Cell 1 Regional Coastal Monitoring Programme
Analytical Report 7: 'Full Measures' Survey 2014

Hartlepool Borough Council
Final Report

February 2015

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Disclaimer

Abbreviations and Acronyms

Acronym / Abbreviation	Definition
AONB	Area of Outstanding Natural Beauty
DGM	Digital Ground Model
HAT	Highest Astronomical Tide
LAT	Lowest Astronomical Tide
MHWN	Mean High Water Neap
MHWS	Mean High Water Spring
MLWS	Mean Low Water Neap
MLWS	Mean Low Water Spring
m	metres
ODN	Ordnance Datum Newlyn

Water Levels Used in Interpretation of Changes

	Water Level (m AOD)			
Water Level Parameter	**River Tyne to Frenchman's Bay**	**Frenchman's Bay to Souter Point**	**Souter Point to Chourdon Point**	**Chourdon Point to Hartlepool Headland**
1 in 200 year	3.41	3.44	3.66	3.91
HAT	2.85	2.88	3.18	3.30
MHWS	2.15	2.18	2.48	2.70
MLWS	-2.15	-2.12	-1.92	-1.90
	Water Level (m AOD)			
Water Level Parameter	**Hartlepool Headland to Saltburn Scar**	**Skinningrove**	**Hummersea Scar to Sandsend Ness**	**Sandsend Ness to Saltwick Nab**
1 in 200 year	3.87	3.86	4.1	3.88
HAT	3.25	3.18	3.15	3.10
MHWS	2.65	2.68	2.65	2.60
MLWS	-1.95	-2.13	-2.15	-2.20

Source: *River Tyne to Flamborough Head Shoreline Management Plan 2*.
Royal Haskoning, February 2007.

Glossary of Terms

Term	Definition
Beach nourishment	Artificial process of replenishing a beach with material from another source.
Berm crest	Ridge of sand or gravel deposited by wave action on the shore just above the normal high water mark.
Breaker zone	Area in the sea where the waves break.
Coastal squeeze	The reduction in habitat area which can arise if the natural landward migration of a habitat under sea level rise is prevented by the fixing of the high water mark, e.g. a sea wall.
Downdrift	Direction of alongshore movement of beach materials.
Ebb-tide	The falling tide, part of the tidal cycle between high water and the next low water.
Fetch	Length of water over which a given wind has blown that determines the size of the waves produced.
Flood-tide	Rising tide, part of the tidal cycle between low water and the next high water.
Foreshore	Zone between the high water and low water marks, also known as the intertidal zone.
Geomorphology	The branch of physical geography/geology which deals with the form of the Earth, the general configuration of its surface, the distribution of the land, water, etc.
Groyne	Shore protection structure built perpendicular to the shore; designed to trap sediment.
Mean High Water (MHW)	The average of all high waters observed over a sufficiently long period.
Mean Low Water (MLW)	The average of all low waters observed over a sufficiently long period.
Mean Sea Level (MSL)	Average height of the sea surface over a 19-year period.
Offshore zone	Extends from the low water mark to a water depth of about 15 m and is permanently covered with water.
Storm surge	A rise in the sea surface on an open coast, resulting from a storm.
Swell	Waves that have travelled out of the area in which they were generated.
Tidal prism	The volume of water within the estuary between the level of high and low tide, typically taken for mean spring tides.
Tide	Periodic rising and falling of large bodies of water resulting from the gravitational attraction of the moon and sun acting on the rotating earth.
Topography	Configuration of a surface including its relief and the position of its natural and man-made features.
Transgression	The landward movement of the shoreline in response to a rise in relative sea level.
Updrift	Direction opposite to the predominant movement of longshore transport.
Wave direction	Direction from which a wave approaches.
Wave refraction	Process by which the direction of approach of a wave changes as it moves into shallow water.

Preamble

The Cell 1 Regional Coastal Monitoring Programme covers approximately 300km of the north east coastline, from the Scottish Border (just south of St. Abb's Head) to Flamborough Head in East Yorkshire. This coastline is often referred to as 'Coastal Sediment Cell 1' in England and Wales (Figure 1). Within this frontage the coastal landforms vary considerably, comprising low-lying tidal flats with fringing salt marshes, hard rock cliffs that are mantled with glacial sediment to varying thicknesses, softer rock cliffs and extensive landslide complexes.

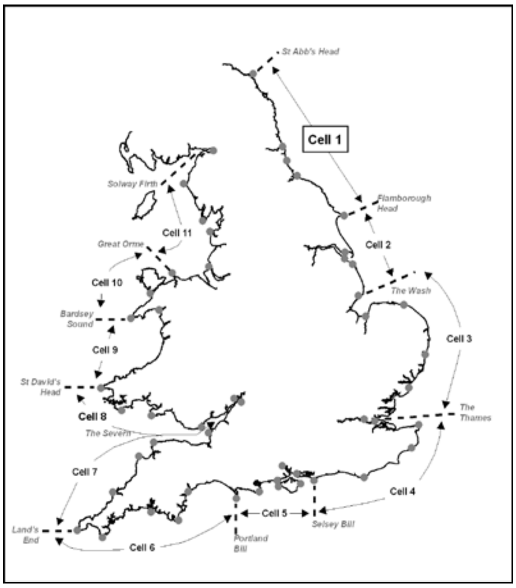


Figure 1 Sediment Cells in England and Wales

The work commenced with a three-year monitoring programme in September 2008 that was managed by Scarborough Borough Council on behalf of the North East Coastal Group. This initial phase has been followed by a five-year programme of work, which started in October 2011. The work is funded by the Environment Agency, working in partnership with the following organisations:

- Northumberland County Council
- North Tyneside Council
- South Tyneside Council
- Northumberland Coast Area of Outstanding Natural Beauty
- Sunderland City Council
- Durham County Council
- Redcar & Cleveland Borough Council
- Hartlepool Borough Council
- Borough of Scarborough – A great place to live, work & play
- East Riding of Yorkshire Council
- Environment Agency
- Natural England
- The National Trust

The original three year programme of work was undertaken as a partnership between Royal Haskoning, Halcrow and Academy Geomatics. For the current five year programme of work the data collection associated with beach profiles, topographic surveys and cliff top surveys is being undertaken by Academy Geomatics. The analysis and reporting for the programme is being undertaken by Halcrow (rebranded as CH2M HILL since 2013).

The main elements of the Cell 1 Regional Coastal Monitoring Programme involve:

- beach profile surveys
- topographic surveys
- cliff top recession surveys
- real-time wave data collection
- bathymetric and sea bed characterisation surveys
- aerial photography
- walk-over surveys

The beach profile surveys, topographic surveys and cliff top recession surveys are undertaken as a 'Full Measures' survey in autumn/early winter every year. Some of these surveys are then repeated the following spring as part of a 'Partial Measures' survey.

Each year, an Analytical Report is produced for each individual authority, providing a detailed analysis and interpretation of the 'Full Measures' surveys. This is followed by a brief Update Report for each individual authority, providing ongoing findings from the 'Partial Measures' surveys.

Annually, a Cell 1 Overview Report is also produced. This provides a region-wide summary of the main findings relating to trends and interactions along the entire Cell 1 frontage. To date the following reports have been produced:

Table 1 Analytical, Update and Overview Reports Produced to Date

Year		Full Measures		Partial Measures		Cell 1 Overview Report
		Survey	Analytical Report	Survey	Update Report	
1	2008/09	Sep-Dec 08	May 09	Mar-May 09		-
2	2009/10	Sep-Dec 09	Mar 10	Feb-Mar 10	July 10	-
3	2010/11	Aug-Nov 10	Feb 11	Feb-April 11	August 11	Sept 11
4	2011/12	Sep-Oct 11	Oct 12	Mar-May 12	Feb 13	-
5	2012/13	Sep 2012	Feb 13	April 13	May 13	-
6	2013/14	Sep-Oct 13	Feb 14	March 14	July 14	
7	2014/15	Sep-Oct 14	Feb 15 (*)			

(*) The present report is **Analytical Report 7** and provides an analysis of the 2014 Full Measures survey for Hartlepool Borough Council's frontage.

In addition, separate reports are produced for other elements of the programme as and when specific components are undertaken, such as wave data collection, bathymetric and sea bed sediment data collection, aerial photography, and walk-over visual inspections.

For purposes of analysis, the Cell 1 frontage has been split into the sub-sections listed in the Table 2.

Table 2 Sub-divisions of the Cell 1 Coastline

Authority	Zone
Northumberland County Council	Spittal A
	Spittal B
	Goswick Sands
	Holy Island
	Bamburgh
	Beadnell Village
	Beadnell Bay
	Embelton Bay
	Boulmer
	Alnmouth Bay
	High Hauxley and Druridge Bay
	Lynemouth Bay
	Newbiggin Bay
	Cambois Bay
	Blyth South Beach
North Tyneside Council	Whitley Sands
	Cullercoats Bay
	Tynemouth Long Sands
	King Edward's Bay
South Tyneside Council	Littehaven Beach
	Herd Sands
	Trow Quarry (incl. Frenchman's Bay)
	Marsden Bay
Sunderland Council	Whitburn Bay
	Harbour and Docks
	Hendon to Ryhope (incl. Halliwell Banks)
Durham County Council	Featherbed Rocks
	Seaham
	Blast Beach
	Hawthorn Hive
	Blackhall Colliery
Hartlepool Borough Council	North Sands
	Headland
	Middleton
	Hartlepool Bay
Redcar & Cleveland Borough Council	Coatham Sands
	Redcar Sands
	Marske Sands
	Saltburn Sands
	Cattersty Sands (Skinningrove)
Scarborough Borough Council	Staithes
	Runswick Bay
	Sandsend Beach, Upgang Beach and Whitby Sands
	Robin Hood's Bay
	Scarborough North Bay
	Scarborough South Bay
	Cayton Bay
	Filey Bay

1. Introduction

1.1 Study Area

Hartlepool Borough Council's frontage extends from Crimdon Beck in the north, to the North Gare Breakwater in the south. For the purposes of this report, it has been sub-divided into four areas, namely:

- North Sands
- Hartlepool Headland
- Middleton
- Hartlepool Bay

1.2 Methodology

Along Hartlepool Borough Council's frontage, the following surveying is undertaken:

- Full Measures survey annually each autumn/early winter comprising:
    - Beach profile surveys along nine transect lines
    - Topographic survey along part of North Sands (referred to as Hartlepool North or 'HN')
    - Topographic survey along Middleton (referred to as Hartlepool Central or 'HC')
    - Topographic survey along Hartlepool Bay (referred to as Hartlepool South or 'HS')
- Partial Measures survey annually each spring comprising:
    - Beach profile surveys along 9 no. transect lines
- Additionally, every five years (starting with 2008 as the baseline year), the Full Measures topographic survey at Hartlepool North is extended to fully cover the whole of North Sands and Hartlepool Headland with a topographic survey. This extends across the boundary of jurisdiction between Hartlepool Borough Council and County Durham Council.

The location of these surveys is shown in Figure 2. The 2014 Full Measures survey was undertaken along this frontage on various dates between 29th September and 23rd October. During this time weather were generally dry with light to moderate breezes from a range of directions. The sea state at all sites was either calm or moderate. The survey reports from Academy Geomatics document details of the weather conditions over this survey period.

All data have been captured in a manner commensurate with the principles of the Environment Agency's *National Standard Contract and Specification for Surveying Services* and stored in a file format compatible with the software systems being used for the data analysis, namely SANDS and ArcGIS. This data collection approach and file format is comparable to that being used on other regional coastal monitoring programmes, such as in the South East and South West of England.

Upon receipt of the data from the survey team, they are quality assured and then uploaded onto the programme's website for storage and availability to others and also input to SANDS and GIS for subsequent analysis. The Analytical Report is then produced following a standard structure for each authority. This involves:

- description of the changes observed since the previous survey and an interpretation of the drivers of these changes (Section 2);
- documentation of any problems encountered during surveying or uncertainties inherent in the analysis (Section 3);
- recommendations for 'fine-tuning' the programme to enhance its outputs (Section 4); and
- providing key conclusions and highlighting any areas of concern (Section 5).

Data from the present survey are presented in a processed form in the Appendices.

1.3 Uncertainties in data and analysis

While uncertainty due to survey accuracy or systematic error is likely to be present in all datasets, the work is carefully managed to ensure data are as accurate as possible and results are not misleading. Error may arise from the limits of precision of survey techniques used, from low accuracy measurements being taken or from systematic failings of equipment.

For beach profiles and topographic surveys, all incoming data are checked allowing systematic errors to be identified, and removed from plots and subsequent analysis. The accuracy of these surveys is not known, but it is likely that all measurements are correct to ±0.1m. Therefore, changes are less than ±0.1m are ignored and greyed out in the topographic change plots. For cliff top erosion surveys, there are commonly problems in precisely recognising the cliff edge due to vegetation growth and the convex shape of the feature. Errors manifest themselves as results that suggest the cliff edge has advanced, which is very unlikely unless a toppling failure has been initiated, but the block has not yet fully detached. The accuracy of cliff top surveys are also unknown, but it is assumed that each measurement is accurate to ±0.1m.

These limits of accuracy mean that comparison of annual or biannual data can be of limited value if the measured change is less than or equal to the assumed error. However, all results become more significant over longer time periods when the errors in measurement in years 1 and *x* are averaged over the monitoring period:

$$\text{Error rate of change per year} = \frac{\text{Error in first measurement + Error in last measurement}}{\text{Years between measurements}}$$

The effect of averaging error over different monitoring periods is summarised in Table 3, which assumes that each annual survey is accurate to 0.1m.

Table 3 Error bands for long-term calculations of change

Years between surveys	**Error in inter-survey comparison** (±m/yr)
1	0.200
2	0.100
3	0.067
4	0.050
5	0.040
5	0.033
7	0.029
8	0.025
9	0.022
10	0.020

While considering the uncertainty in comparing and analysing change between monitoring data sets it is also relevant to raise caution about drawing conclusions about short or longer term trends. Clearly the longer the data set the more confidence that can be given to likely ranges of beach changes and trends in change. Potential for seasonal, annual and longer term cycles need to be considered. Studies of long term monitoring data sets for other coastal and estuarial data have established that there are long period cyclical trends related to the 18.6 years lunar nodal cycle which need to be accounted for. Simply put this means that although the Cell 1 monitoring programme now has data in some locations up to 11 years, another 8 to 10 years of consistent data is needed before confidence can be given in trends from the analysis. In the context of this report “Longer Term Trends” are mentioned in each section and it should be noted that this is based on simple visual interpretation of the available data since the current programme began, and is generally based on only 5 years of data.

2. Wave Data and Interpretation.

2.1 Introduction

Wave monitoring data relevant to the Cell 1 Regional Coastal Monitoring Programme is available from one offshore regional wave buoy located at Tyne and Tees and three regional wave buoys, which are further inshore at Newbiggin, Whitby and Scarborough. The Tyne Tees buoy is managed by Cefas as part of the WaveNet system, while the three inshore buoys is managed by Scarborough BC as part of the Cell 1 monitoring programme.

An assessment of baseline wave data is presented in the 2011 Wave Data Analysis Report, which reviewed all readily available data in the region. In 2014 a wave data update report updated the baseline with analysis of the wave data collected under the programme for 2013, including the 5th and 6th December storm. That report was further updated in 2015 to include the records from 2014. In order to help put the beach and cliff changes discussed in this report into context analysed storm data for the wave buoys is presented in this section.

The longest consistent relevant wave data record in the Cell 1 region is from the WaveNet Tyne Tees buoy deployed under the national coastal monitoring programme by Cefas. Data has been downloaded from WaveNet and loaded into SANDS for analysis alongside the beach and cliff monitoring data. Results from analysis of the data to extract details of significant storms are presented in Table 4 below.

To aid interpretation of the results in Table 4 alternate years have been shaded and the storm with the largest peak wave height each year has been highlighted in bold. The annual storm with the highest wave energy at peak has also been highlighted in bold red text as this depends on wave period as well as wave height and so is not always the same as the largest wave height, e.g. in 2009 and 2010.

Table 4: SANDS Storm Analysis at Tyne/Tees WaveNet Buoy (updated to include data to 7th Dec 2014)

General Storm Information							At Peak					
StartTime	***EndTime***	***Dur (hr)***	***Peak of Storm***	***Mean Dir***	***No of Events***	***Mean Direction Vector***	***Hs (m)***	***Tp (s)***	***Tz (s)***	***Dir***	***Energy @ Peak (KJ/m/s)***	***Total Energy (KJ/m)***
19/03/2007 10:30	21/03/2007 05:30	43	20/03/2007 14:30	23	64	78.2	6.2	12.4	8.5	23	1.7E+04	1.4E+07
25/06/2007 20:30	26/06/2007 13:30	17	26/06/2007 10:00	54	18	77.3	4.4	8.6	7.2	23	4.0E+03	1.7E+06
26/09/2007 03:00	27/09/2007 05:00	26	26/09/2007 19:00	11	33	79.7	4.6	11.6	7.6	6	**7.8E+03**	3.6E+06
08/11/2007 20:00	12/11/2007 15:00	91	09/11/2007 08:30	16	58	77.7	**6.2**	**13.3**	**9.0**	**6**	1.9E+04	1.6E+07
19/11/2007 03:30	25/11/2007 21:30	162	23/11/2007 05:00	88	52	76.8	4.9	10.7	7.6	17	7.6E+03	6.8E+06
08/12/2007 03:00	10/12/2007 14:30	59.5	08/12/2007 03:30	106	8	82.9	4.1	10.7	7.6	17	5.4E+03	7.5E+05
03/01/2008 10:30	04/01/2008 01:30	15	03/01/2008 23:30	77	24	14.6	4.2	9.1	7.6	62	4.2E+03	2.5E+06
01/02/2008 15:00	02/02/2008 09:30	18.5	02/02/2008	41	30	80.1	6.0	13.8	9.0	17	1.9E+04	8.7E+06
10/03/2008 08:30	10/03/2008 12:30	4	10/03/2008 11:00	146	9	307.5	4.6	8.1	6.5	141	3.8E+03	7.3E+05
17/03/2008 15:00	25/03/2008 03:00	180	22/03/2008 05:00	81	58	82.1	**7.9**	**12.4**	**9.0**	**6**	2.7E+04	1.7E+07
05/04/2008 22:00	07/04/2008 05:00	31	06/04/2008 19:00	49	20	83.1	4.6	11.7	7.6	6	7.9E+03	3.0E+06
20/07/2008 16:00	21/07/2008 09:30	17.5	20/07/2008 23:30	15	8	76.0	4.2	9.9	7.6	11	4.9E+03	9.1E+05
03/10/2008 03:00	03/10/2008 20:30	17.5	03/10/2008 16:30	55	17	76.7	4.7	11.4	7.6	23	**8.1E+03**	2.8E+06
21/11/2008 04:00	25/11/2008 12:30	104.5	22/11/2008 11:30	15	112	75.8	6.0	13.1	8.5	11	1.7E+04	2.2E+07

General Storm Information							At Peak					
StartTime	*EndTime*	*Dur (hr)*	*Peak of Storm*	*Mean Dir*	*No of Events*	*Mean Direction Vector*	*Hs (m)*	*Tp (s)*	*Tz (s)*	*Dir*	*Energy @ Peak (KJ/m/s)*	*Total Energy (KJ/m)*
10/12/2008 12:00	13/12/2008 18:00	78	13/12/2008 08:00	109	37	332.1	4.9	8.4	7.2	129	4.7E+03	4.0E+06
31/01/2009 16:30	03/02/2009 09:00	64.5	02/02/2009 22:00	84	57	7.2	5.8	9.6	8.5	84	8.7E+03	8.1E+06
23/03/2009 22:30	28/03/2009 20:30	118	28/03/2009 16:30	217	14	89.4	5.3	8.4	7.6	6	5.4E+03	1.3E+06
10/07/2009 01:30	10/07/2009 02:30	1	10/07/2009 01:30	13	2	78.7	4.2	10.0	7.2	11	5.0E+03	2.3E+05
29/11/2009 20:30	30/11/2009 15:00	18.5	30/11/2009 00:30	18	36	72.7	**6.0**	**9.4**	**8.0**	**11**	9.0E+03	5.9E+06
17/12/2009 10:30	18/12/2009 05:00	18.5	17/12/2009 19:30	64	36	26.3	5.4	10.7	8.0	68	**9.4E+03**	5.7E+06
30/12/2009 09:00	30/12/2009 23:00	14	30/12/2009 12:30	84	24	7.7	5.1	7.6	7.2	90	4.1E+03	2.3E+06
06/01/2010 05:30	06/01/2010 11:00	5.5	06/01/2010 06:30	30	10	63.6	4.2	10.7	7.2	11	5.7E+03	1.1E+06
29/01/2010 10:30	30/01/2010 00:30	14	29/01/2010 22:30	9	21	81.9	5.4	8.6	8.0	6	6.0E+03	2.1E+06
26/02/2010 22:30	27/02/2010 02:30	4	27/02/2010 01:00	18	7	72.4	4.6	8.5	7.6	17	4.2E+03	7.0E+05
19/06/2010 07:00	20/06/2010 08:30	25.5	19/06/2010 20:00	21	49	69.2	5.4	10.7	7.6	23	**9.4E+03**	8.5E+06
29/08/2010 14:00	30/08/2010 06:30	16.5	30/08/2010 01:00	243	17	92.8	4.7	8.6	7.6	6	4.7E+03	1.6E+06
06/09/2010 22:30	07/09/2010 16:00	17.5	07/09/2010 15:30	101	22	353.2	4.6	8.8	8.0	90	4.5E+03	2.3E+06
17/09/2010 07:00	17/09/2010 18:30	11.5	17/09/2010 08:30	10	17	80.7	4.7	11.0	8.0	11	7.5E+03	2.9E+06
24/09/2010 03:00	26/09/2010	45	24/09/2010 10:00	21	80	71.6	5.3	10.2	8.0	11	8.0E+03	1.2E+07
20/10/2010 02:00	24/10/2010 16:30	110.5	20/10/2010 10:00	13	16	78.2	4.2	11.2	7.2	17	6.4E+03	1.8E+06
08/11/2010 14:00	09/11/2010 20:30	30.5	09/11/2010 10:00	88	58	3.0	**5.6**	**8.8**	**8.0**	**73**	6.9E+03	7.8E+06
17/11/2010 11:00	17/11/2010 18:30	7.5	17/11/2010 12:00	136	9	322.4	4.7	7.7	6.9	129	3.7E+03	8.1E+05
29/11/2010 19:30	02/12/2010 08:30	61	29/11/2010 21:00	80	45	11.8	5.1	9.4	7.6	56	6.3E+03	5.4E+06
16/12/2010 15:00	17/12/2010 06:30	15.5	17/12/2010 03:30	12	22	79.1	4.6	10.5	7.6	17	6.4E+03	2.8E+06
23/07/2011 14:00	24/07/2011 11:00	21	24/07/2011 03:00	23	39	67.1	**4.7**	**10.7**	**7.6**	**17**	**7.2E+03**	5.8E+06
24/10/2011 18:30	25/10/2011 09:30	15	25/10/2011 09:30	103	26	348.5	4.1	9.5	6.9	79	4.2E+03	2.6E+06
09/12/2011 08:30	09/12/2011 10:00	1.5	09/12/2011 08:30	7	3	84.0	4.1	11.9	8.0	6	6.7E+03	4.8E+05
05/01/2012 16:00	06/01/2012 05:00	13	06/01/2012 03:00	12	19	79.0	4.6	10.5	7.6	17	6.4E+03	2.6E+06
03/04/2012 13:30	04/04/2012 10:30	21	03/04/2012 17:30	66	38	25.1	5.6	8.1	7.6	56	5.9E+03	5.5E+06
24/09/2012 08:30	25/09/2012 10:30	26	25/09/2012 01:30	74	50	16.7	4.7	10.3	8.0	62	6.6E+03	7.4E+06
26/10/2012 16:30	27/10/2012 14:30	22	26/10/2012 23:00	12	34	79.4	4.9	12.8	7.6	11	1.1E+04	4.9E+06
05/12/2012 16:00	15/12/2012 01:30	225.5	14/12/2012 19:30	78	31	18.4	5.4	8.8	7.6	96	6.4E+03	4.5E+06
20/12/2012 06:00	21/12/2012 14:30	32.5	20/12/2012 23:00	101	56	348.4	5.6	9.5	8.0	96	8.0E+03	8.8E+06
18/01/2013 18:30	22/01/2013 06:00	83.5	21/01/2013 10:00	81	54	9.2	6.7	9.4	8.5	84	1.1E+04	1.1E+07
06/02/2013 08:00	07/02/2013 06:00	22	06/02/2013 12:30	47	38	81.6	5.4	10.0	7.6	11	8.2E+03	6.1E+06
07/03/2013 21:00	10/03/2013 21:30	72.5	08/03/2013 04:00	67	37	24.6	4.9	9.0	7.6	73	5.4E+03	4.3E+06
18/03/2013 09:00	25/03/2013 00:30	159.5	23/03/2013 14:30	85	153	5.1	6.0	10.2	8.0	90	1.0E+04	2.8E+07
23/05/2013 18:00	24/05/2013 12:00	18	23/05/2013 22:30	13	32	77.5	6.7	10.5	8.5	17	1.4E+04	7.1E+06

General Storm Information							At Peak					
StartTime	***EndTime***	***Dur (hr)***	***Peak of Storm***	***Mean Dir***	***No of Events***	***Mean Direction Vector***	***Hs (m)***	***Tp (s)***	***Tz (s)***	***Dir***	***Energy @ Peak (KJ/m/s)***	***Total Energy (KJ/m)***
10/09/2013 13:00	10/09/2013 19:30	6.5	10/09/2013 14:00	11	14	79.3	4.4	9.2	7.2	11	4.6E+03	1.5E+06
09/10/2013 22:30	11/10/2013 09:00	34.5	10/10/2013 17:00	68	62	79.8	5.4	10.7	7.6	22	9.4E+03	1.2E+07
29/11/2013 22:30	30/11/2013 06:30	8	30/11/2013 00:30	42	17	84.5	5.6	10.7	8.0	11	1.0E+04	3.3E+06
05/12/2013 14:00	07/12/2013 04:30	38.5	06/12/2013 20:00	24	59	80.8	4.7	14.3	9.0	6	1.3E+04	1.2E+07
27/12/2013 09:30	27/12/2013 12:30	3	27/12/2013 10:00	218	3	249.3	4.1	6.1	6.5	202	1.8E+03	1.3E+05
05/02/2014 04:00	05/02/2014 18:00	14	05/02/2014 05:30	139	9	318.4	4.4	7.8	6.9	129	3.3E+03	7.2E+05
12/02/2014 20:00	14/02/2014 19:00	47	12/02/2014 21:00	183	8	275.6	4.6	7.5	6.5	141	3.2E+03	7.8E+05
21/10/2014 22:00	22/10/2014 01:30	3.5	21/10/2014 23:00	6	5	84.4	4.4	9.6	7.6	6	5.0E+03	6.0E+05

The storms mostly arrive from the north to northeast direction, 0 to 40 degrees, which has the longest fetch, but there are also a significant number of storms from other directions, particularly 80 to 140 degrees.

Comparing the annual storm records it can be seen that 2010 had the most storms (13). In 2010 the largest storm had an incident direction of 73 degrees which is unusual. We might therefore expect that the alongshore drift on the Cell 1 beaches in 2010 may have been atypical with unusual changes from the storm conditions. This was noted in several of the 2010 Full Measures reports.

The year with the fewest storms was 2011. This was reflected by accretion recorded in a number of the annual Full Measures reports.

The winter of 2012 to 2013 appears to have suffered with larger storms than usual, with the second largest peak wave height (7.3m) recorded on 23rd March 2013. The longest duration storm in the record was from 5th to 15th December 2012 (226.5 hours).

The storm on the 5th to 7th December 2013, was particularly notable. Although this event did not have such large waves as the 23rd March 2013 storm, it had a high peak energy and exceptionally long wave period at 14.3 seconds. The 6th December 2013 storm was also accompanied by a significant storm surge with recorded water levels around 1.75m higher that predicted tides. The combined high water levels and large waves causing significant damage to many coastal defences and beaches.

2.2 Wave data for the Hartlepool frontage.

There are no data from the Hartlepool frontage, but the two local buoys on the Scarborough Borough Council frontage, at Whitby and Scarborough that were deployed in January 2013 provide relevant data. Analysed storm data for these two buoys is presented in Tables 5 and 6.

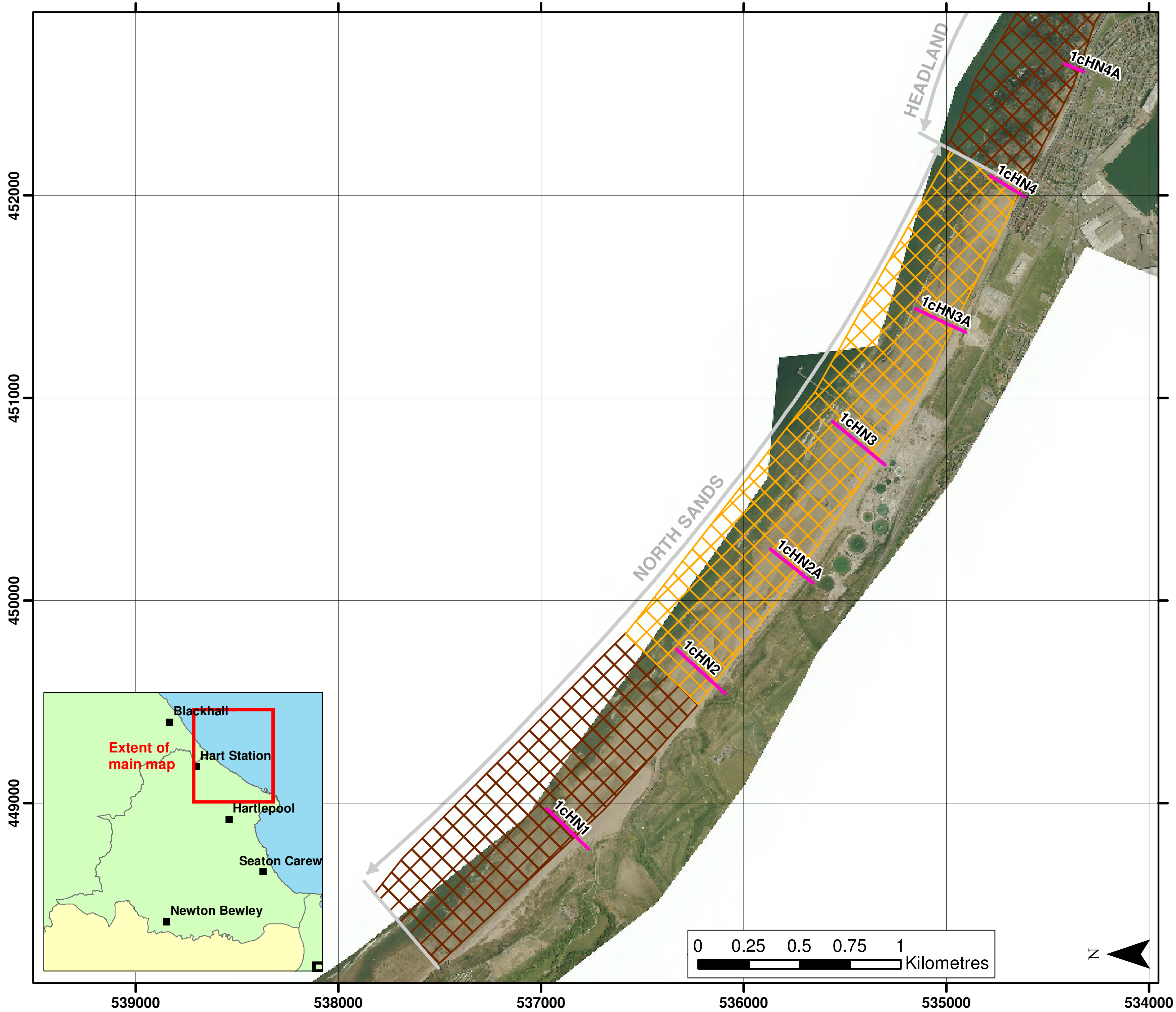
Overall the data for the storms recorded at Scarborough and Whitby are comparable in terms of wave height, period and energy. The highest energy storm recorded at Whitby was the 5th and 6th of December 2013 storm. The second most severe storm at Whitby in terms of wave height and energy was on the 10th October 2013, this is the most severe storm recorded in the Scarborough dataset.

Table 5: Storm analysis for Scarborough WB (data 17/01/2013 to 31/10/2014)

General Storm Information							At Peak					
Start Time	End Time	Dur (hr)	Peak of Storm	Mean Dir	No of Events	Mean Direction Vector	Hs (m)	Tp (s)	Tz (s)	Dir	Energy @ Peak (KJ/m/s)	Total Energy (KJ/m)
21/01/2013 02:00	21/01/2013 20:00	18	21/01/2013 13:00	68	35	22	5.1	9.3	7.8	65	6.4E+03	4.5E+06
06/02/2013 13:30	07/02/2013 02:00	12.5	06/02/2013 17:00	14	15	77	4.3	9.3	7.4	17	4.5E+03	1.7E+06
22/03/2013 20:00	24/03/2013 23:00	51	23/03/2013 15:30	74	99	16	5.1	9.9	7.7	65	7.1E+03	1.4E+07
23/05/2013 21:30	24/05/2013 10:30	13	24/05/2013 00:30	19	27	71	**5.7**	**9.9**	**8.5**	**18**	**9.0E+03**	4.9E+06
10/09/2013 13:00	10/09/2013 22:30	9.5	10/09/2013 19:30	13	19	77	5.0	8.4	7.3	13	4.9E+03	2.3E+06
10/10/2013 02:00	11/10/2013 06:30	28.5	10/10/2013 23:00	28	56	72	5.8	10.5	8.0	21	1.1E+04	1.1E+07
Data missing for 5th / 6th December 2013 storm as buoy was off station												
14/10/2014 03:00	14/10/2014 06:00	3	14/10/2014 04:30	61	4	33	4.4	7.6	6.7	61	3.2E+03	3.2E+05

Table 6: Storm analysis for Whitby WB (data 17/01/2013 to 31/10/2014)

General Storm Information							At Peak					
StartTime	EndTime	Duration (hr)	Peak of Storm	Mean Dir	No of Events	Mean Direction Vector	Hs (m)	Tp (s)	Tz (s)	Dir	Energy @ Peak (KJ/m/s)	Total Energy (KJ/m)
21/01/2013 02:30	22/01/2013 03:00	24.5	21/01/2013 14:30	64	38	27	5.0	9.3	8.2	61	6.0E+03	5.0E+06
06/02/2013 11:00	07/02/2013 04:00	17	06/02/2013 18:30	17	35	73	4.8	9.9	7.1	16	6.4E+03	4.3E+06
08/03/2013 03:30	11/03/2013 05:30	74	11/03/2013 04:00	58	12	36	4.3	8.4	7.1	45	3.7E+03	1.1E+06
18/03/2013 18:30	24/03/2013 17:30	143	23/03/2013 13:00	70	95	20	5.2	9.3	8.2	72	6.6E+03	1.2E+07
23/05/2013 21:00	**24/05/2013 12:30**	**15.5**	**24/05/2013**	**20**	**27**	**70**	**5.8**	**10.5**	**8.3**	**24**	**1.0E+04**	**5.0E+06**
10/09/2013 14:00	10/09/2013 22:30	8.5	10/09/2013 16:00	19	17	72	4.4	9.3	6.9	24	4.6E+03	1.8E+06
10/10/2013 01:30	11/10/2013 06:30	29	11/10/2013	30	57	69	5.7	11.2	8.3	31	1.1E+04	1.1E+07
30/11/2013	30/11/2013 06:30	6.5	30/11/2013 03:30	16	13	75	4.8	10.5	7.4	20	7.1E+03	2.1E+06
05/12/2013 20:00	06/12/2013 22:00	26	06/12/2013 19:30	20	45	71	4.7	14.0	9.1	32	**1.2E+04**	8.2E+06
14/10/2014 04:30	14/10/2014 05:30	1	14/10/2014 05:30	52	2	40	4.1	7.0	6.5	53	2.3E+03	1.2E+05



KEY

Topographic Profiles
- Annual
- 6 monthly

Topographic Surveys
- 6 monthly
- yearly
- 5 yearly

Cliff Top Monitoring Pegs
- 50m centres
- 100m centres
- 300m centres

(Indicative survey extents shown)

Client: North East Coastal Group

Project: Cell 1 Regional Coastal Monitoring Programme 2011 to 2016

Figure 2 - Map 1 Survey Locations North Sands Hartlepool Borough Council

Analytical Report 7
Full Measures Survey
Autumn 2014

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Photography courtesy of North East Coastal Observatory
www.northeastcoastalobservatory.org.uk

KEY

Topographic Profiles
- Annual
- 6 monthly

Topographic Surveys
- 6 monthly
- yearly
- 5 yearly

Cliff Top Monitoring Pegs
- 50m centres
- 100m centres
- 300m centres

(Indicative survey extents shown)

Client: North East Coastal Group

Project: Cell 1 Regional Coastal Monitoring Programme 2011 to 2016

Figure 2 - Map 2
Survey Locations
Headland and Middleton
Hartlepool Borough Council

Analytical Report 7
Full Measures Survey
Autumn 2014

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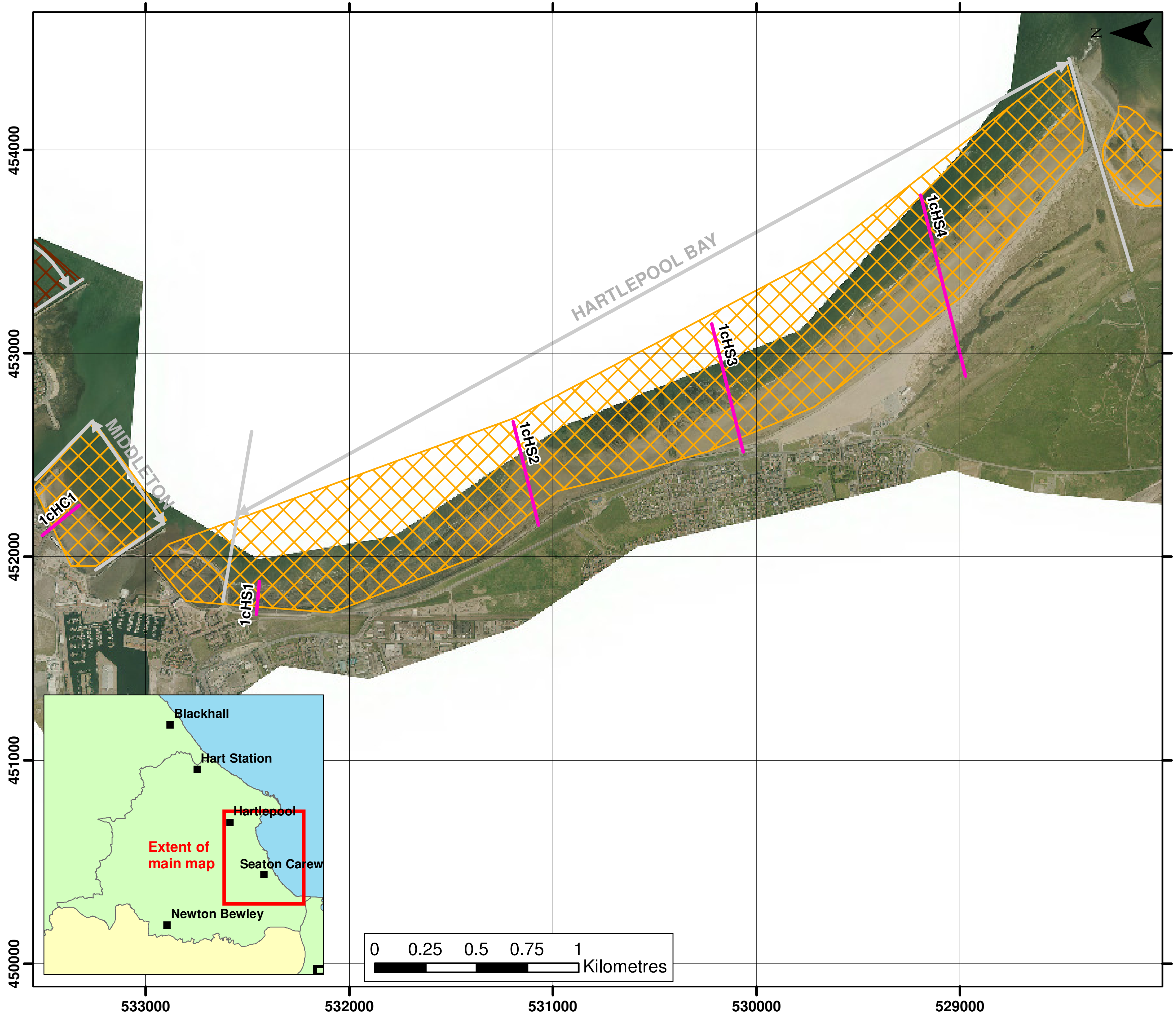

KEY

Topographic Profiles
- Annual
- 6 monthly

Topographic Surveys
- 6 monthly
- yearly
- 5 yearly

Cliff Top Monitoring Pegs
- 50m centres
- 100m centres
- 300m centres

(Indicative survey extents shown)

Client: North East Coastal Group

Project: Cell 1 Regional Coastal Monitoring Programme 2011 to 2016

Figure 2- Map 3 Survey Locations Hartlepool Bay Hartlepool Borough Council

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Full Measures Survey
Autumn 2014

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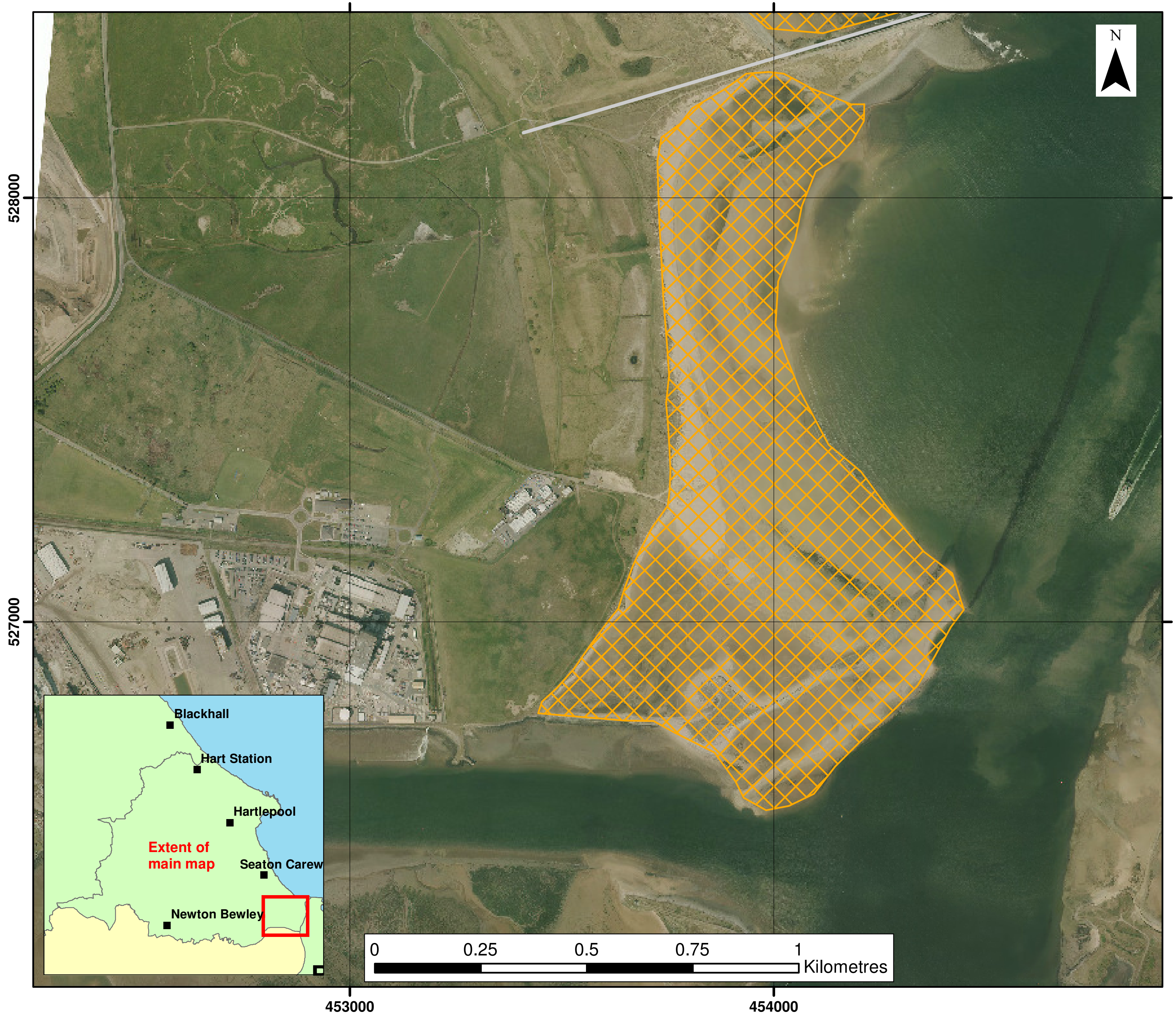

KEY

Topographic Profiles
- Annual
- 6 monthly

Topographic Surveys
- 6 monthly
- yearly
- 5 yearly

Cliff Top Monitoring Pegs
- 50m centres
- 100m centres
- 300m centres

(Indicative survey extents shown)

Client: North East Coastal Group

Project: Cell 1 Regional Coastal Monitoring Programme 2011 to 2016

Figure 2- Map 4
Survey Locations
Hartlepool North Gare
Hartlepool Borough Council

Analytical Report 7
Full Measures Survey
Autumn 2014

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3. Analysis of Survey Data

3.1 North Sands

Survey Date	Description of Changes Since Last Survey	Interpretation
29th September 2014	**Beach Profiles:** North Sands is covered by four beach profile lines during the Full Measures survey (Appendix A). They were last surveyed in March 2014. Profile **1cHN1** is located within Durham County Council's area of responsibility, about 400m north of the outfall of Crimdon Beck, is reported here so changes can be interpreted in association with those observed elsewhere along North Sands at HN2, HN3 and HN4. Overall at **1cHN1**, the beach is near its highest recorded level. The beach above HAT has changed very little. Below the level of HAT as far as 160m chainage, the upper beach has accreted by up to 0.8m and the profile has flattened. Between 160m and 185m chainage erosion of 0.2m has occurred to form a subtle depression. Between 185m and the end of the survey at c.280m chainage, the beach has accreted by up to 1m to form a berm in the lower intertidal zone. At Profile **1cHN2** the profile has not changed above HAT since March 2014. A bar has developed between HAT and 100m chainage, raising the upper beach by 1m. From 100m to 200m chainage erosion of up to 0.8m has occurred. A low berm has developed between 200m and 250m chainage through accretion of up to 0.4m. Between 250m chainage and the end of the survey there has been minor erosion. **Profile 1cHN2a** was established in October 2011 and runs through the dunes close to North Sands. A foredune that had been accreting between 70m and 90m chainage since October 2011 was removed over the winter of 2013/14 (the period of the storm surge), but accretion has since restarted, raising the beach level by up to 1.2m between 80m and 110m chainage. Erosion of 0.4m has occurred between 110m and 170m chainage creating a steep front to the upper beach. Between 170m chainage and the end of the survey at 310m chainage, the beach has accreted by up to 1m, filling a depression previously present. The beach level remains in the middle range of levels surveyed. Profile **1cHN3** had developed a foredune since 2008. The crest of the fore-dune at 35m chainage	Over the short term, the beach profiles at Hartlepool show mixed but limited change with areas of erosion and some deposition within each profile, due to seasonal movements of sand bars. Review of all the beach profiles indicates that those in the north of the survey area at their highest and those in the south of the survey are at their lowest, with much of the rocky shore platform exposed. This indicates a general movement of sediment to the north. The mix of erosion and deposition that has occurred between Autumn 2013 and Autumn 2014 is a return to a more typical pattern recorded at North Sands and contrasts with the widespread erosion record last year. **Longer term trends**: The difference plot from the previous Full Measures report (2013), showed widespread erosion between Autumn 2012 and Autumn 2013, which contrasts with the pattern of accretion towards MLW seen in the present report. **Autumn 2008 to Autumn 2014 trends** In the long-term difference plot, the shore parallel features to the north-west of the jetty indicate the normal migration of berms. The extensive erosion to the south-east of the jetty (also recorded in the beach

Survey Date	Description of Changes Since Last Survey	Interpretation
	remains unchanged since October 2013, but the front of this foredune was substantially eroded over the winter of 2013/14. From 40m to 100m chainage, there has been up to 1.5m of erosion since October 2013 but little change since March 2014. Between 100m and 195m chainage there has been 0.6m of erosion, flattening a berm present in March 2014. Seaward of this there has to the end of the survey of at 280m chainage, there has been accretion of up to 1m since October 2013 continuing the trend seen in March 2013. The upper beach is near its lowest level since monitoring began but the lower beach is at a medium level compared to previous surveys, suggesting a reduction in beach gradient. At Profile **1cHN3a** there has been around 3m retreat of the dune face since October 2013, and lowering of the upper beach by 0.6m between 25m and 60m chainage, although there has been some recovery since March 2014. Little change has occurred between 60m and 120m chainage, but accretion of 0.9m of sand between 120m chainage and the end of the survey at 190m chainage has developed a berm. Overall, the beach is near its lowest level since monitoring began. At Profile **1cHN4** the sand which had accumulated between October 2013 and April 2014 between the base of the sea wall and 65m chainage has been eroded by 0.6m. Seaward of this point, the rocky shore platform is exposed. The beach is near its lowest level since monitoring began. At Profile **1cHN4a** the rocky shore platform is exposed and little has changed since April 2014, except for some intermittent accumulation of sand between high points in the shore platform. The profile is practically unchanged since April 2012. The beach here is at its lowest since monitoring began.	profiles) is likely a residual effect of the December 2013 storm surge. **Extended Survey Autumn 2008 to 2013** The dominance of accretion in the north of the survey area ties in with observations that the northern profiles have been accreting and lately have been near their highest levels. Given the erosion present in the annually surveyed area, this indicates a northwards migration of sand from further south in the bay which has exposed the rocky foreshore at Throston. The mixture of limited erosion and accretion on the rocky headland proper is likely due to movements of relatively small pockets of sand on the predominantly rocky foreshore.
	Topographic Survey: North Sands is covered by an annual topographic survey. Data from the 2014 Full Measures survey have been used to create a DGM (Appendix B – Map 1a) using a GIS package. The majority of the frontage is characterised by shore-parallel contours, except in the vicinity of outfalls, groynes and the pier where contours change direction. The GIS has also been used to calculate the differences between the Autumn 2013 and Autumn 2014 topographic surveys, as shown in Appendix B – Map 1b, to identify areas of net erosion and accretion. Overall 2014 has seen a mixed pattern of erosion and accretion. Accretion is generally found on the lower half of the beach, with 1 to 2m has been deposited in localised areas. Erosion occurs at the back	

Survey Date	Description of Changes Since Last Survey	Interpretation
	of the beach and in the middle of the beach, where up to 1m has been lost. **Long Term Topographic Trends Autumn 2008 to Autumn 2014:** The long term difference plots (Appendix B – Map 1c(i)) provide information on net of change in beach levels between Autumn 2008 and Autumn 2014 at North Sands. The beach dominated by erosion, particularly towards the back of the beach where up to 1m has bene lost. Accretion was recorded as shore-parallel strips in the north-west of the survey area associated with migration of sand bars. **North Sands and Headland Extended Survey 2008 to 2013** Appendix B – Map 1a(ii) shows the topography of an extended survey area at North Sands, which includes the beach to the north-west of the annual survey area as far as Crimdon Dene Holiday Park, The Headland outside of the Breakwater. Appendix B – Map 1c(ii) shows the difference in elevation between the Autumn 2008 and Autumn 2013 survey. The difference plot shows that in the northern part of the extended survey area, there has been a mixture of erosion and accretion in shore parallel, linear strips, but with accretion being slightly more dominant (over 1m in a large area of the foreshore). This contrasts to the annually surveyed area and the extended survey area at Throston where up to 2m of erosion has occurred. On the headland proper, the plot shows mixed, limited (generally <1m) pockets of erosion and deposition.	

3.2 Middleton

<table>
<tr><th>Survey Date</th><th>Description of Changes Since Last Survey</th><th>Interpretation</th></tr>
<tr><td rowspan="2">29th Sept 2014</td><td>Beach Profiles:

Middleton is covered by one beach profile line during the Full Measures survey (Appendix A). The upper beach at Profile 1cHC1 between the seawall at 50m chainage and 60m chainage has recovered to a similar level to that seen in September 2013, after having been much lower in March 2014. The middle part of the beach between 60m chainage and 150m chainage has accreted by 0.5m since September 2013, but this is a similar level to April 2014. The lower part of the foreshore between 150m chainage and 230m chainage has eroded by 0.5m since March 2014. The beach has steepened overall.</td><td rowspan="2">The sediment drift towards the east seen in the last survey, which lessened the difference in gradient between the eastern and western ends of the beach has been reversed. The change in beach profile reflects the erosion and steepening of the beach toe in the east and deposition of sediment in the west to flatten the profile here. These changes are in response to short term drivers such as storms and tides which move sediment around this small bay.

Longer term trends:

The beach has returned to the pattern seen in earlier surveys where the eastern end of the beach is steeper than the western end.

Autumn 2008 to Autumn 2014 trends

The long term plot of change between 2008 and 2014 shows a spatially complex pattern of change that tends to be less than ±0.5m. Within this relatively closed system, this reflects a limited redistribution of sand due to bar migration across the beach.</td></tr>
<tr><td>Topographic Survey:

The frontage is covered by an annual topographic survey between Middleton Jetty and North Pier. Data from the 2014 Full Measures survey have been used to create a DGM (Appendix B – Map 2a) using GIS software. Beach contours indicate a steeper beach in the east than the west, with the contours locally affected by pipelines and groynes. In the Autumn 2013 survey, differences between the eastern and western ends of the beach were less marked. Earlier years show a similar topography to 2014.

The GIS has also been used to calculate the differences between the Autumn 2013 and Autumn 2014 topographic surveys, as shown in Appendix B – Map 2b, to identify areas of net erosion and accretion. The difference plot shows a clear distinction between areas of erosion and accretion separated by a zone of zero change between MHW in the east and MLW in the centre of the beach. The upper and western part of the beach is dominated by accretion of up to 0.75m while the lower and eastern parts of the beach, adjacent to the breakwaters have eroded by up to 1m. This is a reversal of the pattern seen at the previous Full Measures survey.

Long Term Topographic Trends Autumn 2008 to Autumn 2014:

The long term plot of change at Middleton (Appendix B – Map 2c) shows erosion in the upper beach in the west of the survey area and in the foreshore further east. Between the two areas there is an area of accretion that runs diagonally from MLW in the west to the upper beach in the east. Change very rarely exceeds 0.75m.</td></tr>
</table>

3.3 Hartlepool Bay

Survey Date	Description of Changes Since Last Survey	Interpretation
23rd - 24th Oct 2014	**Beach Profiles:** Hartlepool Bay is covered by four beach profile lines during the Full Measures survey (Appendix A). The profiles were last surveyed in March 2014. Profile **1cHS1** is located approximately 150m south of the root of the South Pier. The profile starts at the wall to the rear of the promenade and extends across the promenade, over the fronting concrete splash wall and down the sloping face of the rock armour revetment before reaching the beach. Accretion of up to 0.6m has occurred between 50m chainage and the end of the survey at 150m chainage. The beach is at its highest level since monitoring began. Profile **1cHS2** has smoother, more concave profile than in previous surveys. Further accretion of up to 0.3m of sand has occurred between the base of the rock armour and 220m chainage, and between 230m chainage and the end of the survey at 330m chainage since last surveyed. The beach is now at one of its highest levels as far as 330m chainage, but the lower beyond this chainage. At profile **1cHS3** no change has occurred as far as 30m chainage at the base of the sea defences since March 2013. Between 30m and 140m chainage and to a lesser extent between 160m and 200m chainage, around 0.3m of accretion has occurred at former depressions and a berm that existed in the March 2014 survey between 200 and 240m has been eroded by up to 0.4m. These changes have formed a steeper and smoother profile where the upper beach is at its highest level on record, but the lower beach is near its lowest. The profile **1cHS4** is located further south, around 1km north of the North Gare breakwater in an area of undefended dunes at Seaton Sands. The profile covers approximately 325m of dunes before the beach. The dune section is stable, with a foredune continuing to accrete at around 320m chainage. However, the depression landward of this has deepened by around 0.4m since March 2014. Limited accretion has occurred to fill in an upper beach depression just above HAT. Two berms, one between HAT and 410m chainage, and one between 500m and 580m chainage, have been eroded and the depression between them has infilled to give a smoother and shallower profile. Overall the beach is near the highest level seen since monitoring began.	The profiles in Hartlepool Bay all show smoother, profiles than in previous surveys. The upper beaches tend to be very high reflecting, the effect of surging summer waves acting to build the upper beach. The changes recorded have been < ±1m for the majority of the frontage, although exceed 1m in small patches, notably in front of the sea defences at the south of Seaton Sands. The linear nature of erosion indicates it may be related to bar migration or an indirect impact of the defences. Further monitoring is required to determine the impacts of the defences. **Longer term trends**: The difference plots indicate inter-annual patterns of erosion and accretion are complex, but appear to show alternating erosion and accretion in each survey. An exception to this is the southern end of the survey area towards North Gare Breakwater where erosion has been consistent for the previous two surveys. **Autumn 2010 to Autumn 2014 trends** Previously, the southern part of the bay had been steepening with widespread erosion on the lower beach and accretion on the upper beach. The northern bay had generally accreted throughout. However, with the exception of the area to the south of the promontory between the two smaller bays and towards North Gare Breakwater, this pattern appears

Survey Date	Description of Changes Since Last Survey	Interpretation
	Topographic Survey: Hartlepool Bay is covered by an annual topographic survey between the South Pier and the North Gare Breakwater. Data from the 2014 Full Measures survey have been used to create a DGM (Appendix B – Map 3a) using a GIS software package. The plot shows the two smaller bays within the larger Hartlepool Bay frontage. These smaller bays are separated by a slight promontory at Carr House Sands between Hartlepool and Seaton Carew. The beach contours are generally shore parallel, except where linear features (e.g. outfalls) and rock outcrops are present, such as in the northern part of Seaton Sands. Elevations at the rear of the beach are lowest in the north of the survey area near South Pier and higher further south. The GIS has also been used to calculate the differences between the Autumn 2013 and Autumn 2014 topographic surveys, as shown in Appendix B – Map 3b, to identify areas of erosion and accretion. The changes recorded over 2014 show a series of semi-continuous shore parallel bands of change that are rarely more than ±0.5m. The dominant trend in the north of the bay is accretion, and more erosion is evident in the south, particularly in front of the new sea defences south of Seaton Carew. Here, a second elongate area of erosion is present at the back of the beach. **Long Term Topographic Trends Autumn 2010 to Autumn 2014:** The net changes observed between the first full measures survey in 2010 and the most recent in Autumn 2014 are shown in Appendix B – Map 3c. The plot shows that the majority of the beach has accreted generally by c. 0.5m but locally up to 1m. Erosion is of c. 0.5m but up to 1m is concentrated to the south of the Carr House Sands promontory and at an elongate section of the lower beach in the lower foreshore in the south of the bay.	to have reversed in the last year with a pattern of accretion now dominating. This is supported by the beach profiles which, in the upper beach, are all near their highest levels since monitoring started. This result highlights that inter-annual changes are significant and can mask any underlying long-term trends.

3.4 North Gare

Survey Date	Description of Changes Since Last Survey	Interpretation
22nd October 2014	**Topographic Survey:** North Gare is covered by an annual topographic survey between the North Gare Breakwater and the Seaton on Tees Channel. The area is designated as the Teesmouth National Nature Reserve. Surveys have been carried out since Autumn 2011. Data from the 2014 Full Measures survey have been used to create a DGM (Appendix B – Map 4a) using GIS software. The beach contours recorded in 2014 show the promontory and the contours run shore parallel to the beach in the north. In the south of the study area the contours diverge from the shore line and there is an extensive flat area between the shoreline and MHW. However, the lower beach and foreshore are much steeper in the south of the survey area than in the north. The GIS has also been used to calculate the differences between the Autumn 2013 and Autumn 2014 topographic surveys, as shown in Appendix B – Map 4b, to identify areas of net erosion and accretion. The difference plot shows that the part of the frontage facing Teesmouth have broadly shore parallel bands of accretion and erosion and the locations of areas of accretion and erosion have ‘swapped’ since the last survey. The extensive flat top of the promontory shows only a subtle trend (changes mostly ±0.25m), but where discernible this trend is one of accretion. The vast majority of changes are within ±1m of the previous survey. **Long Term Topographic Trends Autumn 2011 to Autumn 2014:** The long term plot of change at North Gare (Appendix B – Map 4c) is very similar to the plot for Autumn 2013 to Autumn 2014. There is little change on the flat part of the promontory which comprises stable sandflats. The remainder of the frontage is characterised by shore parallel bands of accretion and erosion within ±1m, which change position between surveys.	The changes seen in the 2014 Full Measures survey are reversals of the trends seen in the previous survey, with the more discernible areas of shore parallel erosion and accretion in the north of the survey area now showing the reverse trend. **Autumn 2011 to Autumn 2013 trends** The longer-term change plot shows a similar pattern to that experienced over the past 12 months suggesting stability of this landform. With more data, the persistence of this pattern will become clearer.

4. Problems Encountered and Uncertainty in Analysis

Beach profile HN1 is located within Durham County Council's area of responsibility but has been reported here so changes can be interpreted in association with those observed elsewhere along North Sands, along HN2, HN3 and HN4.

At Middleton there was no access to the top part of profile 1cHC1.

At Hartlepool South the excavation works noted in previous surveys seemed complete, although the surveyors noted that there was a tractor grooming the 'central plateau' and piling collected rubble against the sea wall near section 1cHS3.

At North Gare the flat upper beach to the south and the area south of the southern breakwater was very soft sand. As a result, the surveyor was unable to complete south west corner of survey.

5. Recommendations for 'Fine-tuning' the Monitoring Programme

No changes are needed at the present time.

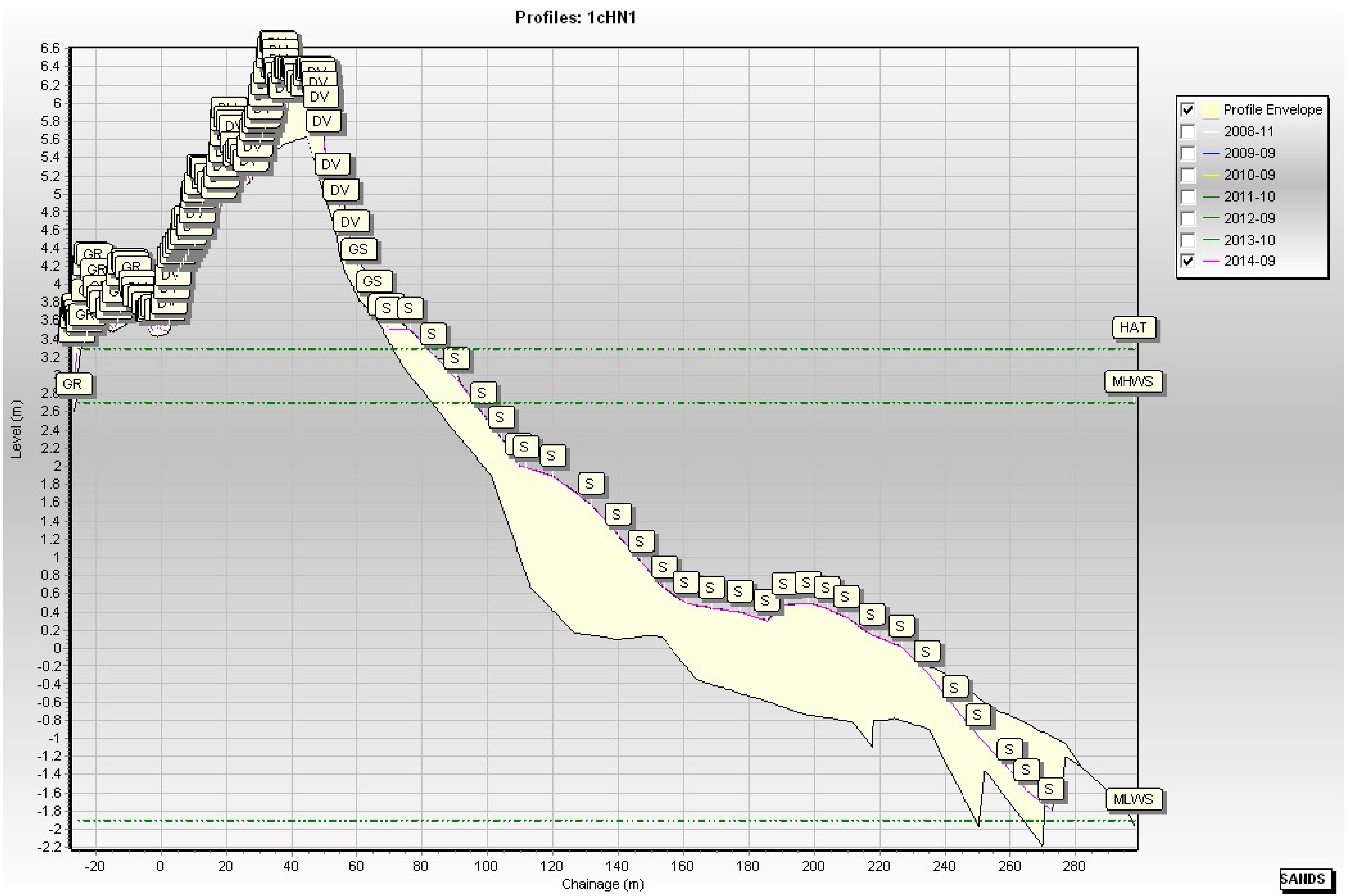
6. Conclusions and Areas of Concern

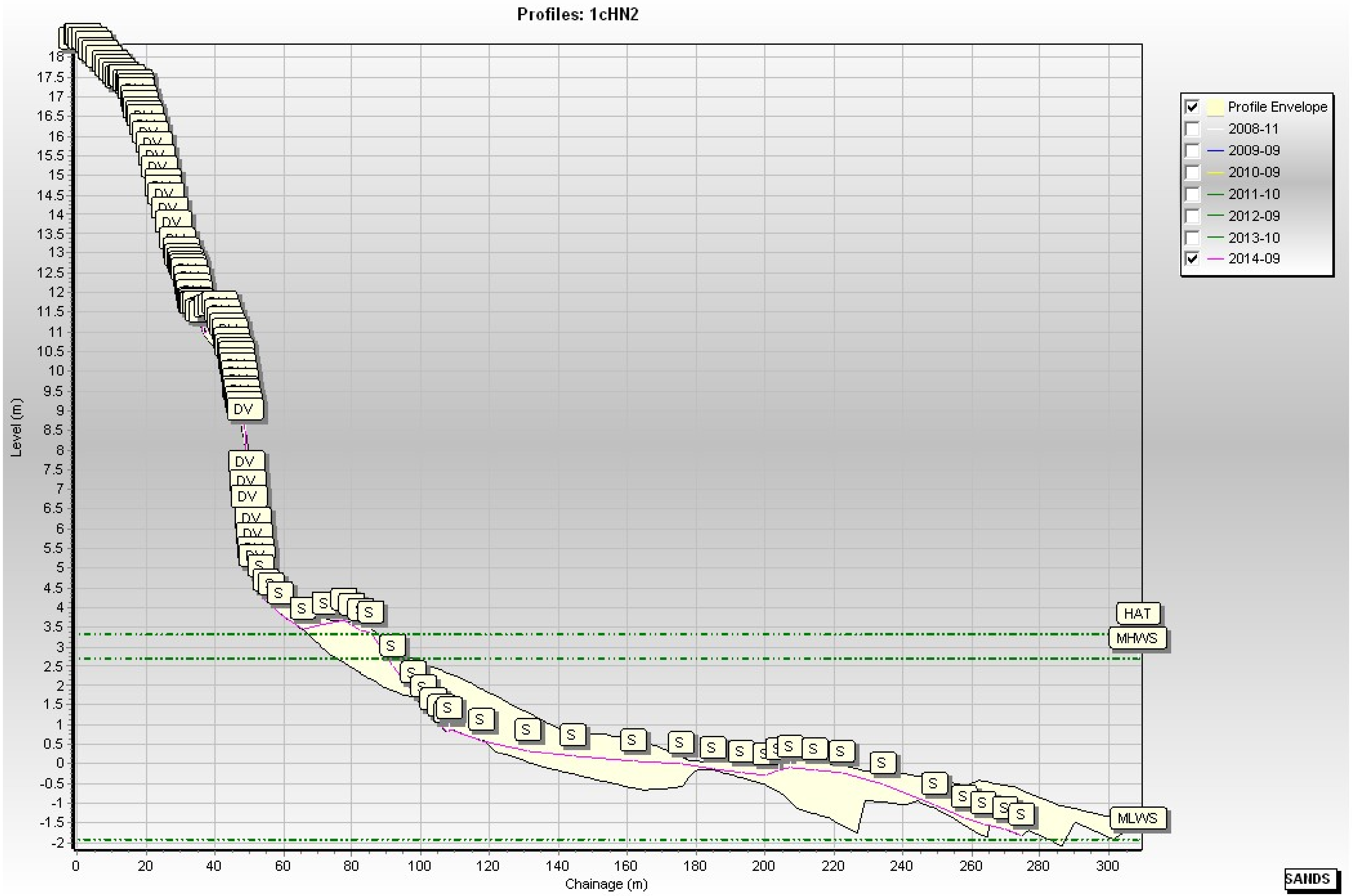
- At North Sands, the difference plots show a return to a more usual pattern of a mixture of accretion and deposition, whereas the previous Full Measures survey showed more widespread erosion. The beach profiles and topographic plots show that the beach is at its lowest point in the record towards the south of the survey area and higher in the north indicating that the current underlying trend is one of sediment drifting northwards in the bay.
- At Middleton, the beach appears to have regained its previous form with a steeper beach in the east and a shallower gradient in the west. This appears to be a return to 'normal' conditions after a departure in 2013. Inter-annual variation seems greater than long term variation as the long term plot shows very little change between 2008 and 2014.
- The majority of changes in Hartlepool bay are within ±1m of previous surveys. The beach profiles and difference plots indicate that the upper beach is near its highest level since monitoring began and has likely benefitted from surging waves building the upper beach over the summer. It should be expected that erosion will take place as more erosive waves pull sediment towards MLW over the winter.
- The topographic plots show a reversal of the limited elevation changes that had previously occurred at North Gare, with areas of erosion and deposition 'swapping places' in the north of the survey area and very subtle reversal of the previous accretion on the flat top of the promontory to become subtle erosion.
- There is no cause for concern at any of these areas.

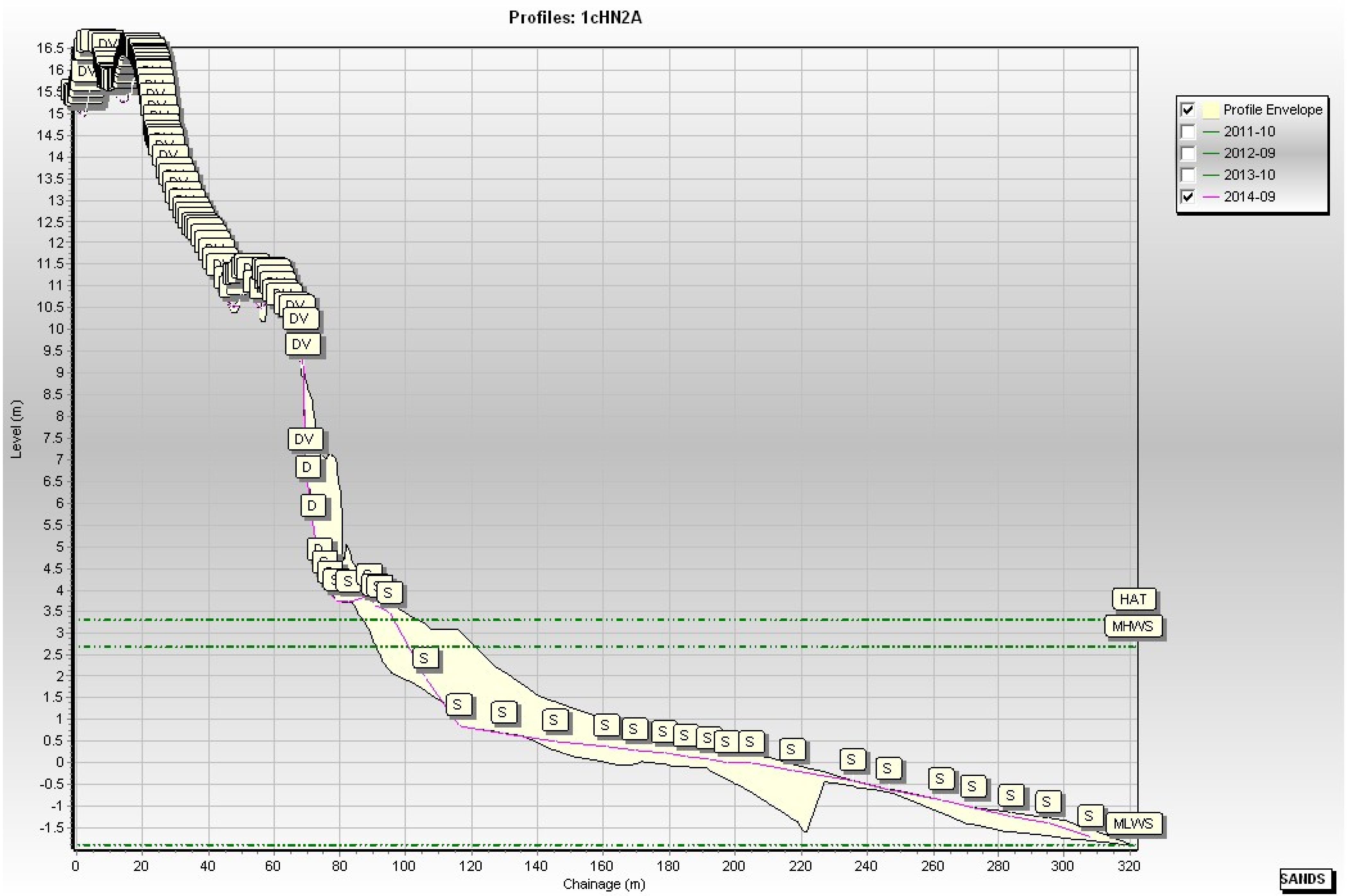
Appendices

Appendix A

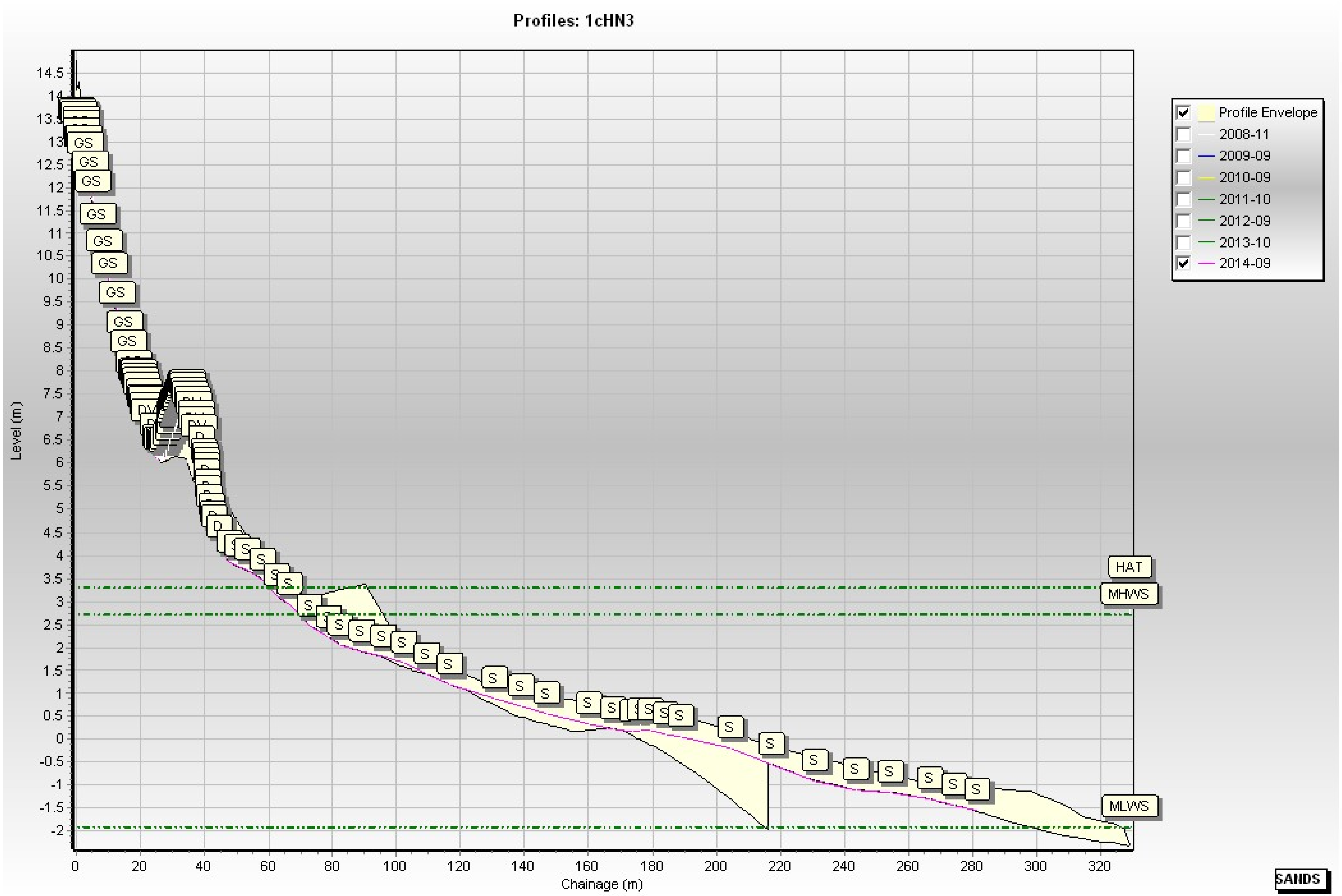
Beach Profiles


Profiles: 1cHN1
Level (m)
Chainage (m)
Profile Envelope
2008-11
2009-09
2010-09
2011-10
2012-09
2013-10
2014-09
HAT
MHWS
MLWS
SANDS


Profiles: 1cHN2
Level (m)
Chainage (m)
Profile Envelope
2008-11
2009-09
2010-09
2011-10
2012-09
2013-10
2014-09
HAT
MHWS
MLWS
DV
S
SANDS



Profiles: 1cHN2A
Level (m)
Chainage (m)
Profile Envelope
2011-10
2012-09
2013-10
2014-09
HAT
MHWS
MLWS
SANDS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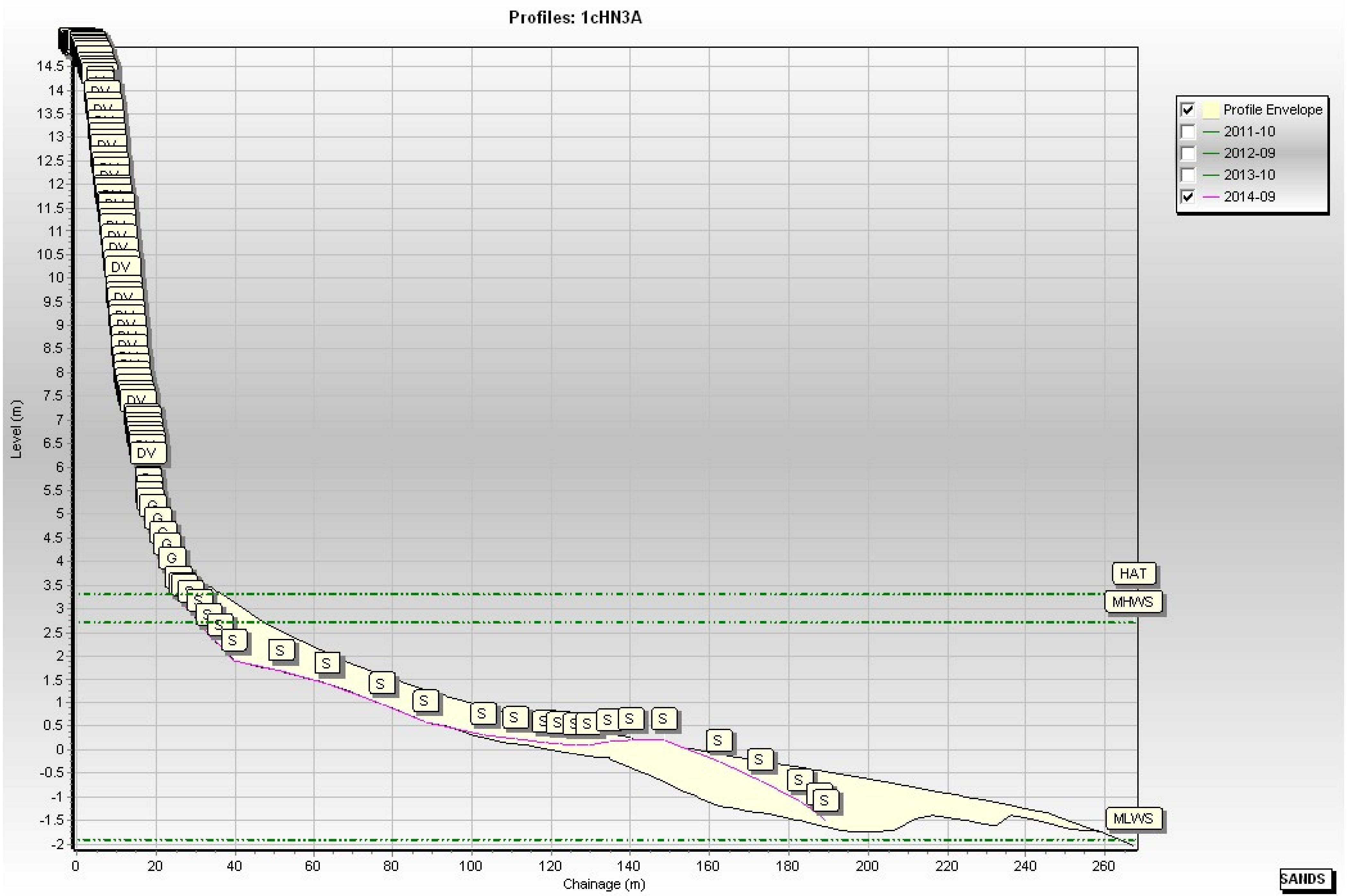
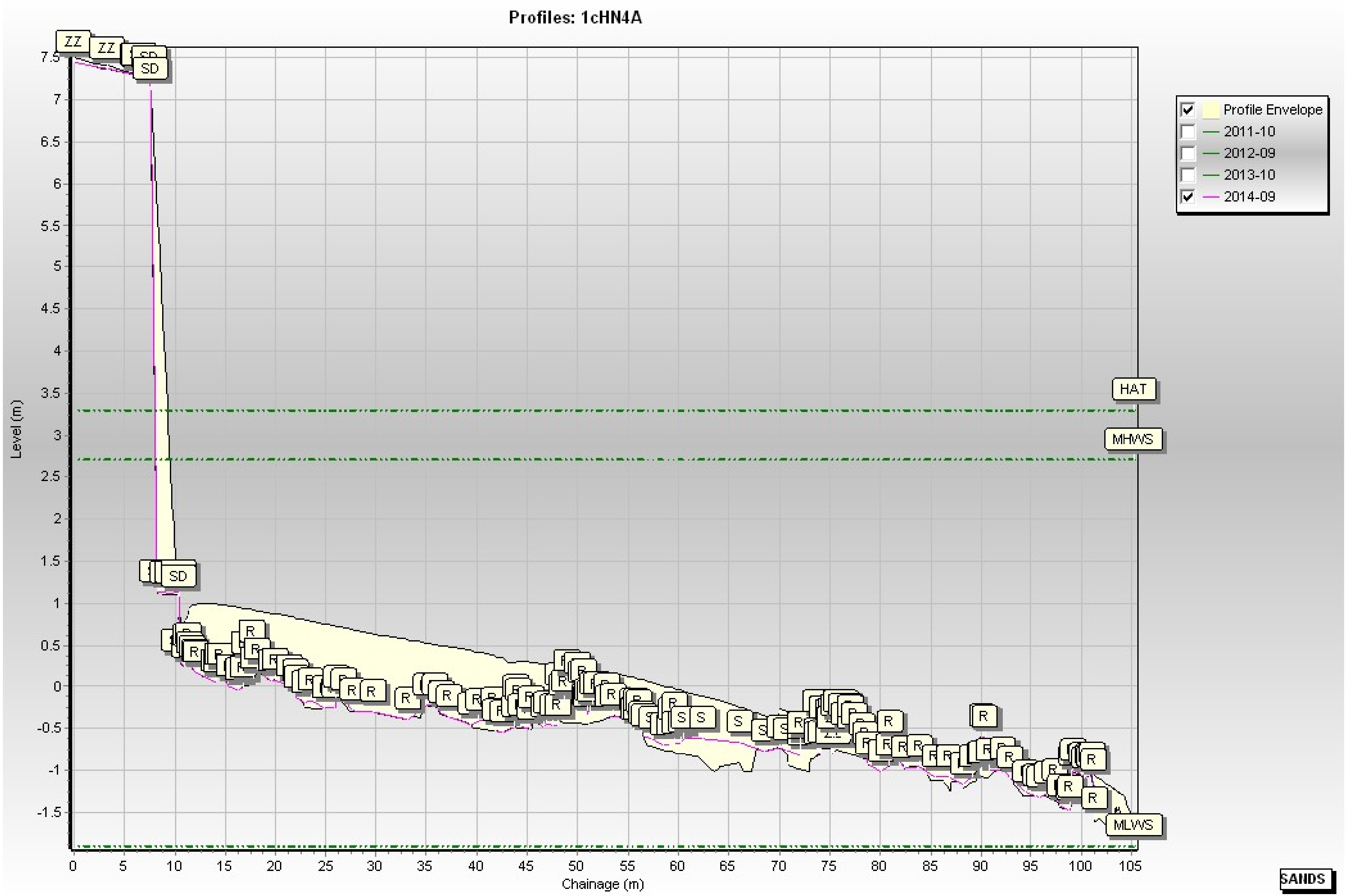
Level (m)
Chainage (m)
Profile Envelope
2008-11
2009-09
2010-09
2011-10
2012-09
2013-10
2014-09
HAT
MHWS
MLWS
GS
D
S
SANDS

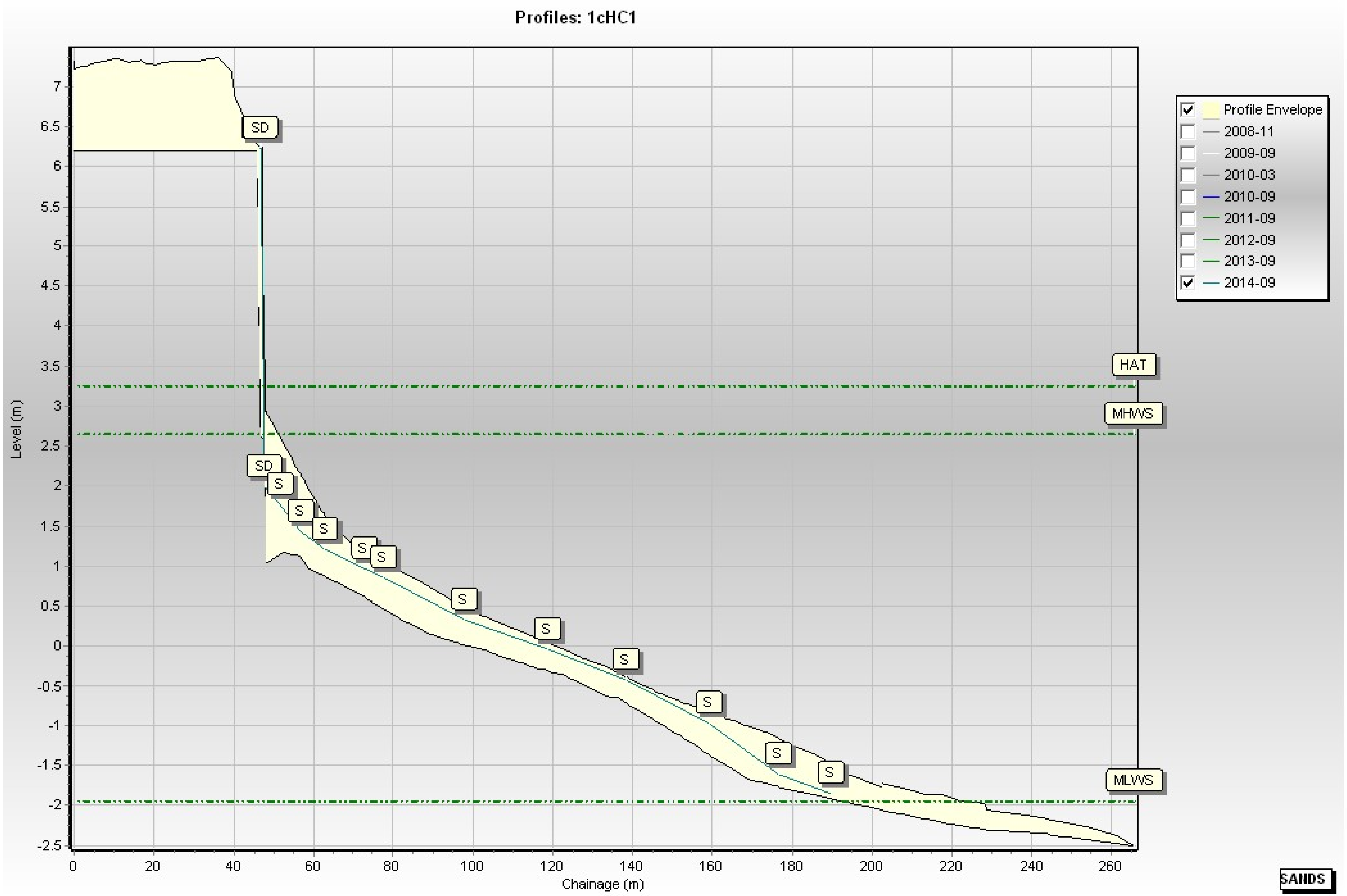


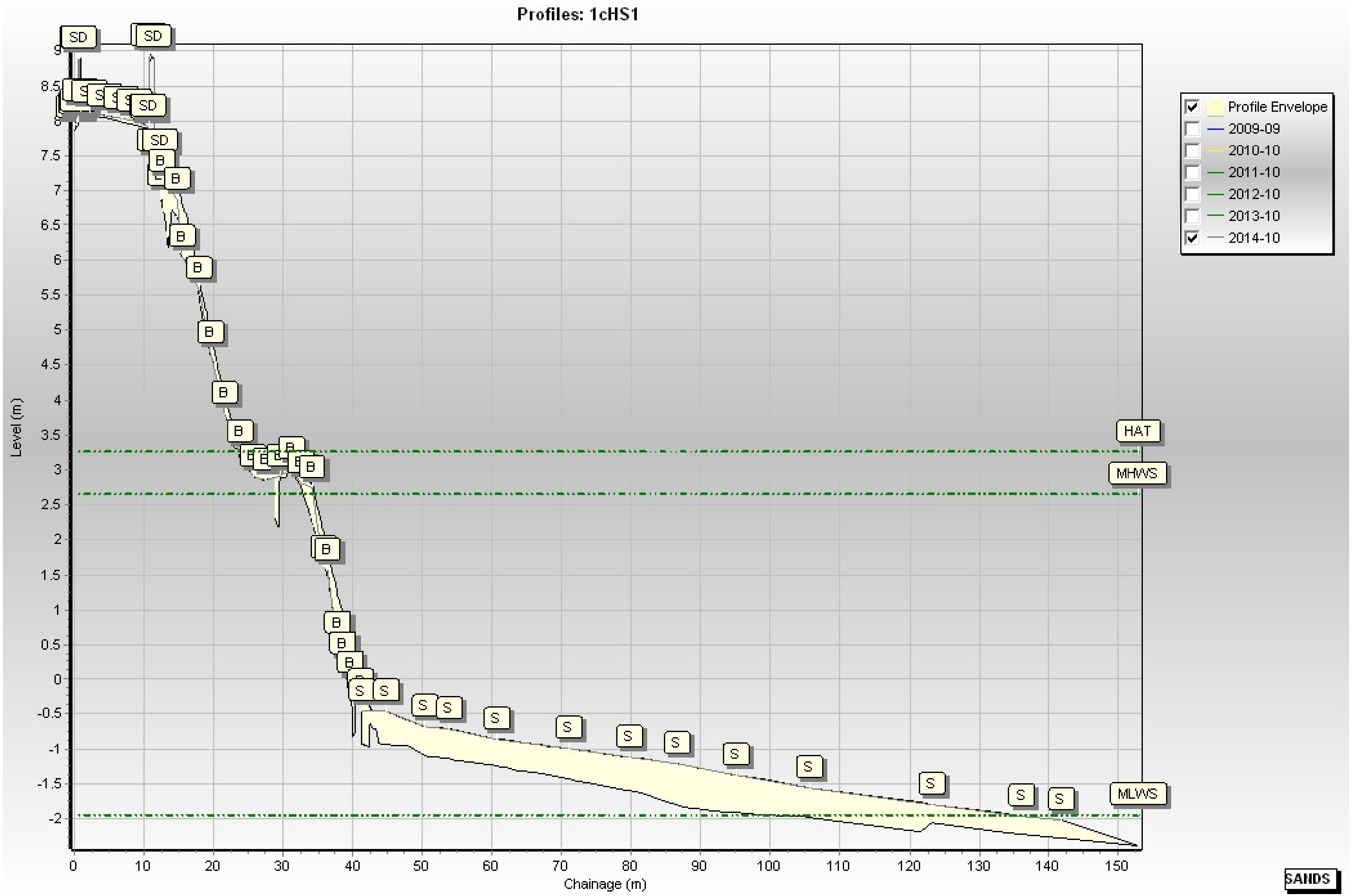
Profiles: 1cHN3A
Profile Envelope
2011-10
2012-09
2013-10
2014-09
Level (m)
Chainage (m)
HAT
MHWS
MLWS
DV
G
S
SANDS


Profiles: 1cHN4
Level (m)
Chainage (m)
Profile Envelope
2008-11
2009-09
2010-09
2011-10
2012-09
2013-10
2014-09
HAT
MHWS
MLWS
SANDS

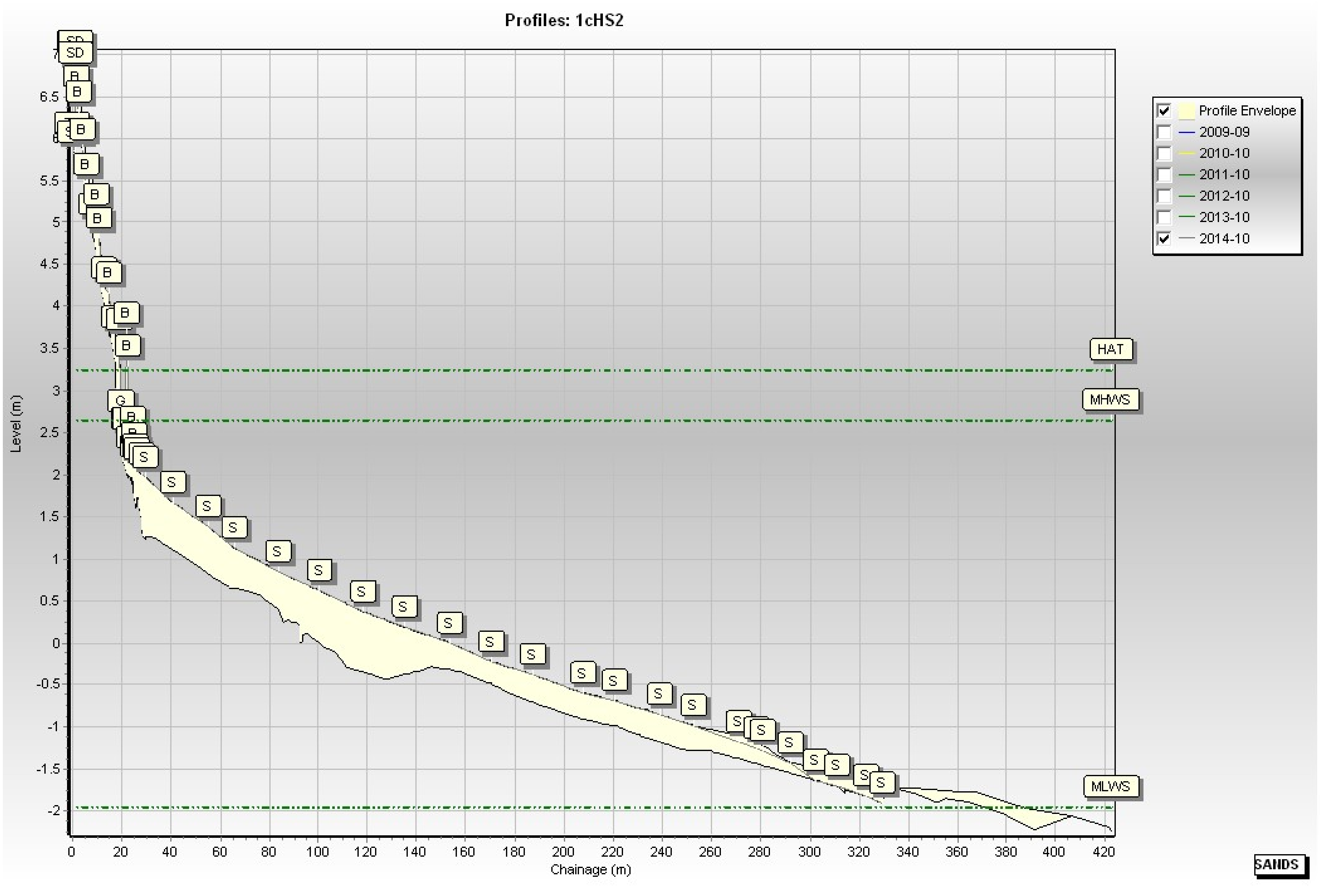


Profiles: 1cHN4A
Profile Envelope
2011-10
2012-09
2013-10
2014-09
HAT
MHWS
MLWS
Level (m)
Chainage (m)
SANDS

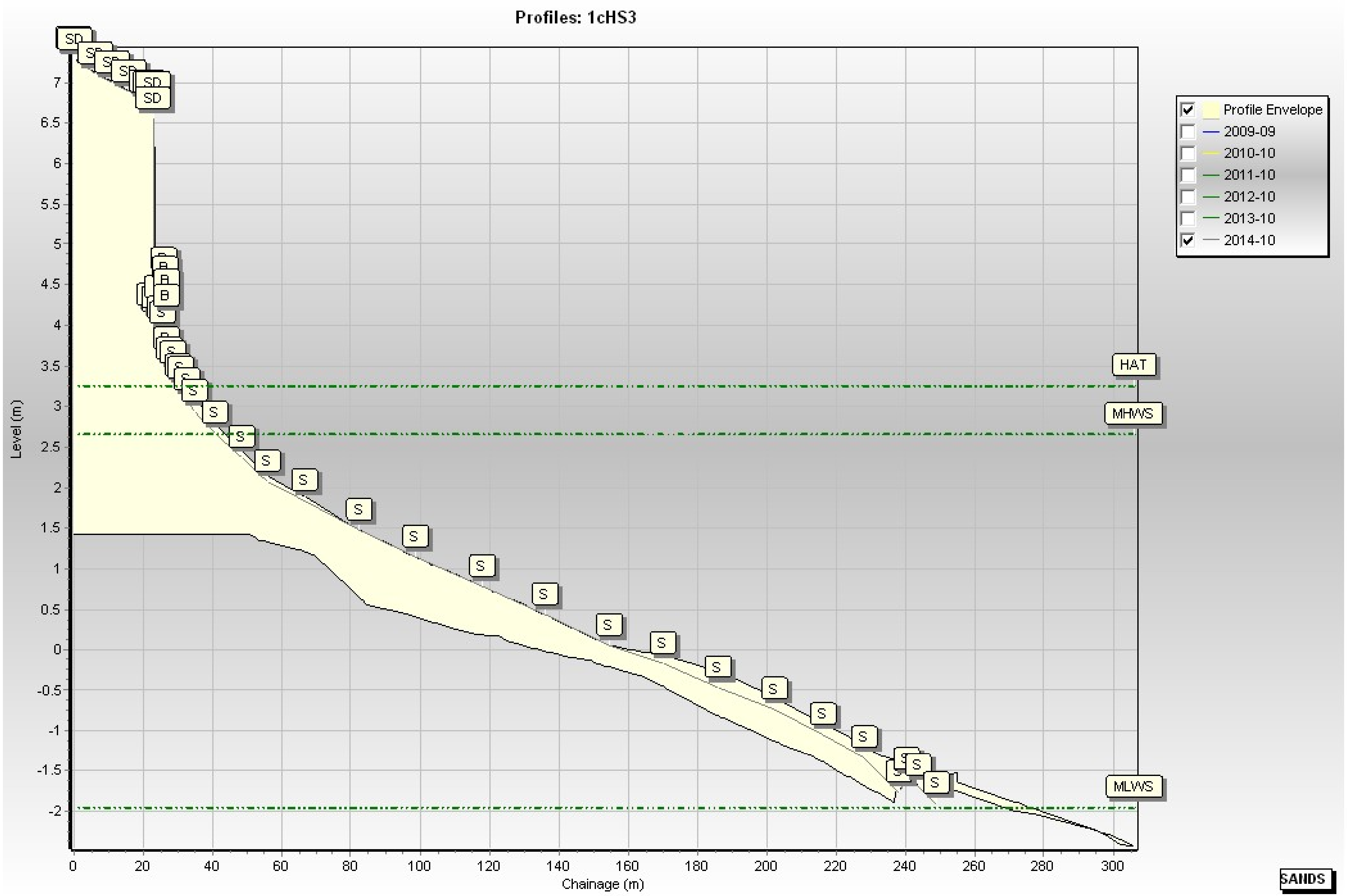

Profiles: 1cHC1
Level (m)
Chainage (m)
SD
SD
S
HAT
MHWS
MLWS
Profile Envelope
2008-11
2009-09
2010-03
2010-09
2011-09
2012-09
2013-09
2014-09
SANDS



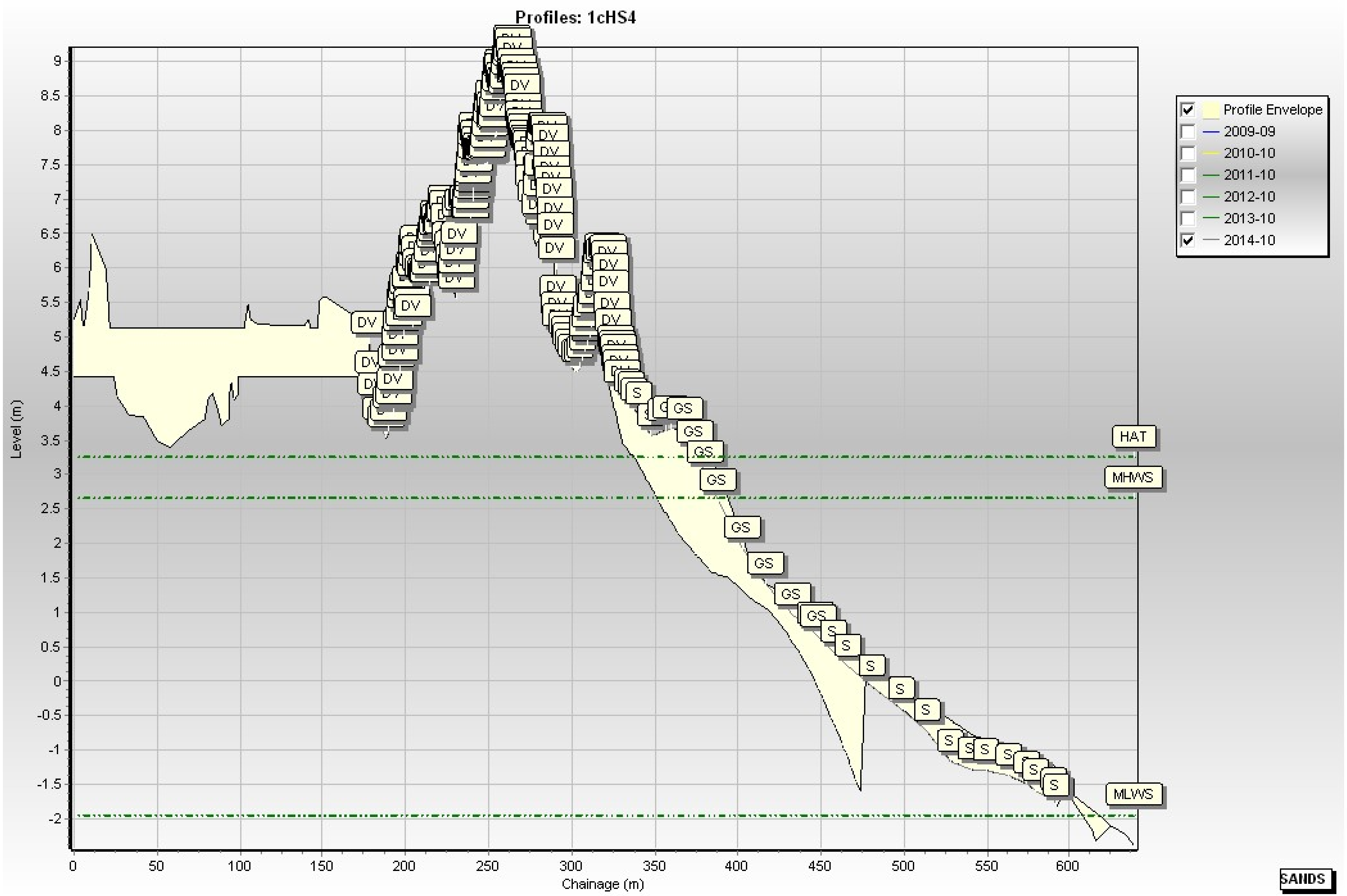
Profiles: 1cHS1
Level (m)
Chainage (m)
Profile Envelope
2009-09
2010-10
2011-10
2012-10
2013-10
2014-10
HAT
MHWS
MLWS
SD
B
S
SANDS



Profiles: 1cHS2
Level (m)
Chainage (m)
Profile Envelope
2009-09
2010-10
2011-10
2012-10
2013-10
2014-10
HAT
MHWS
MLWS
SANDS



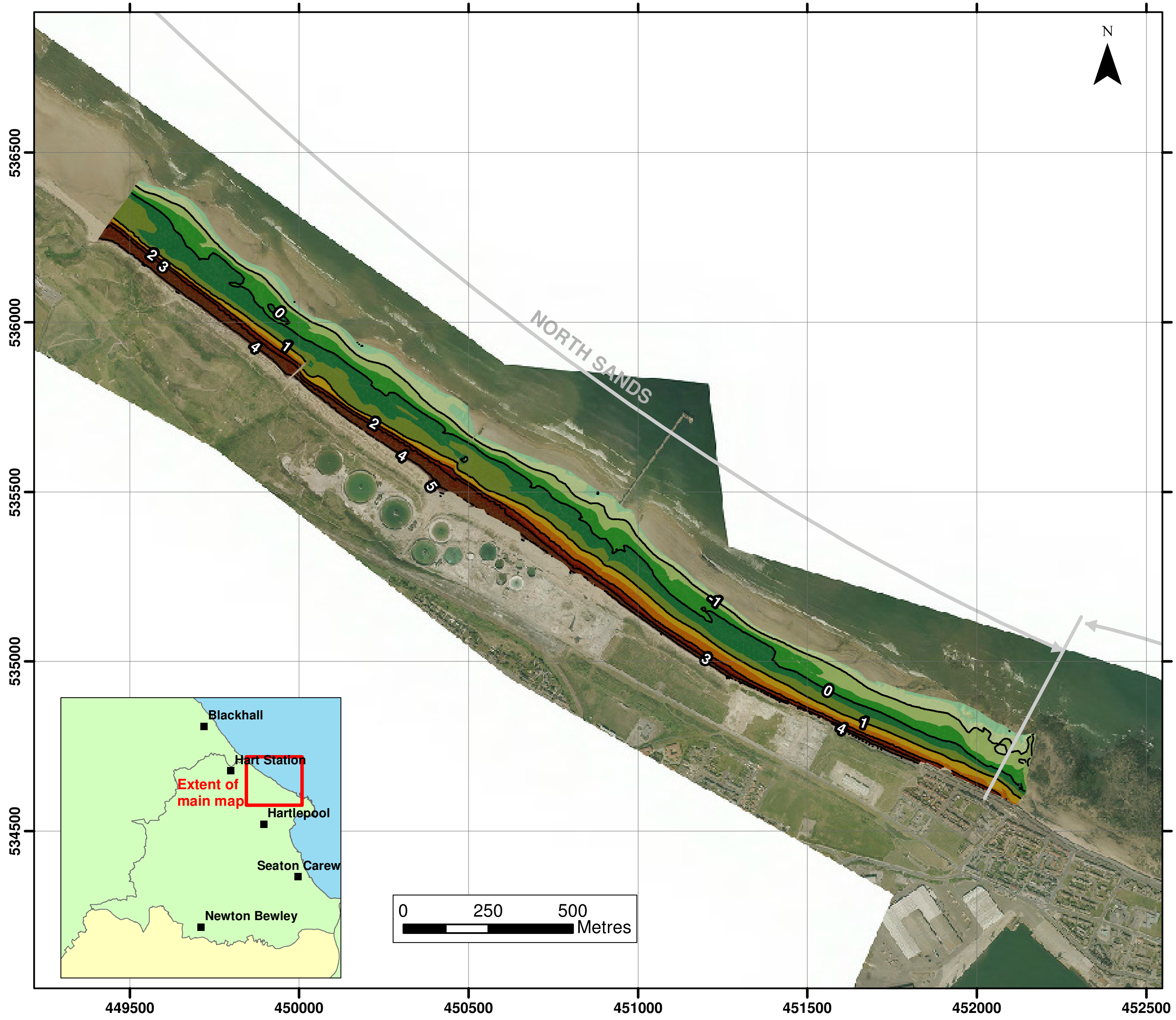
Profiles: 1cHS3
Level (m)
Chainage (m)
Profile Envelope
2009-09
2010-10
2011-10
2012-10
2013-10
2014-10
HAT
MHWS
MLWS
SD
B
S
SANDS



Profiles: 1cHS4
Level (m)
Chainage (m)
Profile Envelope
2009-09
2010-10
2011-10
2012-10
2013-10
2014-10
HAT
MHWS
MLWS
DV
GS
S
SANDS

Appendix B

Topographic Survey



KEY

Elevation

6 - 6.5	1.5 - 2
5.5 - 6	1 - 1.5
5 - 5.5	0.5 - 1
4.5 - 5	0 - 0.5
4 - 4.5	-0.5 - 0
3.5 - 4	-1 - -0.5
3 - 3.5	-1.5 - -1
2.5 - 3	-2 - -1.5
2 - 2.5	-2.5 - -2
	Contour 1m

Client: North East Coastal Group
Project: Cell 1 Regional Coastal Monitoring Programme 2011 to 2016

Appendix B - Map 1a(i)
Topographic Survey
North Sands
Hartlepool Borough Council

Analytical Report 7
Full Measures Survey
Autumn 2014

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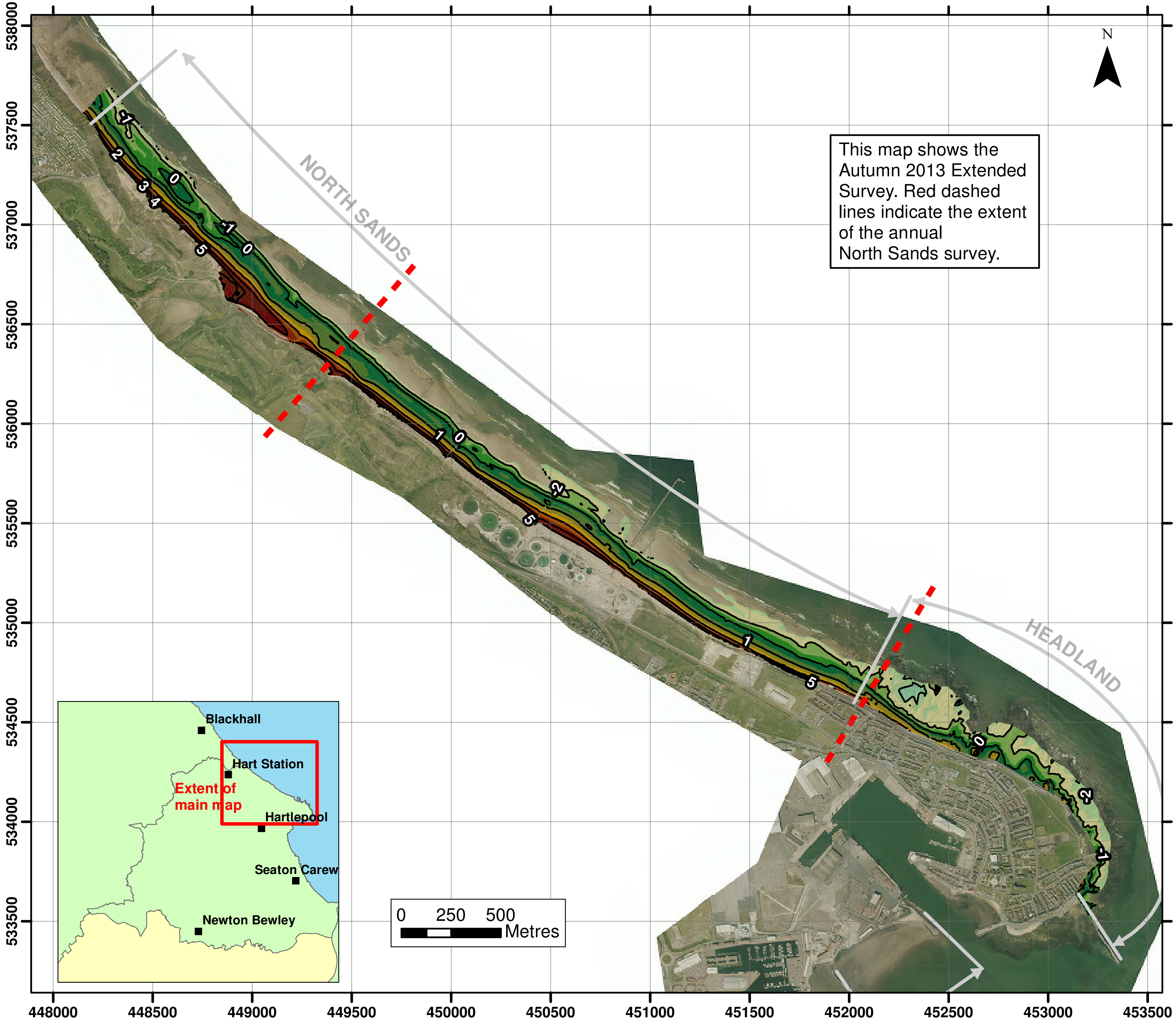

KEY

Elevation (m OD)

7.5 - 8	2 - 2.5
7 - 7.5	1.5 - 2
6.5 - 7	1 - 1.5
6 - 6.5	0.5 - 1
5.5 - 6	0 - 0.5
5 - 5.5	-0.5 - 0
4.5 - 5	-1 - -0.5
4 - 4.5	-1.5 - -1
3.5 - 4	-2 - -1.5
3 - 3.5	-2.5 - -2
2.5 - 3	-3 - -2.5
	Contour 1m

Client: North East Coastal Group
Project: Cell 1 Regional Coastal Monitoring Programme 2011 to 2016

Appendix B - Map 1a(ii)
Topographic Survey
North Sands (Extended)
Hartlepool Borough Council

Analytical Report 7
Full Measures Survey
Autumn 2014

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KEY Autumn 2013 and Autumn 2014
Change in elevation (m)

- <-2
- -2 - -1.75
- -1.75 - -1.5
- -1.5- -1.25
- -1.25 - -1
- -1 - -0.75
- -0.75 - -0.5
- -0.5 - -0.25
- -0.25 - -0.1
- -0.1 - 0
- 0 - 0.1
- 0.1 - 0.25
- 0.25 - 0.5
- 0.5 - 0.75
- 0.75 - 1
- 1 - 1.25
- 1.25 - 1.5
- 1.5 - 1.75
- 1.75 - 2
- >2

Loss

Change < 0.1 m

Gain

Contours of change

Client: North East Coastal Group
Project: Cell 1 Regional Coastal Monitoring Programme 2011 to 2016

Appendix B - Map 1b
Short-term Elevation Change North Sands Hartlepool Borough Council

Analytical Report 7
Full Measures Survey
Autumn 2014

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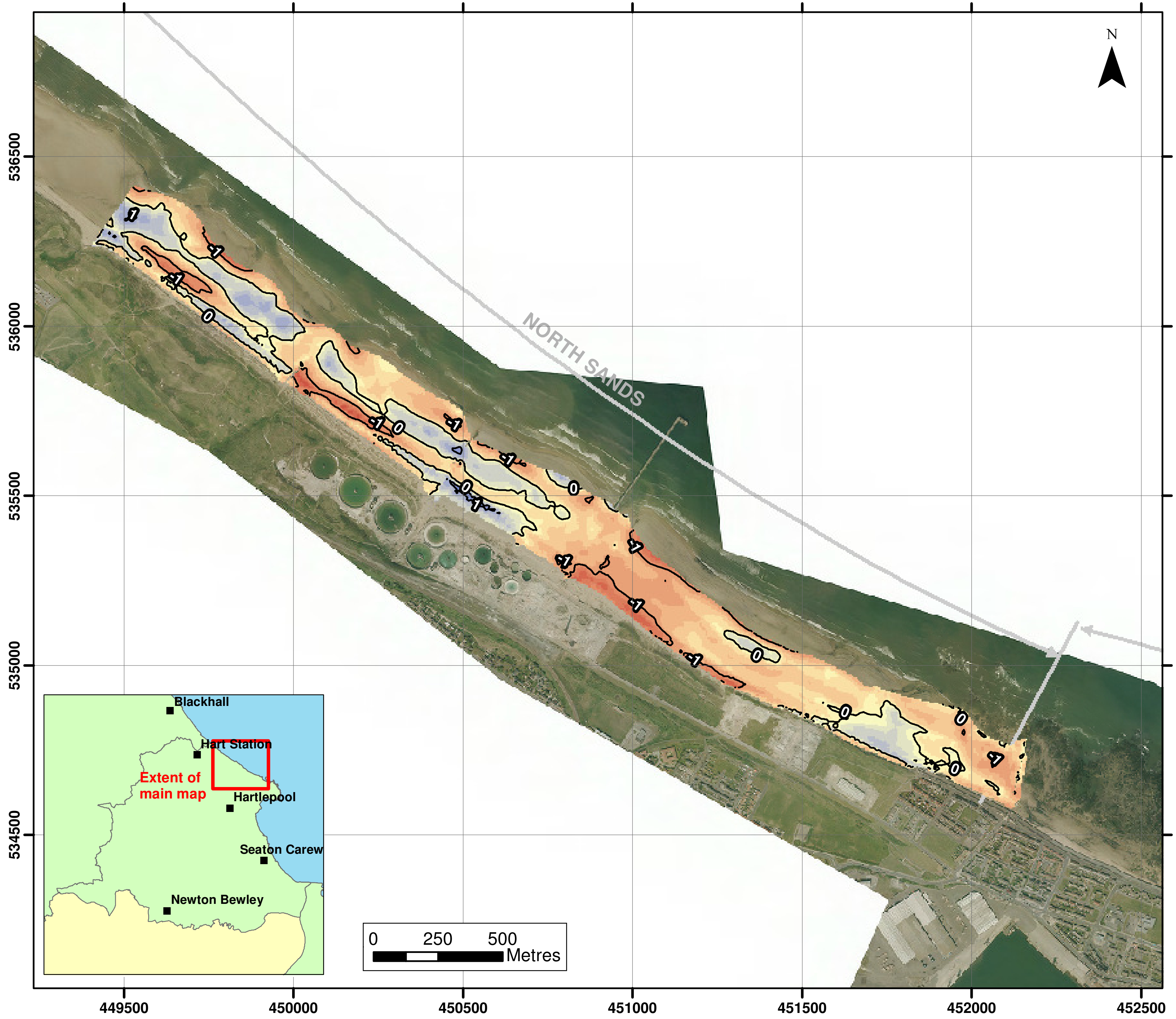

KEY Autumn 2008 and Autumn 2014
Change in elevation (m)

- <-2
- -2 - -1.75
- -1.75 - -1.5
- -1.5- -1.25
- -1.25 - -1
- -1 - -0.75
- -0.75 - -0.5
- -0.5 - -0.25
- -0.25 - -0.1
- -0.1 - 0
- 0 - 0.1
- 0.1 - 0.25
- 0.25 - 0.5
- 0.5 - 0.75
- 0.75 - 1
- 1 - 1.25
- 1.25 - 1.5
- 1.5 - 1.75
- 1.75 - 2
- >2

Loss

Change < 0.1 m

Gain

Contours of change

Client: North East Coastal Group
Project: Cell 1 Regional Coastal Monitoring Programme 2011 to 2016

Appendix B - Map 1c(i) Long-term Elevation Change North Sands Hartlepool Borough Council

Analytical Report 7
Full Measures Survey
Autumn 2014

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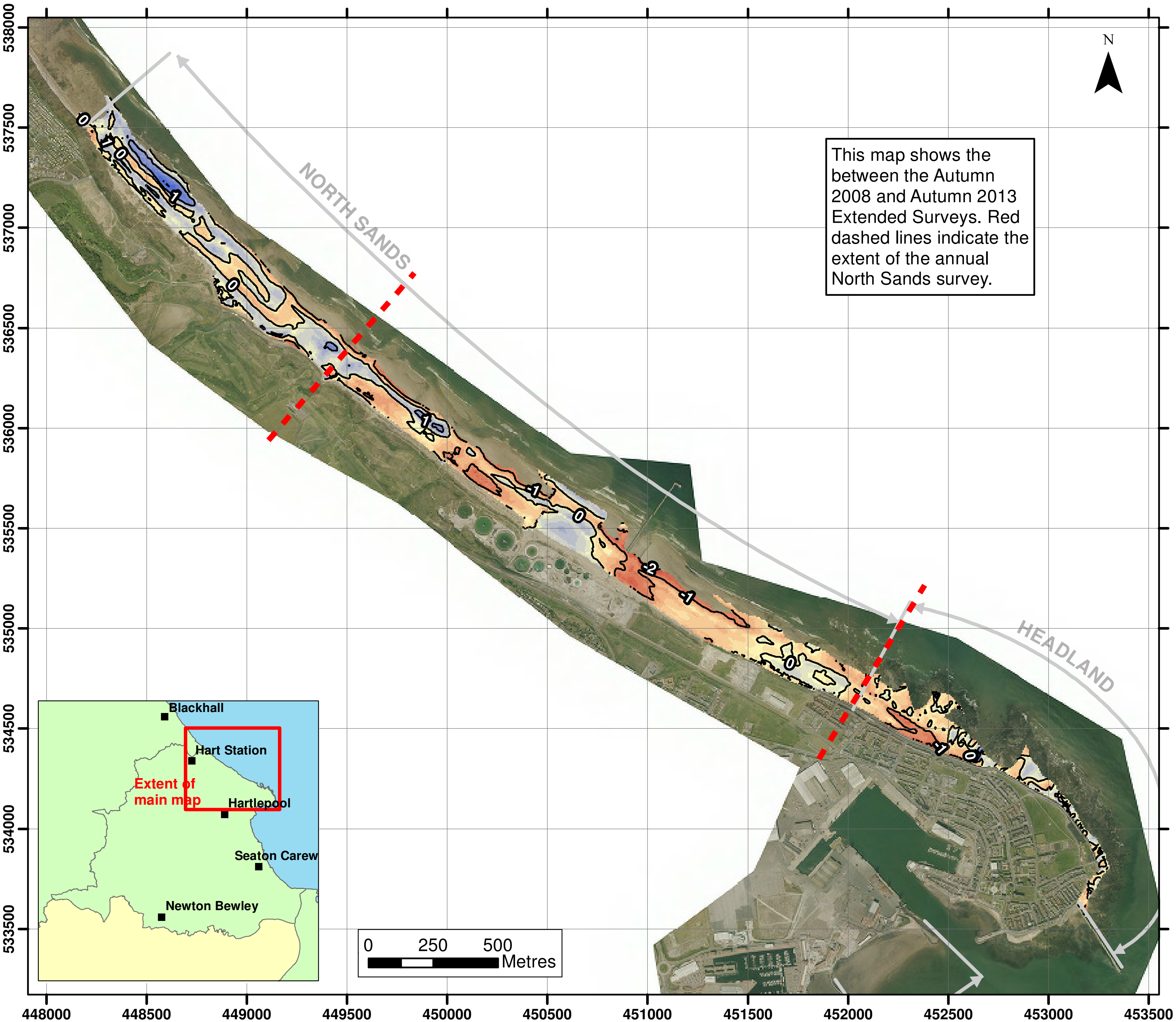

KEY Autumn 2008 and Autumn 2013
Change in elevation (m)

Loss:
- <-2
- -2 - -1.75
- -1.75 - -1.5
- -1.5- -1.25
- -1.25 - -1
- -1 - -0.75
- -0.75 - -0.5
- -0.5 - -0.25
- -0.25 - -0.1

Change < 0.1 m:
- -0.1 - 0
- 0 - 0.1

Gain:
- 0.1 - 0.25
- 0.25 - 0.5
- 0.5 - 0.75
- 0.75 - 1
- 1 - 1.25
- 1.25 - 1.5
- 1.5 - 1.75
- 1.75 - 2
- >2

Contours of change

Client: North East Coastal Group
Project: Cell 1 Regional Coastal Monitoring Programme 2011 to 2016

Appendix B - Map 1c(ii)
5-Year Extended Survey
Elevation Change
North Sands
Hartlepool Borough Council

Analytical Report 7
Full Measures Survey
Autumn 2014

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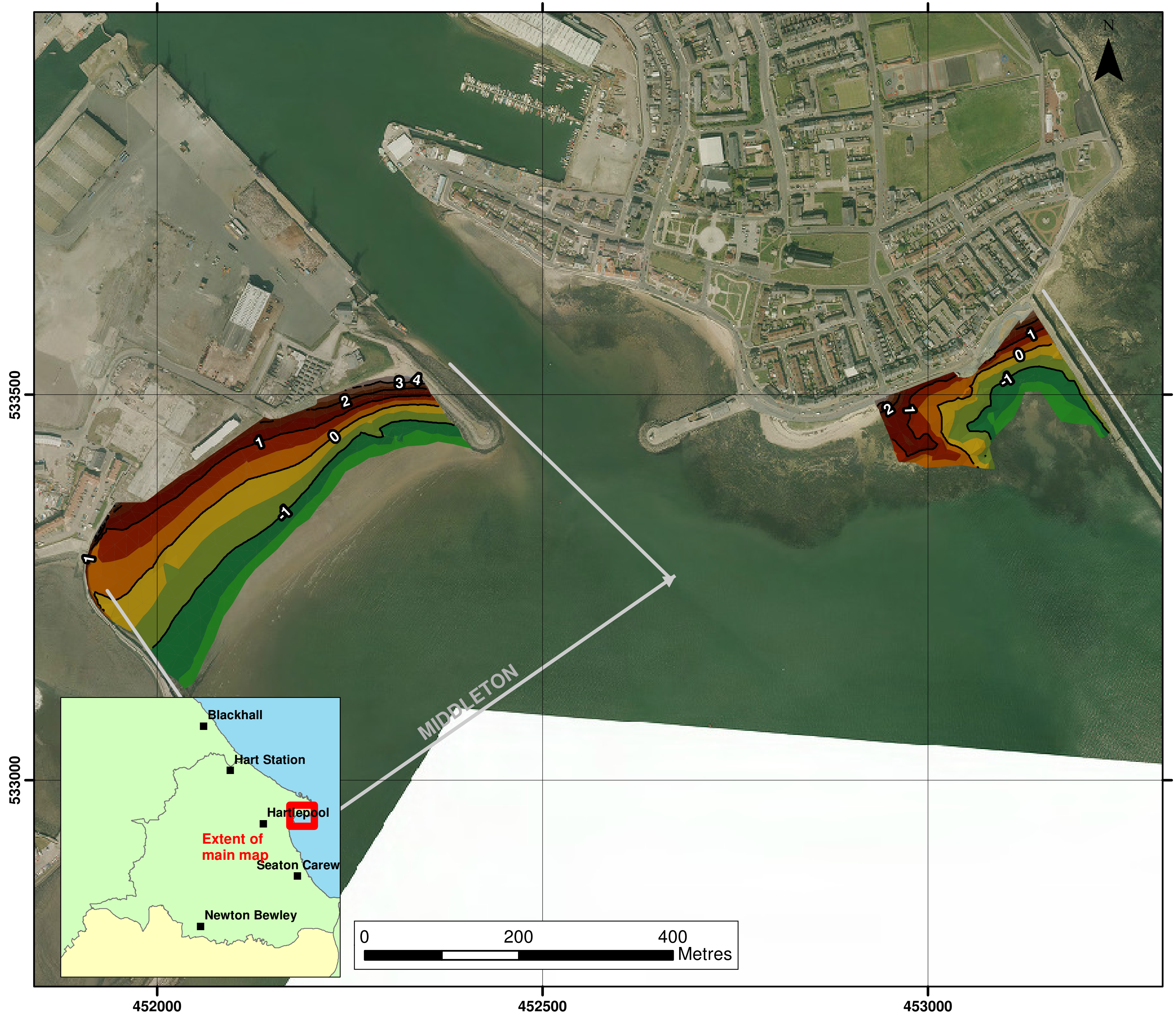

KEY

Elevation

- 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
- Contour 1m

Client: North East Coastal Group

Project: Cell 1 Regional Coastal Monitoring Programme 2011 to 2016

Appendix B - Map 2a
Topographic Survey
Headland and Middleton
Hartlepool Borough Council

Analytical Report 7
Full Measures Survey
Autumn 2014

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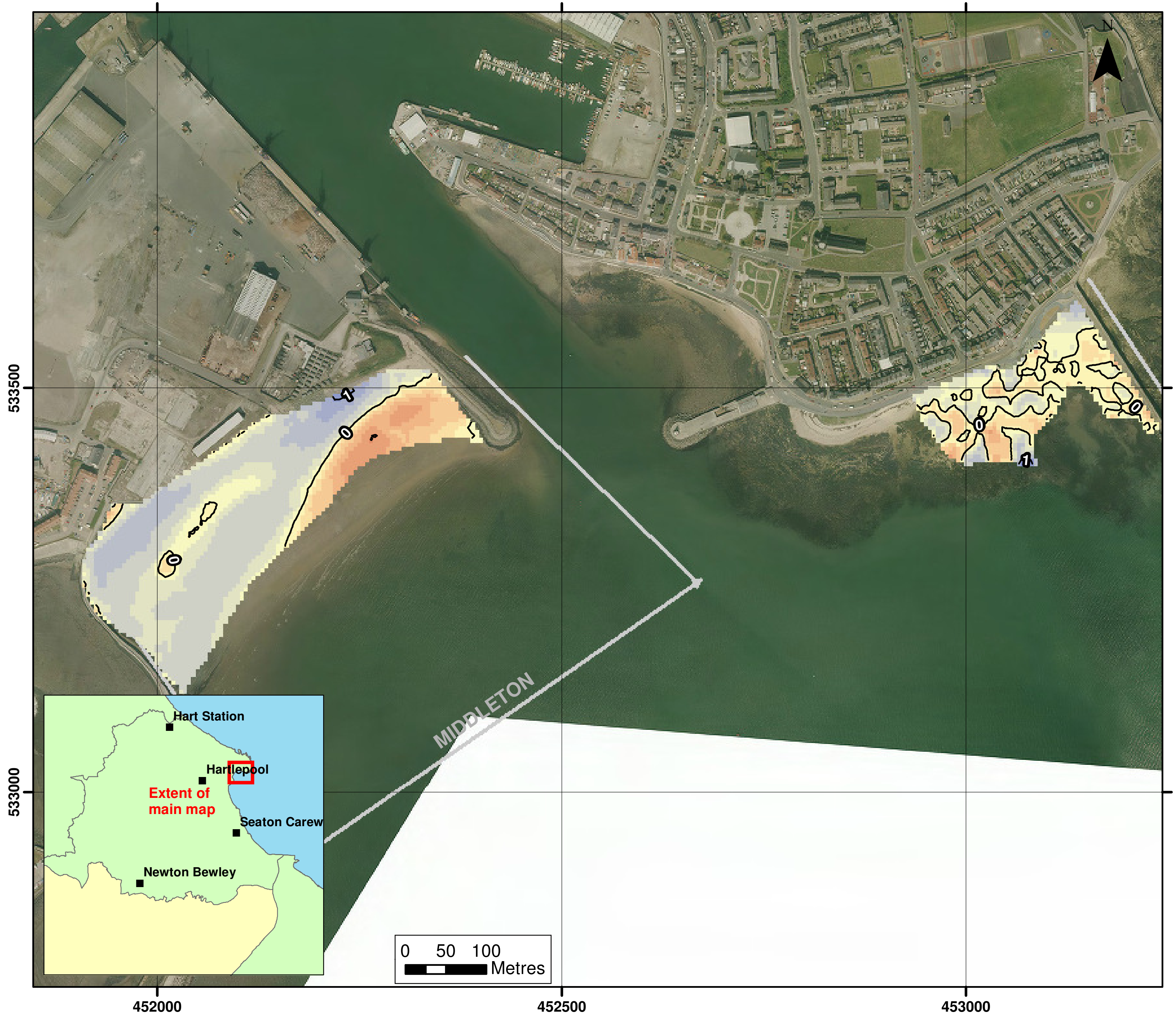

KEY Autumn 2013 and Autumn 2014
Change in elevation (m)

Change in elevation (m)	
<-2	Loss
-2 - -1.75	Loss
-1.75 - -1.5	Loss
-1.5- -1.25	Loss
-1.25 - -1	Loss
-1 - -0.75	Loss
-0.75 - -0.5	Loss
-0.5 - -0.25	Loss
-0.25 - -0.1	Loss
-0.1 - 0	Change < 0.1 m
0 - 0.1	Change < 0.1 m
0.1 - 0.25	Gain
0.25 - 0.5	Gain
0.5 - 0.75	Gain
0.75 - 1	Gain
1 - 1.25	Gain
1.25 - 1.5	Gain
1.5 - 1.75	Gain
1.75 - 2	Gain
>2	Gain

Contours of change

Client: North East Coastal Group
Project: Cell 1 Regional Coastal Monitoring Programme 2011 to 2016

Appendix B- Map 2b
Short-term Elevation Change
Middleton and Headland
Hartlepool Borough Council

Analytical Report 7
Full Measures Survey
Autumn 2014

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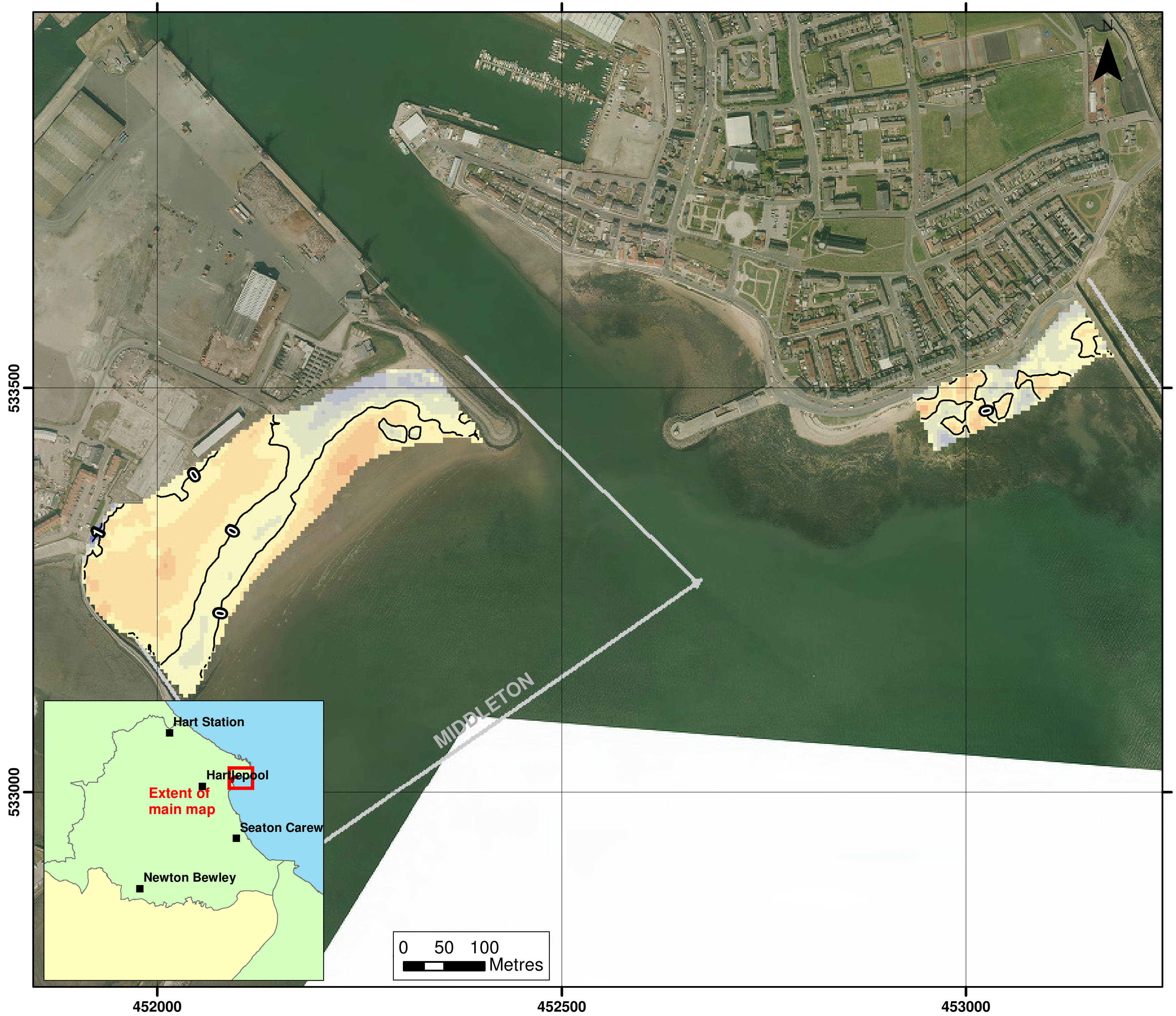

KEY Autumn 2008 and Autumn 2014
Change in elevation (m)

Change in elevation (m)	
<-2	Loss
-2 - -1.75	
-1.75 - -1.5	
-1.5- -1.25	
-1.25 - -1	
-1 - -0.75	
-0.75 - -0.5	
-0.5 - -0.25	
-0.25 - -0.1	
-0.1 - 0	Change < 0.1 m
0 - 0.1	
0.1 - 0.25	Gain
0.25 - 0.5	
0.5 - 0.75	
0.75 - 1	
1 - 1.25	
1.25 - 1.5	
1.5 - 1.75	
1.75 - 2	
>2	

Contours of change

Client: North East Coastal Group
Project: Cell 1 Regional Coastal Monitoring Programme 2011 to 2016

Appendix B - Map 2c
Long-term Elevation Change Headland and Middleton Hartlepool Borough Council

Analytical Report 7
Full Measures Survey
Autumn 2014

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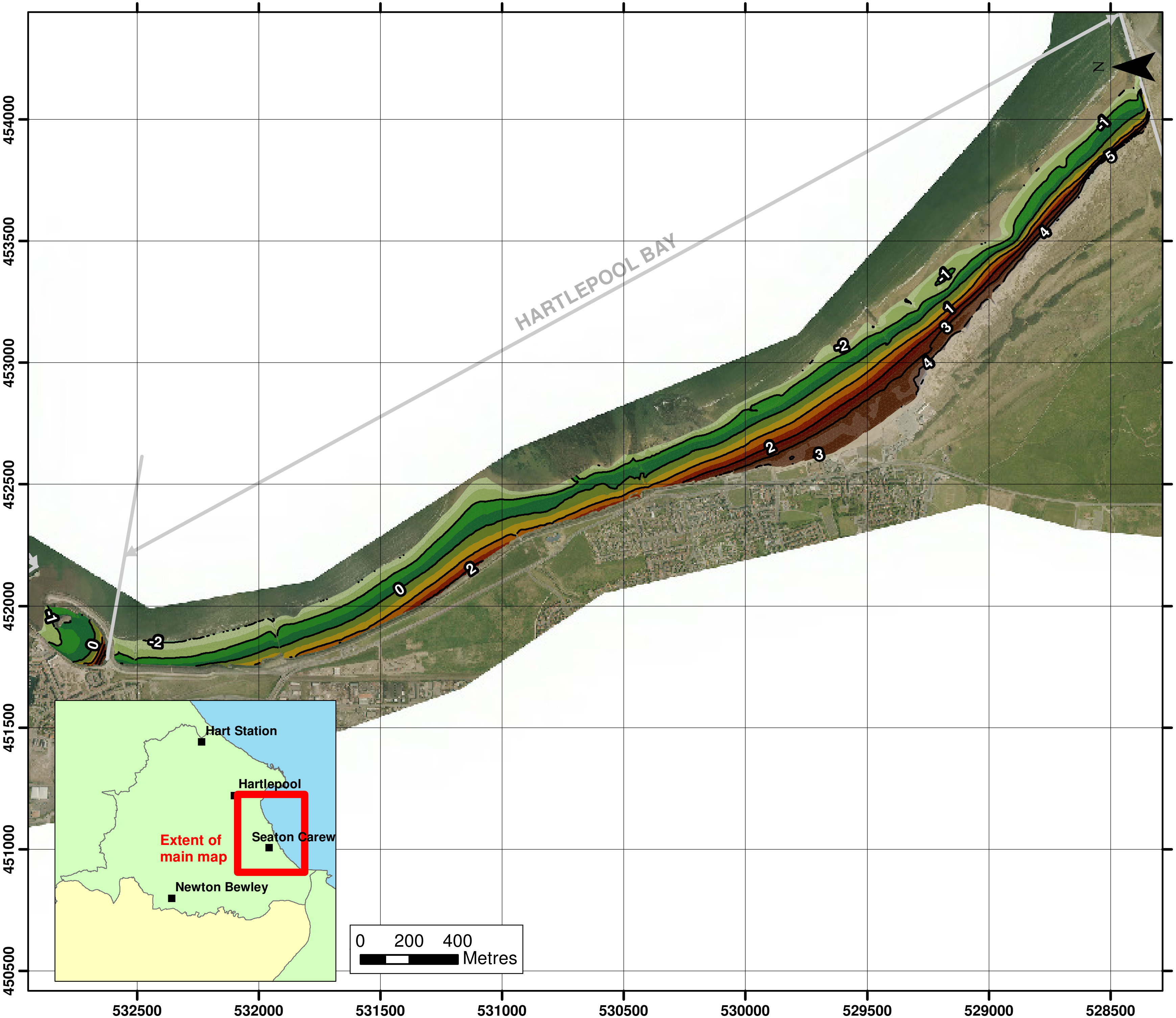

KEY

Elevation (m OD)

- 5.5 - 6
- 5 - 5.5
- 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
- -2.5 - -2
- -3 - -2.5
- Contour 1m

Client: North East Coastal Group

Project: Cell 1 Regional Coastal Monitoring Programme 2011 to 2016

Appendix B - Map 3a Topographic Survey Hartlepool Bay Hartlepool Borough Council

Analytical Report 7
Full Measures Survey
Autumn 2014

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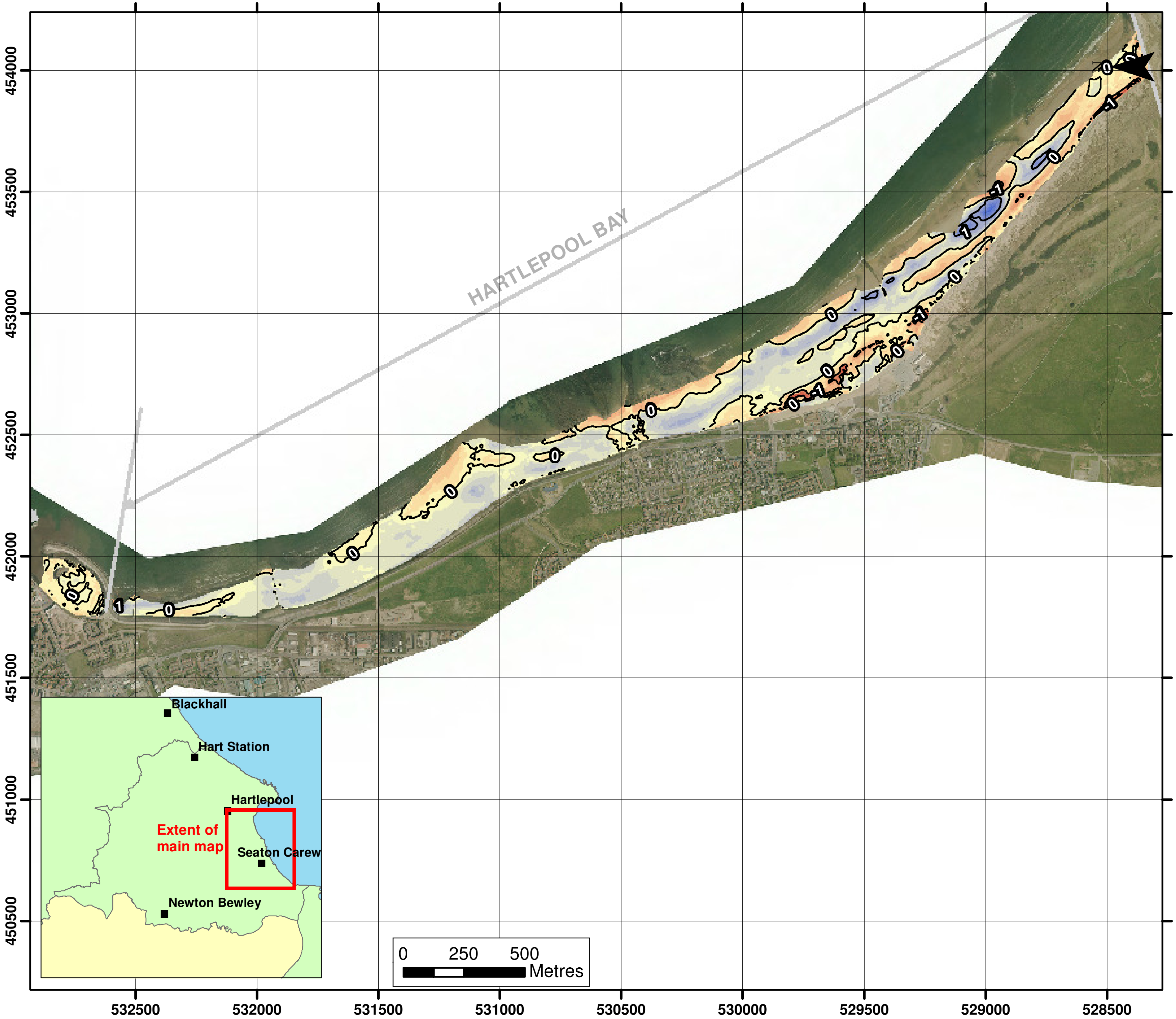

KEY Autumn 2013 and Autumn 2014
Change in elevation (m)

Change in elevation (m)	
<-2	Loss
-2 - -1.75	
-1.75 - -1.5	
-1.5- -1.25	
-1.25 - -1	
-1 - -0.75	
-0.75 - -0.5	
-0.5 - -0.25	
-0.25 - -0.1	
-0.1 - 0	Change < 0.1 m
0 - 0.1	
0.1 - 0.25	Gain
0.25 - 0.5	
0.5 - 0.75	
0.75 - 1	
1 - 1.25	
1.25 - 1.5	
1.5 - 1.75	
1.75 - 2	
>2	

Contours of change

Client: North East Coastal Group
Project: Cell 1 Regional Coastal Monitoring Programme 2011 to 2016

Appendix B- Map 3b Short-term Elevation Change Hartlepool Bay Hartlepool Borough Council

Analytical Report 7
Full Measures Survey
Autumn 2014

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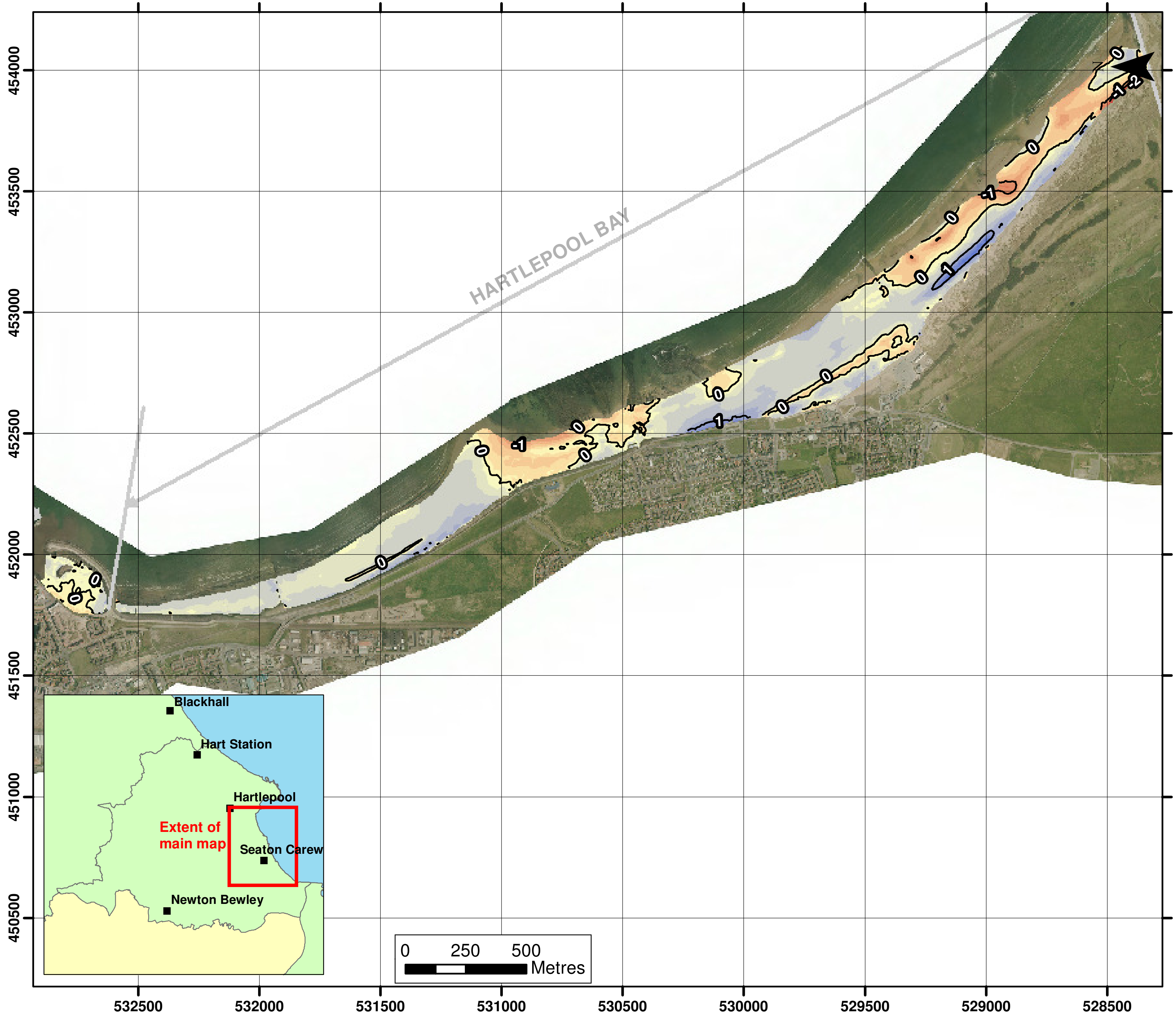

KEY **Autumn 2010 and Autumn 2014**
Change in elevation (m)

Change in elevation (m)	
<-2	Loss
-2 - -1.75	
-1.75 - -1.5	
-1.5- -1.25	
-1.25 - -1	
-1 - -0.75	
-0.75 - -0.5	
-0.5 - -0.25	
-0.25 - -0.1	
-0.1 - 0	Change < 0.1 m
0 - 0.1	
0.1 - 0.25	Gain
0.25 - 0.5	
0.5 - 0.75	
0.75 - 1	
1 - 1.25	
1.25 - 1.5	
1.5 - 1.75	
1.75 - 2	
>2	

Contours of change

Client: North East Coastal Group
Project: Cell 1 Regional Coastal Monitoring Programme 2011 to 2016

Appendix B- Map 3c
Long-term Elevation Change
Hartlepool Bay
Hartlepool Borough Council

Analytical Report 7
Full Measures Survey
Autumn 2014

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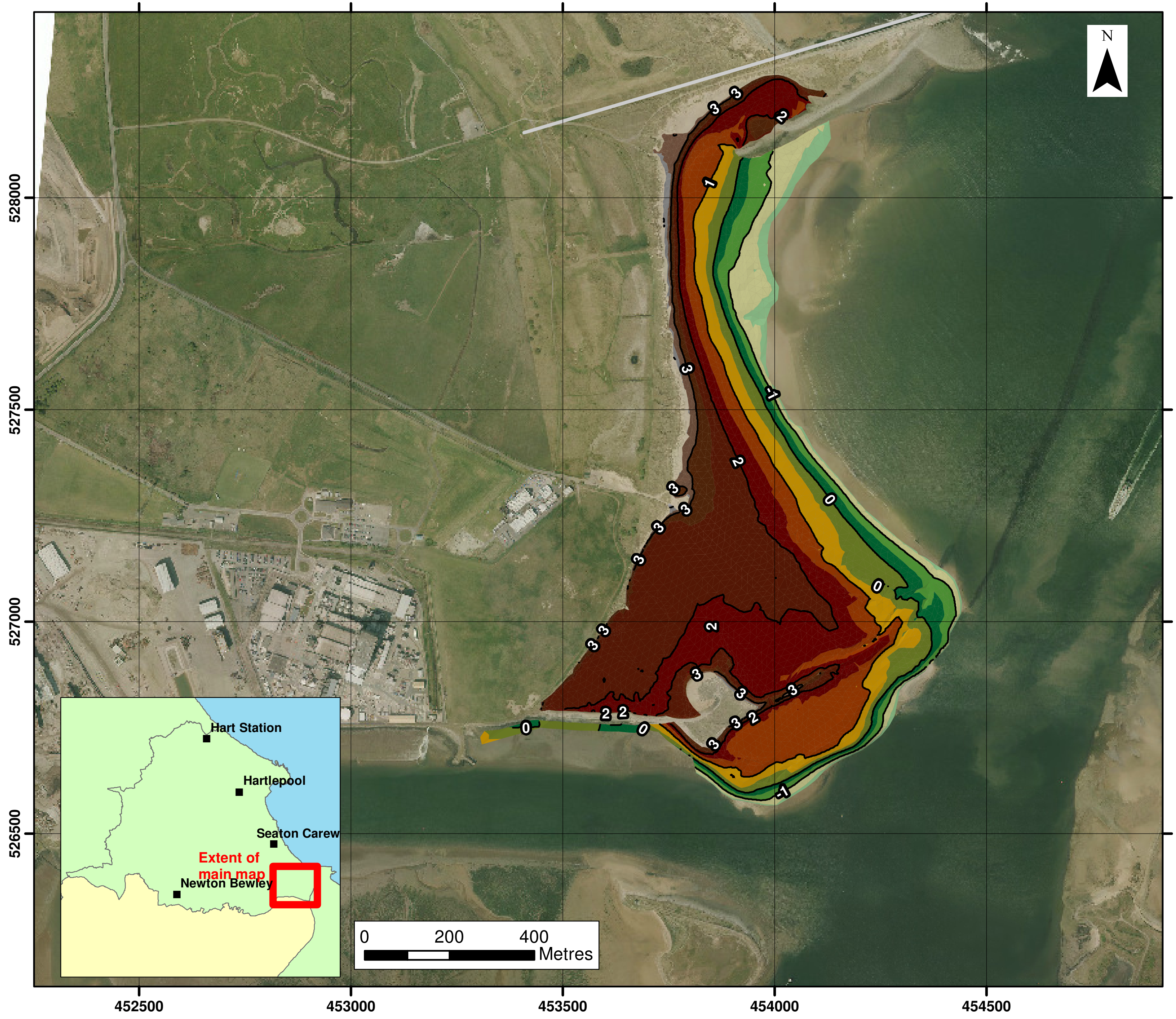

Client: North East Coastal Group

Project: Cell 1 Regional Coastal Monitoring Programme 2011 to 2016

Appendix B - Map 4a
Topographic Survey
Hartlepool North Gare
Hartlepool Borough Council

Analytical Report 7
Full Measures Survey
Autumn 2014

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KEY Autumn 2013 and Autumn 2014
Change in elevation (m)

- <-2
- -2 - -1.75
- -1.75 - -1.5
- -1.5- -1.25
- -1.25 - -1
- -1 - -0.75
- -0.75 - -0.5
- -0.5 - -0.25
- -0.25 - -0.1
- -0.1 - 0
- 0 - 0.1
- 0.1 - 0.25
- 0.25 - 0.5
- 0.5 - 0.75
- 0.75 - 1
- 1 - 1.25
- 1.25 - 1.5
- 1.5 - 1.75
- 1.75 - 2
- >2

Loss
Change < 0.1 m
Gain

Contours of change

Client: North East Coastal Group
Project: Cell 1 Regional Coastal Monitoring Programme 2011 to 2016

Appendix B - Map 4b Short-term Elevation Change Hartlepool North Gare Hartlepool Borough Council

Analytical Report 7
Full Measures Survey
Autumn 2014

CH2MHILL.
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Photography courtesy of North East Coastal Observatory
www.northeastcoastalobservatory.org.uk

KEY Autumn 2011 and Autumn 2014
Change in elevation (m)

- <-2
- -2 - -1.75
- -1.75 - -1.5
- -1.5- -1.25
- -1.25 - -1
- -1 - -0.75
- -0.75 - -0.5
- -0.5 - -0.25
- -0.25 - -0.1
- -0.1 - 0
- 0 - 0.1
- 0.1 - 0.25
- 0.25 - 0.5
- 0.5 - 0.75
- 0.75 - 1
- 1 - 1.25
- 1.25 - 1.5
- 1.5 - 1.75
- 1.75 - 2
- >2

Loss

Change < 0.1 m

Gain

Contours of change

Client: North East Coastal Group
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Appendix B - Map 4c
Long-term Elevation Change Hartlepool North Gare Hartlepool Borough Council

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