Southeast Strategic Regional Coastal Monitoring Programme

ANNUAL SURVEY REPORT
2015

Beachy Head to Selsey Bill

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<table>
<thead>
<tr>
<th>L. Warman</th>
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</thead>
<tbody>
<tr>
<td>Checked By:</td>
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<td>Approved By:</td>
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</tbody>
</table>
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1 Introduction

This Annual Report provides an overview of beach and cliff changes, and wave and tidal measurements for Coastal Process Sub-Cell 4d since the commencement of the Strategic Regional Coastal Monitoring Programme (SRCMP) in 2003. Figure 1.1 shows the location and extent of the Coastal Process Cells in Southeast England.

Sub-Cell 4d is split into Survey Units, based on the ‘Management Units’ used in previous Annual Reports, but rationalised so that boundaries line up with natural changes in the coastline or physical structures. Figure 1.2 shows the locations of the Survey Units for Sub-Cell 4d.

In previous Annual Reports, the changes to the beaches were presented using cross-sectional area calculations for Profiles. All beaches and cliffs in Sub-Cell 4d are now surveyed using mobile laser scanning. As a result, Profile analysis is no longer included in Annual Reports and is replaced with a more comprehensive analysis that includes volumetric data, trend and confidence mapping along with a separate analysis of cliff changes.

Annex A outlines the survey programme conducted for the 2014 to 2015 reporting period.
2 Volume Change Summary

2.1 Volumetric Changes

The difference in beach volumes for spring 2014 to spring 2015, and for baseline to spring 2015 have been calculated for this report. Annex B describes the methodology used to present volume changes and Annex C displays the changes on maps.

The baseline\(^1\) survey for each Survey Unit has been chosen as the earliest survey that sufficiently covered the beach to an appropriately low level, i.e. Mean Low Water Neaps or lower where possible. Table 2.1 lists the dates of the surveys for each Survey Unit, with the datum used for volume calculation. Areas fronted with Chalk Cliffs are analysed separately in Section 3.

<table>
<thead>
<tr>
<th>Survey Unit</th>
<th>Area</th>
<th>Survey Dates</th>
<th>MLWN (mODN)</th>
<th>Datum Used (mODN)</th>
</tr>
</thead>
<tbody>
<tr>
<td>4dSU01</td>
<td>Birling Gap to Beachy Head</td>
<td>25/07/2012 15/08/2014 05/08/2015</td>
<td>-1.620</td>
<td></td>
</tr>
<tr>
<td>4dSU02</td>
<td>Birling Gap</td>
<td>25/07/2012 15/08/2014 05/08/2015</td>
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<tr>
<td>4dSU03</td>
<td>Cuckmere Haven to Birling Gap</td>
<td>25/07/2012 15/08/2014 05/08/2015</td>
<td>-1.620</td>
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</tr>
<tr>
<td>4dSU04</td>
<td>Cuckmere Haven</td>
<td>25/07/2012 15/08/2014 05/08/2015</td>
<td>-1.620</td>
<td></td>
</tr>
<tr>
<td>4dSU05</td>
<td>Seaford Head to Cuckmere Haven</td>
<td>25/07/2012 15/08/2014 05/08/2015</td>
<td>-1.620</td>
<td></td>
</tr>
<tr>
<td>4dSU06</td>
<td>Seaford</td>
<td>13/01/2005 24/03/2014 20/02/2015</td>
<td>-1.620</td>
<td>-1.620</td>
</tr>
<tr>
<td>4dSU07</td>
<td>Newhaven Harbour</td>
<td>24/07/2012 15/08/2014 10/09/2015</td>
<td>-1.620</td>
<td></td>
</tr>
<tr>
<td>4dSU08</td>
<td>Peacehaven Heights to Newhaven Harbour</td>
<td>24/07/2012 15/08/2014 10/09/2015</td>
<td>-1.620</td>
<td></td>
</tr>
<tr>
<td>4dSU09</td>
<td>Telscombe to Peacehaven Heights</td>
<td>24/07/2012 15/08/2014 10/09/2015</td>
<td>-1.620</td>
<td></td>
</tr>
<tr>
<td>4dSU10</td>
<td>Telscombe Cliffs</td>
<td>24/07/2012 15/08/2014 10/09/2015</td>
<td>-1.500</td>
<td></td>
</tr>
<tr>
<td>4dSU11</td>
<td>Brighton Marina to Saltdean</td>
<td>24/07/2012 15/08/2014 10/09/2015</td>
<td>-1.500</td>
<td></td>
</tr>
<tr>
<td>4dSU12</td>
<td>Brighton</td>
<td>24/07/2012 15/08/2014 10/09/2015</td>
<td>-1.500</td>
<td></td>
</tr>
<tr>
<td>4dSU13</td>
<td>Brighton</td>
<td>10/03/2003 07/03/2014 06/03/2015</td>
<td>-1.500</td>
<td>-1.500</td>
</tr>
<tr>
<td>4dSU14</td>
<td>Southwick</td>
<td>29/11/2007 27/02/2014 09/03/2015</td>
<td>-1.370</td>
<td>-1.500</td>
</tr>
<tr>
<td>4dSU15</td>
<td>Lancing to Shoreham Harbour</td>
<td>29/11/2007 05/03/2014 24/03/2015</td>
<td>-1.370</td>
<td>-1.500</td>
</tr>
<tr>
<td>4dSU16</td>
<td>Goring to Lancing</td>
<td>06/06/2005 05/03/2014 24/03/2015</td>
<td>-1.300</td>
<td>-1.500</td>
</tr>
<tr>
<td>4dSU17</td>
<td>Rustington to Goring</td>
<td>30/01/2008 04/03/2014 23/03/2015</td>
<td>-1.350</td>
<td>-1.200</td>
</tr>
<tr>
<td>4dSU18</td>
<td>Littlehampton Harbour to Rustington</td>
<td>30/01/2008 04/03/2014 23/03/2015</td>
<td>-1.350</td>
<td>-1.200</td>
</tr>
<tr>
<td>4dSU19</td>
<td>Climping</td>
<td>18/07/2007 21/02/2014 02/02/2015</td>
<td>-1.350</td>
<td>-1.350</td>
</tr>
<tr>
<td>4dSU20</td>
<td>Elmer</td>
<td>06/01/2008 21/02/2014 02/02/2015</td>
<td>-1.350</td>
<td>-1.000</td>
</tr>
<tr>
<td>4dSU21</td>
<td>Bognor</td>
<td>06/01/2008 04/02/2014 25/03/2015</td>
<td>-1.350</td>
<td>-1.000</td>
</tr>
<tr>
<td>4dSU22</td>
<td>Pagham</td>
<td>10/03/2003 20/02/2014 27/01/2015</td>
<td>-1.250</td>
<td>-1.000</td>
</tr>
<tr>
<td>4dSU23</td>
<td>Church Norton to Pagham</td>
<td>10/03/2003 20/02/2014 27/01/2015</td>
<td>-1.000</td>
<td>-1.000</td>
</tr>
<tr>
<td>4dSU24</td>
<td>Selsey to Church Norton</td>
<td>10/03/2003 20/02/2014 26/01/2015</td>
<td>-1.000</td>
<td>-1.000</td>
</tr>
</tbody>
</table>

Table 2.1 Baseline survey dates and datums

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\(^1\) The term ‘baseline’ refers to a full coverage survey, specifically the first full coverage survey undertaken for a given Survey Unit.
Table 2.2 below summarises the total beach volume changes for each Survey Unit.

<table>
<thead>
<tr>
<th>Survey Unit</th>
<th>Total Volume (m$^3$)</th>
<th>Total Volume Change (m$^3$)</th>
<th>Total Percentage Change (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>4dSU06</td>
<td>1,720,700</td>
<td>1,688,900</td>
<td>1,688,900</td>
</tr>
<tr>
<td>4dSU13</td>
<td>2,362,000</td>
<td>2,510,100</td>
<td>2,526,200*</td>
</tr>
<tr>
<td>4dSU14</td>
<td>749,000</td>
<td>747,800</td>
<td>765,100</td>
</tr>
<tr>
<td>4dSU15</td>
<td>2,718,900</td>
<td>2,774,600</td>
<td>2,790,000</td>
</tr>
<tr>
<td>4dSU16</td>
<td>1,987,800</td>
<td>1,975,200</td>
<td>2,014,700</td>
</tr>
<tr>
<td>4dSU17</td>
<td>2,195,600</td>
<td>2,241,500</td>
<td>2,271,300</td>
</tr>
<tr>
<td>4dSU18</td>
<td>787,100</td>
<td>809,000</td>
<td>812,300</td>
</tr>
<tr>
<td>4dSU19</td>
<td>1,125,800</td>
<td>1,138,800</td>
<td>1,199,800</td>
</tr>
<tr>
<td>4dSU20</td>
<td>450,600</td>
<td>441,900</td>
<td>443,200</td>
</tr>
<tr>
<td>4dSU21</td>
<td>1,079,000</td>
<td>1,153,200</td>
<td>1,177,500</td>
</tr>
<tr>
<td>4dSU22</td>
<td>1,131,900</td>
<td>1,172,400</td>
<td>1,160,300</td>
</tr>
<tr>
<td>4dSU23</td>
<td>1,938,200</td>
<td>2,205,200</td>
<td>2,197,700</td>
</tr>
<tr>
<td>4dSU24</td>
<td>356,500</td>
<td>327,400</td>
<td>321,300</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>18,603,100</strong></td>
<td><strong>19,186,000</strong></td>
<td><strong>19,368,300</strong></td>
</tr>
</tbody>
</table>

Table 2.2 Summary of total Survey Unit beach volumes and changes (to the nearest 100m$^3$)

*Groyne bay 4dSU13.054 was inaccessible during the spring 2015 survey. The spring 2014 value for 4dSU13.054 was used as the volume for 2015 in this case.

It should be noted that the bottom row of totals (in italics) should be considered as only indicative of the overall Sub-Cell 4d volumes, as the datums and survey dates for each Survey Unit vary significantly.

### 2.2 Trend and Confidence

The trend in beach growth based on all full-coverage surveys for each Survey Unit have been calculated. Annex D introduces this analysis and describes the methodology used in the calculations. Annex E displays the trends and associated confidences on maps for each Survey Unit.
3 Cliff Change Summary

The coast between Brighton Marina and Beachy Head (excluding Seaford 4dSU06) consists entirely of chalk cliff. In Annual Reports before 2014, changes to cliffs have been included in the Profile analysis, due to a lack of a more suitable method of measuring the changes.

Annex F clarifies how this previous method is not appropriate for steep and near-vertical cliffs, and outlines the new methodology used to present cliff changes. Annex G contains a detailed analysis of the changes to the cliffs for this reporting period.

The laser scan data allows a distinction between erosion due to rock falls and that due to removal of rock fall debris, and so a calculation of the amount of new material entering the sediment transport system has been made. Chalk itself has a relatively low resistance to abrasion, and as such it is essentially only the flint content of the rock mass that will eventually become distal shingle. Table 3.1 below (Dornbusch, 2005*) shows the expected percentage of flint within the chalk by location.

<table>
<thead>
<tr>
<th>Coastal Stretch</th>
<th>Flint Content (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Saltdean to Newhaven (4dSU08 to 11)</td>
<td>1.5 ± 0.5</td>
</tr>
<tr>
<td>Seaford Head (4dSU05)</td>
<td>3.5 ± 0.5</td>
</tr>
<tr>
<td>Cuckmere Haven to Belle Tout (4dSU02 to 04)</td>
<td>2.5 ± 0.5</td>
</tr>
<tr>
<td>Belle Tout to Beachy Head (4dSU01)</td>
<td>4.5 ± 0.5</td>
</tr>
</tbody>
</table>


Table 3.2 presents a summary of the total material entering sediment transport system from the cliff analysis. It should be noted that as the analysis can only include the larger rock falls, the below results represent only minimum overall values for new sediment transport material. It is possible that a potentially large contribution has been overlooked in the form of numerous isolated falls that are too small for accurate detection with this technique.
## Material Entering Sediment Transport System (m³)

<table>
<thead>
<tr>
<th>Year</th>
<th>4dSU01, Section 02</th>
<th>4dSU02, Section 03</th>
<th>4dSU03, Section 03</th>
<th>4dSU08, Section 03</th>
<th>4dSU08, Section 05</th>
<th>Total (m³)</th>
<th>Total Flint* (m³)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Total</td>
<td>Total Flint*</td>
<td>Total</td>
<td>Total Flint*</td>
<td>Total</td>
<td>Total</td>
<td>Total Flint*</td>
</tr>
<tr>
<td>2012 to 2013</td>
<td>2,006</td>
<td>90 ± 10</td>
<td>1,486</td>
<td>37 ± 7</td>
<td>7,353</td>
<td>184 ± 37</td>
<td>3,498 ± 17</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>16,694 ± 83</td>
</tr>
<tr>
<td>2013 to 2014</td>
<td>3,984</td>
<td>179 ± 20</td>
<td>14,668</td>
<td>367 ± 73</td>
<td>12,388</td>
<td>310 ± 62</td>
<td>4,321 ± 27</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>37,145 ± 186</td>
</tr>
<tr>
<td>2014 to 2015</td>
<td>7,024</td>
<td>316 ± 35</td>
<td>0</td>
<td>0 ± 0</td>
<td>1,109</td>
<td>28 ± 6</td>
<td>791 ± 12</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>4,226 ± 21</td>
</tr>
</tbody>
</table>

*Based on Table 3.1 (Dornbusch, 2005)

Table 3.2 Summary of total material entering sediment transport system
4 Hydrodynamic and Meteorological Data

The facility to set up email and text message alerts is now available for any WaveRider Buoy, Meteorological station or Tide Gauge on the Channel Coast Observatory Website. More details on this facility are available at: http://www.channelcoast.org/data_management/real_time_data/charts/.

4.1 Waves
Directional WaveRider buoys were deployed off Rustington and Seaford in July 2003 and January 2008 respectively. The wave buoy reports for 2014/15 can be found in Annex H of this report. Near real-time data from the buoys are also available from the project website at http://www.channelcoast.org.

The most significant storm event recorded at Rustington during 2014/15, in terms of significant wave height ($H_s$), occurred on:

15 January 2015, reaching 3.98m, 2 hours before high water (neaps).

The most significant storm event recorded at Seaford during 2014/15, in terms of significant wave height ($H_s$), also occurred on:

15 January 2015, reaching 4.61m, 1 hour before high water (neaps).

4.2 Tides
A tide gauge was installed on the Arun platform, 4km offshore from Rustington, West Sussex, during April 2008.

The tide data from the network of SCRMP gauges is available on the project website at http://www.channelcoast.org/data_management/real_time_data/charts/.

4.3 Meteorological data
A meteorological station was deployed on 28th May 2008 on the Arun Platform, 4km offshore from Rustington, West Sussex.

Another meteorological station was deployed in July 2010 on Worthing Pier, West Sussex.

Weather data is for both of these stations available on the project website at: http://www.channelcoast.org/data_management/real_time_data/charts/.
Annex A

Survey Programme 2014 to 2015
<table>
<thead>
<tr>
<th>Survey Unit</th>
<th>June - August</th>
<th></th>
<th>September - December</th>
<th></th>
<th>January - April</th>
</tr>
</thead>
<tbody>
<tr>
<td>Date of survey</td>
<td>Date of Type</td>
<td>Delivery</td>
<td>Date received</td>
<td>QC'd by</td>
<td>Date of survey</td>
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<tr>
<td>4dSU24</td>
<td>15/09/2014</td>
<td>Profile</td>
<td>20/10/2014</td>
<td>01/10/2014</td>
<td>No</td>
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<tr>
<td>4dSU24</td>
<td>15/09/2014</td>
<td>Profile</td>
<td>20/10/2014</td>
<td>01/10/2014</td>
<td>No</td>
</tr>
<tr>
<td>4dSU23</td>
<td>15/09/2014</td>
<td>Profile</td>
<td>20/10/2014</td>
<td>01/10/2014</td>
<td>No</td>
</tr>
<tr>
<td>4dSU17</td>
<td>09/09/2014</td>
<td>Profile</td>
<td>14/10/2014</td>
<td>22/09/2014</td>
<td>No</td>
</tr>
<tr>
<td>4dSU14</td>
<td>19/05/2014</td>
<td>Baseline</td>
<td>23/06/2014</td>
<td>02/06/2014</td>
<td>No</td>
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<tr>
<td>4dSU08</td>
<td>16/07/2014</td>
<td>Baseline</td>
<td>20/08/2014</td>
<td>01/08/2014</td>
<td>No</td>
</tr>
<tr>
<td>4dSU05</td>
<td>15/08/2014</td>
<td>Baseline</td>
<td>19/09/2014</td>
<td>08/09/2014</td>
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<td>15/08/2014</td>
<td>Baseline</td>
<td>19/09/2014</td>
<td>08/09/2014</td>
<td>No</td>
</tr>
<tr>
<td>4cSU24</td>
<td>13/06/2014</td>
<td>Baseline</td>
<td>18/07/2014</td>
<td>25/06/2014</td>
<td>No</td>
</tr>
<tr>
<td>4cSU20</td>
<td>16/06/2014</td>
<td>Baseline</td>
<td>21/07/2014</td>
<td>30/06/2014</td>
<td>No</td>
</tr>
</tbody>
</table>

Key:
- Pending
- Extra
- Revised

Extra

Print Date: 02/11/2015
Annex B

*Volumetric Analysis Methodology*
Volumetric Analysis Methodology

Sub-Cell 4d is split into Survey Units, which in turn are separated into smaller areas for volume calculation. These smaller areas are groyne bays where possible, or areas between Interim Profile lines where there are no groynes. Figure B.1 shows an example of the smaller areas.

![Figure B.1 Example of smaller areas within Survey Unit](image)

For each area, the volume of beach material above a fixed datum is calculated from the survey data for the spring interim survey for the current year, the previous year, and for the baseline survey.

The difference in volumes for the previous spring to the current spring, and for the baseline to the current spring are analysed, showing the areas of accretion and erosion in a difference model (Figure B.2).

![Figure B.2 Example of difference model map](image)

The difference models therefore show short and long term changes. To develop this analysis further, future reports will include volume calculations on all available full coverage surveys for every Survey Unit. This will allow trends to be established, both in volume change and elevation change for each area. It is hoped this detail will shed light on the potential and expected long term evolution of each Survey Unit.
Annex C

Beach Volume Change Maps
4dSU24 Selsey Bill Volume Change (m³) between February 2014 & January 2015

4dSU24 Selsey Bill Volume Change (%) between February 2014 & January 2015
4dSU24 Selsey Bill Volume Change (m³) between March 2003 Baseline & January 2015

4dSU24 Selsey Bill Volume Change (%) between March 2003 Baseline & January 2015
4d-SU23 Volume Change Summary for Spring 2014 to Spring 2015 (2 of 5)
4dSU23 Pagham Harbour Volume Change (m$^3$) between February 2014 & January 2015

4dSU23 Pagham Harbour Volume Change (%) between February 2014 & January 2015
4d-SU22 Volume Change Summary for Spring 2014 to Spring 2015 (2 of 3)

Change in Elevation (m) between February 2014 and January 2015

Net Volume Change (m³)
- Red = Material Loss
- Blue = Material Gain

Area Ref: 4cSU22.001

0 100 200m

Pegham to West Bognor Regis
4dSU22 Pagham Volume Change (m³) between February 2014 & January 2015

4dSU22 Pagham Volume Change (%) between February 2014 & January 2015
4dSU22 Pagham Volume Change (m³) between March 2003 Baseline & January 2015

4dSU22 Pagham Volume Change (%) between March 2003 Baseline & January 2015
4d-SU21 Volumes Change Summary for Baseline 2008 to Spring 2015 (3 of 5)

West Bognor Regis to Elmer
4dSU21 Bognor Regis Volume Change (m³) between January 2008 Baseline & March 2015

4dSU21 Bognor Regis Volume Change (%) between January 2008 Baseline & March 2015
Southeast Strategic Regional Coastal Monitoring Programme

Annual Report 2015

Change in Elevation (m)
between February 2014
and February 2015

Accretion

>= 3
2.5 to 3
2 to 2.5
1.5 to 2
1 to 1.5
0.5 to 1
0.25 to 0.5
No Change
-0.25 to 0.25
-0.5 to -0.25
-1 to -0.5
-1.5 to -1
-2 to -1.5
-2.5 to -2
-3 to -2.5
<= -3

Erosion

Area Ref: 4dSU20.001

Net Volume Change (m³)
Red = Material Loss
Blue = Material Gain

4d-SU20 Volume Change Summary for Spring 2014 to Spring 2015 (2 of 2)

Eimer
4dSU20 Elmer Volume Change (m³) between February 2014 & February 2015

4dSU20 Elmer Volume Change (%) between February 2014 & February 2015
4d-SU19 Volume Change Summary for Spring 2014 to Spring 2015 (1 of 3)

Red = Material Loss
Blue = Material Gain

Area Ref: 4cSU19.001
Net Volume Change (m^3) → 100

Change in Elevation (m) between February 2014 and February 2015

Accretion:
- >= 3
- 2.5 to 3
- 2 to 2.5
- 1.5 to 2
- 1 to 1.5
- 0.5 to 1
- 0.25 to 0.5
- No Change
- -0.25 to 0.25
- -0.5 to -0.25
- -1 to -0.5
- -1.5 to -1
- -2 to -1.5
- -2.5 to -2
- -3 to -2.5
- <= -3
4dSU19 Climping Volume Change (m³) between February 2014 to February 2015

4dSU19 Climping Volume Change (%) between February 2014 to February 2015
4dSU19 Climping Volume Change (m³) between July 2007 Baseline & February 2015

4dSU19 Climping Volume Change (%) between July 2007 Baseline & February 2015
4dSU17 Rustington to Goring-by-Sea Volume Change (m³) between March 2014 & March 2015

4dSU17 Rustington to Goring-by-Sea Volume Change (%) between March 2014 & March 2015
(2013 Aerial Photography)

Change in Elevation (m) between March 2014 and March 2015

Net Volume Change (m$^3$)

Red = Material Loss
Blue = Material Gain

Area Ref: 4cSU16.001

4d-SU16 Volume Change Summary for Spring 2014 to Spring 2015 (3 of 5)
4d-SU15 Volume Change Summary for Spring 2014 to Spring 2015 (1 of 5)
4d-SU15 Volume Change Summary for Spring 2014 to Spring 2015 (2 of 5)

Lancing to Shoreham Harbour Arm (West)
Southeast Strategic Regional Coastal Monitoring Programme

Annual Report 2015

4d-SU15 Volume Change Summary for Spring 2014 to Spring 2015 (3 of 5)

Lancing to Shoreham Harbour Arm (West)

(2013 Aerial Photography)
4d-SU15 Volumes Change Summary for Baseline 2007 to Spring 2015 (1 of 5) - Lancing to Shoreham Harbour Arm (West)
4d-SU15 Volumes Change Summary for Baseline 2007 to Spring 2015 (3 of 5)

Lancing to Shoreham Harbour Arm (West)
4dSU13 Brighton Volume Change (m³) between March 2014 & March 2015

4dSU13 Brighton Volume Change (%) between March 2014 % March 2015
4dSU13 Brighton Volume Change (m³) between March 2003 Baseline & March 2014

4dSU13 Brighton Volume Change (%) between March 2003 Baseline & March 2015
Southeast Strategic Regional Coastal Monitoring Programme

Annual Report 2015

4d-SU06 Volume Change Summary for Baseline 2005 to Spring 2015 (1 of 4)

Seaford Bay
4dSU06 Seaford Volume Change (m³) between March 2014 & February 2015

4dSU06 Seaford Volume Change (%) between March 2014 & February 2015
4dSU06 Seaford Volume Change (m³) between Jan 2005 Baseline & February 2015

4dSU06 Seaford Volume Change (%) between Jan 2005 Baseline & February 2015
Annex D

Trend Analysis Methodology
Trend Mapping Methodology

Trend mapping is intended to summarise the changes in elevation of a frontage through time in a single model. Whilst this aim is also achieved by a simple graph of total volume over time, trend mapping allows the independent consideration of the history and future of any points of interest and sub-regions within the modelled study area.

The ‘least squares’ method is used to establish the linear trend of elevation at each point, then the correlation of the trend is checked using the ‘root mean squared’ deviation of the measured heights from the trend line. A coloured map of trend values is produced, accompanied by a coloured map of correlation values to show which parts of the trend map are the most and least valid in terms of linear correlation (a ‘confidence’ map).

The ‘root mean squared (RMS) deviation from the trend’ is used as the correlation measure in this methodology instead of the ‘correlation coefficient’ (CC), which is widely used in statistics to test of the strength of the linear dependence between two variables. The primary reason for this is that CC is undefined in cases where the slope of the least squares trend line is zero, as the variance of the elevations will also be zero. The scenario of little or no elevation change occurs commonly in the context of trend mapping of beaches. Using the RMS deviation as a correlation measure avoids this problem as it tests against a predetermined hypothesised linear trend, whereas the CC tests for any non-zero sloped trend.

An outline of the method used to generate the source data for the trend and correlation maps are given below.

1. Establishing the Trend

A closely-spaced grid of points is firstly created to cover the study area, then the elevations for each of the surveys at each of the grid points is determined using GIS software, giving a table such as the following:

<table>
<thead>
<tr>
<th>Easting</th>
<th>Northing</th>
<th>DTM_Oct03</th>
<th>DTM_Mar04</th>
<th>DTM_Nov04</th>
<th>DTM_May05</th>
<th>DTM_Dec05</th>
<th>DTM_Feb06</th>
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<td>6.84016</td>
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<td>6.50149</td>
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<td>6.58675</td>
<td>6.75843</td>
<td>6.91049</td>
<td>6.61048</td>
<td>6.77374</td>
</tr>
</tbody>
</table>

These columns are the elevation values from the Survey DTM’s

For each row (i.e. each point on the beach) the gradient of the least squares trend of the survey dates (x-axis values) and elevations (y-axis values) is calculated. This value is then converted into the appropriate units of ‘metres growth per year’.

2. Establishing Confidence in the Model

To establish confidence in the trend at each beach point, the difference between each of the survey elevations and the height of the trend line is calculated for each row. These differences are then each squared and the mean of the results calculated. The mean is
then square-rooted to give the correlation value (the confidence) for the trend at that beach point.

This can be summarised with the following algorithm:

For each Table Row
   For each Survey Elevation
      ‘Squared Deviation from trend line’ = (‘Measured beach height’ – (‘trend’ * ‘survey date’) + ‘Intercept’)²
   Next survey elevation
   Mean Squared Deviation = Sum of ‘Squared Deviations from trend line’ / No. of Survey Elevations
   RMS Deviation = (Mean Squared Deviation)⁰.⁵
   Next Table Row

The Diagram below shows a table of values calculated as above.

The confidence values measure the validity of the trend of each point, with zero being a perfect correlation, reflecting a perfectly well-defined trend.

In the above example the correlation values are very large, implying that the validity of each of the corresponding trends are low. This is primarily because the number of surveys (six) is very small. More surveys, over a longer period of time, will generally result in better confidence values.
Annex E

Trend and Confidence Maps
4d-SU24 Elevation Trend Map from March 2003 to January 2015 (2 of 3)
4d-SU23 Confidence in Elevation Trend Map from March 2003 to January 2015 (2 of 3)
4d-SU21 Confidence in Elevation Trend Map from March 2003 to March 2015 (2 of 5)

West Bognor Regis to Elmer
4d-SU21 Confidence in Elevation Trend Map from March 2003 to March 2015 (5 of 5)
4d-SU20 Elevation Trend Map from March 2003 to February 2015 (1 of 2)
4d-SU20 Confidence in Elevation Trend Map from March 2003 to February 2015 (1 of 2)
4d-SU06 Confidence in Elevation Trend Map from March 2003 to April 2015 (2 of 3)

Seaford Bay
Annex F

Cliff Analysis Methodology
Cliff Analysis Methodology

Previous Annual Reports have used Profiles taken from Lidar data to analyse cliff change. As Figure F.1 shows, Lidar Profiles are based on a plan grid of points, and so can miss detail on the cliff face. This results in Profiles that are poor approximations of the actual cliff cross-sections, and so cannot adequately represent changes to steep cliffs.

Since the introduction of mobile laser scanning as a survey methodology in 2012, the cliffs have been measured using a grid on the cliff face, so that the difference models show changes in the vertical plane to give a better representation, as in the example below in Figure F.2.

The detailed nature of the source laser scan data allows a distinction between erosion due to rock falls, and that due to removal of rock fall debris. From this, a calculation of the amount of material entering the sediment transport system can be made. In the above example, this amount is the volume of the rock fall (5,162) less the remaining volume in the debris slope (1,743). This would equate to some 3,419m$^3$ of new material entering the system.

As erosion to cliffs is a cumulative process, successive year to year changes are analysed, rather than short-term and long-term changes.
Annex G

Cliff Change Maps
Cliff Fall Analysis – 4dSU01 to 4dSU05, and 4dSU07 to 4dSU12

Laser scan surveys of the cliffs between Brighton Marina and Beachy Head have been conducted each summer since 2012 (Table G.1).

<table>
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<th>Area Surveyed</th>
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<th></th>
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<td>Newhaven to Brighton Marina (4dSU07 to 4dSU12)</td>
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<td>24/07/2012</td>
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<tr>
<td>2015</td>
<td>05/08/2015</td>
<td>10/09/2015</td>
<td></td>
</tr>
</tbody>
</table>

Table G.1 Cliff Laser Scan Survey Dates

During the surveys, five areas of significant rock fall activity were identified, as shown below in Figure G.1.

The year to year changes for each of these locations have been analysed, with cliff face difference models created between each consecutive survey. The detailed nature of the source laser scan data allows a distinction between erosion due to rock falls and that due to removal of rock fall debris. Given this, an estimation of the amount of material entering the sediment transport system can be made. The difference models are annotated with the net volumetric change (m³), along with the type of change, i.e. ‘RF’ stands for rock fall, ‘DR’ for debris removal and ‘ACC’ for accumulation of rock fall debris.
Survey Unit 4dSU08- Cliff Section 03

This section of cliff is located immediately south of Cornelius Avenue, Newhaven.

Figure G.2 Location of 4dSU08 Cliff Section 03

Figure G.3 shows the cliff face difference models for this section.
Figure G.3 Cliff Face Difference Models for 4dSU08 Cliff Section 03

Figure G.4 summarises these changes, showing the contribution of each change to the supply of new material entering the transport system.
The changes to this section between 2012 and 2013 consisted of a large rock fall (RF1) and the removal of debris (DR1) from a fall that occurred before 2012. More of this old debris was removed during 2013 to 2014 (DR2), along with most of the accumulation from RF1 (DR3).

This pattern of change continued from 2014 to 2015 (DR4 and DR5), with no further rock falls observed.
Survey Unit 4dSU08- Cliff Section 05

This section of cliff is located immediately southwest of the Newhaven Heights residential estate (Figure G.5).

Figure G.5 Location of 4dSU08 Cliff Section 05

Figure G.6 shows the cliff face difference models for this section.
Figure G.7 summarises these changes, showing the contribution of each change to the supply of new material entering the transport system.
The summary shows that following the two rock falls between 2012 and 2013, there were no new falls between 2013 and 2014, with the only changes in this later period being the removal of some of the debris (DR1 and DR2).

A large rock fall (RF3) occurred between 2014 and 2015, with much of the remaining debris from rock fall RF2 (ACC2) removed in the same time frame (DR3).
Survey Unit 4dSU03- Cliff Section 03

This section of cliff is located at the Seven Sisters, one kilometre east of Cuckmere Haven (Figure G.8).

![Figure G.8 Location of 4dSU03 Cliff Section 03](image)

Figure G.9 shows the cliff face difference models for this section.
Figure G.9 Cliff Face Difference Models for 4dSU03 Cliff Section 03

Figure G.10 summarises these changes, showing the contribution of each change to the supply of new material entering the transport system.
Between 2012 and 2013 the cliff section experienced a very large fall (RF1), which resulted in a large debris slope (ACC1). Most of this debris was removed between 2013 and 2014 (DR1), and a further large fall occurred at the same location (RF2). A separate fall (RF3) occurred between 2013 and 2014 due to the partial collapse of a small cave.

Further removal of the debris from rock fall RF1 (ACC1) occurred between 2014 and 2015 in two separate places (DR2 and DR3), with no further falls observed at this cliff section.
Survey Unit 4dSU02- Cliff Section 03

This section is located immediately east of Birling Gap residential properties (Figure G.11).

![Figure G.11 Location of 4dSU02 Cliff Section 03](image)

Figure G.12 shows the cliff face difference models for this section.
Figure G.12 Cliff Face Difference Models for 4dSU02 Cliff Section 03

Figure G.13 summarises these changes, showing the contribution of each change to the supply of new material entering the transport system.
The summary suggests that the removal of the debris from RF1 (ACC1) before 2013, allowed a large rock fall (RF3) to follow at the same location between 2013 and 2014. It is significant to note that the debris from all four rock falls, some 14,975m$^3$, was almost entirely removed between 2013 and 2014, with just 62m$^3$ remaining (ACC3).

There were no observed differences between 2014 and 2015 at this location.
Survey Unit 4dSU01- Cliff Section 02

This section of cliff is located adjacent to Belle Tout Lighthouse, Beachy Head (Figure G.14).

Figure G.14 Location of 4dSU01 Cliff Section 02

Figure G.15 shows the cliff face difference models for this section.
Figure G.16 summarises these changes, showing the contribution of each change to the supply of new material entering the transport system.
The summary suggests that removal of old debris from before 2012 (DR1 and DR2) was followed by the small rock fall, RF2. With the removal of the debris from rock falls RF1, RF3 and RF4 after 2013, further falls RF5, RF6, and RF7 then occurred at the same locations between 2013 and 2014.

A large rock fall (RF9) occurred between 2014 and 2015, and much of the debris from rock fall RF8 (ACC8) was removed in the same time frame (DR6).
Annex H

Rustington and Seaford Wave Buoy Reports 2014/15
Rustington Directional Waverider Buoy

### Location

<table>
<thead>
<tr>
<th>OS</th>
<th>506331 E</th>
<th>93783 N</th>
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</thead>
<tbody>
<tr>
<td>WGS84</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Latitude: 50° 44.036' N  
Longitude: 00° 29.677' W

### Instrument type

- Datawell
- Directional Waverider Mk III

### Water depth

~10m CD  
Buoy in situ off Rustington beach. Photo courtesy of Fugro EMU Limited

Location of buoy (Google mapping)

### Summary

During this reporting period from April 2014 to March 2015, two storms for the site exceeded the 3.5m storm threshold during the winter months. The largest storm on 15 January 2015 occurred close to High Water on neap tides reaching a significant wave height of 3.98m. Wave direction is predominantly from the SW.

### Data Quality

<table>
<thead>
<tr>
<th>Recovery rate (%)</th>
<th>Sample interval</th>
</tr>
</thead>
<tbody>
<tr>
<td>96</td>
<td>30 minutes</td>
</tr>
</tbody>
</table>

### Monthly Averages – 2014/15

<table>
<thead>
<tr>
<th>Month</th>
<th>$H_s$ (m)</th>
<th>$T_p$ (s)</th>
<th>$T_z$ (s)</th>
<th>Dir. (°)</th>
<th>SST (°C)</th>
<th>No. of days</th>
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<td>0.71</td>
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All times are GMT
Storm Analysis

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<th>$T_p$ (s)</th>
<th>$T_z$ (s)</th>
<th>Dir. (°)</th>
<th>Water level elevation* (OD)</th>
<th>Tidal stage (hours re. HW)</th>
<th>Tidal range (m)</th>
<th>Tidal surge* (m)</th>
<th>Max. surge* (m)</th>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Distribution plots

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

- Wave rose (percentage of occurrence of Direction vs. $H_s$) for all measured data
- Percentage of occurrence of $H_s$, $T_p$, $T_z$ and Direction from April 2014 to March 2015
- Monthly time series of $H_s$ (red line is 3.5 m storm threshold)
- Incidence of storms during the reporting period and for all previous years. Storm events are defined using the Peaks-over-Threshold method. The highest $H_s$ of each storm event is shown

General

The buoy was first deployed on 15 July 2003, at which time the magnetic declination at the site was 2.7° west, changing by 0.14° east per year.

Acknowledgements

TASK2000 tidal prediction software was kindly provided by the Permanent Service for Mean Sea Level, Proudman Oceanographic Laboratory.

* Tidal information is usually obtained from the nearest recording tide gauge (the tide gauge on Arun Platform) although this was out of action for most of the reporting period. The maximum tidal surge is the largest positive surge during the storm event and has been taken from the next closest tide gauge (the National Network gauge at Newhaven).
Seaford Directional Waverider Buoy

Location
OS 546444 E  98366 N
WGS84
Latitude: 50° 45.984’ N
Longitude: 00° 04.517’ E

Instrument type
Datawell
Directional Waverider Mk III

Water depth
~11m CD

Buoy in situ off Seaford beach. Photo courtesy of Fugro EMU Limited

Location of buoy (Google mapping)

Summary
During this reporting period from April 2014 to March 2015, four storms for the site exceeded the 3.75m storm threshold during the winter and early spring months. The largest storm on 15 January 2015 reached 4.61m significant wave height close to High Water on a neap tide, with a large surge of over 0.5m.

Data Quality

<table>
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<tr>
<th>Recovery rate (%)</th>
<th>Sample interval</th>
</tr>
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<tr>
<td>98</td>
<td>30 minutes</td>
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Monthly Averages – 2014/15

All times are GMT

<table>
<thead>
<tr>
<th>Month</th>
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<th>$T_p$ (s)</th>
<th>$T_z$ (s)</th>
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<th>SST (°C)</th>
<th>No. of days</th>
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Storm Analysis

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<th>$T_p$ (s)</th>
<th>$T_z$ (s)</th>
<th>Dir. (°)</th>
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<th>Tidal stage (hours re. HW)</th>
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<th>Tidal surge* (m)</th>
<th>Max. surge* (m)</th>
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Distribution plots

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

- Wave rose (percentage of occurrence of Direction vs. $H_s$) for all measured data
- Percentage of occurrence of $H_s$, $T_p$, $T_z$ and Direction from April 2014 to March 2015
- Monthly time series of $H_s$ (red line is 3.75 m storm threshold)
- Incidence of storms during the reporting period and for all previous years. Storm events are defined using the Peaks-over-Threshold method. The highest $H_s$ of each storm event is shown

General

The buoy was first deployed on 22 January 2008, at which time the magnetic declination at the site was 1.8° west, changing by 0.14° east per year.

Acknowledgements

The shore station is kindly hosted by Newhaven Fort. Tidal data were supplied by the British Oceanographic Data Centre as part of the function of the National Tidal and Sea Level Facility, hosted by the Proudman Oceanographic Laboratory and funded by DEFRA and the Natural Environment Research Council.

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*Tidal information is obtained from the nearest recording tide gauge (the National Network gauge at Newhaven). The surge shown is the residual at the time of the highest $H_s$. The maximum tidal surge is the largest surge during the storm event.*