# Preston Beach Sediment Tracer Study

## Southern Coastal Group and SCOPAC Report

Date: Jan 2022

Version: Final

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We help people and wildlife adapt to climate change and reduce its impacts, including flooding, drought, sea level rise and coastal erosion.

We improve the quality of our water, land and air by tackling pollution. We work with businesses to help them comply with environmental regulations. A healthy and diverse environment enhances people's lives and contributes to economic growth.

We can't do this alone. We work as part of the Defra group (Department for Environment, Food & Rural Affairs), with the rest of government, local councils, businesses, civil society groups and local communities to create a better place for people and wildlife.

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| D Picksley | R Sparke / S Neill / S Cope / J Griffiths | Sept 2021 | Draft v1 |
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# Contents

# Summary

A tracer pebble study was conducted at Preston beach, Weymouth between the 18th January 2019 and 14th May 2021 to examine sediment transport pathways and rates of movement. Of particular interest were the movement of pebbles along the beach to the far north and south extremes, noting if there was evidence of transport around the structures of Greenhill rock groyne and the Bowleaze pier.

Pebbles were deployed in two separate deployments at a level of MSL on the location of pre-existing Regional Monitoring Programme profile lines (www.coastalmonitoring.org). 446 pebbles were deployed in total across the survey area, with almost half of these pebbles (217) detected on at least one occasion. Some pebbles were able to be tracked up to 10 times, showing variable movement along the shore.

Results indicate that during the period of study there is a general trend for movement northeast along the main section of Preston beach backed by promenade, supporting the SCOPAC Sediment Transport Study (STS, 2012), however this movement was episodic and experienced frequent reversal to the southwest. Further north at Furzy cliffs, the pattern of movement can be in either direction but tends towards an area of general accretion or sediment sink, fed over the longer term by material from both the south, at Preston and the north, at Bowleaze cove.

There is evidence at Bowleaze cove that pebbles were able to bypass the pier and River Jordan outlet, moving in both directions. No evidence was found that confirms if pebbles move south around the Greenhill rock groyne with no pebble found within 15m. However, no pebble tracing was conducted south of the groyne due to a lack of evidence in the data already collected.

Rates and direction of transport appear to be very episodic and likely dependant on the wind and wave conditions. The front face of the beach can be quickly lost in storm events with material deposited below the intertidal area, where it is able to slowly recover in calmer conditions. Average daily transport rates of less than 10m per day are suggested by recorded movement of pebbles although this can at times be much larger. Several pebbles were recorded to have moved over 1km during the period of the study. The largest consistent rates of movement are along the central section of Preston beach with a generally lower rate seen further north around Bowleaze. The weight and roundness of pebbles did not draw any strong relationship to the recorded movement observed on site.

Longer term volume trends from coastal monitoring data suggest an average net transport volume northeast of between 3,000-4,000m$^3$ per annum from Preston beach to the Furzy frontage. However, this volume and transport direction can alter significantly between years and volume gains of up to 10,000m$^3$ have been recorded between these two areas. Whilst the beach at Preston is losing volume and the beach at Furzy is gaining volume, the overall beach volume along the whole frontage has remained relatively consistent for the last 20 years at approximately 230,000m$^3$.

# Background

Preston beach is a 1.4km long mixed sand and shingle beach at the northern end of Weymouth Bay, in Dorset. Prior to management, the beach here was originally a fine to medium sand with isolated patches of gravel and cobbles. The coastline here is orientated north-east to south-west, with a promenade adjacent to the B3155 Preston Beach Road. Beyond this to the north the beach is backed by soft cliffs at Furzy before they descend to Bowleaze Cove and the mouth of the River Jordan (Figure 1). Preston beach and promenade are currently maintained by the Environment Agency, with Dorset Council having responsibility for the wave return wall adjacent to Furzy Cliffs and the slope stabilisation scheme here.

A capital scheme comprising a new seawall and promenade; 214,000m3 of beach recharge; and a terminal rock groyne at the south-western end of Preston beach was constructed by the Environment Agency between 1995 and 1996. The objective of the scheme was to manage the risk of coastal flooding and erosion to assets on the low-lying land inshore which, at the time, included 86 residential properties; the (now former) A353 Preston Beach Road; infrastructure; a municipal tip and environmentally designated areas such as Overcombe SNCI and Lodmoor SSSI and RSPB reserve (Preston BMP, 2016). The scheme also included a single layer of 1-3T rock armour placed against the seaward edge of the prom, which was subsequently repaired and supplemented with 3-6T rock following the 2013/14 winter storms.

The beach from the Greenhill groyne to Bowleaze Cove is mixed sand and shingle, largely consisting of shingle up to 50mm in size concentrated towards the upper beach with a sandy foreshore. It is reasonably homogenous in nature, although the shingle element of the beach trends towards slightly finer at Bowleaze Cove (with the exception of large cobbles located around the mouth and bed of the River Jordan). The beach is approximately 3.5mAOD in height, reducing slowly at the Bowleaze end to approximately 2mAOD. It is consistently around 50m wide, with a crest width of approximately 15m and an average foreshore slope around 1 in 7. The beach crest and slope angle are gradually lost at Bowleaze Cove to a flat sand beach backed by a revetment. The latest digital ground model from the February 2021 topographic survey is shown in Figure 2.


Typical view of Preston beach (looking northeast)
River Jordan
Bowleaze Cove
Bowleaze Pier
Furzy Cliff
Tracer Study Extent
Greenhill Rock Groyne
Preston Beach Tracer Pebble Study - Overview map
Environment Agency
N
0 62.5 125 250 (m)


Elevation (mOD)
5 - 6
4.5 - 5
4 - 4.5
3.5 - 4
3 - 3.5
2.5 - 3
2 - 2.5
1.5 - 2
1 - 1.5
0.5 - 1
0 - 0.5
-0.5 - 0
-1 - -0.5
-1.5 - -1
-2 - -1.5
Preston Beach Tracer Pebble Study - February 2021 topographic survey
Environment Agency
N
0 50 100 200 (m)

To the south of the Greenhill groyne the beach is almost exclusively shingle, gradually altering to a mixed beach to the south around the Weymouth Pier Bandstand. Further south the beach begins to widen and becomes entirely fine sand. Weymouth Bay is shallow and covered by sand deposits, with the offshore bathymetry contours approximately parallel with the beaches, causing large waves to shoal and break before reaching the beach toe.

Preston beach is actively managed by the Environment Agency under an agreed beach management plan, with works largely consisting of periodic beach re-profiling and occasional beach recycling works. Beach shingle has tended to accumulate towards the north-eastern end of the beach, in front of the wave return wall, café and Furzy Cliffs. When there is sufficient material here, it is transported via dump trucks further south to the depleted central section of the beach backed by the promenade. The quantity and frequency of beach material recycled is dependent on the condition of the beach in front of the Preston Beach Road, as there is a tendency for frequent and often abrupt draw down of material during storm conditions, followed by rapid recovery during the calmer periods. An annual beach re-profiling exercise is usually sufficient to rebuild the crest and beach slope as per the design profile.

In order to better understand the sediment transport processes within the bay and the movement of material along Preston beach, it was decided to work with Coastal Partners to conduct a sediment tracer survey using tagged native shingle pebbles deployed at strategic locations along the frontage that could be tracked via specialist equipment. The pebbles were deployed in batches between the Greenhill rock groyne and Bowleaze Cove and monitored regularly to track their movement (Figure 1). The Southern Coastal Group via SCOPAC, provided an initial contribution of £5,000 for the preparation of the tracer pebbles, with the remainder of the study funded by the Environment Agency.

Current research analysis from the SCOPAC 2012 sediment transport study (STS) suggests the rate of littoral drift at Preston beach may be as high as 15,000$m^3$ a year to the northeast, although the actual gain of material is often a lot less than this due to periodic beach recycling operations conducted by the Environment Agency. Previous studies have suggested that a weak littoral drift may have existed from north to south pre re-nourishment, transferring fine material from Preston beach to Weymouth beach, although the quantities transferred would likely have been small. A potential net drift rate south of 2,900$m^3$ was suggested by HR Wallingford in 1998.

Previous research and monitoring of the beach at Furzy since 1996 has shown that there is a drift divide at approximately the central point of this cliff backed beach, with a northwards and southwards transport direction either side of the divide. However, reversals of this movement have been observed under short term incident wave conditions and it is clear from the previous studies and observations that the cross-shore movement of material is a more dominant feature of this stretch of coastline rather than longshore movements.

Figure 3 shows the theorised sediment transport mechanisms and pathways around Weymouth Bay based on the best available evidence and data at the time of the STS update (2012).

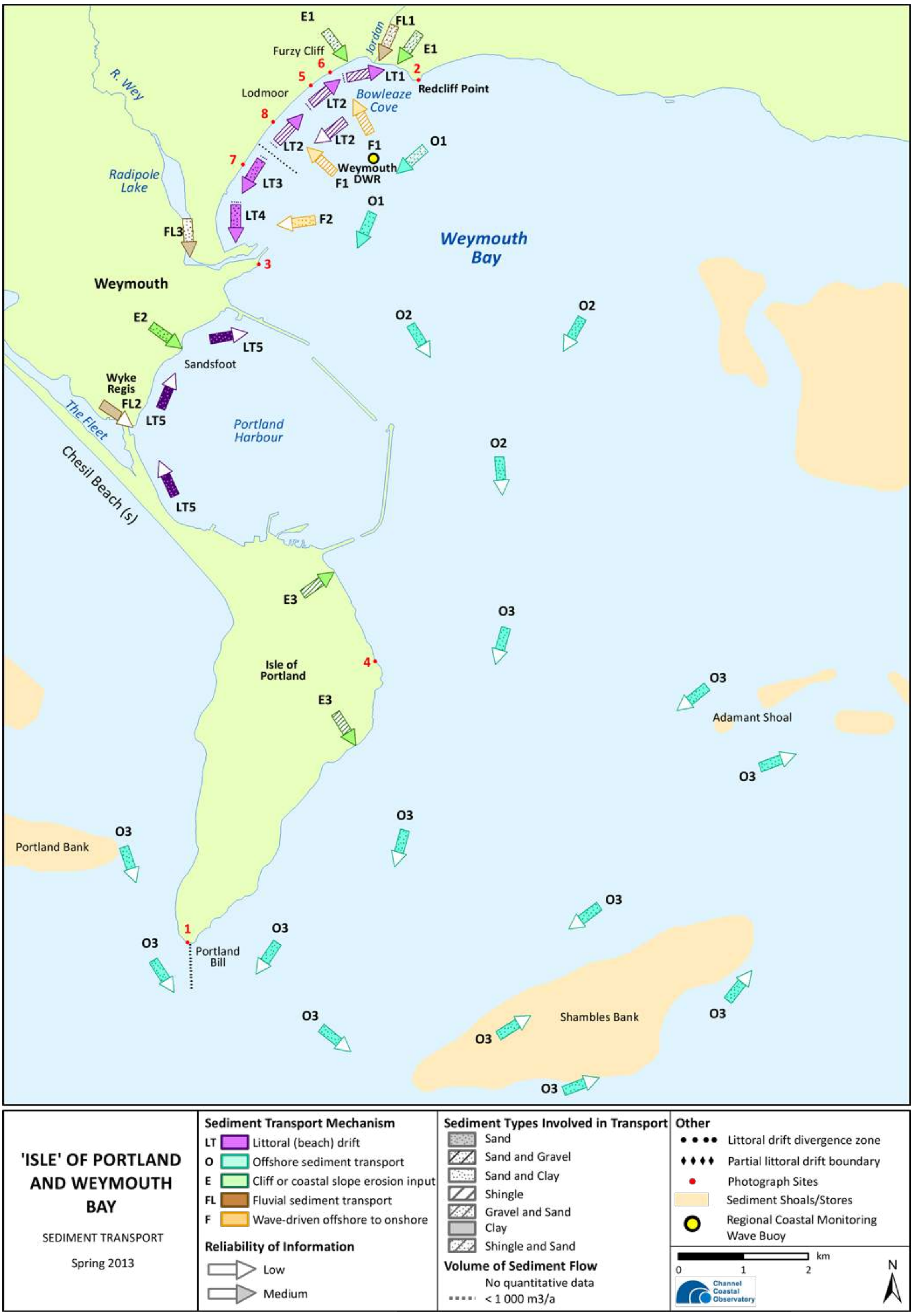



Figure 3. The current published SCOPAC sediment transport mapping for Weymouth Bay

The Regional Coastal Monitoring Programme collects regular topographic survey data for Preston Beach, with at least 3 surveys a year, including a full baseline survey and 2 interim profile surveys (plus any additional post storm surveys as required). There is survey data from 2005 to 2021 which can be used in the analysis later in the report to examine and support beach volumes and profile trends. The beach between Preston and Bowleaze Cove is split in to 3 separate survey units as part of the coastal monitoring programme survey data collection, these are shown in the map below (Figure 4). For consistency, the same naming convention and survey unit areas will be used in this reporting for any analysis work.


# Objectives

Several objectives were conceived for the original study plan, these are listed below:

- To investigate the general patterns of sediment transport along the beach and estimate rates of transport where possible
- To determine if sediment is able to pass the pier at Bowleaze cove in both directions
- To determine if sediment is able to pass south around the rock groyne at Greenhill

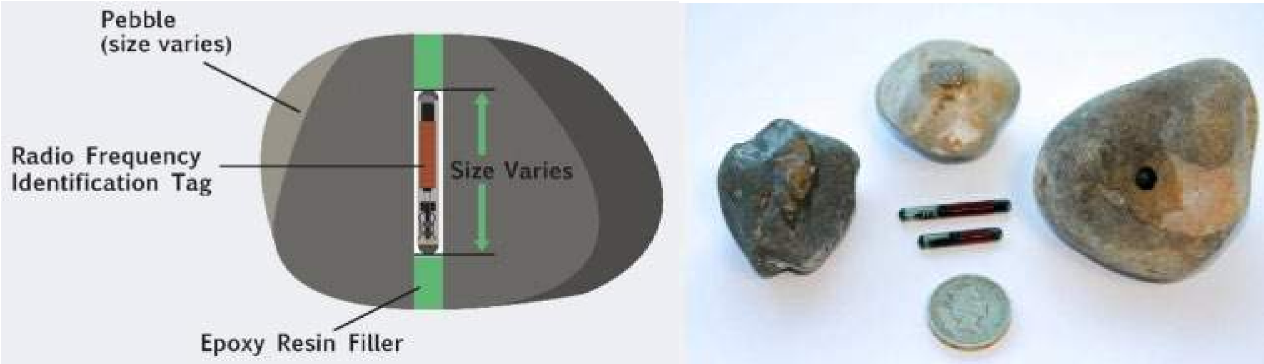
It was hoped that any results could help inform future management decisions for the frontage and determine the effectiveness of any control structures. Results and data would also be used to support any future updates of the SCOPAC Sediment Transport Study (2012).

# Methodology

This study utilised the RFID tag (Radio Frequency Identification) methodology for tracking tagged pebbles along the beach frontage, via the use of a handheld receiver device and associated electronics carried in a backpack (Figure 5). The RFID tracer pebble technology was originally developed by the Eastern Solent Coastal Partnership (ESCP) (now Coastal Partners) and has been successfully used in numerous studies across the SCOPAC region to monitor beach sediment movement and transportation rates (https://southerncoastalgroup-scopac.org.uk/tracer-pebble-studies/).

Figure 5. Example of the tracer kit in use on site (credit. Coastal Partners)

For this particular study at Preston, the methodology for pebble collection, production and deployment remained the same as previous tracer pebble studies conducted in the Eastern Solent area. Suitable pebbles were drilled to accommodate an RFID tag, then filled with resin (Figure 6), with each pebble then catalogued for size and weight.




600 native pebbles were collected from Preston Beach during July 2018, with particular care taken that each pebble would be suitable to accommodate at least the 12mm RFID tag. During production, where applicable the larger pebbles were fitted with the 23mm RFID tag as previous studies had shown these to provide a stronger return signal and thus have a greater chance of successfully locating them in the field. This also gave a mix of larger and small pebbles of varying size and shape.

The pebbles were initially deployed at 5 different locations along Preston Beach, with 100 mixed pebbles deployed at each site at the approximate point of mean sea level (+0.11mOD). The full tidal range is shown in Table 1 below.

| HAT | MHWS | MHWN | MSL | MLWN | MLWS | LAT |
|---|---|---|---|---|---|---|
| 1.57 | 1.17 | 0.47 | 0.11 | -0.13 | -0.83 | -1.13 |

Table 1. Tidal range heights for Portland (mOD)

The locations of each deployment site were equally spaced along the main Preston beach frontage from the Greenhill rock groyne to Furzy Cliffs (Figure. 7) and were chosen as existing locations of Regional Coastal Monitoring beach profile lines (Figure. 8).

Following deployment of the pebbles and subsequent surveys, it was established that there was an issue with the smaller RFID tags, which rendered them unreadable and thus could not be tracked via the surveys. This consequently resulted in only 83 readable tags (the larger 23mm ones) actually being deployed at the various sites along the beach. It was therefore decided that an additional batch of pebbles would be produced, with a further 363 pebbles deployed at 6 locations along the frontage (Figure 7). Three new locations were chosen, based on initial results from the pebbles deployed to date, with the remaining three locations to further add to the central section of beach at the same locations used previously. As previously, all pebbles for the 2$^{nd}$ deployment phase were deployed on coastal monitoring lines at MSL as before (Figure 9).


Site 1. 5g00309

Site 2. 5g00305

Site 3. 5g00301

Site 4. 5g00297

Site 5. 5g00293

Figure 8. 1st Deployment sites 1-5 with corresponding coastal monitoring profile line

Site A. 5g00310 | Site B. 5g00305 | Site C. 5g00301

Site D. 5g00297 | Site E. 5g00291 | Site F. 5g00287

Figure 9. 2nd Deployment sites A-F with corresponding coastal monitoring profile line

## Survey Regime

- **First pebble deployment – 18th January 2019 (83 pebbles)**

Surveys from 21st January 2019 until 14th June 2019

- **Second pebble deployment – 18th November 2019 (363 pebbles)**

Surveys from 20th November 2019 until 28th February 2020

Additional final survey 14th May 2021 (surveys paused due to Covid-19)

A full list of all survey dates is available in the Appendix.

# Results Discussion

## General

Detection of tracer pebbles across the full range of surveys has been generally good, with 217 individual pebbles recorded on at least one occasion (Table 2). Of the initial 83 pebbles deployed across sites 1-5, 76 individual pebbles (or 92%) have been recorded at least once. For the second deployment of sites A-F, 141 individual pebbles (39%) have been recorded at least once. This lower return rate possibly reflects the mix of different sized RFID tags used in the second deployment, with the return rate from smaller tags known to be much lower than the larger ones.

<table>
<tr><th>Site</th><th>Number</th><th>Total</th><th>% total of those deployed</th></tr>
<tr><td>1</td><td>13</td><td rowspan="5">76</td><td rowspan="5">92</td></tr>
<tr><td>2</td><td>18</td></tr>
<tr><td>3</td><td>15</td></tr>
<tr><td>4</td><td>12</td></tr>
<tr><td>5</td><td>18</td></tr>
<tr><td>A</td><td>39</td><td rowspan="6">141</td><td rowspan="6">39</td></tr>
<tr><td>B</td><td>5</td></tr>
<tr><td>C</td><td>5</td></tr>
<tr><td>D</td><td>8</td></tr>
<tr><td>E</td><td>33</td></tr>
<tr><td>F</td><td>51</td></tr>
</table>

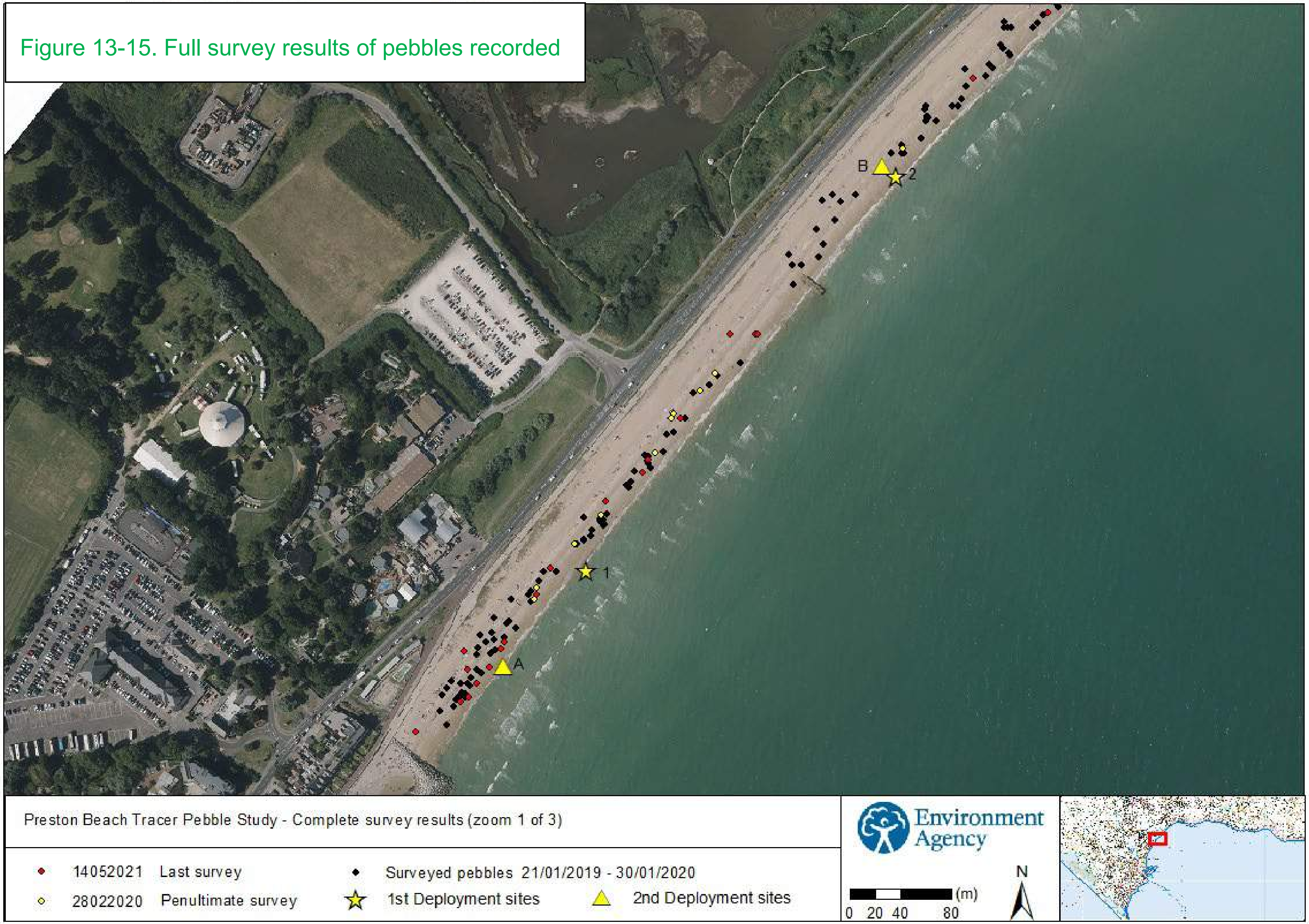
Table 2. Number of individual pebbles detected per deployment location

Analysis of pebble movements in general across the whole period suggest a weak transport north-eastward along the main section of beach from the Greenhill groyne to approximately Furzy Cliffs (covering deployment sites 1-4 / A-D) coinciding with survey unit 5gSU14. This movement appears to be episodic and likely driven by the localised wind and wave climate, although the data collected from each survey is too widely spaced to directly link it. There is strong evidence for a south-easterly transport of material from Bowleaze Cove towards Furzy Cliff approximately covering survey units 5gSU13 and 5gSU12 (deployment sites 5 / E-F), with evidence that pebbles are able to by-pass the River Jordan outlet at Bowleaze and then move south beyond the pier.

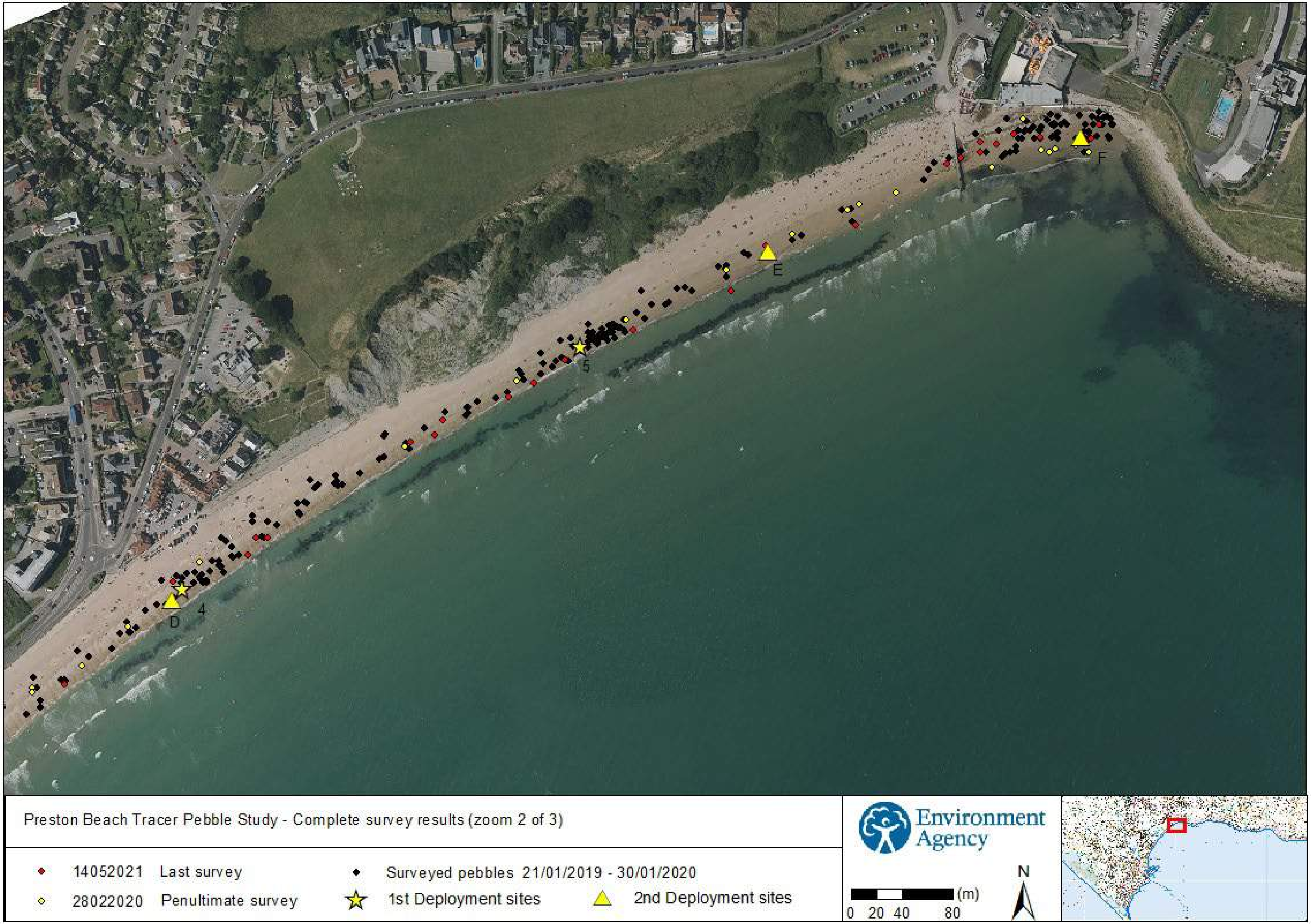
Although some pebbles were recorded to have moved southwest from deployment site 1 towards the Greenhill rock groyne, no pebbles were recorded immediately adjacent to the structure and only 1 pebble was recorded within 15m of it. Given the lack of recorded movement for pebbles towards the rock groyne, tracer surveys were not conducted south of the groyne for this study. Whilst not conclusive, no evidence was obtained to support the notion that pebbles are able to bypass the structure and continue south towards Weymouth.

Distribution plots showing the location of every recorded pebble, with the last and penultimate surveys highlighted, are shown in Figures 13-15. It is evident from these plots that there has been pebble movement in all directions across the course of the study, both longshore and cross shore, with pebbles being recorded beyond the extent of the deployment sites across the length of the frontage.

Figure 13-15. Full survey results of pebbles recorded



4
D
C
3
Preston Beach Tracer Pebble Study - Complete survey results (zoom 2 of 3)
14052021 Last survey
28022020 Penultimate survey
Surveyed pebbles 21/01/2019 - 30/01/2020
1st Deployment sites
2nd Deployment sites
Environment Agency
(m)
0 20 40 80
N


E
F
D
4
5
Preston Beach Tracer Pebble Study - Complete survey results (zoom 2 of 3)
14052021 Last survey
28022020 Penultimate survey
Surveyed pebbles 21/01/2019 - 30/01/2020
1st Deployment sites
2nd Deployment sites
Environment Agency
(m)
0 20 40 80
N

For every pebble that was recorded, the distance from its original position was calculated as a vector. Table 3 and 4 show the maximum and minimum movement of pebbles from each deployment site, with the maximum recorded movement of 1213m for a pebble from site 1. An average daily rate of movement of 6m across the sites was recorded, however for the individual locations mean daily transport rates varied from approximately 2-18m.

| | Distance From Start (m) | | | |
|---|---|---|---|---|
| **Site** | **Mean** | **Median** | **Min** | **Max** |
| 1 | 174 | 80 | 3 | 1213 |
| A | 203 | 231 | 15 | 333 |
| 2 | 223 | 141 | 4 | 814 |
| B | 106 | 109 | 63 | 147 |
| 3 | 129 | 103 | 3 | 757 |
| C | 150 | 104 | 57 | 439 |
| 4 | 79 | 53 | 6 | 459 |
| D | 251 | 83 | 65 | 808 |
| 5 | 88 | 28 | 0 | 435 |
| E | 174 | 132 | 7 | 1157 |
| F | 35 | 28 | 2 | 172 |

Table 3. Maximum and minimum pebble movement per deployment site

| | Distance Per Day* (m) | | | |
|---|---|---|---|---|
| **Site** | **Mean** | **Median** | **Min** | **Max** |
| 1 | 2.1 | 1.0 | 0.2 | 26.3 |
| A | 11.8 | 4.3 | 0.0 | 121.5 |
| 2 | 2.6 | 1.3 | 0.0 | 13.4 |
| B | 10.5 | 7.3 | 1.4 | 36.2 |
| 3 | 2.7 | 0.8 | 0.1 | 15.5 |
| C | 6.3 | 2.4 | 0.8 | 19.6 |
| 4 | 2.1 | 1.0 | 0.0 | 9.4 |
| D | 17.7 | 4.8 | 0.1 | 115.5 |
| 5 | 1.7 | 1.0 | 0.0 | 10.2 |
| E | 9.3 | 2.8 | 0.0 | 165.3 |
| F | 2.6 | 1.2 | 0.0 | 23.3 |

*Not accounting for change in direction

Table 4. Maximum and minimum daily pebble movement per deployment site

The distance travelled from each site by individual pebbles is also shown graphically in Figure 10, indicating the majority of pebbles from each site have moved less than 500m from their starting position. There are several outliers which have increased the maximum recorded distance travelled for several of the sites. At location F (Bowleaze Cove) the movement of pebbles is noticeably less than the other sites and generally less than 125m.

Figure 11 shows the distribution of pebble weight to distance travelled from the start, plotted for individual locations and roundness. There is no clear trend in the data shown between pebble weight and distance travelled, however the plot does demonstrate there was a mix of pebble weights deployed across each site.

Figure 12 displays the distance travelled by angularity or roundness, with the sub-rounded pebbles having travelled the lowest maximum distance. There are a number of outliers to the angular and sub-angular categories with several pebbles in each having moved over 1km. The rounded pebbles generally show the greatest distanced moved across the 4 subcategories, with the remaining categories similar in movement if you exclude the outliers.

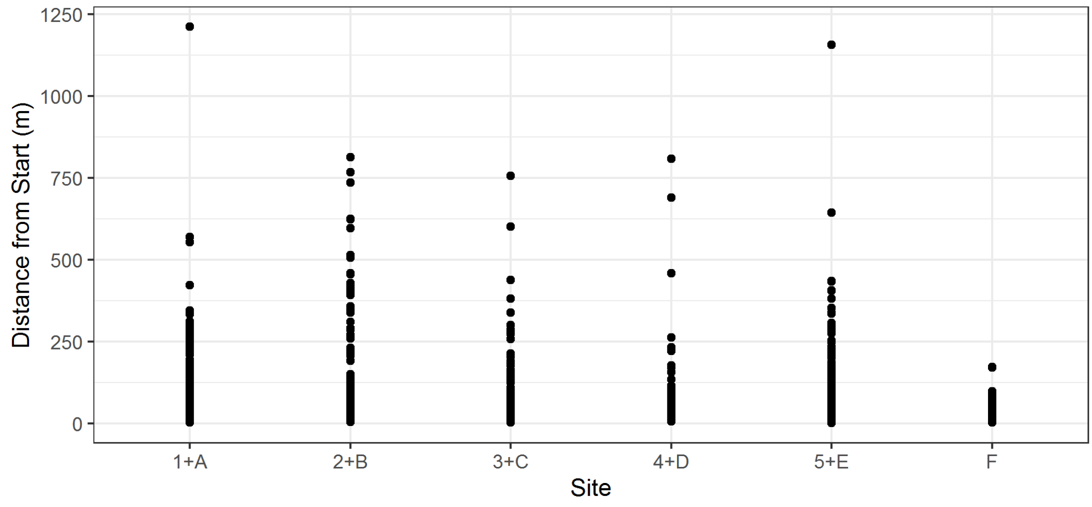



Figure 10. Distance travelled of each pebble from individual deployment locations

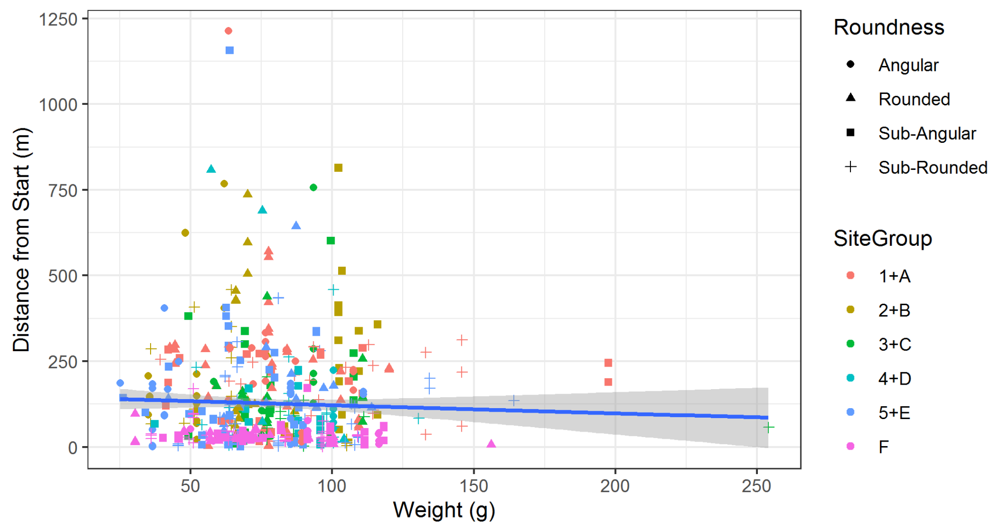



Figure 11. Distribution of pebble weights compared to distance travelled

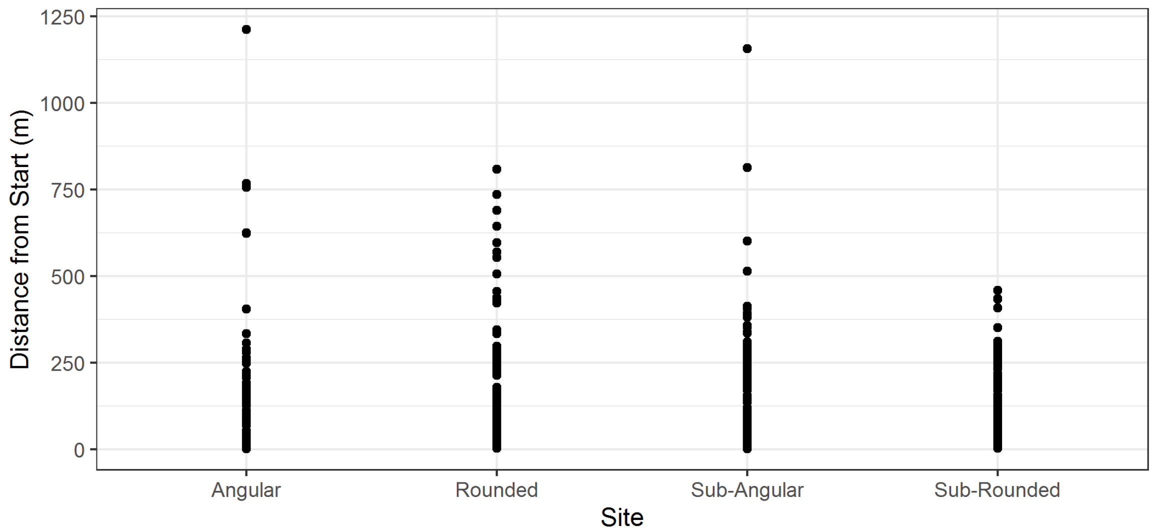



Figure 12. Angularity and roundness of pebbles compared to distance travelled

## Pebble detection rates

Analysis of the most frequently detected pebbles indicates that one pebble deployed at site 5 was detected 10 times between surveys from 21st Jan 2019 – 28th February 2020. Four pebbles were detected at least 9 times and two pebbles were detected at least 8 times, with the best detection rates coming from pebbles previously deployed at sites 5 and 4. A breakdown of number of pebbles found at least 5 times is provided below (Table 4). All these pebbles utilised the larger 23mm tag which is known to have a stronger return signal.

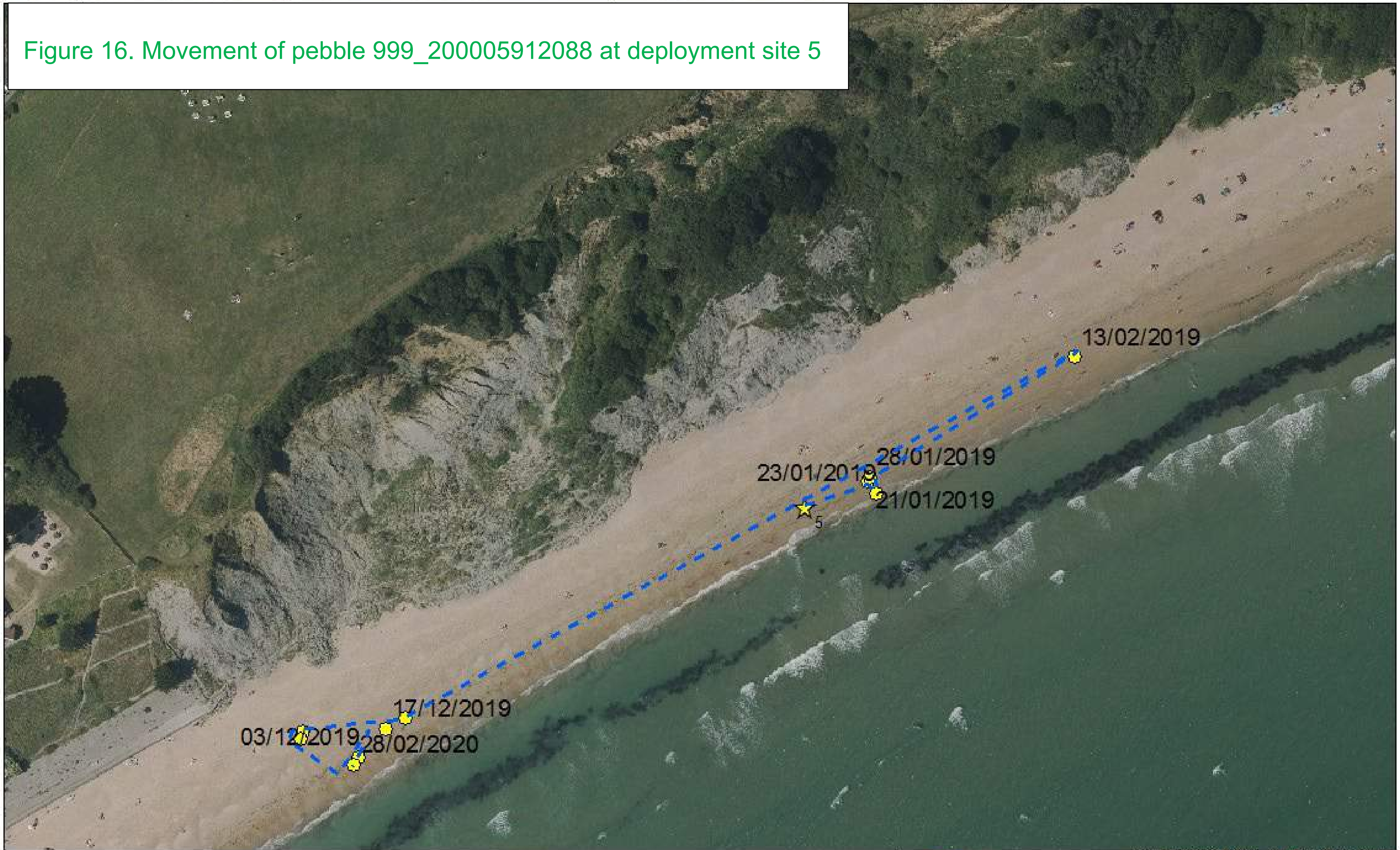
| Detection rate | Number of individual pebbles | Initial deployment sites |
|---|---|---|
| **10 times** | 1 | 5 |
| **9 times** | 4 | 5,4,3,2 |
| **8 times** | 2 | 5,4 |
| **7 times** | 7 | 5,4,2,1,F |
| **6 times** | 4 | 5,4 |
| **5 times** | 16 | 5,4,3,2,1,A,C,F |

Table 4. Detection rates for individual pebbles

Individual pebbles can be tracked along the beach based on their last recorded location from the survey data. This can give a more detailed picture of sediment movement and rates and highlight rapid changes that have occurred which may not be apparent from occasional visual inspections or topographic surveys.

Examples of individual movement of pebbles is shown in Figures 16-20 with the blue dashed line highlighting the track route along the beach. All the examples show movement in both longshore directions (north and south), often with notable movement between successive surveys in the opposite direction to previous movement. In these examples, maximum recorded movement of pebbles varies, with averaged daily transport rates of between approximately 1m and 12m.

Figure 16. Movement of pebble 999_200005912088 at deployment site 5




Preston Beach Tracer Pebble Study - Most frequently found pebbles (999_200005912088 found 10 times)

pebble_999_200005912088

1st Deployment sites

Environment Agency

0 12.5 25 50 (m)

N

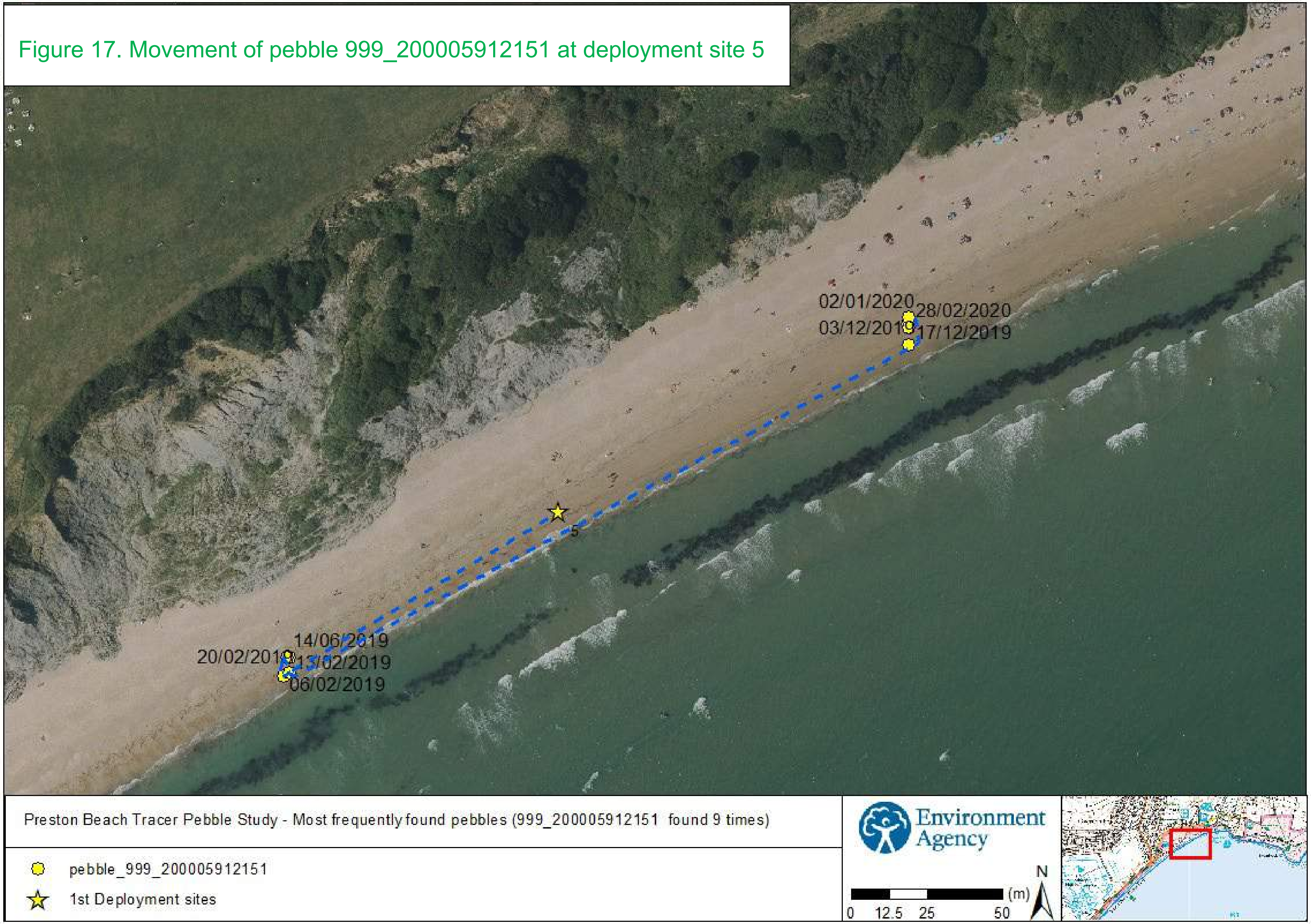



Figure 17. Movement of pebble 999_200005912151 at deployment site 5

Figure 18. Movement of pebble 999_200005911338 at deployment site 4


Preston Beach Tracer Pebble Study - Most frequently found pebbles (999_200005911338 found 9 times)

pebble_999_200005911338

1st Deployment sites

Environment Agency

(m) 0 12.5 25 50

N

Figure 19. Movement of pebble 999_200005917165 at deployment site 3


Preston Beach Tracer Pebble Study - Most frequently found pebbles (999_200005917165 found 9 times)

pebble_999_200005917165

1st Deployment sites

Figure 20. Movement of pebble 999_200005917872 at deployment site 3

## Individual site data

Pebble movement for each individual site deployment has been plotted separately to examine the direction and maximum spread of pebbles. Initial deployment sites 1-5 are shown in Figures 21-25, with the 2nd deployment sites A-F shown in Figures 26-31. Maximum, minimum and mean rates of transport from all sites are also shown in Table 3 on p19.

Movement of pebbles from locations 1 and 2 is dominantly to the northeast with one pebble from site 1 recorded 1213m away. This pebble was deployed on the 18th January 2019 and recorded again on the 14th May, averaging 10.6m per day in transport northwards and was the largest recorded distance for any site. There was only one pebble recorded southwest of deployment site 2 and a small number from site 1 recorded to the southwest.

At site 3 the dominant direction of travel was again to the northeast, although a small percentage of pebbles were recorded to the southeast of the deployment site including one pebble that had moved 550m from the source. At site 4 the split of recorded pebble distribution is approximately equal from the source, bar one outlier to the north at Furzy cliffs.

At site 5 the distribution of pebbles is both to the north and south suggesting no dominant direction of transport here. There is evidence from this deployment of pebbles moving in to Bowleaze Cove, past the pier and River Jordan, indicating that these are not obstructing sediment transport.

For sites 1-5, the mean and max distance travelled from the start was lower for the northern end of the beach (sites 4-5) compared with the southern end, with the larger distances travelled seen around the southern and central sites 1,2 and 3.


Figure 21. Deployment site 1 results


Figure 22. Deployment site 2 results


Figure 23. Deployment site 3 results

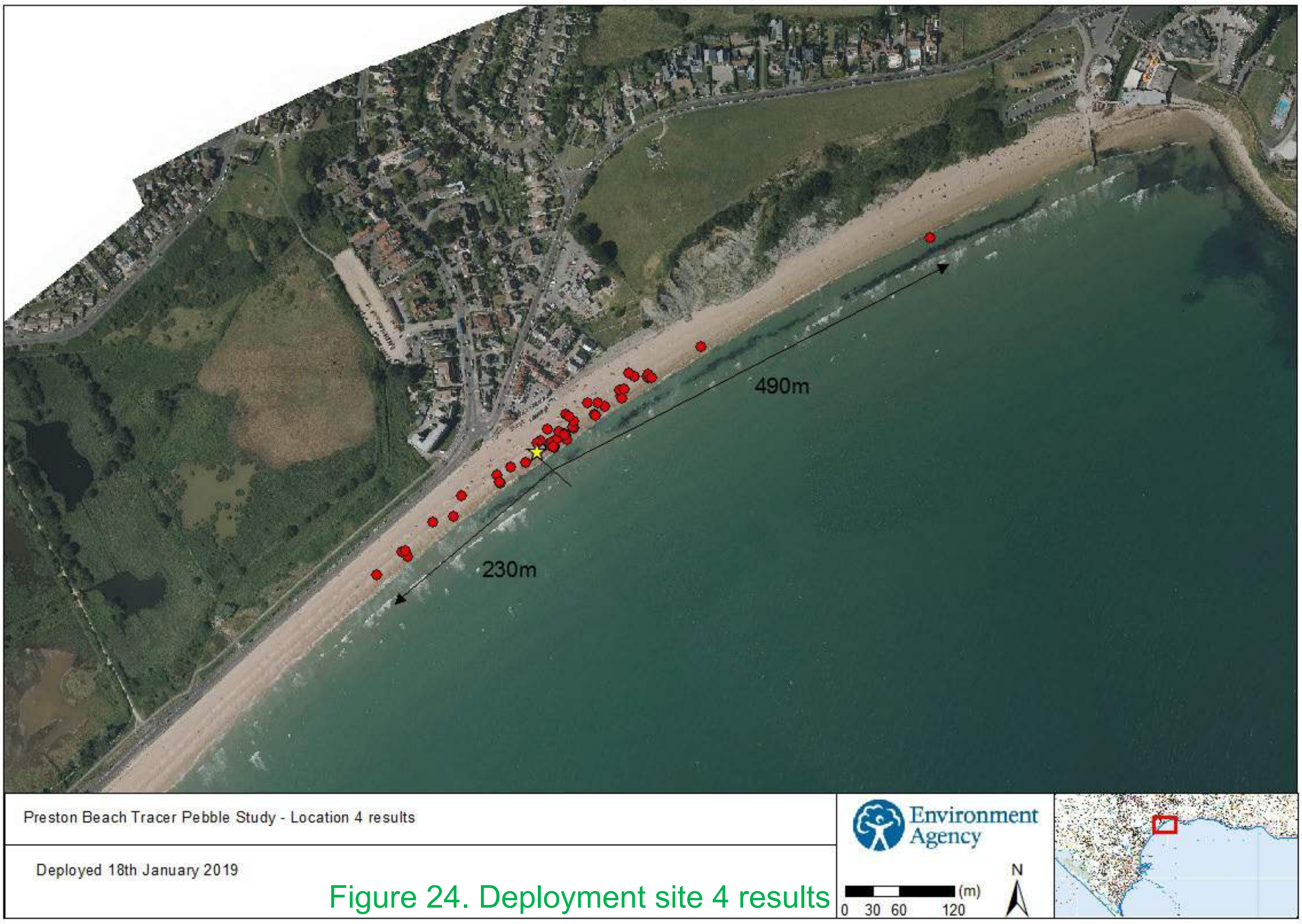



Figure 24. Deployment site 4 results


Figure 25. Deployment site 5 results

The 2nd deployment of pebbles focussed more on the far extents of the tracer study site, based on the results recorded so far and the strong movement of pebbles northwards.

Deployment site A was chosen as an additional location adjacent to the Greenhill rock groyne to further test if pebbles appeared to be trapped by this groyne or moving southwest. Whilst more pebbles were recorded to the southwest of this deployment site than site 1, the dominant direction of movement was again to the northeast with no pebbles recorded against the rock groyne and the closest recorded 15m away.

At site B the recorded movement was approximately equal in both directions, whilst at site C more pebbles were recorded to the southeast (6) although the largest movement was from pebbles (3) to the northeast at 470m from source.

At site D, the pebbles were recorded to have moved northeast by up to 800m, whilst 2 pebbles from this site were recorded at the far north end of the beach at Bowleaze Cove.

At sites E and F, the dominant direction of drift was to the southeast, which has similarities with the previous deployments at site 4 and 5. At site F in Bowleaze Cove, the movement of pebbles appears to be relatively slow compared with other sites, with a maximum recorded movement of 190m although the majority of pebbles moved in a much smaller zone of up to 120m from source. This is demonstrated by the lower values shown for this site in Table 3, with a mean distance travelled of 35m from the start.

In general, all the individual site deployments support the trend of southwest to northeast transport for Preston beach (SU14), whilst at Furzy cliff there appears to be a weak convergence zone with transport from the north and south. At Bowleaze Cove the evidence collected suggests that transport is to the southeast, although for the majority of pebbles the rate of movement recorded was slow and largely confined to the Cove north of the pier. However, the rate of movement here can be notable and of similar rates to that seen along the main Preston beach frontage, with one pebble having moved 190m between 18$^{th}$ November 2019 – 3$^{rd}$ December 2019 representing an average of 12m per day. There was little evidence to suggest pebbles were moving northeast further around the headland as almost all pebbles deployed at this location moved in the opposite direction towards Furzy cliffs.


Figure 26. Deployment site A results


Figure 27. Deployment site B results


Figure 28. Deployment site C results


Figure 29. Deployment site D results

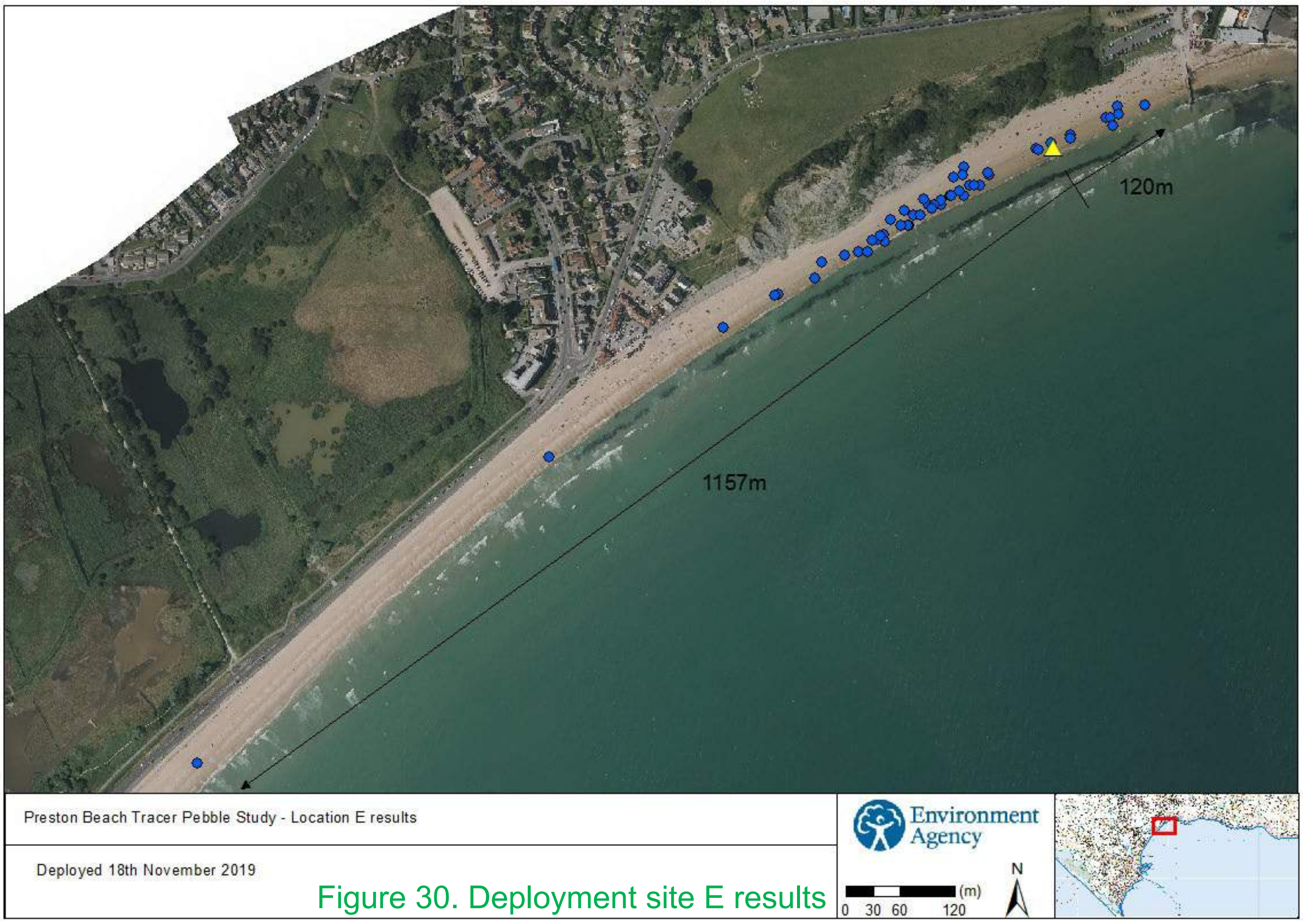



Figure 30. Deployment site E results

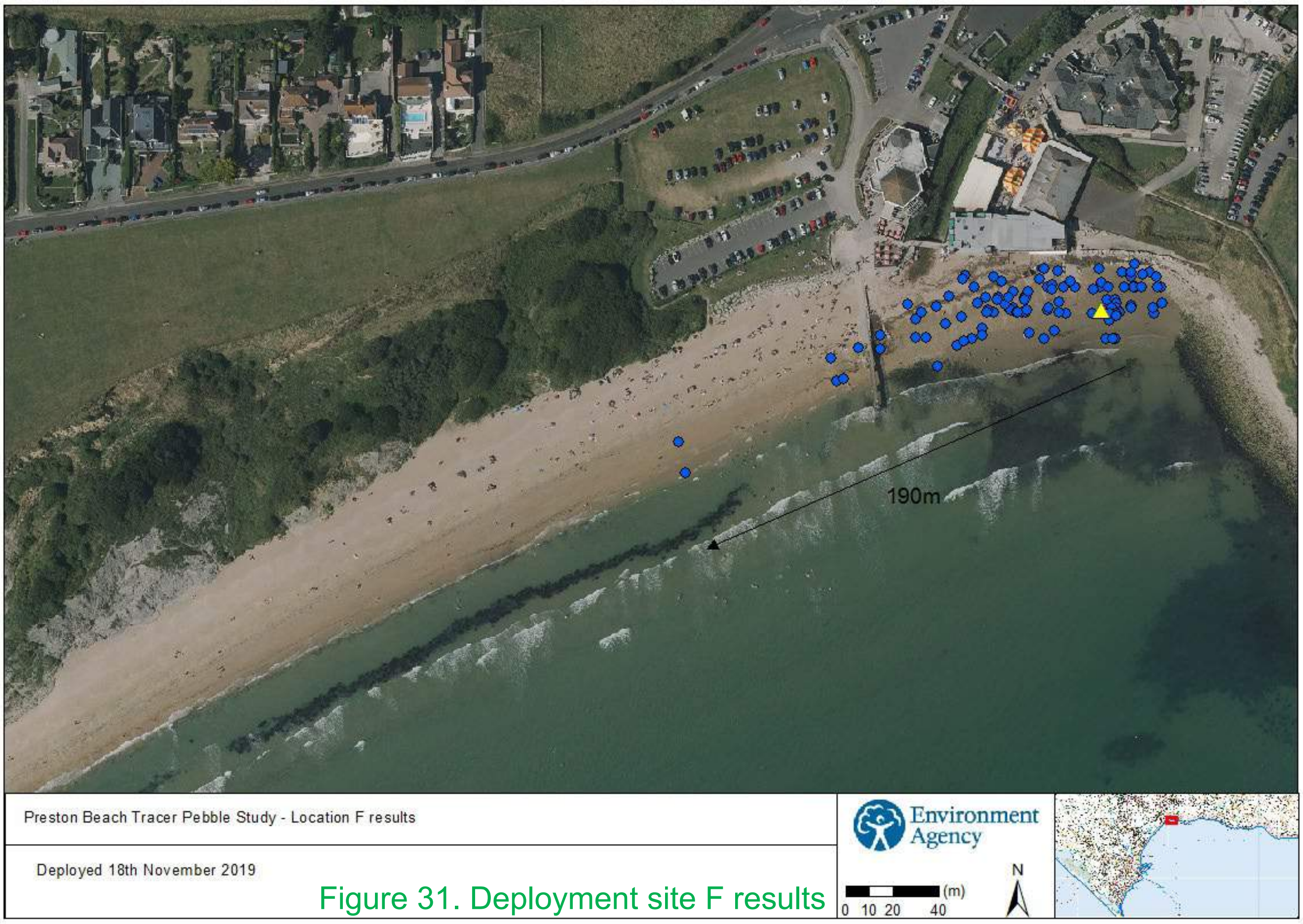



Figure 31. Deployment site F results

# Coastal monitoring data

## Topographic data

Regional coastal monitoring data is available as full topographic baseline data for the Preston to Furzy section of beach from 2005 until present day, whilst Bowleaze Cove has survey data from 2007. Topographic profiles are available from 2002 until present day and include some post storm surveys conducted after notable storm events.

The baseline survey data has been used to create annual topographic difference plots to cover the period of the tracer study (2018-2021) with an additional difference plot of 2007 – 2021 to show the longer-term beach trends. These plots are shown in Figures 32-36 below. The long-term plot shows clear evidence of a loss of beach material from Preston beach (SU14), with an accumulation of material around to the north at Furzy cliffs (SU13). There is some accretion of beach material at Bowleaze cove (SU12) although this is relatively minor in comparison to that at Furzy. However, analysis of the data suggests a loss of 18,700m$^3$ from SU14 with gains of 20,200m$^3$ at SU13 and 3,300m$^3$ at SU12. It is unclear why there is a difference of 5,000m$^3$ in overall volume, some material may have been lost offshore or was below the level of the survey (MLWS).

More detailed analysis can be derived from the topographic profile surveys which occur at least 3 times a year for this area of coastline. By calculating the cross-sectional area below each profile and then interpolating between successive profiles it is possible to calculate beach volumes on a more frequent basis. By combining the coastal monitoring data with Environment Agency data collected since the 1994 renourishment it is possible to show the beach volume trends for Preston beach to Bowleaze Cove since 1994. These are shown in Figure 37. It can be seen that the long-term trend for Preston beach is for continued loss of volume, whilst the opposite is true for Furzy and Bowleaze beaches. It is noteworthy that the total combined volume of the beaches initially declined for the first eight years after recharge but appears to have been relatively stable since, fluctuating around a volume of approximately 230,000m$^3$. Typical beach profiles for Preston beach and Furzy are shown in Figures 38 and 39 respectively, showing the gradual decline of the crest width at Preston beach and the gradual growth of the beach at Furzy cliffs.

Volume changes and rates of transport between individual years appear highly variable, with some years seeing a net loss of material from Preston (SU14) and Furzy (SU13/12) and some years experiencing a net gain. Detailed analysis of individual years suggests volume variation by as much as +or- 10,000m$^3$ although the losses and gains for each section of beach rarely balance equally, suggesting much of this material loss is below the area of survey. The long-term trend graphs indicate an average rate of transport of material north-eastwards of approximately 3000-4000m$^3$ per annum, with most of this accumulation in front of Furzy cliffs with only minor increases experienced at Bowleaze Cove.

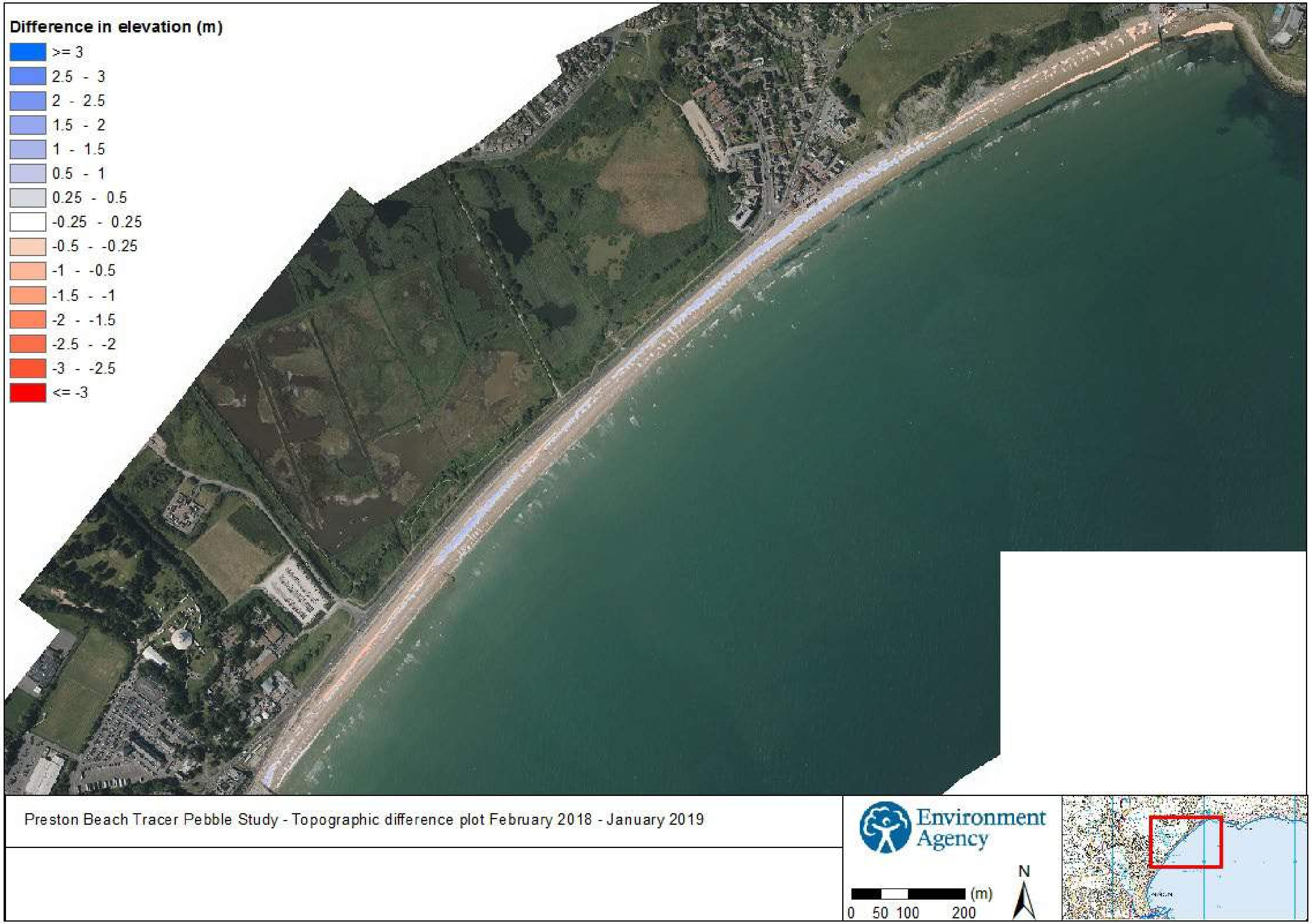



Figure 32. Topographic difference plot from February 2018 – January 2019

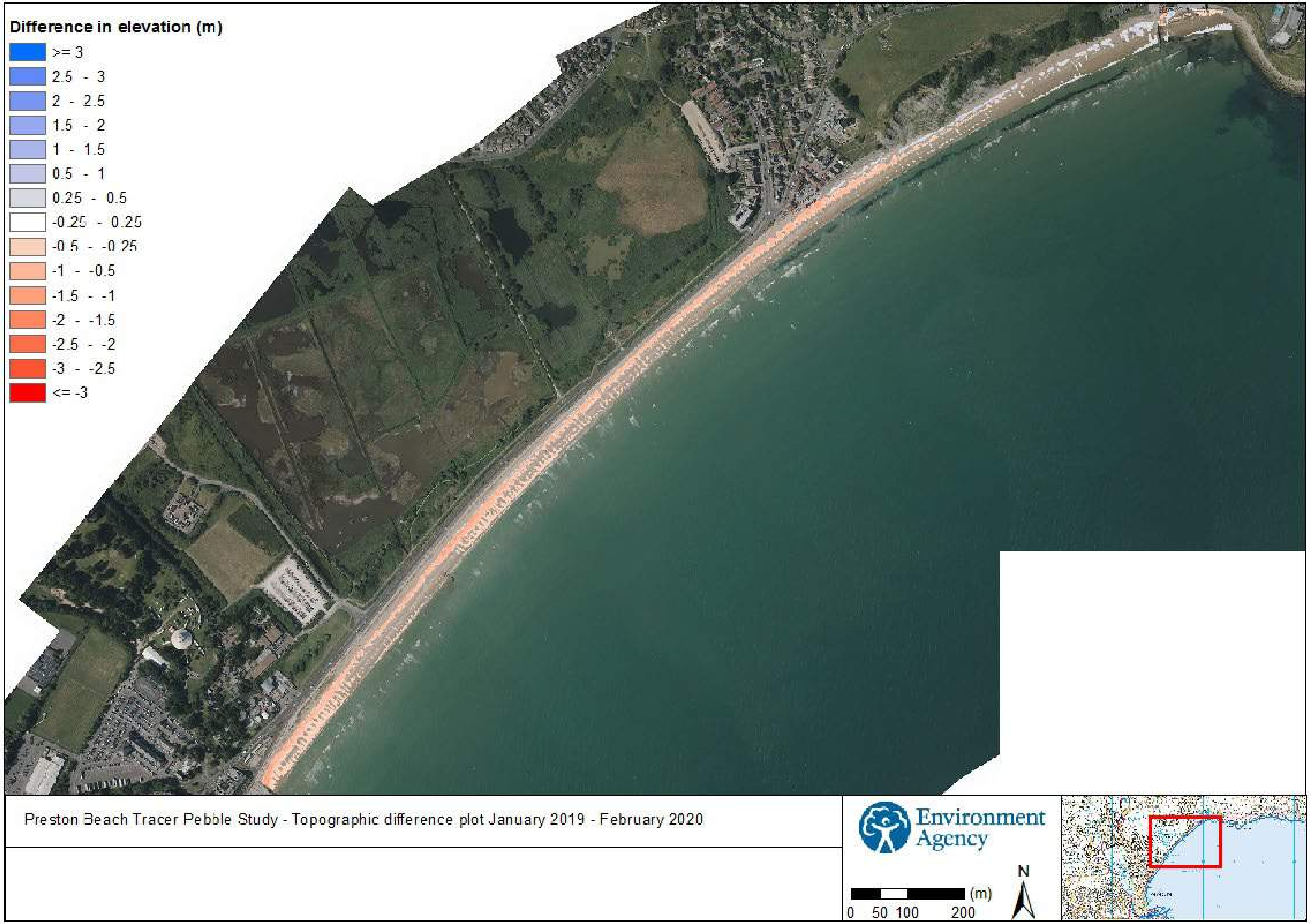



Figure 33. Topographic difference plot from January 2019 – February 2020

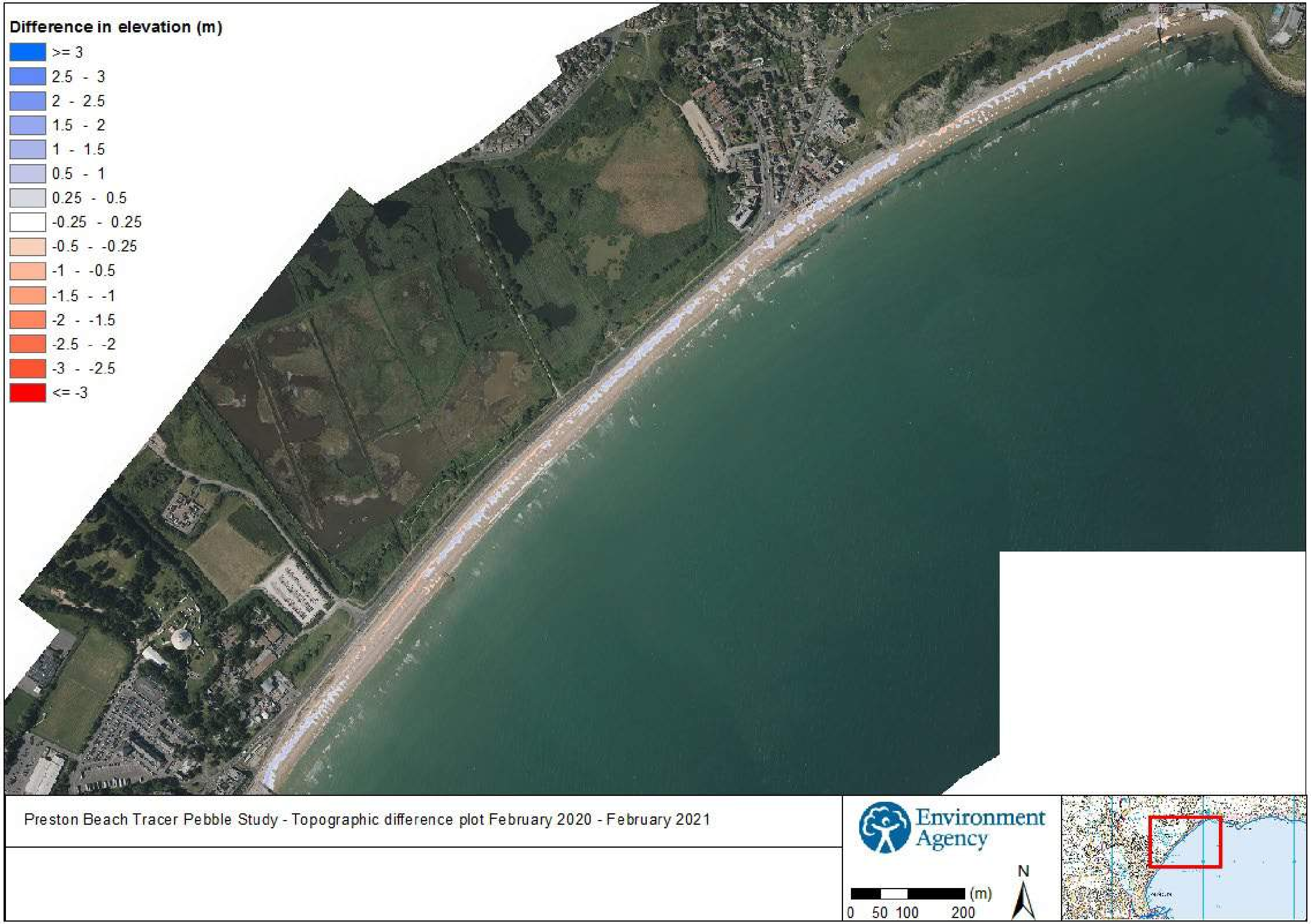



Figure 34. Topographic difference plot from February 2020 – February 2021

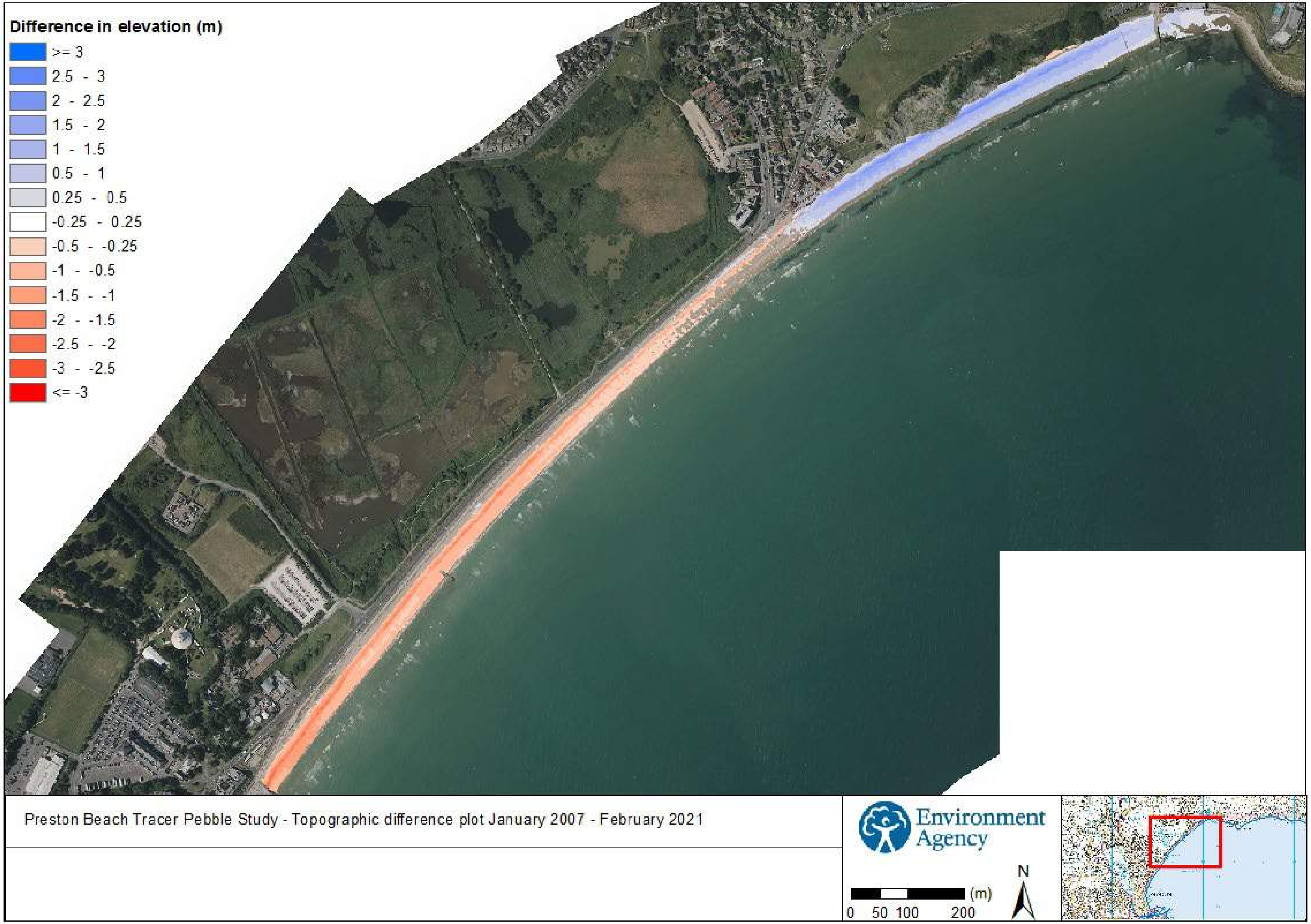



Figure 35. Topographic difference plot from January 2007 – February 2021


Figure 36. Topographic difference plot from January 2019 – February 2021

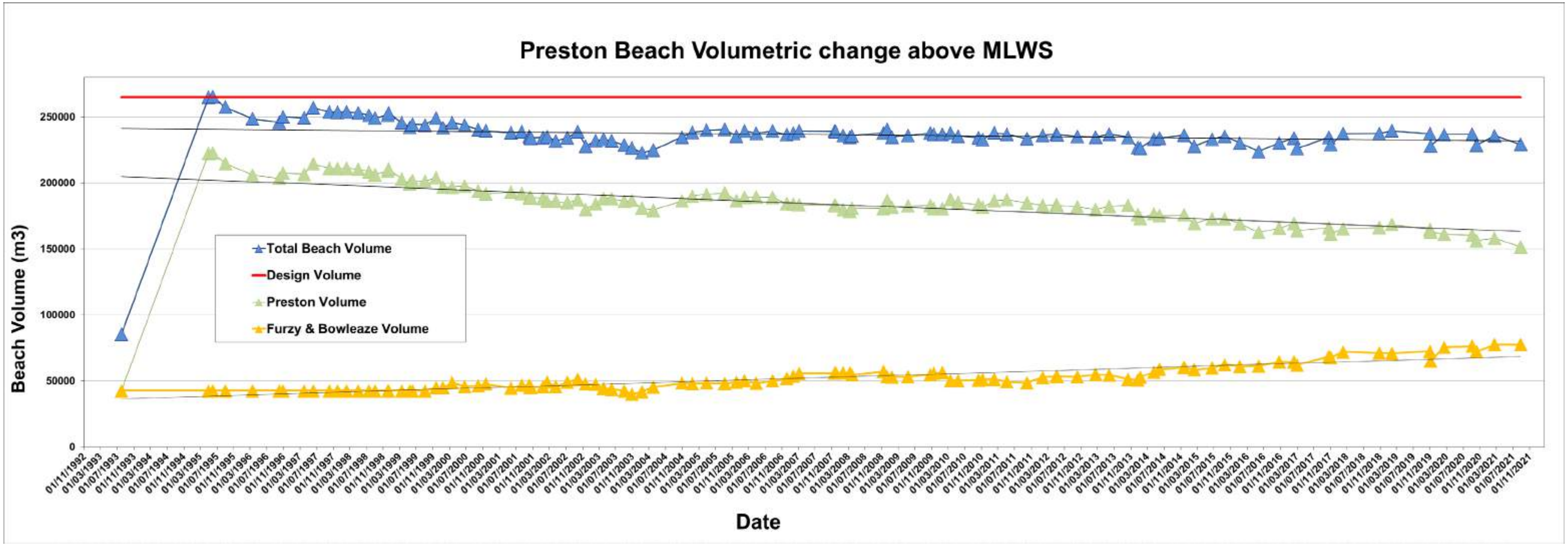



Figure 37. Trend of beach volumes at Preston and Furzy beaches

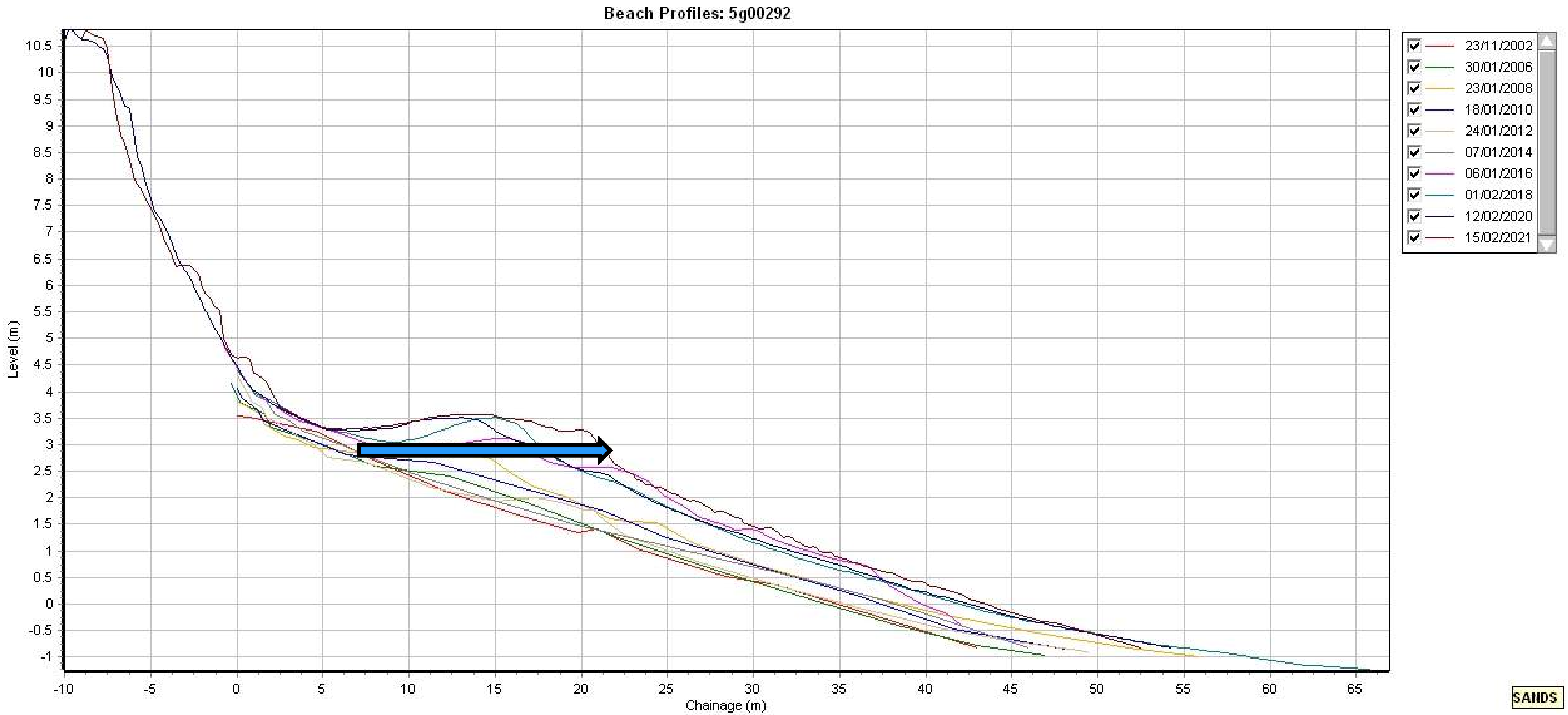



Figure 38. Typical beach profile for Furzy Cliffs showing gradual accretion

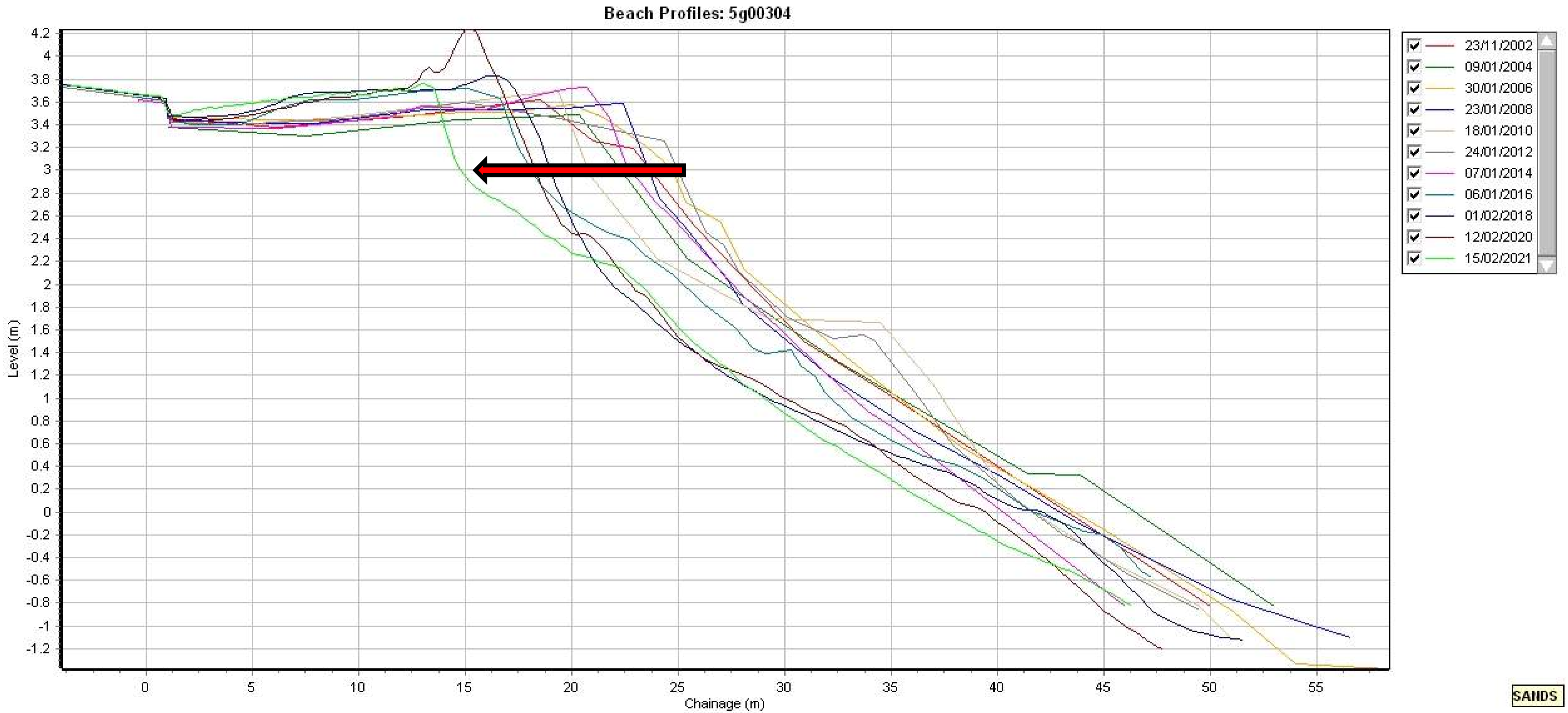



Figure 39. Typical beach profile for Preston beach showing gradual erosion

# Hydrodynamic data

As part of the Regional Coastal Monitoring Programme there has been a Waverider buoy situated in Weymouth Bay since 2006, recording data every 30 minutes. Details of the buoy are described below.

<table>
<tr><td colspan="2">Location</td><td rowspan="5"></td><td rowspan="5">
</td></tr>
<tr><td>OS</td><td>370799 E 80412 N</td></tr>
<tr><td>WGS84</td><td>Latitude: 50° 37.36' N<br>Longitude: 02° 24.85' W</td></tr>
<tr><td colspan="2">Instrument type</td></tr>
<tr><td colspan="2">Datawell<br>Directional Waverider Mk III</td></tr>
<tr><td>Water depth</td><td>~11 m CD</td><td>Buoy in situ in Weymouth Bay. Photo courtesy of Fugro GB Marine Limited</td><td>Location of buoy (Google mapping, image ©2016 Getmapping plc)</td></tr>
</table>

Image courtesy, Channel Coastal Observatory (CCO)

Wave heights within Weymouth Bay average approximately 0.5m Hs and periods of 6-8s Tp, with maximum storm wave heights up to 4m Hs. Waves are predominately from the southeast or southerly direction, given the sheltered nature of the bay, meaning that the largest waves approach approximately shore normal and are likely the biggest cause of cross shore transport. This results in the rapid loss of beach face and draw down which is characteristic of storm events for this section of beach frontage. The much smaller waves, driven by the local winds in the bay are likely to be the principal cause of longshore sediment transport, given its low rates and frequent changes of direction. A wave rose for the period 2006-2020 is shown in Figure 40.

Given the infrequent nature of the tracer surveys and the low frequency of locating specific pebbles, it is very difficult to directly relate the movement of individual or collective pebbles to specific storm or wave events. Therefore for this study, no further analysis has been conducted on the relationship between the wave data and pebble movement. It is suggested that high intensity frequent surveys would be needed to better draw relationships between the waves and sediment transport rates on the beaches or some targeted pre/post storm surveys to identify results from specific events.

The latest CCO Weymouth Buoy report is attached in the Appendix.

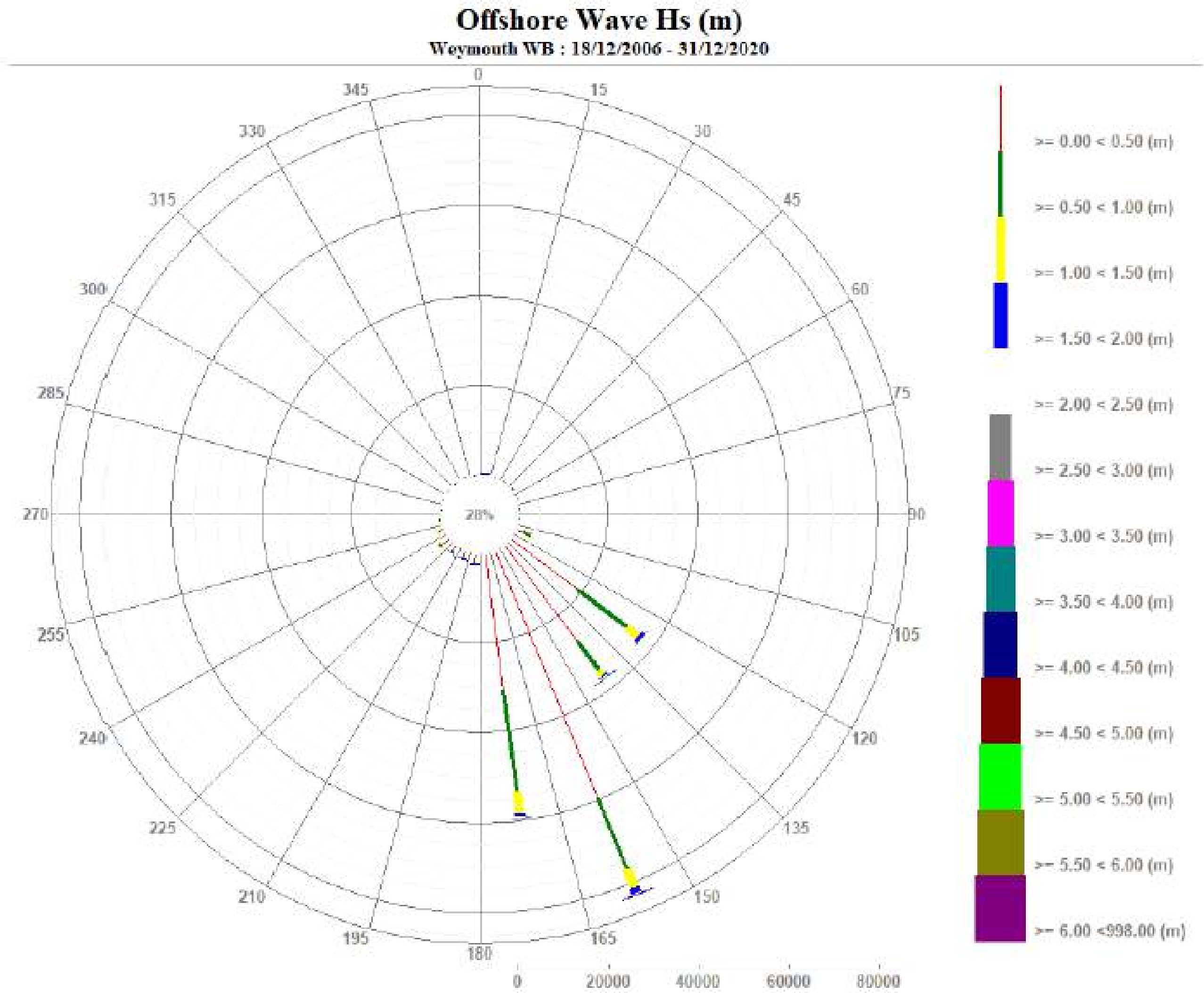



Figure 40. Wave rose for Weymouth Bay (2006-2020) courtesy CCO

# Conclusions & Recommendations

The objectives of this study were

- To investigate the general patterns of sediment transport along the beach and estimate rates of transport where possible
- To determine if sediment is able to move passed the pier at Bowleaze cove in both directions
- To determine if sediment is able to pass south around the rock groyne at Greenhill

The data collected during the tracer study suggests that the direction and rate of pebble movement along this stretch of coastline is highly variable and likely dominated by the wind and wave conditions at the time. Movement of pebbles in all directions was recorded across the whole frontage, however the general trend in all the data is for a northeast transport of material along Preston beach (SU14) towards Furzy Cliff with a southeast transport of material from Bowleaze Cove (SU12) towards the same location. This was confirmed by the coastal monitoring data and long-term beach profiles, with a gradual accumulation of material seen at Furzy with a gradual loss of material along Preston beach.

Rates of pebble transport were found to vary greatly between surveys, with as much as 165m a day suggested by the data for site E, although the daily average along the frontage for all sites is less than 10m. At two deployment sites, pebbles were recorded more than 1km from the initial deployment location and there was evidence to suggest the movement of pebbles can be in any direction at any location.

There was clear evidence collected that pebbles are able to bypass the pier at Bowleaze Cove in either direction, although the general trend is for material to move southeast towards the cliffs. There was insufficient evidence recorded that pebbles were moving beyond Bowleaze Cove around the headland, although several pebbles were recorded in the very northeast corner the surveys did not extend around the headland as the terrain becomes rocky and inaccessible. Analysis of coastal monitoring data for Bowleaze (SU12) does not add any support to the theory that pebbles are moving further east, with no notable accumulation of sediment evident adjacent to the headland.

At the Greenhill rock groyne, no pebbles were recorded immediately adjacent to the groyne with the nearest pebble 15m away. Transport of recorded pebbles within the vicinity was predominately to the northeast and therefore it was decided not to survey to the south of the rock groyne along Weymouth beach. Whilst not conclusive, there was no evidence found to suggest any pebbles are able to bypass this structure and continue southeast.

The data collected is supportive to the current practices within the beach management plan, noting the evidence for an accumulation of material at Furzy cliffs and the dominant drift of material northeast from Preston beach. Reprofiling of the beach after storm events and periodic recycling from Furzy to Preston would appear to be the most suitable management practice in order to maintain the desired beach profile and level of defence at Preston. Without periodic beach recycling, it is likely the beach at Furzy would continue to accumulate sediment, whilst the beach at Preston would rapidly deplete and expose the underlying rock revetment fronting the seawall and promenade. Although material was recorded to travel southeast on occasion, the longer-term trends suggest this would not be enough to maintain the beach at Preston without intervention.

Current coastal monitoring practices should continue and are sufficient for beach management requirements and long-term trends analysis, although additional focus at Bowleaze Cove would be of interest to further investigate coastal processes in this area of the bay and headland.

It is recommended that the results of this tracer study are used in consideration for any changes or further analysis of the current published SCOPAC STS, 2012. In particular, the transport direction arrow circled below in Figure 41 suggests a dominant transport northeast at this location which is not supported by this study. Consideration should be given to reorientate the arrow in the opposite direction, feeding sediment to the southwest from Bowleaze Cove to Furzy. The remaining arrows (LT2) for the tracer study extent appear complimentary to the overall findings.

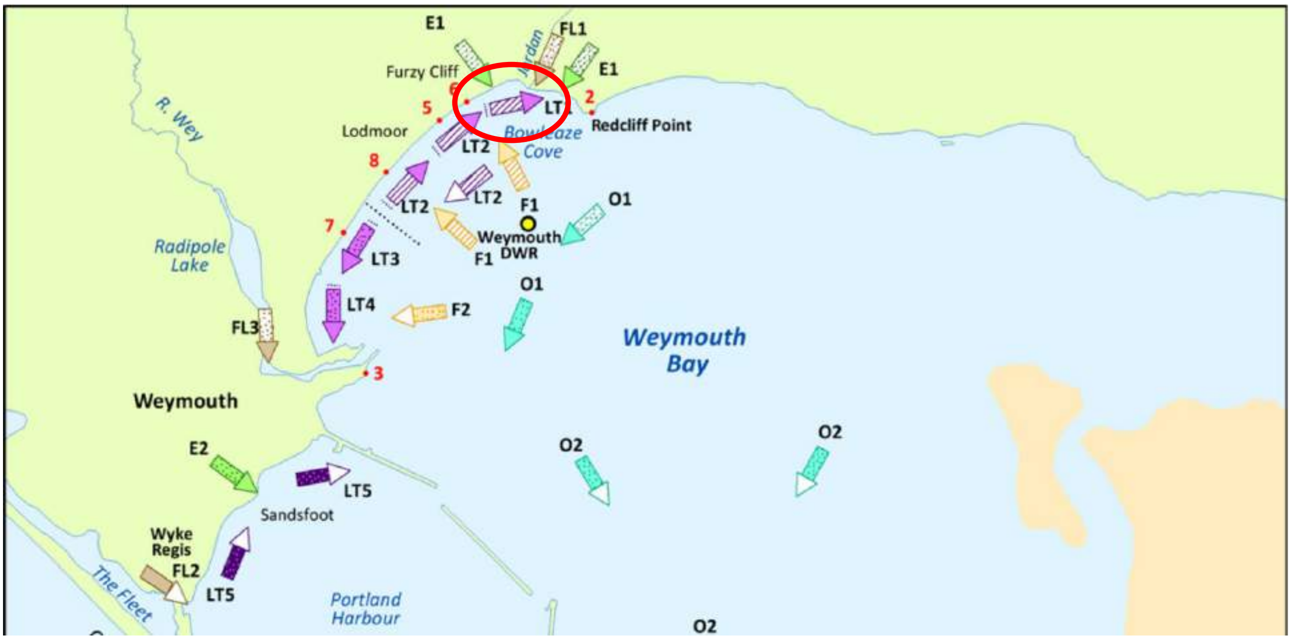



Figure 41. Extract from the latest STS, 2012

Further, more detailed analysis of the data collected would help improve understanding of the results and it is recommended that additional surveys are conducted in the future to add to the long-term understanding of coastal processes in this region. Increasing the current survey extents further north and south would help better understand the transport of material around the Greenhill rock groyne and adjacent to the headland, as would additional deployments of pebbles south of the rock groyne along Weymouth beach.

# References

New Forest District Council (2017). 2012 Update of Carter, D., Bray, M., & Hooke, J., 2004 SCOPAC Sediment Transport Study, www.scopac.org.uk/sts

CH2M (2016). Preston Beach Management Plan. Environment Agency South West Region, 2016.

# Appendix

- List of survey dates (*yyyy/mm/dd*)

20190121
20190123
20190125
20190128
20190130
20190201
20190206
20190213
20190220
20190227
20190313
20190402
20190503
20190614
20191120
20191122
20191125
20191127
20191203
20191211
20191217
20200102
20200130
20200228
20210514

- Weymouth Buoy wave report 2020

# Weymouth Directional Waverider Buoy

| **Location** | |
|---|---|
| OS | 370799 E 80412 N |
| WGS84 | *Latitude:* 50° 37.36' N<br>*Longitude:* 02° 24.85' W |
| **Instrument type** | |
| Datawell<br>Directional Waverider Mk III | |
| **Water depth** | ~11 m CD |

Buoy in situ in Weymouth Bay. Photo courtesy of Fugro GB Marine Limited


Location of buoy (Google mapping, image ©2016 Getmapping plc)

## Data Quality

| **Recovery rate (%)** | **Sample interval** |
|---|---|
| 99 | 30 minutes |

## Monthly Averages - 2020

*All times are GMT*

| **Month** | **$H_s$ (m)** | **$T_p$ (s)** | **$T_z$ (s)** | **Dir. (°)** | **SST (°C)** | **Bimodal seas (%)** | **No. of days** |
|---|---|---|---|---|---|---|---|
| January | 0.62 | 8.2 | 4.1 | 158 | 9.6 | 2 | 31 |
| February | 0.81 | 8.3 | 4.0 | 166 | 9.1 | 6 | 29 |
| March | 0.66 | 7.0 | 4.0 | 149 | 9.1 | 0 | 31 |
| April | 0.43 | 6.6 | 3.7 | 141 | 10.7 | 0 | 30 |
| May | 0.39 | 6.5 | 3.7 | 146 | 12.8 | 0 | 31 |
| June | 0.37 | 5.0 | 3.3 | 153 | 15.5 | 0 | 30 |
| July | 0.33 | 4.8 | 3.3 | 163 | 16.9 | 0 | 31 |
| August | 0.38 | 5.4 | 3.5 | 153 | 18.5 | 1 | 31 |
| September | 0.34 | 5.6 | 3.5 | 157 | 17.5 | 0 | 30 |
| October | 0.59 | 6.5 | 3.9 | 159 | 15.0 | 2 | 31 |
| November | 0.62 | 6.7 | 3.8 | 154 | 12.9 | 1 | 30 |
| December | 0.66 | 7.6 | 4.5 | 155 | 10.9 | 3 | 30 |

## Monthly Averages - All Years (December 2006 – December 2020)

| **Month** | **$H_s$ (m)** | **$T_p$ (s)** | **$T_z$ (s)** | **Dir. (°)** | **SST (°C)** | **Bimodal seas (%)** |
|---|---|---|---|---|---|---|
| January | 0.62 | 7.6 | 4.2 | 157 | 9.0 | 2 |
| February | 0.60 | 8.3 | 4.2 | 156 | 8.1 | 2 |
| March | 0.50 | 7.1 | 3.9 | 154 | 8.4 | 1 |
| April | 0.42 | 6.5 | 3.8 | 150 | 10.0 | 0 |
| May | 0.37 | 5.7 | 3.6 | 152 | 12.2 | 0 |
| June | 0.35 | 5.6 | 3.5 | 154 | 14.9 | 0 |
| July | 0.34 | 5.2 | 3.4 | 161 | 17.0 | 0 |
| August | 0.36 | 5.2 | 3.5 | 160 | 17.8 | 0 |
| September | 0.40 | 5.6 | 3.6 | 155 | 17.3 | 0 |
| October | 0.53 | 6.3 | 3.8 | 154 | 15.5 | 1 |
| November | 0.59 | 6.5 | 4.0 | 156 | 13.0 | 1 |
| December | 0.62 | 7.3 | 4.1 | 157 | 10.5 | 2 |

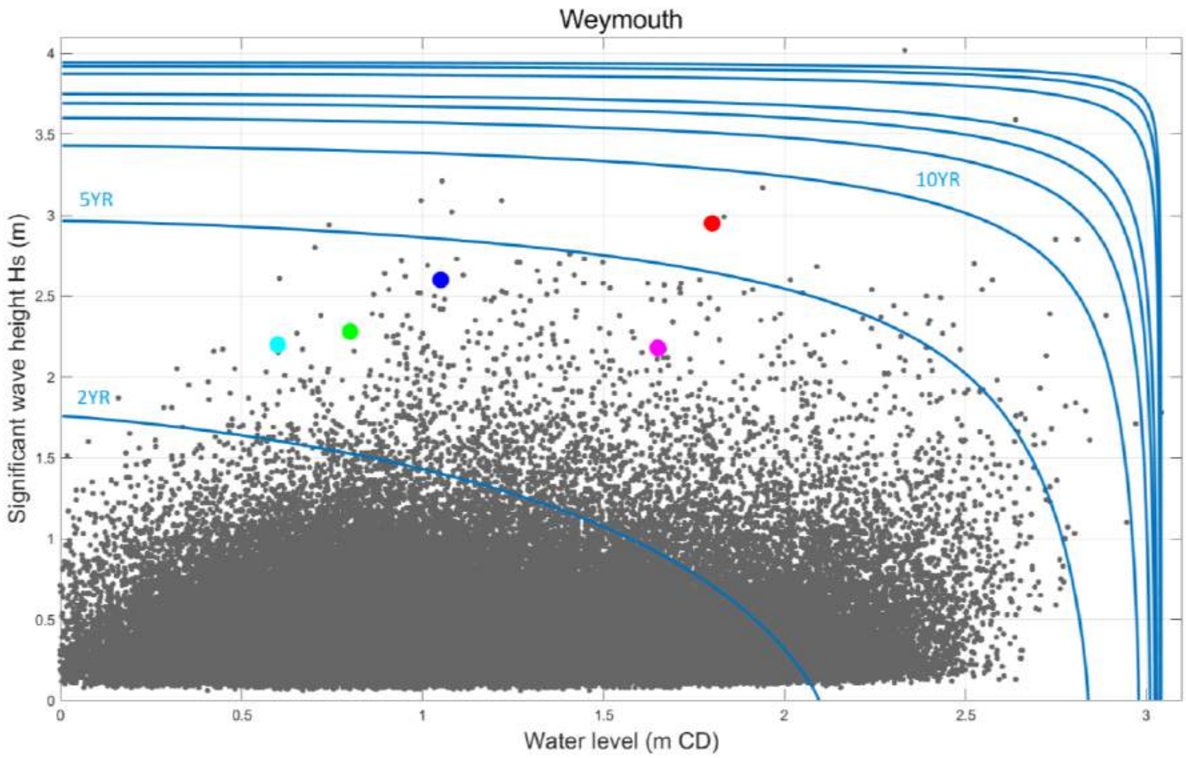
## Storm Analysis

| Date/Time | $H_s$ (m) | $T_p$ (s) | $T_z$ (s) | Dir. (º) | Water level elevation* (OD) | Tidal stage (hours re. HW) | Tidal range (m) | Tidal surge* (m) | Max. surge* (m) |
|---|---|---|---|---|---|---|---|---|---|
| 02-Oct-2020 08:30:00 | 2.95 | 10.0 | 6.6 | 135 | 0.87 | HW +1 | 1.80 | - | - |
| 11-Nov-2020 20:30:00 | 2.60 | 7.7 | 5.6 | 153 | 0.12 | HW +4 | 1.25 | 0.35 | 0.36 |
| 16-Jan-2020 14:00:00 | 2.28 | 7.7 | 5.5 | 160 | -0.13 | HW +3 | 1.70 | - | - |
| 21-Mar-2020 11:00:00 | 2.20 | 7.7 | 5.4 | 121 | -0.33 | HW +6 | 1.20 | - | - |
| 31-Oct-2020 09:30:00 | 2.18 | 7.1 | 5.2 | 162 | 0.72 | HW +3 | 1.59 | 0.41 | 0.44 |
| 09-Feb-2020 07:30:00 | 2.16 | 9.1 | 5.1 | 170 | 1.17 | HW +1 | 2.20 | - | - |

** Tidal information is obtained from the National Network gauge at Weymouth and/or estimated from the predicted tide levels (Admiralty Total Tide). The surge shown is the residual at the time of the highest Hs. The maximum tidal surge is the largest surge during the event.*

## Joint return periods

Joint return periods for water level and significant wave height are based on 0.5 hourly records and calculated using a copula function. For more details on the copula function, see Dhoop & Thompson 2021. The grey point cloud represents the measured joint wave heights and water levels at Weymouth DWR and the Weymouth National Network gauge respectively, plotted against one another.




| Date/Time | Symbol | $H_s$ (m) | Water level elevation | | Joint Return Period |
|---|---|---|---|---|---|
| | | | OD | CD | |
| 02-Oct-2020 08:30:00 | red | 2.95 | 0.87 | 1.80 | 1 in 5 years |
| 11-Nov-2020 20:30:00 | blue | 2.60 | 0.12 | 1.05 | 1 in 2 years |
| 16-Jan-2020 14:00:00 | green | 2.28 | -0.13 | 0.80 | 1 in 2 years |
| 21-Mar-2020 11:00:00 | cyan | 2.20 | -0.33 | 0.60 | 1 in 2 years |
| 31-Oct-2020 09:30:00 | magenta | 2.18 | 0.72 | 1.65 | 1 in 2 years |

## Annual Statistics

| Year | Annual $H_s$ exceedance** (m) | | | | | | Annual Maximum $H_s$ | |
|---|---|---|---|---|---|---|---|---|
| | 0.05% | 0.5% | 1% | 2% | 5% | 10% | Date | $A_{max}$ (m) |
| 2007 | 2.29 | 1.72 | 1.43 | 1.24 | 1.03 | 0.85 | 18-Nov-2007 13:00 | 2.56 |
| 2008 | 2.57 | 1.94 | 1.74 | 1.44 | 1.09 | 0.88 | 03-Feb-2008 12:30 | 2.74 |
| 2009 | 2.17 | 1.75 | 1.63 | 1.48 | 1.18 | 0.90 | 13-Nov-2009 23:00 | 2.62 |
| 2010 | 2.54 | 1.84 | 1.54 | 1.29 | 1.00 | 0.81 | 17-Nov-2010 09:30 | 2.81 |
| 2011 | 2.16 | 1.77 | 1.54 | 1.26 | 1.03 | 0.85 | 23-Oct-2011 23:30 | 2.30 |
| 2012 | 2.82 | 1.80 | 1.60 | 1.38 | 1.08 | 0.86 | 30-Apr-2012 04:30 | 3.34 |
| 2013 | 2.47 | 1.89 | 1.65 | 1.47 | 1.21 | 0.98 | 18-Dec-2013 20:00 | 2.70 |
| 2014 | 3.22 | 2.30 | 1.97 | 1.65 | 1.28 | 0.99 | 05-Feb-2014 00:00 | 4.02+ |
| 2015 | 2.43 | 1.71 | 1.52 | 1.31 | 1.11 | 0.95 | 30-Dec-2015 11:00 | 2.72 |
| 2016 | 3.25 | 1.95 | 1.66 | 1.44 | 1.12 | 0.88 | 20-Nov-2016 01:30 | 3.87 |
| 2017 | 2.07 | 1.65 | 1.50 | 1.29 | 1.01 | 0.78 | 03-Feb-2017 16:00 | 2.40 |
| 2018 | 2.60 | 2.17 | 1.88 | 1.55 | 1.24 | 0.98 | 13-Feb-2018 09:30 | 2.98 |
| 2019 | 2.39 | 1.78 | 1.63 | 1.51 | 1.24 | 0.99 | 05-Apr-2019 04:30 | 2.86 |
| 2020 | 2.36 | 1.90 | 1.73 | 1.52 | 1.20 | 1.01 | 02-Oct-2020 08:30 | 2.95 |

*** i.e. 5 % of the $H_s$ values measured in 2007 exceeded 1.03 m*

*+ Note that waves were breaking at the buoy for several hours during this storm; where breaking waves were clearly present in the measured time series, the parameters have been omitted. Accordingly, there may have been short periods where measured significant wave heights exceeded this value.*

## 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). For more details, see Dhoop & Thompson 2018.

| Observation period | December 2006 to December 2020 | |
|---|---|---|
| **Return period (years)** | **Significant wave height (m)** | **Comments** |
| 0.25 | 2.16 | No depth limitation |
| 1 | 2.73 | |
| 2 | 3.01 | |
| 5 | 3.38 | |
| 10 | 3.65 | |
| 20 | 3.92 | Depth-limited at MLWS |
| 50 | 4.27 | Depth-limited at MHWS |
| 100 | 4.52 | Depth-limited at HAT |

## Distribution plots

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

- Annual time series of $H_s$ (red line is 2.16 m storm alert threshold)
- Incidence of storm waves for 2020. 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 2020
- 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

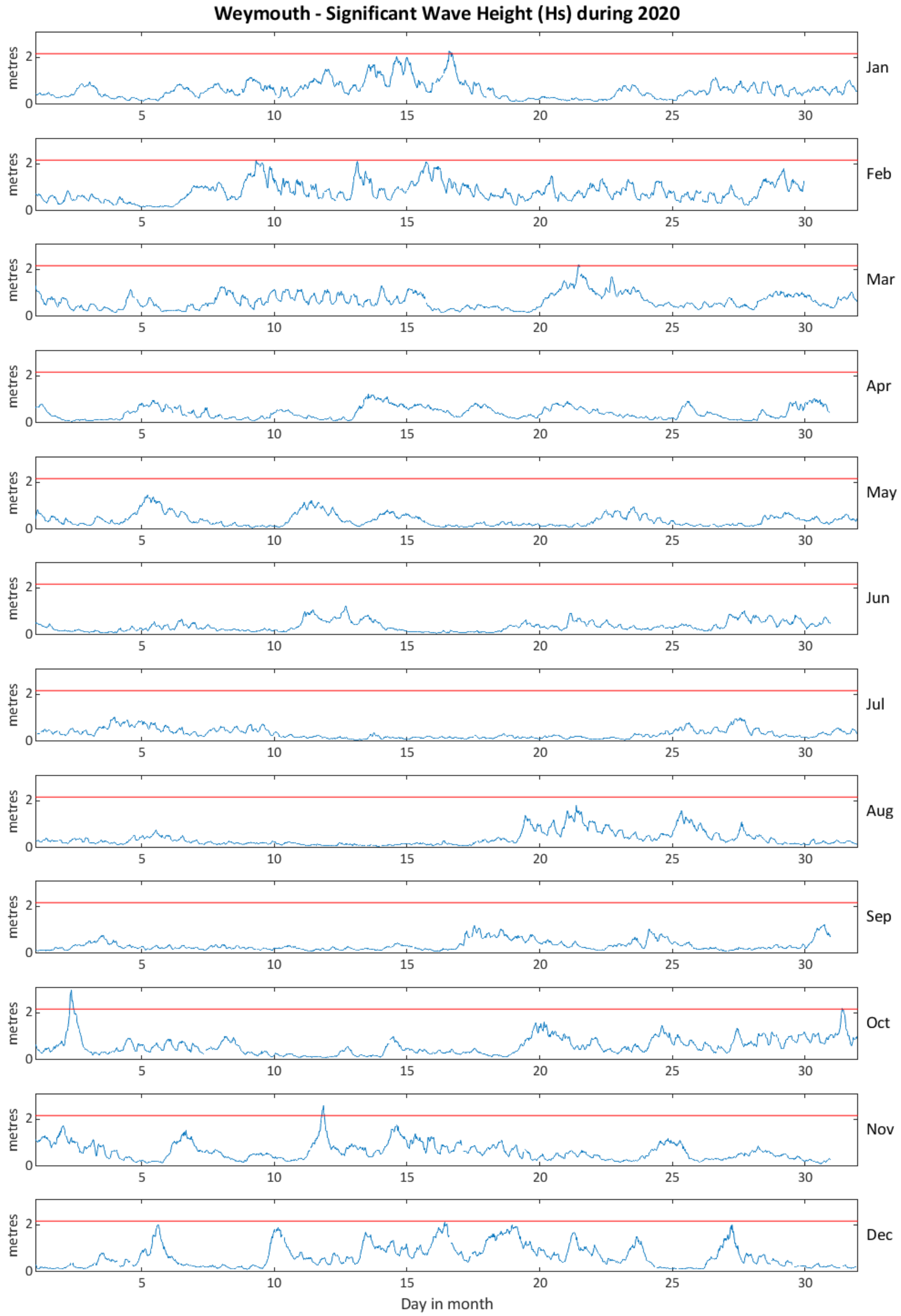
## General

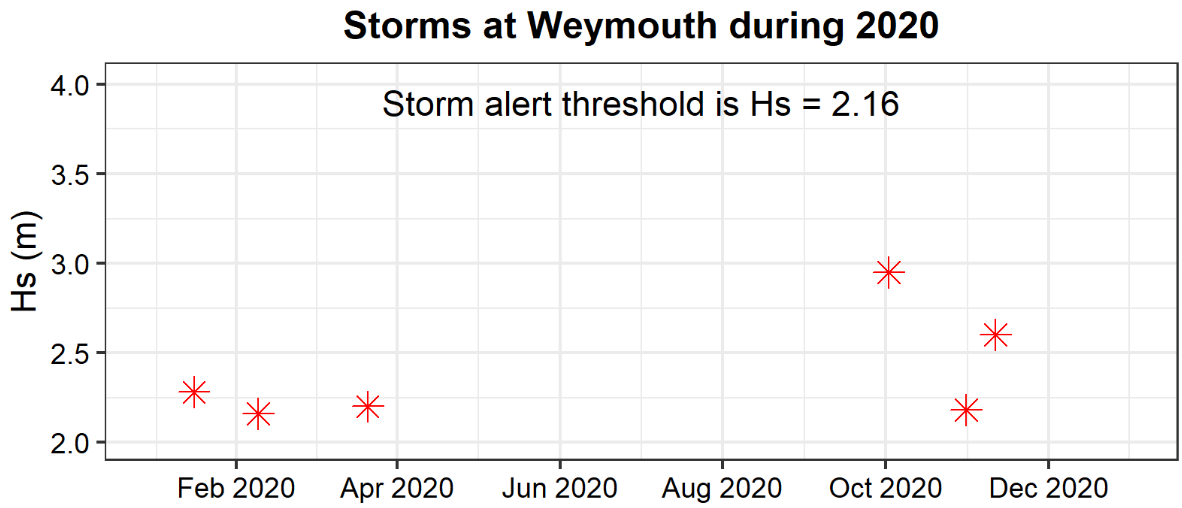
The buoy, owned by New Forest District Council, was first deployed on 18 December 2006, at which time the magnetic declination at the site was 2.9° west, changing by 0.15° east per year.

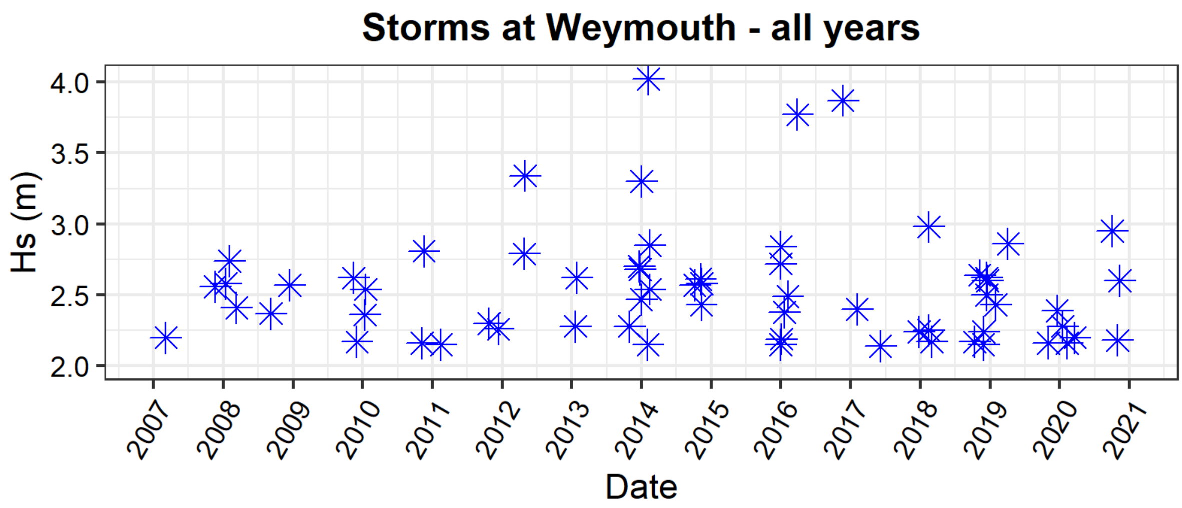
## Acknowledgements

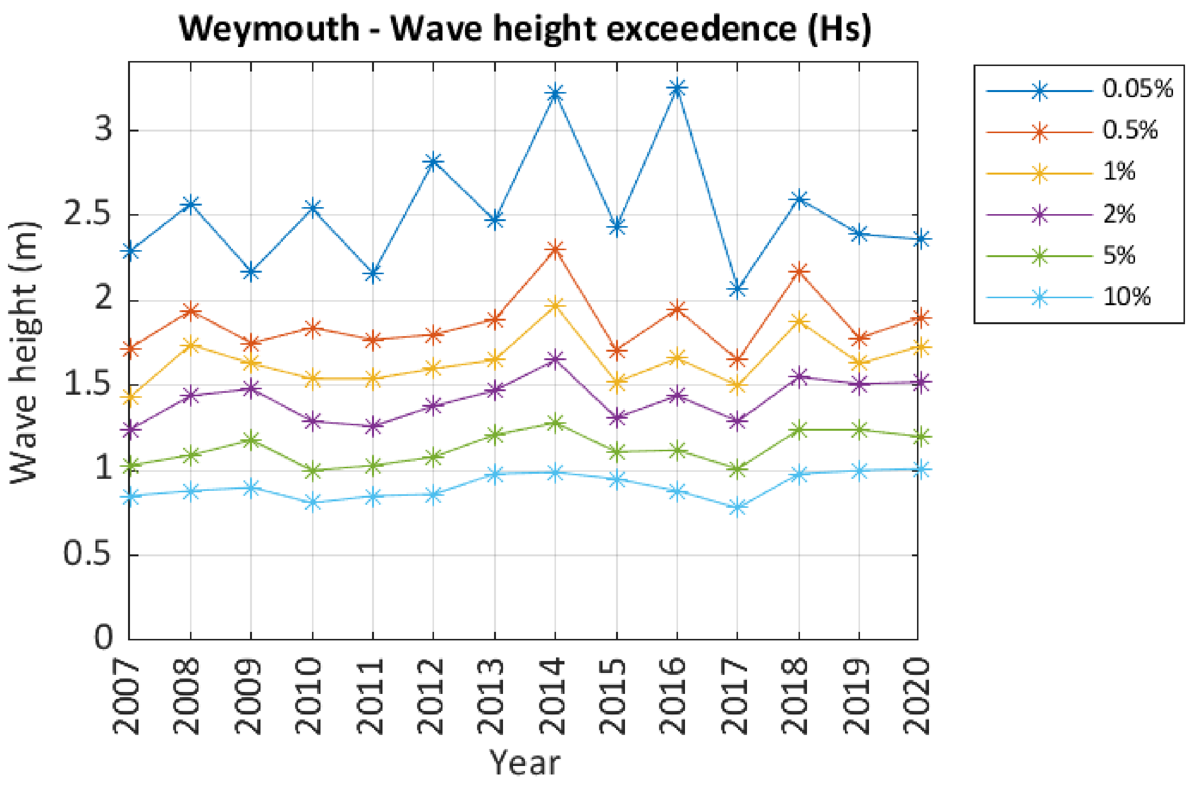
The shore station is kindly hosted by the Weymouth and Portland National Sailing Academy.

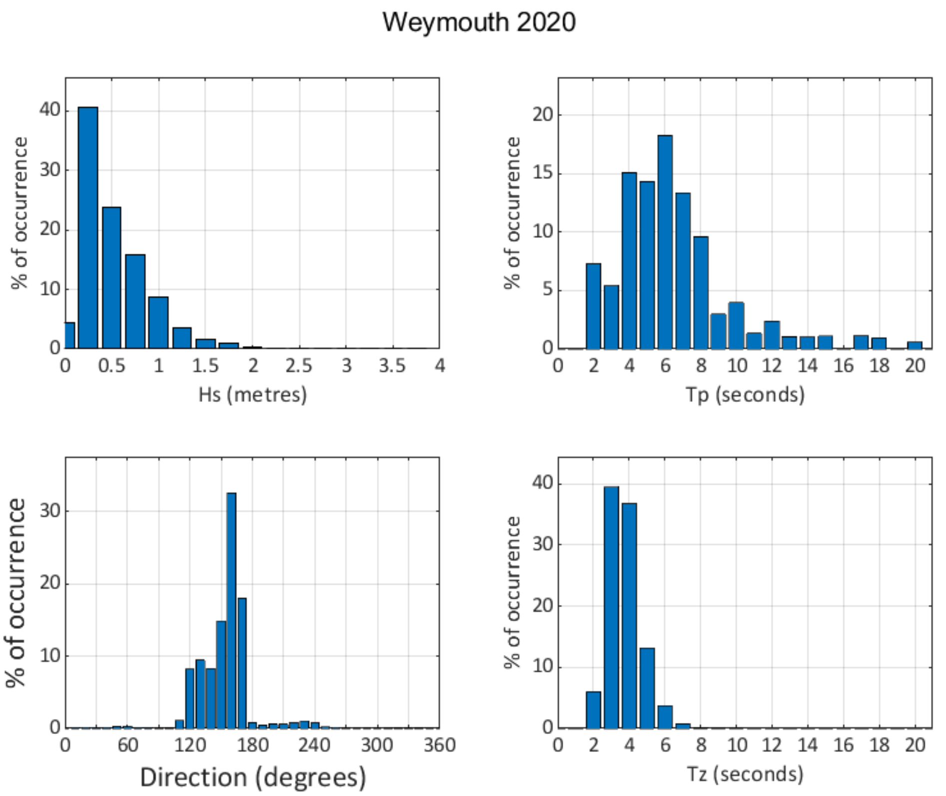
Tidal data at Weymouth were provided by the British Oceanographic Data Centre from the UK national tide gauge network, owned and operated by the Environment Agency.

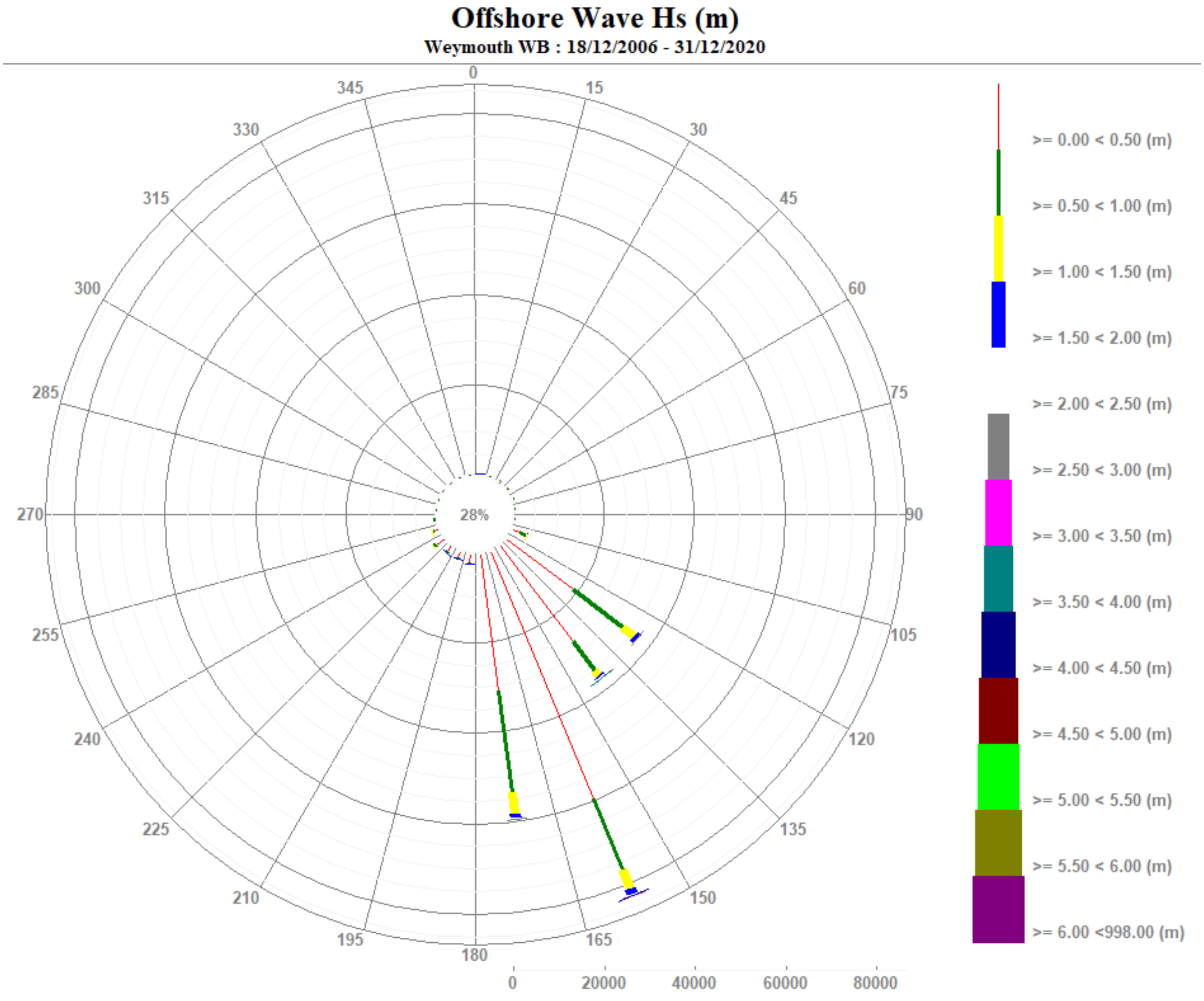

Weymouth - Significant Wave Height (Hs) during 2020
metres
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
0
2
5
10
15
20
25
30
Day in month

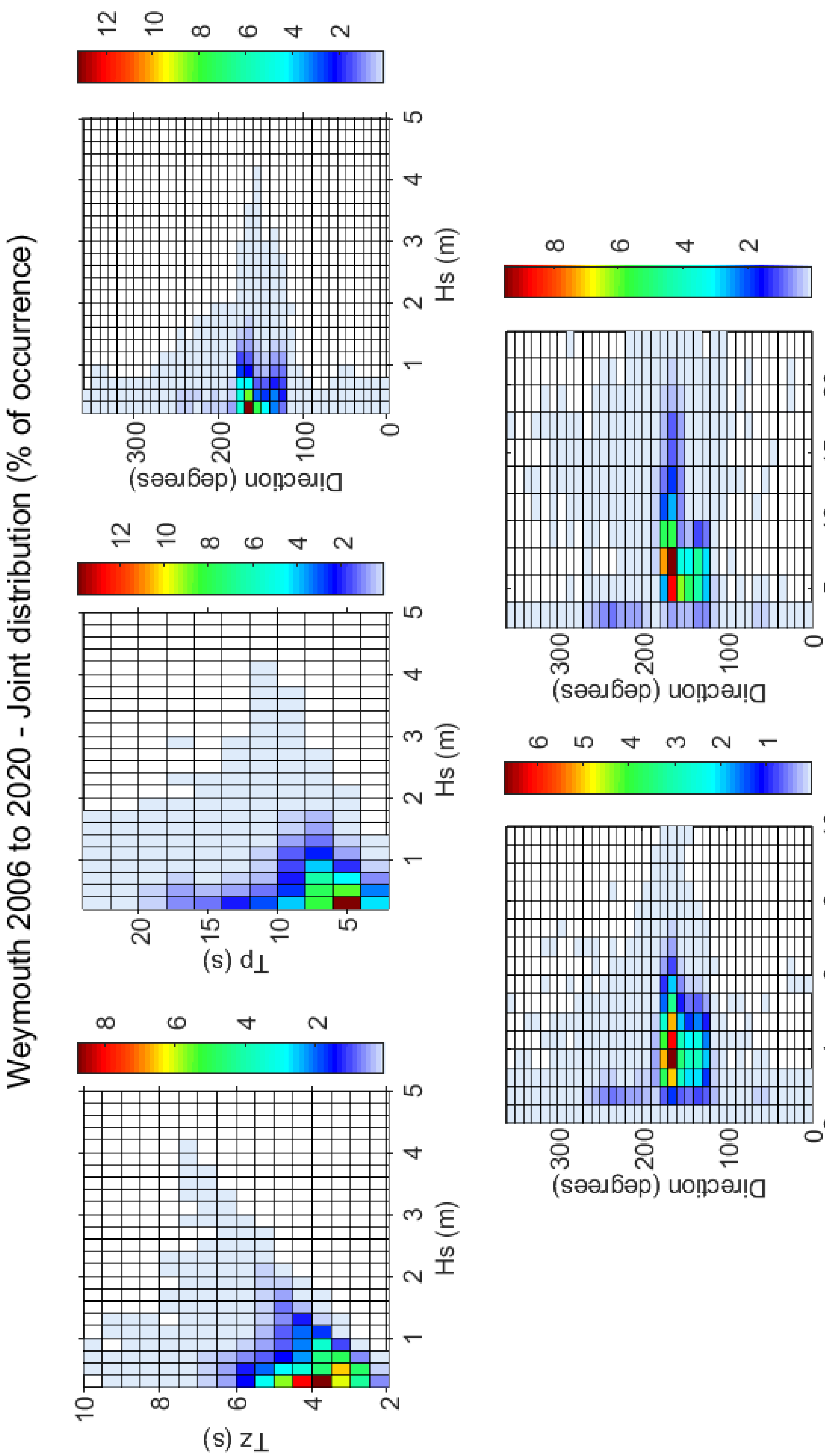

Storms at Weymouth during 2020
Storm alert threshold is Hs = 2.16
Hs (m)
4.0
3.5
3.0
2.5
2.0
Feb 2020
Apr 2020
Jun 2020
Aug 2020
Oct 2020
Dec 2020


Storms at Weymouth - all years
Hs (m)
4.0
3.5
3.0
2.5
2.0
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
2020
2021
Date


Weymouth - Wave height exceedence (Hs)
Wave height (m)
3
2.5
2
1.5
1
0.5
0
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
2020
Year
0.05%
0.5%
1%
2%
5%
10%


Weymouth 2020
% of occurrence
Hs (metres)
Tp (seconds)
Direction (degrees)
Tz (seconds)


Offshore Wave Hs (m)
Weymouth WB : 18/12/2006 - 31/12/2020
28%
>= 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)


Weymouth 2006 to 2020 - Joint distribution (% of occurrence)
Tz (s)
Hs (m)
Tp (s)
Hs (m)
Direction (degrees)
Hs (m)
Direction (degrees)
Tz (s)
Direction (degrees)
Tp (s)

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# Environment first

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