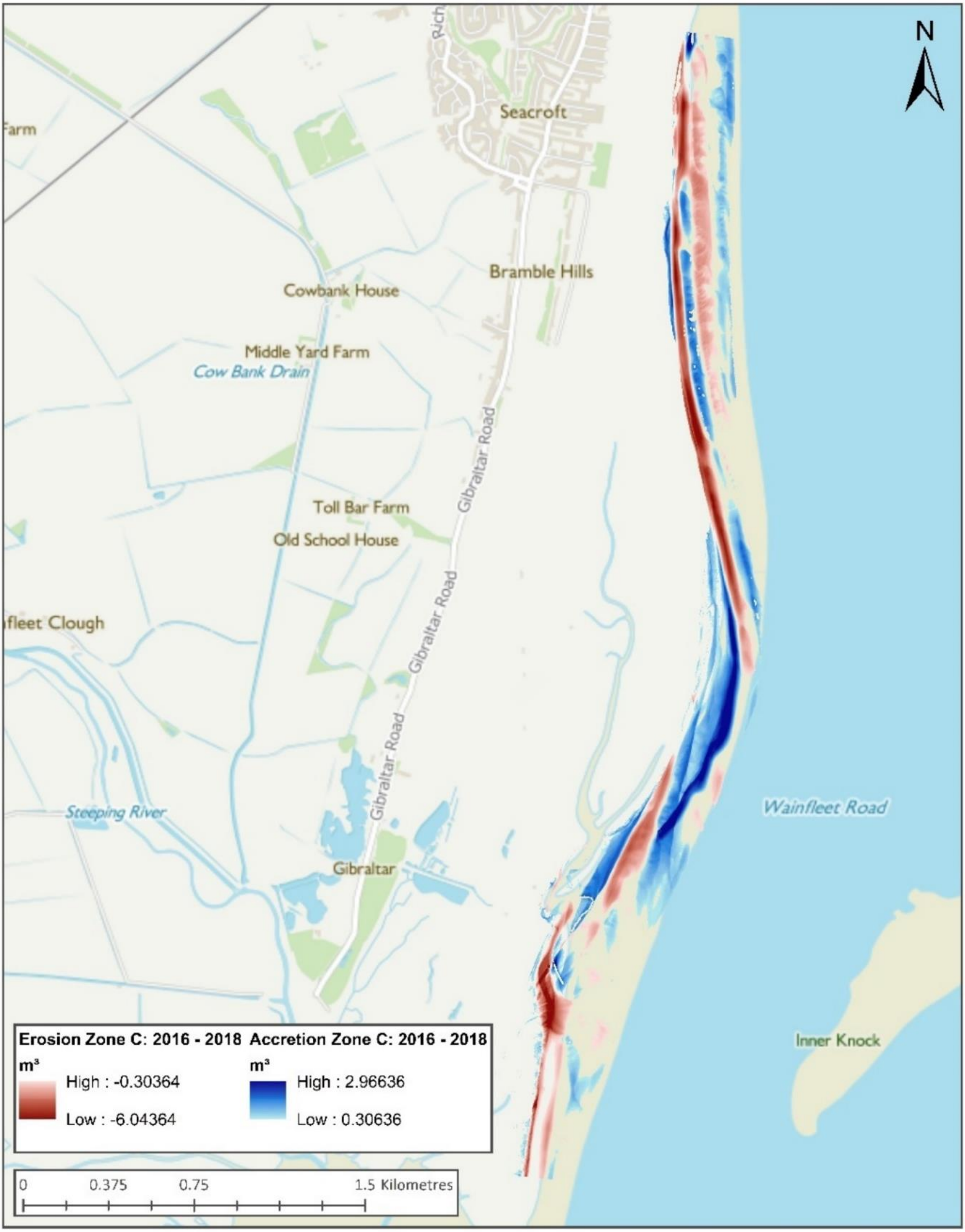


Figure 11: Zone C Change in volume 2016 - 2018

Hydrodynamics

The following data tables and analysis summarise the data collected by the Anglian Coastal Monitoring Programme's Directional WaveRider Buoy at Chapel Point. The summary has been prepared by the Channel Coastal Observatory on behalf of the ACMP.

See https://coastalmonitoring.org/realtimedata/ for real time and historic wave buoy data from the Chapel Point buoy situated offshore from Chapel St Leonards.

Chapel Point Directional WaveRider Buoy

Location	
OS	563362 E 374881 N
WGS84	*Latitude:* 53° 14.75' N *Longitude:* 00° 26.81' E
Instrument type	
Datawell Directional Waverider Mk III	
Water depth	~13m CD

Example buoy in situ. Photo courtesy of Fugro Marine GB Limited

Location of buoy (Google mapping, image ©2019 Landsat / Copernicus)

Data Quality

Recovery rate (%)	Sample interval
97	30 minutes

Hs	Significant Wave height is the average of the highest third of waves (meters)
Tp	Peak Wave Period (seconds)
Tz	Wave period spectrally calculated at zero crossing point (seconds)
Dir	Direction of wave approach (degrees)
SST	Sea Surface Temperature

Monthly Averages – 2019

All times are GMT

Month	H_s (m)	T_p (s)	T_z (s)	Dir. (º)	SST (ºC)	Bimodal seas (%)	No. of days
January	1.00	8.5	4.4	62	6.0	-	30
February	0.61	6.7	3.9	99	-	-	28
March	0.82	7.6	4.1	101	7.1	-	31
April	0.83	5.7	3.8	74	9.3	-	30
May	0.75	7.5	4.2	53	12.3	-	30
June	0.67	5.2	3.4	100	15.4	-	29
July	0.59	5.6	3.7	93	18.4	-	31
August	0.57	4.6	3.2	139	18.8	0	30
September	0.72	5.9	3.6	108	16.6	1	30
October	0.84	6.2	3.7	97	13.2	7	31
November	1.05	6.9	4.4	72	9.4	2	27
December	0.73	6.2	3.6	114	6.9	3	30

Monthly Averages - All Years (June 2012 – December 2019)

Month	H_s (m)	T_p (s)	T_z (s)	Dir. (º)	SST (ºC)	Bimodal seas (%)
January	0.87	6.9	4.0	100	5.6	-
February	0.87	6.7	4.0	98	4.9	-
March	0.85	6.9	4.0	93	6.0	-
April	0.76	6.3	3.8	82	8.6	-
May	0.75	6.1	3.8	83	11.9	-
June	0.64	5.7	3.7	86	14.9	-
July	0.56	4.8	3.4	107	17.9	-
August	0.57	5.0	3.3	119	18.5	-
September	0.67	5.6	3.6	96	16.6	-
October	0.90	6.0	3.8	99	13.5	-
November	0.93	6.3	4.0	103	9.9	-
December	0.81	6.4	3.7	121	7.3	-

Storm Analysis

Date/Time	H_s (m)	T_p (s)	T_z (s)	Dir. (°)	Water level elevation* (OD)	Tidal stage (hours re. HW)	Tidal range (m)	Tidal surge* (m)	Max. surge* (m)
27-Jan-2019 20:30:00	3.75	11.8	6.5	18	0.95	HW -2	4.40	-	-
04-May-2019 15:30:00	2.94	9.5	5.6	51	-0.45	HW -3	5.10	-	-
09-Jan-2019 06:30:00	2.87	10.0	5.5	7	1.65	HW -2	4.80	-	-
09-Dec-2019 13:30:00	2.82	10.0	5.6	25	0.35	HW -3	4.20	-	-
11-Jun-2019 10:00:00	2.78	7.7	5.0	72	1.55	HW -1	3.80	-	-
17-Jan-2019 14:00:00	2.67	10.0	5.4	18	1.65	HW -1	3.40	-	-

** Tidal information is obtained from the predicted tide levels (Admiralty Total Tide).*

Annual Statistics

Year	Annual H_s exceedance (m)						Annual Maximum H_s	
	0.05%	0.5%	1%	2%	5%	10%	Date	A_{max} (m)
2012	2.97	2.37	2.17	1.92	1.52	1.22	27-Oct-2012 05:00:00	3.16
2013	3.45	2.71	2.56	2.34	1.86	1.49	10-Oct-2013 19:30:00	3.63
2014	2.50	2.09	1.89	1.68	1.41	1.22	02-Dec-2014 12:00:00	2.67
2015	3.10	2.08	1.88	1.70	1.43	1.23	21-Nov-2015 12:00:00	3.54
2016	3.20	2.42	2.19	1.95	1.63	1.38	14-Jan-2016 20:00:00	3.49
2017	3.23	2.72	2.53	2.30	1.94	1.63	13-Jan-2017 17:00:00	3.59
2018	2.88	2.28	2.10	1.86	1.49	1.26	27-Oct-2018 16:30:00	3.17
2019	3.06	2.47	2.18	1.93	1.59	1.33	27-Jan-2019 20:30:00	3.75

The table above shows the expected recurrence of waves that exceed the average height (Hs) values in the table. A higher percentage equates to more frequent occurrence of these wave heights. The largest waves are the least frequently recorded, and hence have the lowest annual exceedance probability. Example using data from table: *5 % of waves measured in 2012 exceeded an average height of 1.52, and 10% exceeded 1.22m*

Significant wave height return periods

Return periods for significant wave height can be calculated since the buoy has been deployed for more than 5 years. The return periods are based on 0.5 hourly records and are calculated for periods up to 10 times the record length using a peaks-over-threshold method and Generalised Pareto Distribution (GPD).

Observation period	May 2012 to December 2019	
Return period (years)	**Significant wave height (m)**	**Comments**
0.25	2.67	No depth limitation
1	3.23	
2	3.41	
5	3.59	
10	3.69	
20	3.76	
50	3.84	

Distribution plots

The distribution of wave parameters are shown in the accompanying graphs/tables of:

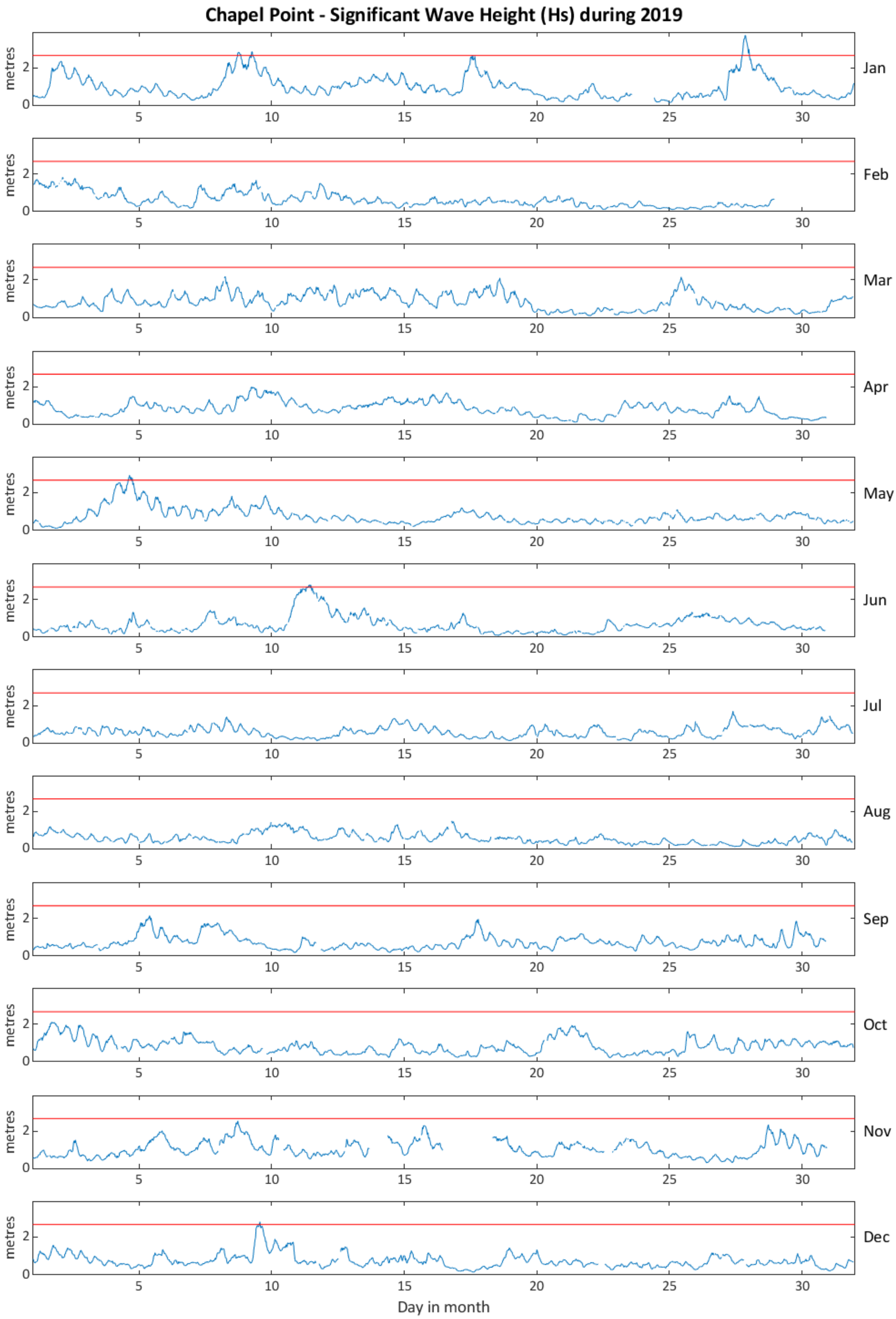
- Annual time series of H_s (red line is 2.67 m storm threshold)
- Incidence of storm waves for 2019. Storm events are defined using the Peaks-over-Threshold method. The highest H_s of each storm event is shown
- Wave height exceedance each year since deployment
- Percentage of occurrence of H_s, T_p, T_z and Direction for 2019
- Wave rose (percentage of occurrence of direction vs. H_s) for all measured data
- Joint distribution of all parameters for all measured data, given as percentage of occurrence

General

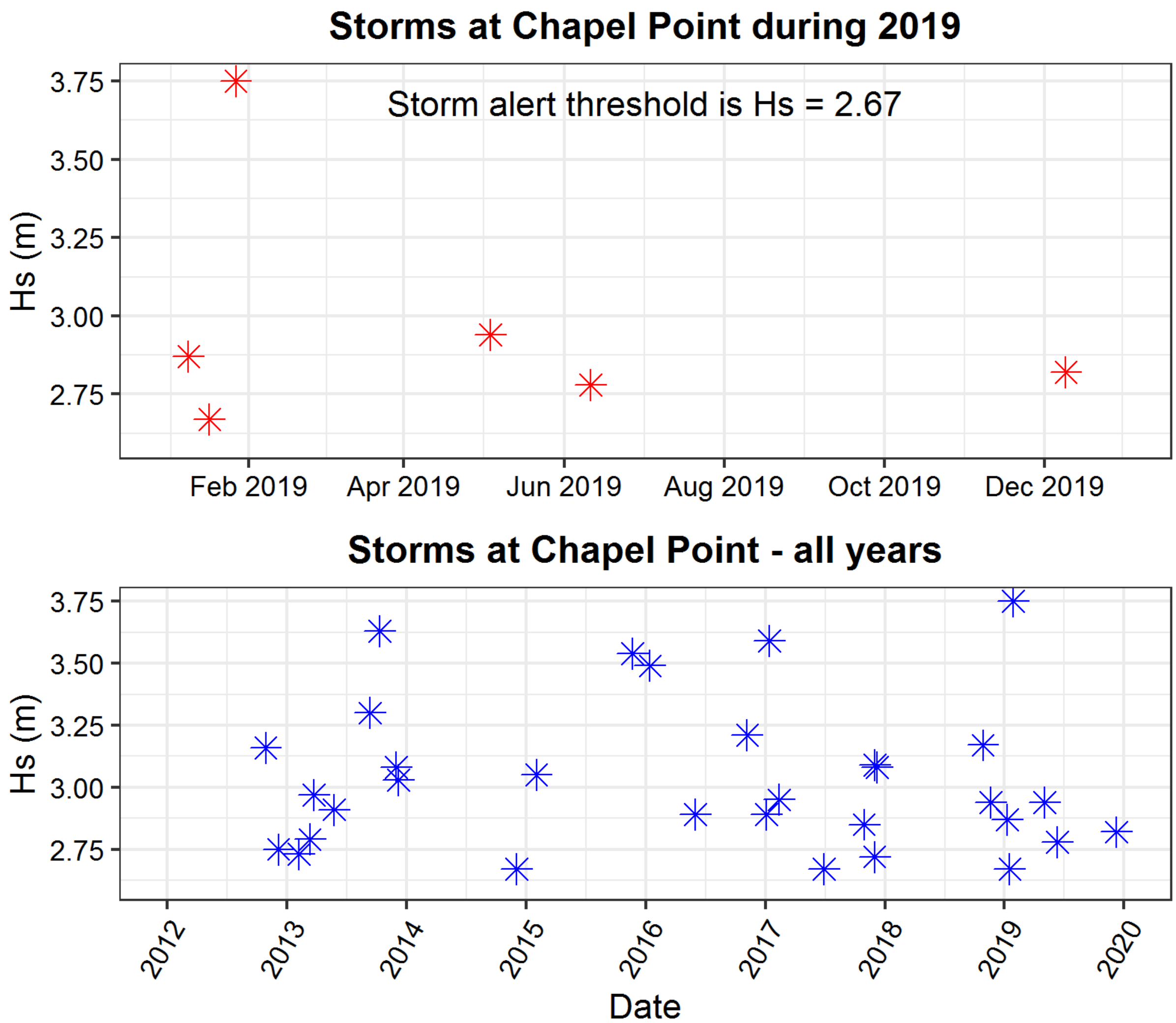
The buoy, owned by the Environment Agency, was first deployed on 04 September 2012, at which time the magnetic declination at the site was 1.43° west, changing by 0.18° east per year.

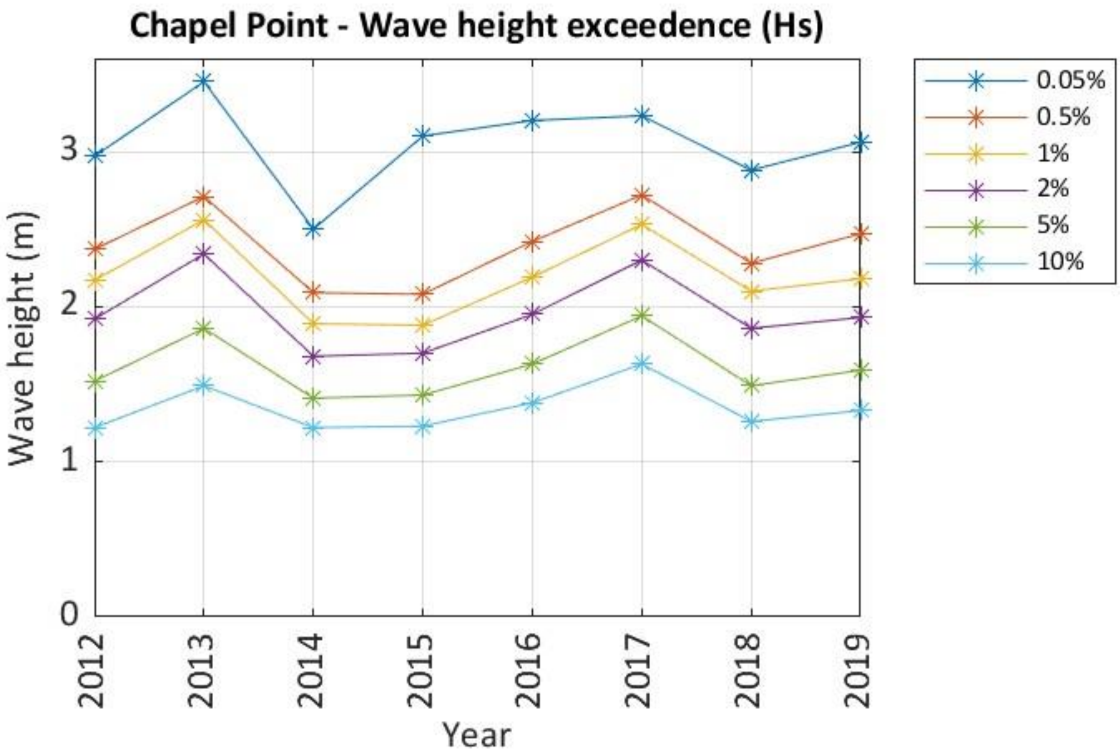
Acknowledgements

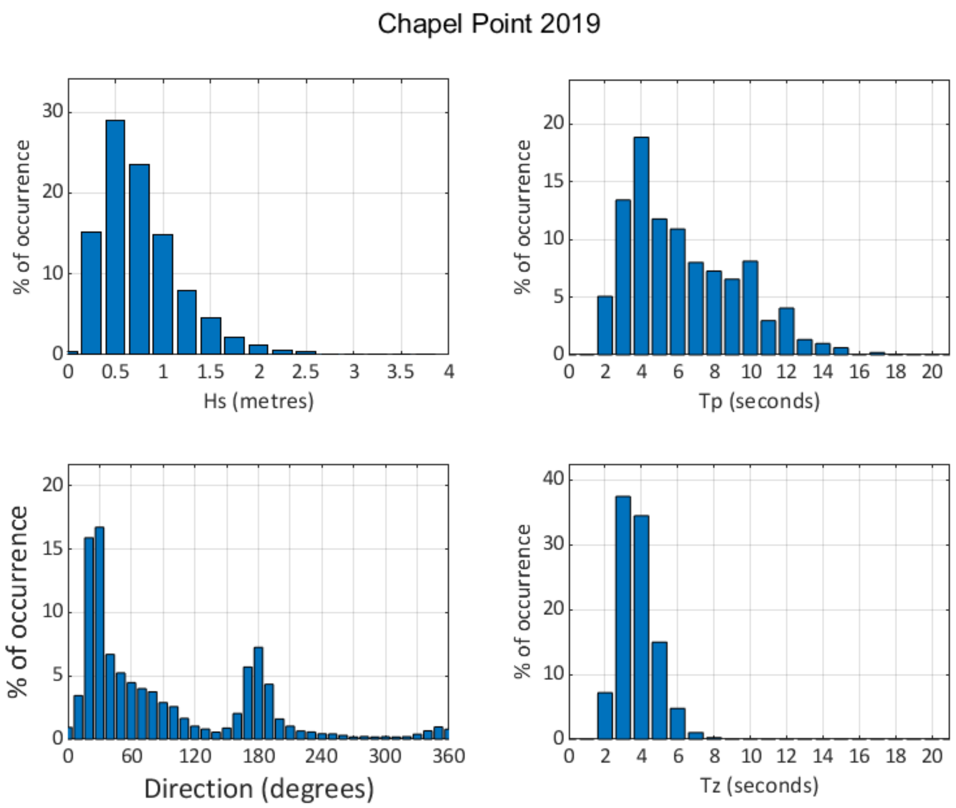
The shore station is kindly hosted by Mablethorpe RNLI Lifeboat Station.

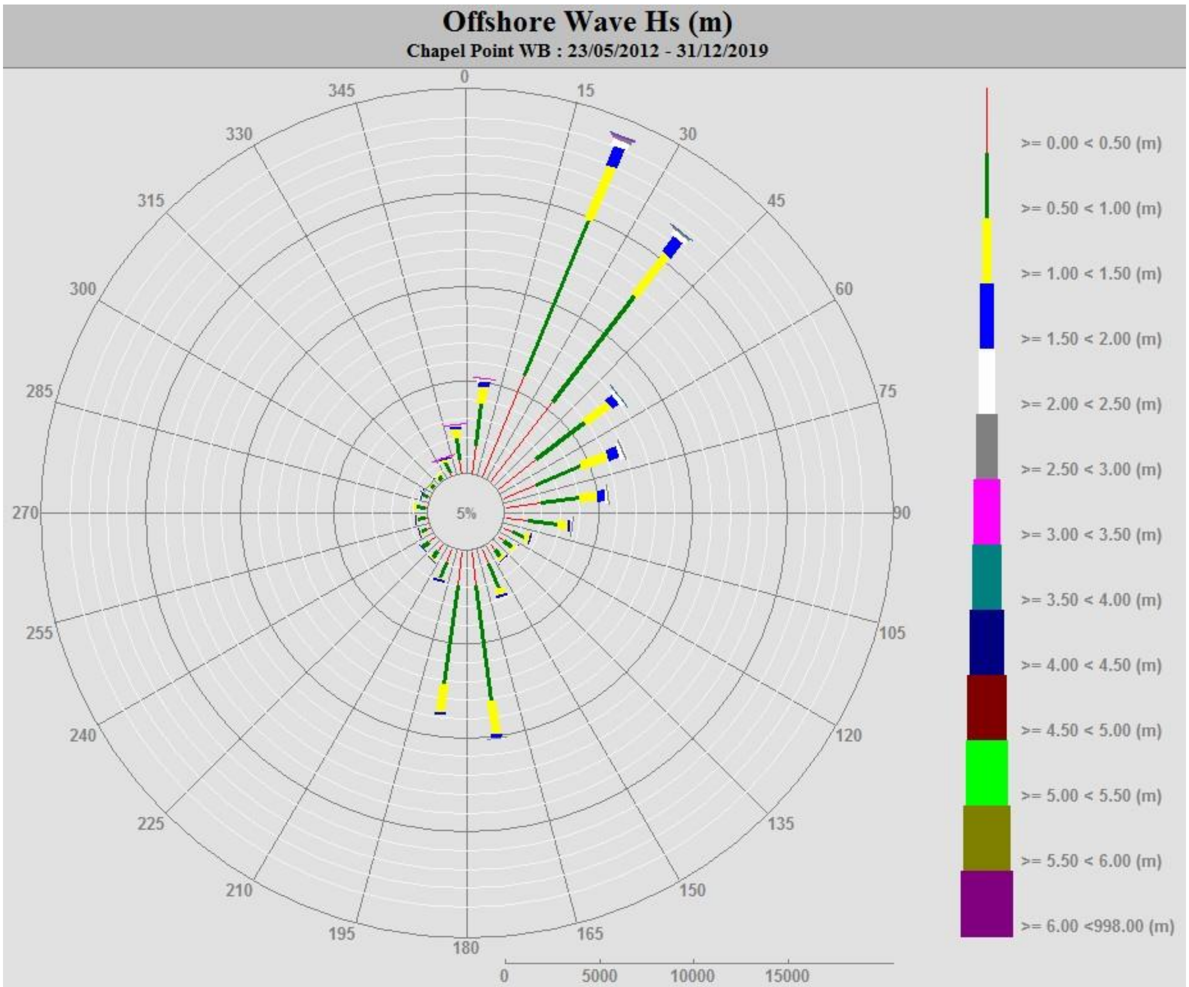


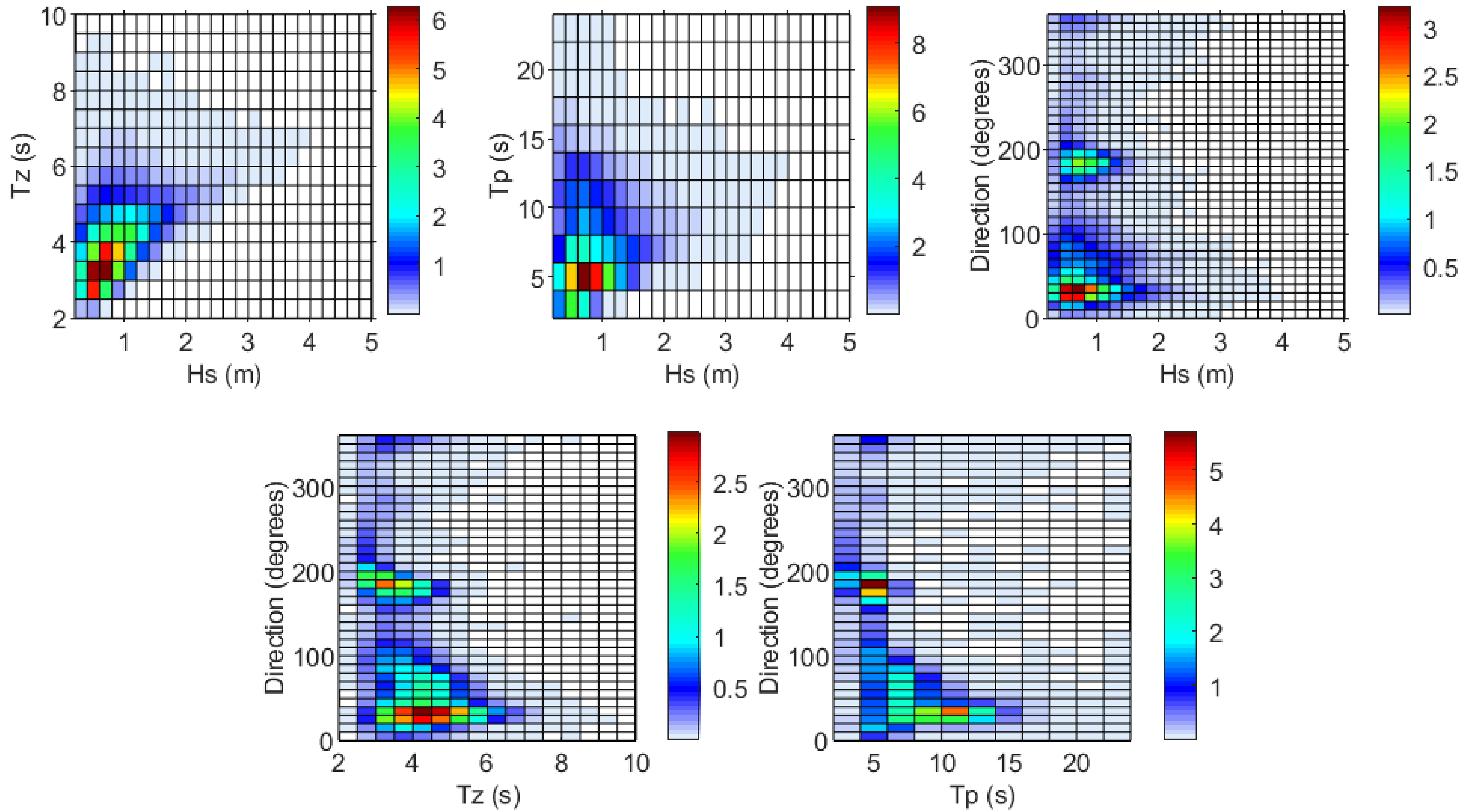
Chapel Point - Significant Wave Height (Hs) during 2019
metres
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
0
2
5
10
15
20
25
30
Day in month


Storms at Chapel Point during 2019
Storm alert threshold is Hs = 2.67
Hs (m)
3.75
3.50
3.25
3.00
2.75
Feb 2019
Apr 2019
Jun 2019
Aug 2019
Oct 2019
Dec 2019
Storms at Chapel Point - all years
2012
2013
2014
2015
2016
2017
2018
2019
2020
Date


Chapel Point - Wave height exceedence (Hs)
Wave height (m)
0.05%
0.5%
1%
2%
5%
10%
Year


Chapel Point 2019
% of occurrence
Hs (metres)
Tp (seconds)
Direction (degrees)
Tz (seconds)


Offshore Wave Hs (m)
Chapel Point WB : 23/05/2012 - 31/12/2019
5%
>= 0.00 < 0.50 (m)
>= 0.50 < 1.00 (m)
>= 1.00 < 1.50 (m)
>= 1.50 < 2.00 (m)
>= 2.00 < 2.50 (m)
>= 2.50 < 3.00 (m)
>= 3.00 < 3.50 (m)
>= 3.50 < 4.00 (m)
>= 4.00 < 4.50 (m)
>= 4.50 < 5.00 (m)
>= 5.00 < 5.50 (m)
>= 5.50 < 6.00 (m)
>= 6.00 <998.00 (m)



Chapel Point 2013 to 2019 - Joint distribution (% of occurrence)

Hydrodynamic Summary

The hydrodynamic data, provided by our colleagues in the Channel Coastal Observatory, conveys a bimodal wave approach from predominantly the Northeast but also South-easterly directions. Despite being a macro-tidal zone (i.e. the tidal range is >4m) this is a wave-dominant coast and therefore the processes of erosion, transportation and deposition are influenced by the direction and power of incident waves and associated nearshore currents. Between 2013 and 2019, the larger, hence more powerful waves, arrive from the former (NE) direction, as do the longer period swell waves that have greater capability to bring about geomorphological change. The north-easterly wave approach yields the net north to south net sediment transport direction along this frontage, i.e. from Zone A to C. An interesting observation derived by the annual statistics of significant wave height, is that the annual maximum has grown from 3.16m in 2012 to 3.75m in 2019. It is important to regard such hydrodynamic data, indicating changes in the wave climate, for the design, contracting and management of coastal engineering/adaptation projects going forward.

Summary

The purpose of this report is to offer understanding of how the annual recharge of beaches in Zone B, as part of the Lincshore project managed by the Environment Agency, has affected beach volumes in Zones A to the north, and zone C to the south (see Figure 1). The analysis herein compares airborne LiDAR data from (winter) surveys in years: 2012, 2016 and 2018. Zones A, B and C are all considered part of the same sediment circulation cell; Donna Nook to Gibraltar point. To the north of Zone A is the Humber estuary and to the South of Zone C is the Wash which are both considered sediment sinks.

In Zone A, the changes in beach volume between 2012 – 2018 (see Figure 2) portray an onshore movement of nearshore sand bars over the period of monitoring and negligible change to the majority of the upper, or supra-tidal, beach. The intertidal beach volume increases in the southern portion of Zone A, which is adjacent to the ‘fed’ Zone (B). Both the volume change and LRR analysis show a net loss of material to the north of the River Eau, with some transects diminishing by 11 to–28 m/year. In Zone A the statistics describe a slightly greater loss than gain of material over time.

In Zone C, there is a clear separation of erosion and accretion processes happening with a convergence of sediment from either side of the ness feature at Gibraltar Point Nature Reserve. As Zone C lies down drift of Zone B, the area benefits from the annual replenishment of beach material. The statistics presented herein show that an almost equal number of profiles experience erosion and accretion, however the beach profiles that are accreting are doing so at a much faster rate. Therefore, a net gain of material has occurred over the 6-year monitoring phase. This gain is localised around the ness feature ~2.5km north of Gibraltar Point. Any sediment transported south of this accumulation zone is likely to continue to The Wash.

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