Cell 1 Regional Coastal Monitoring Programme
Analytical Report 8: 'Full Measures' Survey 2015

Redcar and Cleveland
Borough Council
Final Report

February 2016

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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 Parameter	Water Level (m AOD) Hartlepool Headland to Saltburn Scar	Skinningrove	Hummersea Scar to Sandsend Ness	Sandsend Ness to Saltwick Nab
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
Water Level Parameter	**Water Level (m AOD) Saltwick Nab to Hundale Point**	**Hundale Point to White Nab**	**White Nab to Filey Brigg**	**Filey Brigg to Flamborough Head**
HAT	3.10	3.05	3.05	3.10
MHWS	2.60	2.45	2.45	2.50
MLWS	-2.20	-2.35	-2.35	-2.30

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.

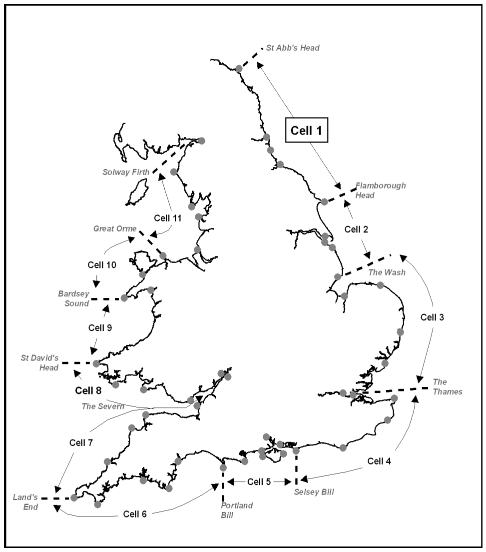


Figure 1 Sediment Cells in England and Wales

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
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
Whitby Scarborough Filey 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 CH2M.

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	Jul 10	-
3	2010/11	Aug-Nov 10	Feb 11	Feb-Apr 11	Aug 11	Sep 11
4	2011/12	Sep-Oct 11	Oct 12	Mar-May 12	Feb 13	
5	2012/13	Sep 12	Mar 13	Feb- Mar 13	May 13	
6	2013/14	Oct-Nov 13	Feb 14	Mar-Apr 14	Jul 14	
7	2014/15	Sep-Oct 14	Feb 15	Mar-Apr	July 15	
8	2015/16	Sep-Oct 15	Feb 16 (*)			

* The present report is **Analytical Report 8** and provides an analysis of the 2015 Full Measures survey for Redcar and Cleveland 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 sections listed in 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

Redcar & Cleveland Borough Council's frontage extends from the South Gare breakwater at the mouth of the River Tees to Cowbar Nab, Staithes. For the purposes of this report, report and for consistency with previous reporting, it has been sub-divided into six areas, namely:

- Coatham Sands
- Redcar Sands
- Marske Sands
- Saltburn Sands
- Cattersty Sands (Skinningrove)
- Staithes

The Staithes frontage straddles the boundary of jurisdiction of Redcar & Cleveland Council and Scarborough Borough Council and therefore reporting has been duplicated in both reports.

1.2 Methodology

Along Redcar & Cleveland Borough Council's frontage, the following surveying is undertaken:

- Full Measures survey annually (since 2008) each autumn/early winter comprising:
    - Beach profile surveys along nine transect lines
    - Topographic survey along Coatham Sands
    - Topographic survey along Redcar Sands
    - Topographic survey along Marske Sands
    - Topographic survey along Saltburn Sands
    - Topographic survey along Cattersty Sands
- Partial Measures survey annually each spring (since 2009) comprising:
    - Beach profile surveys along nine transect lines
    - Topographic survey along Redcar Sands
    - Topographic survey along Saltburn Sands
    - Topographic survey along Cattersty Sands
- Cliff top survey annually at:
    - Staithes

The Full Measures survey was undertaken along this frontage in September, October and November 2015. The weather and sea state varied considerably, for further details please refer to the Survey Report from Academy Geomatics.

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:

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

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 wave buoy located at Tyne and Tees deployed under the national monitoring programme and three Cell 1 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 are managed by Scarborough BC as part of the Cell 1 monitoring programme.

An assessment of baseline wave data was presented in the Cell 1 2011 Wave Data Analysis Report, which reviewed all readily available wave data in the region. Wave data update reports for 2013-14 and 2014-15 provide an update to the baseline with analysis of the wave data collected under the programme between 2011 and March 2015. These wave data reports are also available from the reports page on the Cell 1 monitoring website:
http://www.northeastcoastalobservatory.org.uk/Default.aspx?view=pnlTexts&text=Reports

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 which includes storm analysis for data collected up to the end of November 2015, extending the wave analysis to cover the period prior to the Full Measure surveys.

An overview plot of wave height data from the three Cell 1 wave buoys is shown in Figure 2. Note that there were significant gaps in the data at both Scarborough and Whitby, but the record is nearly continuous from Newbiggin. There were a large number of small storms over the wither 2014-15 with the largest wave heights occurring in mid-October 2014 and beginning of February 2015. A storm with significant wave heights over 4m occurred in early September, before the 2015 Full Measures survey data were collected.

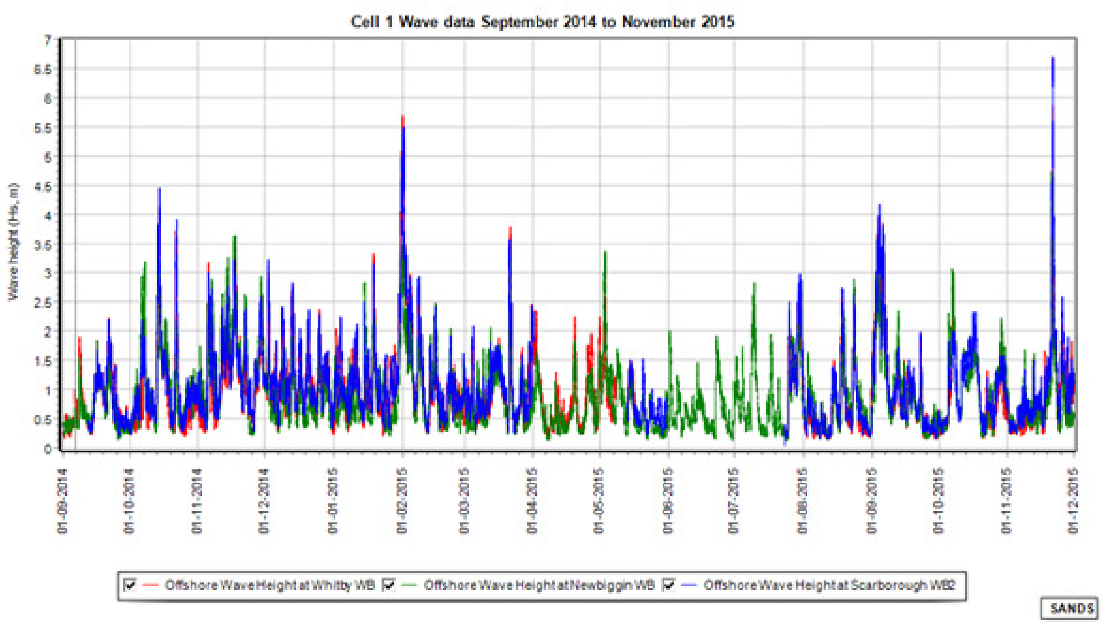


Figure 3 Wave monitoring data from the Three Cell 1 wave buoys

2.2 Tyne/Tees WaveNet Buoy storms analysis

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 and results of a SANDS Storms analysis is 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 2007 and 2008.

Table 4: SANDS Storm Analysis at Tyne/Tees WaveNet Buoy (updated to include data to Dec 2015)

General Storm Information							At Peak					
Start Time	**End Time**	**Dur (hr)**	**Peak of Storm**	**Mean Dir (°)**	**No Events**	**Mean Dir 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	14.8	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	10.3	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	13.8	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**	15.9	**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	12.7	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	12.8	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	10.9	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	16.4	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	9.6	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**	14.8	**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	13.9	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	11.8	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	13.6	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	15.6	8.5	11	1.7E+04	2.2E+07
10/12/2008 12:00	13/12/2008 18:00	78	13/12/2008 08:00	109	37	332.1	4.9	10.0	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	11.4	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	10.0	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	11.9	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**	11.2	**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	12.7	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	9.0	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	12.7	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	10.2	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	10.1	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	12.7	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	10.3	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	10.5	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	13.1	8.0	11	7.5E+03	2.9E+06

General Storm Information							At Peak					
Start Time	**End Time**	**Dur (hr)**	**Peak of Storm**	**Mean Dir (°)**	**No Eve nts**	**Mean Dir Vector (°)**	**Hs (m)**	**Tp (s)**	**Tz (s)**	**Dir (°)**	**Energy @ Peak (KJ/m/s)**	**Total Energy (KJ/m)**
24/09/2010 03:00	26/09/2010	45	24/09/2010 10:00	21	80	71.6	5.3	12.1	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	13.4	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**	10.5	**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	9.2	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	11.2	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	12.5	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**	12.8	**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	11.3	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	14.2	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	12.5	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	9.7	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	12.3	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	15.3	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	10.5	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**	11.3	**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	11.2	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	11.9	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	10.7	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	12.1	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**	12.5	**8.5**	**17**	**1.4E+04**	**7.1E+06**
10/09/2013 13:00	10/09/2013 19:30	6.5	10/09/2013 14:00	11	14	79.3	4.4	11.0	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	12.7	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	12.7	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	17.0	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	7.3	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	9.3	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**	8.9	**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	11.5	7.6	6	**5.0E+03**	6.0E+05
31/01/2015 08:30	01/02/2015 19:30	35.0	31/01/15 23:30	78	71	88.7	6.2	13.1	8.0	6	1.3 E+4	1.4 E+7
03/09/2015 05:30:00	04/09/2015 06:00:00	24.5	03/09/2015 18:30:00	13	15	78.1	4.4	10.5	6.8	11	4.2 E+3	1.6 E+6
21/11/2015 01:30:00	**21/11/2015 14:30:00**	**13.0**	**21/11/2015 05:30:00**	**72**	**27**	**85.9**	**7.1**	**11.8**	**8.5**	**356**	**1.4 E+4**	**5.7 E+6**

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.

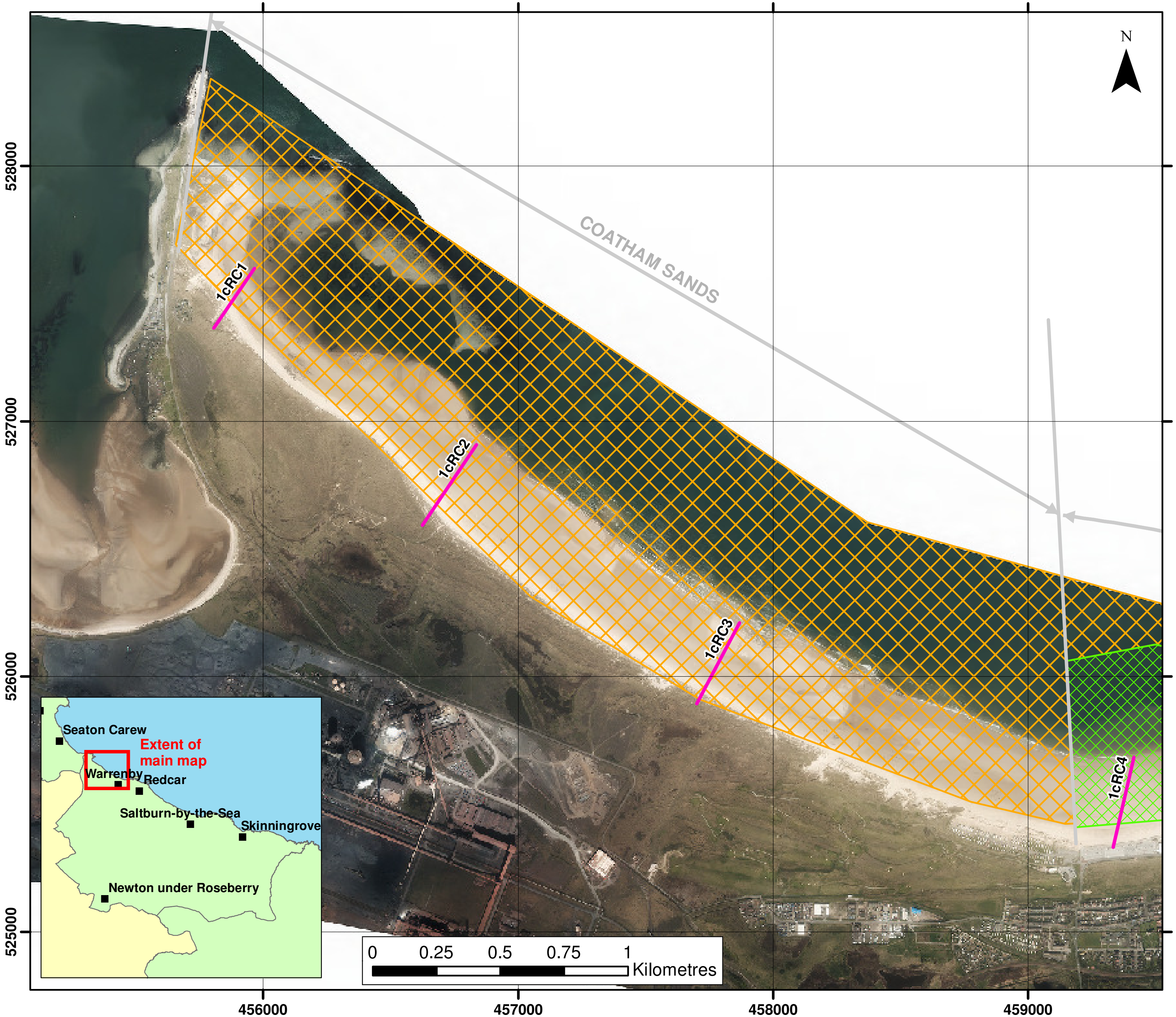
The years with the fewest storms was 2011, 2014 and 2015. In 2011 and 2014 this was reflected by a combination of accretion and overall stability recorded within the annual Full Measures reports.

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 and 6th 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 storm was also accompanied by a significant storm surge with recorded water levels around 1.75m higher that predicted tides in some locations. The combined high water levels and large waves causing significant damage to many coastal defences and beaches in the north east.

The 2014 storms did appear to have an influence on beach behaviour, as shown by the profile analysis included within the 2014 Full Measures reports, with the movement of material across and along the beach. Dune toe erosion was more dominant than in previous years and could be explained by particularly high tides rather than storm erosion alone.

During 2015 there were only three storms with peak wave heights above the threshold, but all had large wave heights and much greater wave energy than the 2014 storms. The winter storms were just before the Cattersty survey but the rest of the areas were surveyed later, in October. May of the profiles and topographic plots show stability in spite of the autumn storms.



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
Coatham Sands
Redcar & Cleveland Borough Council

Analytical Report 8
Full Measures Survey
Autumn 2015

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Photography courtesy of North East Coastal Observatory
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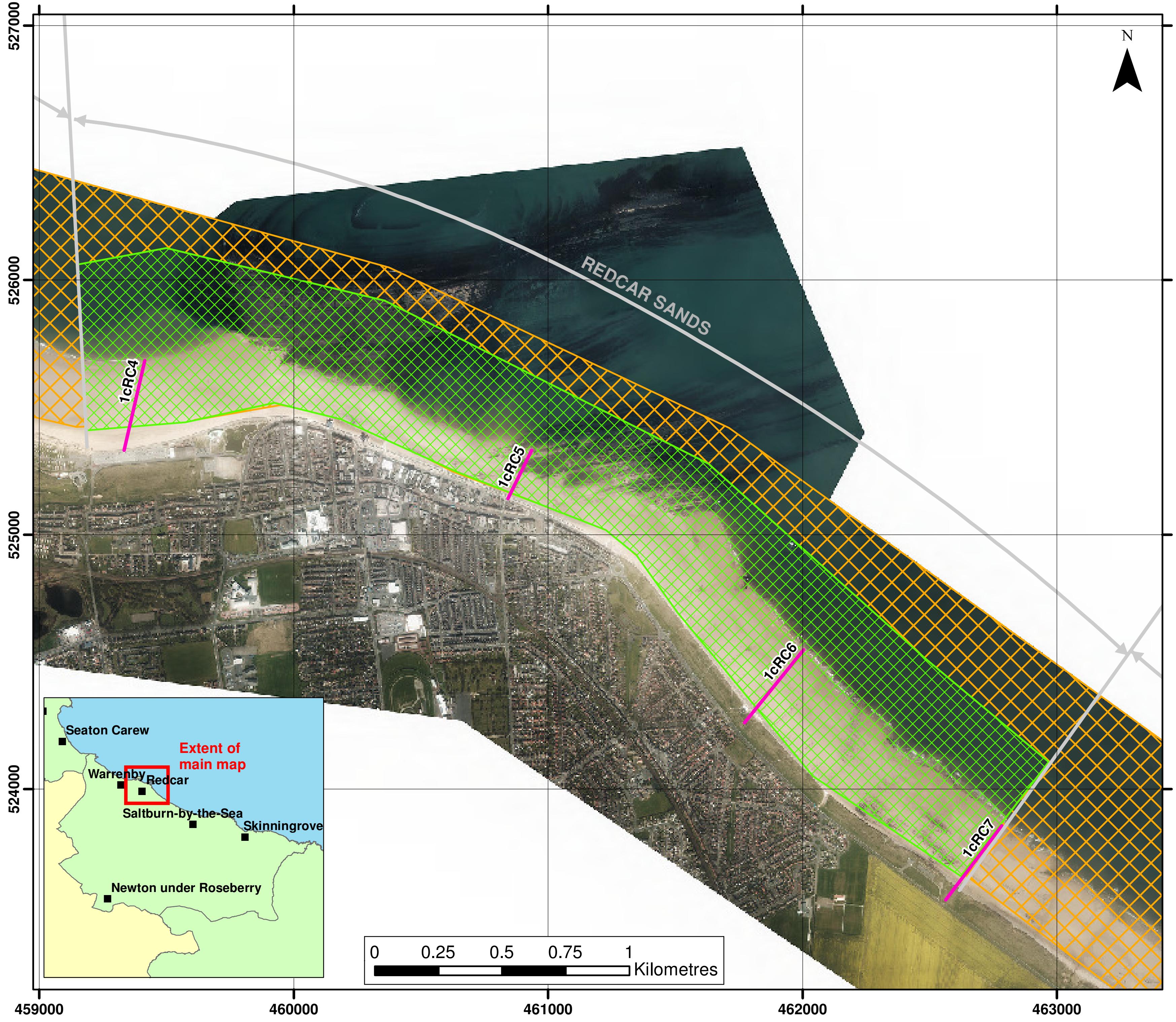

KEY

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 2
Survey Locations
Redcar Sands
Redcar & Cleveland
Borough Council

Analytical Report 8
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Autumn 2015

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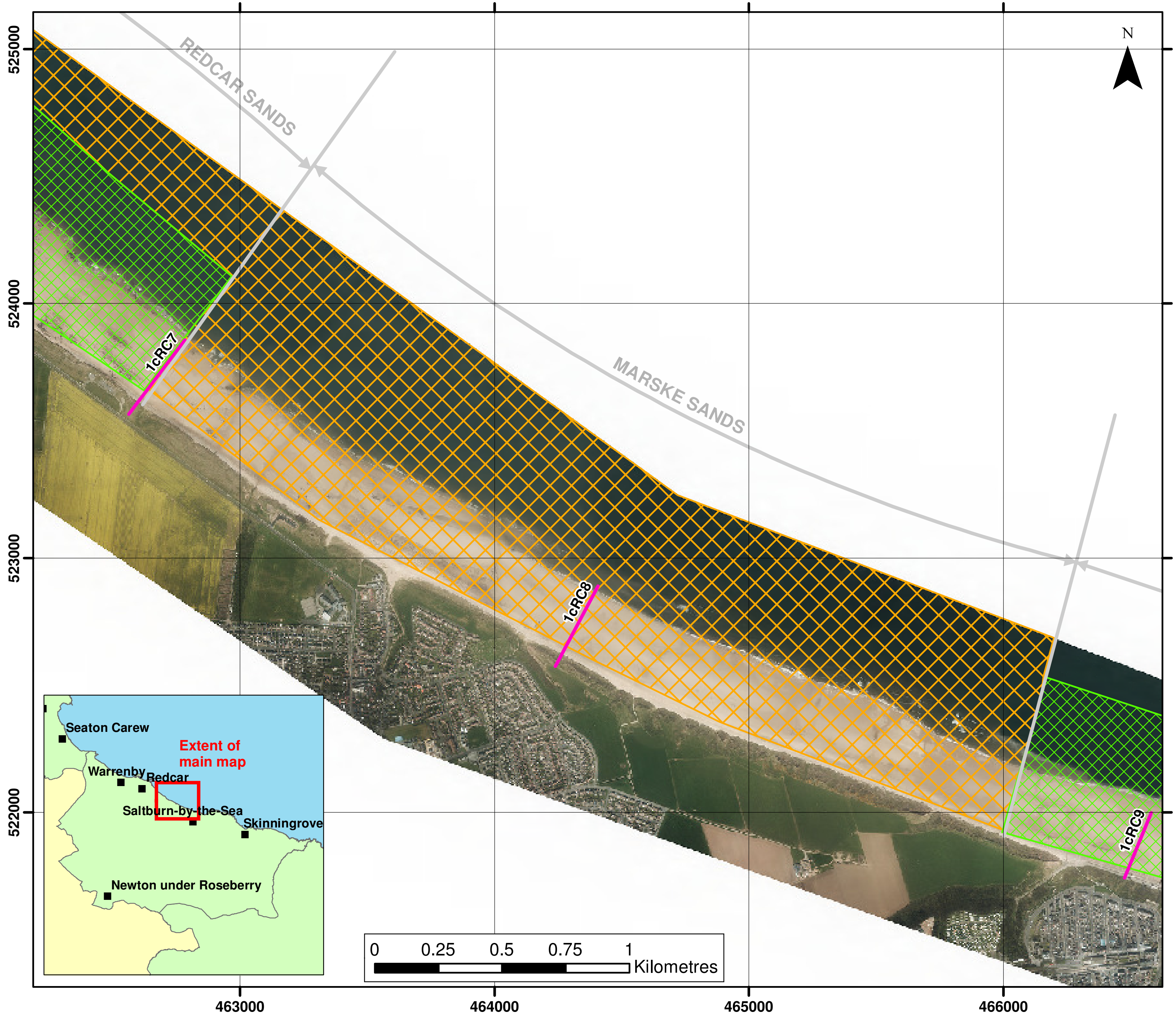

KEY

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
Marske Sands
Redcar & Cleveland Borough Council

Analytical Report 8
Full Measures Survey
Autumn 2015

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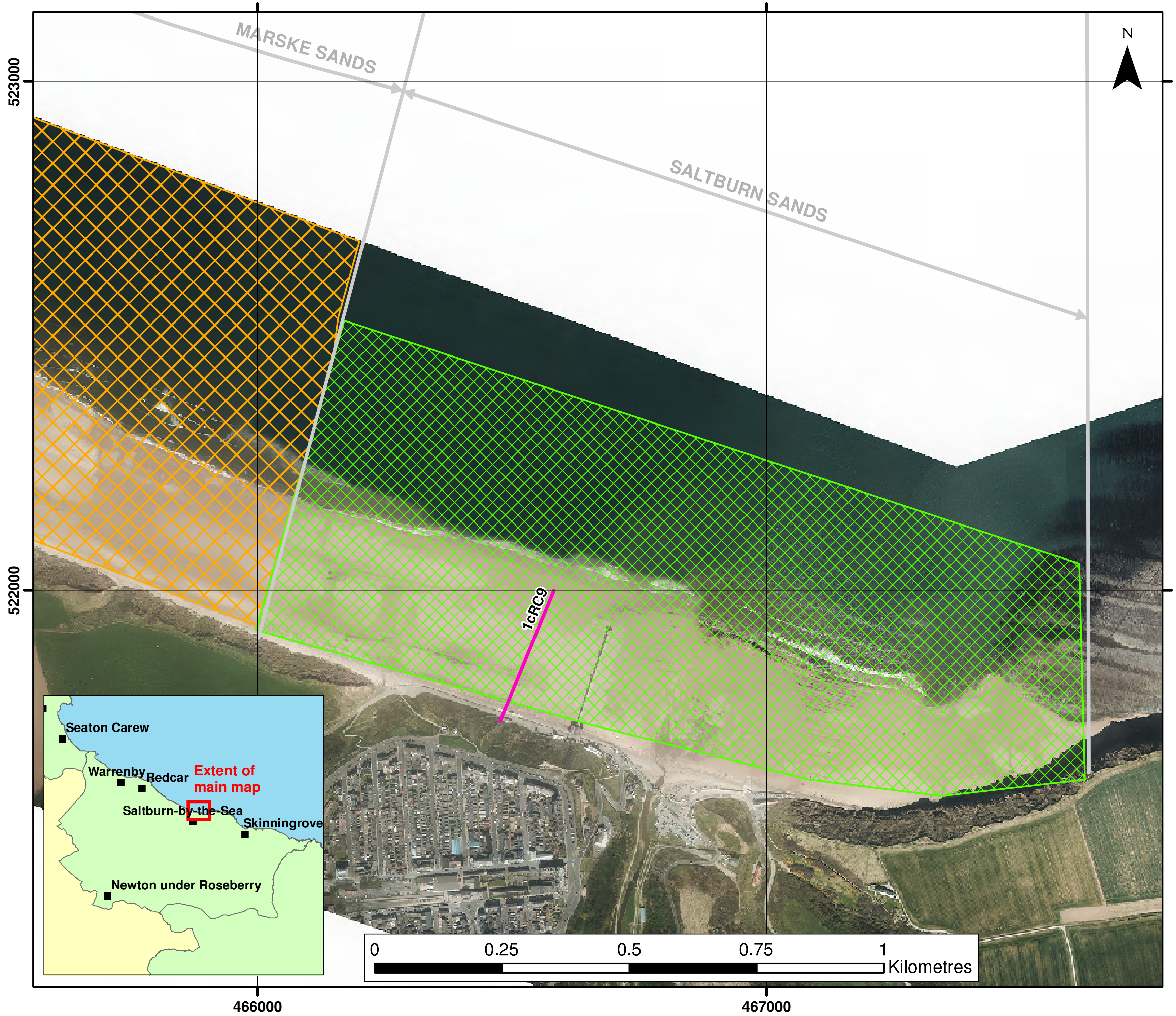

KEY

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
Saltburn Sands
Redcar & Cleveland
Borough Council

Analytical Report 8
Full Measures Survey
Autumn 2015

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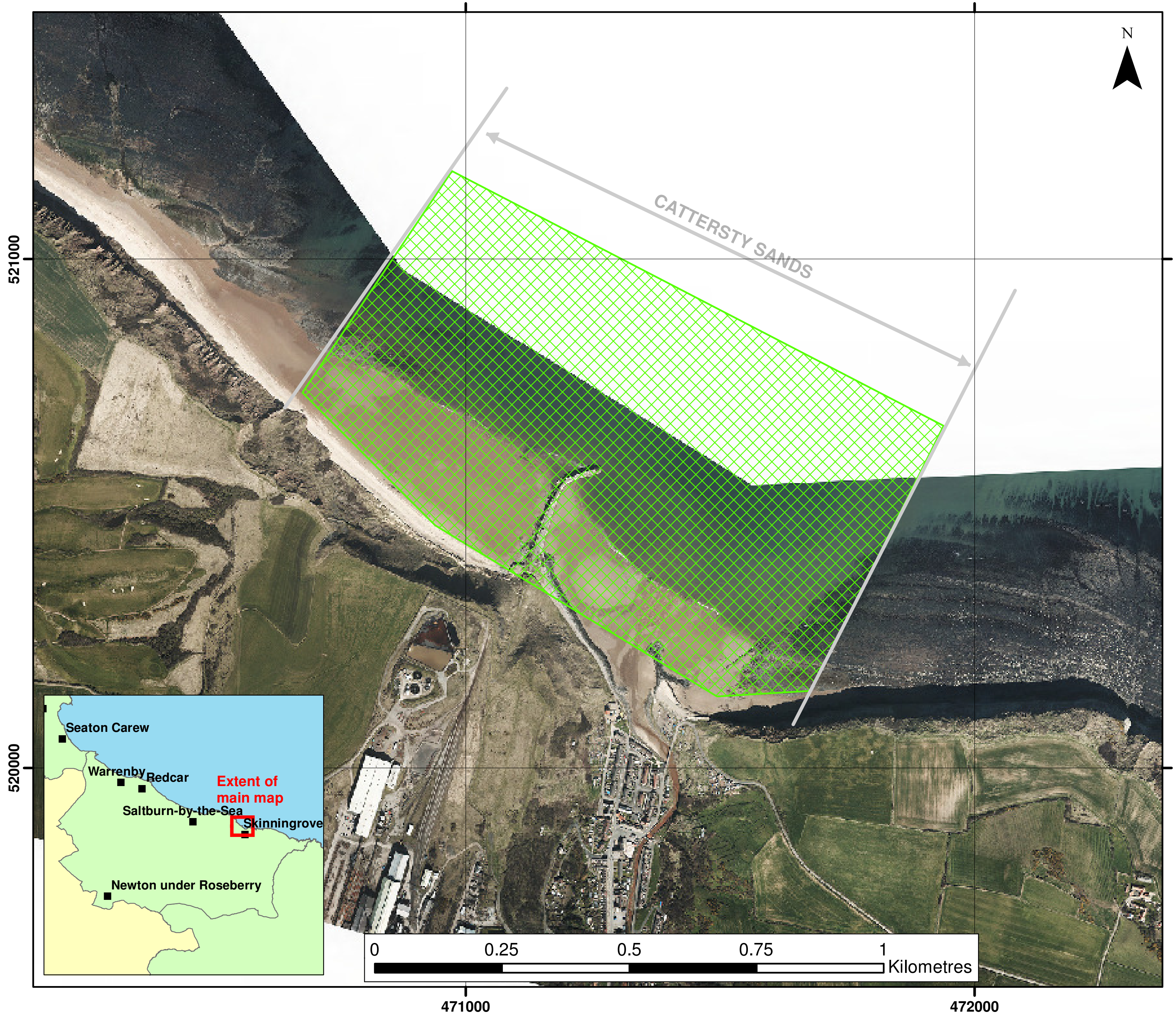

KEY

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 5
Survey Locations
Cattersty Sands
Redcar & Cleveland
Borough Council

Analytical Report 8
Full Measures Survey
Autumn 2015

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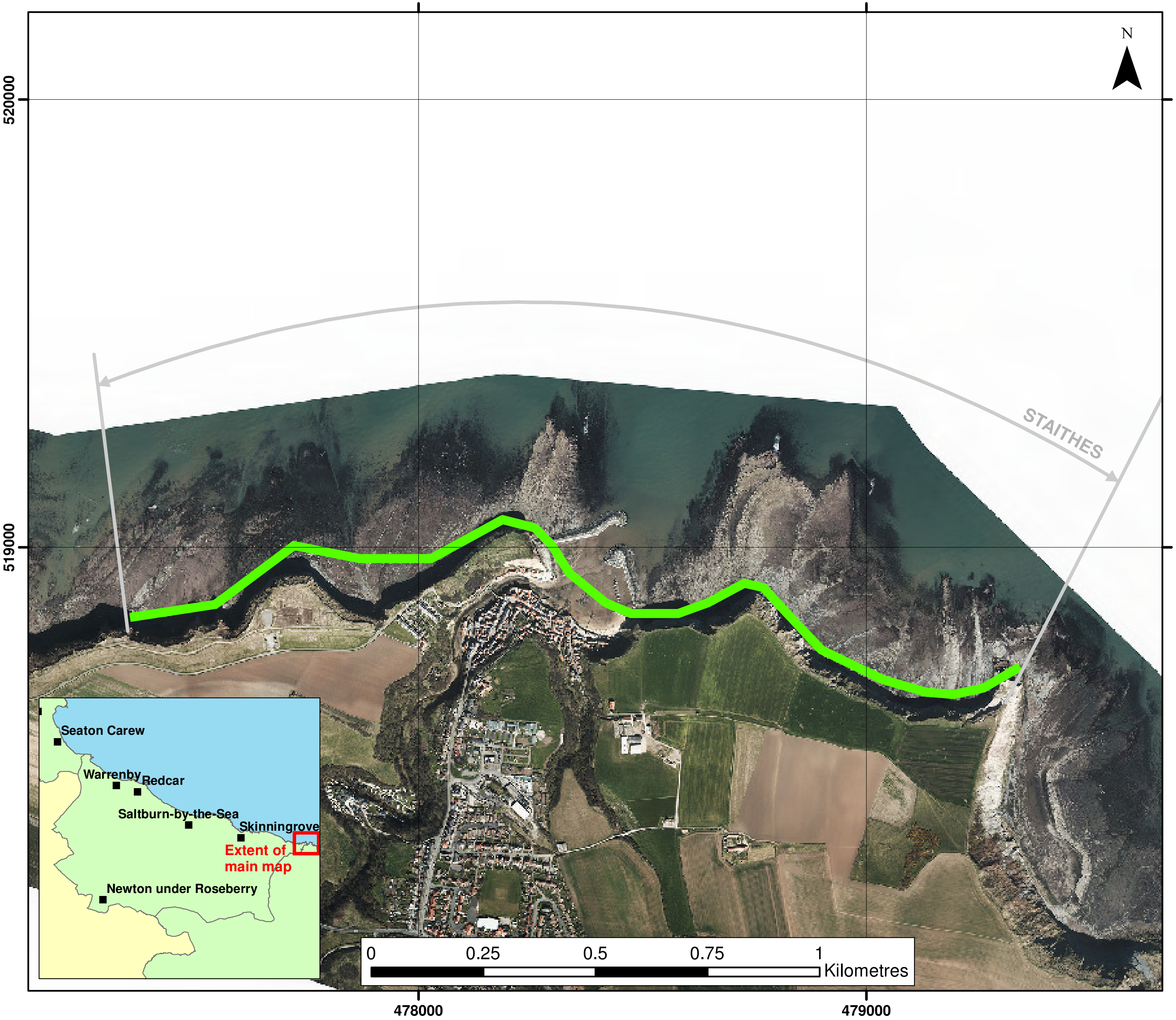

KEY

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 6
Survey Locations
Staithes
Redcar & Cleveland
Borough Council

Analytical Report 8
Full Measures Survey
Autumn 2015

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Photography courtesy of North East Coastal Observatory
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3. Analysis of Survey Data

3.1 Coatham Sands

Survey Date	Description of Changes Since Last Survey	Interpretation
30th Oct 2015	**Beach Profiles:** Coatham Sands is covered by four beach profile lines during the Full Measures survey (RC1 to RC4; Appendix A). Profile **1cRC1** is located approximately 300m south of the South Gare breakwater, in the lee of the German Charlies slag banks. The upper profile is dominated by dune ridges, which have remained stable since the 2009 surveys. No change has occurred in the profile as far as 80m chainage, which is equivalent to HAT. For much of the profile the beach level has increased by 0.2-0.4 over the summer of 2015. Overall the beach level was high compared to previous profiles. At Profile **1cRC2** the beach and dunes continue to be high compared to the profiles recorded since 2008. The dune profile has changed little since October 2014 and April 2014. Over the summer of 2015 the foredune at 80m chainage has continued to accrete. Between 80m and 140m the beach accreted by 0.2m. The rest of the profile has seen limited change with a berm accreting between 240m and 280m chainage. From 280m to 340m chainage the beach has eroded with 0.2m having been lost. Profile **1cRC3** shows a reasonably stable dune area as far as 50m chainage. The upper and mid beach has seen very little change since October 2014. From 160m to 190m chainage the beach has eroded by 0.2m. Between 190m and 250m the beach has accreted by 0.4m as a berm has moved seawards. Overall the beach level is low compared with the previous surveys. Profile **1cRC4** is the beginning of the defended section at Redcar. There has been very little (less than ±0.1m) change since April 2014, with the largest difference being the removal of an upper beach berm between 20m and 40m chainage. **Topographic Survey:** Coatham Sands is covered by an annual topographic survey extending from the South Gare Breakwater, although the survey is contiguous with the 6-monthly Redcar Sands survey. Data have been used to create a DGM (Appendix B – Map 1a) using GIS. This shows that the beach contours	Profile 1cRC1 and 1RC2 have experienced accretion with the Autumn 2015 profiles being among the highest Profile 1cRC3 and 1RC4 have shown little change over the summer of 2015. The difference plots show a patchy distribution of variable change. The southern extent of the survey is dominated by erosion of less than 1m, while part of the centre of the frontage have more than 1m accretion. **Longer term trends**: The magnitude of change in 2015 is more modest than that seen in the past. The upper beach in the southern part of the frontage has shown consistent erosion. **Autumn 2008 to Autumn 2015 trends** The long term plots shows that in the north of the bay the foreshore has accreted by up to 2m, the difference plot shows that change in a cuspate form, matching the shape of the small bay. The centre of the bay has a uniform pattern of accretion by 0.5m. The southern third of the bay has a uniform pattern of erosion of around 0.5m. This pattern suggests a net movement of sediment in the bay towards the north.

Survey Date	Description of Changes Since Last Survey	Interpretation
	recorded in Autumn 2015 were relatively shore parallel along the frontage, with a gently shelving beach slope. The beach is narrower and steeper to the north west of the subtle promontory around 1km SE of the breakwater and of shallower gradient further south-east. The GIS has also been used to calculate the differences between the current topographic (Autumn 2015) survey and the earlier topographic survey (Autumn 2014), as shown in Appendix B – Map 1b, to identify areas of erosion and accretion. The topographic difference plot shows an almost equal distribution of accretion and erosion. In the west beach has successive bands of accretion and erosion which run down the beach perpendicular to the shore, the distribution of change becomes patchier as you move east. The magnitude of accretion and erosion is more pronounced near the South Gare Breakwater, where change is up to ±1m. **Long Term Topographic Trends Autumn 2008 to Autumn 2015:** The long term difference plot (Appendix B – Map 1c) shows two main areas of change, the western half of the plot has experienced accretion, the largest change was near the South Gare Breakwater where up to 2m has accreted. There has also been limited erosion of 0.5m at the top of the beach in this section. The eastern half of the bay has eroded by up to 0.75m on the mid-beach and 1m at the top of the beach. There are areas of little or no change in the middle of the beach and at the eastern extent of the survey near the high water line.	

3.2 Redcar Sands

<table>
<tr><th>Survey Date</th><th>Description of Changes Since Last Survey</th><th>Interpretation</th></tr>
<tr><td rowspan="2">30th Oct 2015</td><td>Beach Profiles:

Redcar Sands is covered by three beach profile lines during the Full Measures survey (RC5 to RC7; Appendix A), with RC7 being approximately on the boundary with the Marske Sands area.

At profile 1cRC5 the beach has accreted by up to 0.4m between the base of the sea defences and 120m chainage since April 2015. For the rest of the survey the rocks on the lower beach are exposed, as they were in October 2014 and April 2015.

At profile 1cRC6 there has been very little change since both the October 2014 and April 2015 surveys. The main change has been accretion of around 0.2m in the upper and mid beach. As a result the October 2015 profile is the highest recorded beach level.

Profile 1cRC7 has experienced very little change on the dune frontage and the upper beach since April 2015. Between 60m and 210m chainage there has been little change of less than ±0.2m. On the lower beach between 210m and 340m two beach berms have formed with a gain of 0.2m of material.</td><td rowspan="2">All three of the profiles show beach levels in autumn 2015 which are a little higher than those previously recorded.

The topographic change plot reflects this pattern with moderate accretion on the eastern third of the difference plots. The accretion observed over the summer of 2015 is still visible on the beach profiles, but more accretion has occurred on the north east facing section, which is likely to be due to the wave environment.

Longer term trends: The beach levels are high compared to previous years, suggesting recovery since the storms and surge of winter 2013/14.

Autumn 2008 to Autumn 2015 trends

Long term net change between Autumn 2008 and Autumn 2015 shows predominantly accretion of up to 1m, with erosion of around 0.5m associated with the thin sediment cover over the rocky foreshore of Redcar Rocks and West Scar and at the lower beach at the western part of the frontage.

The most substantial accretion of 1m south-east of the new defences may relate to the defence improvements introducing a less reflective seawall and improvements and repairs to the groynes in this area, which limit north-westwards drift.</td></tr>
<tr><td>Topographic Survey:

Redcar Sands is covered by a six-monthly topographic survey. Data have been used to create a DGM (Appendix B – Map 2a) using GIS. The plot shows shore-parallel contours for most of the frontage with the exception of the beach in front of Redcar, where there is a bay between the Redcar Rocks and West Scar. The most landward part of this embayment is close to Redcar Esplanade, where the beach is steeper than on any of the surrounding coast. The coastal defence scheme here was constructed between the October 2012 and March 2013 surveys.

The GIS has also been used to calculate the differences between the current topographic survey (Spring 2014) and the most recent (Autumn 2015) topographic survey, as shown in Appendix B – Map 2b, to identify areas of erosion and accretion. Over the summer of 2015 erosion of up to 0.75m occurred just landward of Coatham Rocks. There are shore parallel lines of accretion and erosion to the east and west of Redcar but the changes are limited to less than ±0.5m.</td></tr>
</table>

Survey Date	Description of Changes Since Last Survey	Interpretation
	Long Term Topographic Trends Autumn 2008 to Autumn 2015: The plot of changes between Autumn 2008 and Autumn 2015 (Appendix B Map 2c) shows three distinct zones of change. In the west, the NNW-facing section of beach has experienced erosion of up to 0.75m on the lower beach and little change or 0.25m accretion on the upper beach The central section, which faces NNE, is characterised by a thin beach covering a rocky foreshore that shows accretion in the middle of the small bay and erosion over the rock outcrops. The eastern section that faces NE is dominated by accretion of up to 1m, with a thin but continuous strip of erosion at the back of the beach and toe of cliffs.	

3.3 Marske Sands

Survey Date	Description of Changes Since Last Survey	Interpretation
7th – 10th Oct 2014	**Beach Profiles:** Marske Sands is covered by two beach profile lines during the Full Measures survey (RC7 to RC8; Appendix A), with RC7 being approximately on the boundary with the Redcar Sands area. Profile **1cRC7** is located along The Stray and has been discussed in Section 3.2. Profile **1cRC8** experienced significant erosion at the cliff toe between October 2013 and April 2014, but there has been very little further change above HAT since April 2014. The October 2015 profile is very similar to the April 2015 profile, although between 110m and 290m three berms have formed in the mid to lower beach. The beach has become shallower since October 2014, with the upper beach dropping by 0.2m and the lower beach level increasing by up to 0.5m. **Topographic Survey:** Marske Sands is covered by an annual topographic survey. This survey is contiguous with the Redcar Sands and Saltburn Sands topographic surveys that are both surveyed six-monthly. Data have been used to create a DGM (Appendix B – Map 3a) using GIS. The GIS has also been used to calculate the differences between the Autumn 2014 and Autumn 2015 topographic survey, as shown in Appendix B – Map 3b. The topographic contours are generally shore parallel except where the outfalls of small, culverted streams issue in front of the Marske itself. Since the previous topographic survey in Autumn 2015, erosion and accretion of up to c.1m has taken place in discontinuous elongate strips along the frontage with change of up to 1m, which is similar to the previous year. **Long Term Topographic Trends Autumn 2008 to Autumn 2015:** The changes observed over the seven years shown in Appendix B – Map 3c shows a similar pattern to that seen over the past 12 months. The west part of the frontage has seem accretion of up to 1m. There has been erosion in the east and along the top of the beach of up to 0.25. Throughout the whole plot, but more particularly in the middle of the beach, there is a patchy distribution of change of ±0.5.	The impact of the December 2013 storm surge is still evident at the cliff toe in the profiles above HAT because the dune face is steep with no sand accreting at the toe. However, the general pattern is of stability. The difference plot for Autumn 2014 to Autumn 2015 shows erosion on the upper beach and primarily deposition in the mid-lower beach, although there is evidence for migration of sand bars on the mid beach. **Longer term trends:** Current beach profiles are among the highest in the mid to lower beach and shallowest recorded. The change is due to the movement of bars on the beach, which is also shown on the topographic difference plots. **Autumn 2008 to Autumn 2015 trends:** The long term difference plot is dominated by up to 1m accretion in the west and up to 0.75m erosion in the east with patchy change in the centre of the beach. This suggests westward movement of sediment in this part of the larger beach system. There was widespread erosion along the back of the beach, which is likely to be due to severe storms of 2013.

3.4 Saltburn Sands

Survey Date	Description of Changes Since Last Survey	Interpretation
30th Oct 2015	**Beach Profiles:** Saltburn Sands is covered by one beach profile during the Full Measures survey (RC9; Appendix A). Profile **1cRC9** was stable where there are sea defences between 0m and 30m chainage over the summer of 2015. The rest of the profile was stable overall but a number of berms have formed in the mid and lower beach. The beach level is among one of the lowest, which shows that there has been progressive erosion since the first profile in November 2008. **Topographic Survey:** Saltburn Sands is covered by a six-monthly topographic survey, although the survey is contiguous with the Marske Sands topographic survey that is surveyed annually. Data have been used to create a DGM (Appendix B – Map 4a) using a GIS software package. This shows that the beach contours are shore parallel and gently shelving for the majority of the frontage. The contours are slightly indented opposite Skelton Beck, where the stream has eroded the foreshore. The GIS has also been used to calculate the differences over the six month period between Spring 2015 and Autumn 2015 topographic survey, as shown in Appendix B – Map 4b, to identify areas of net erosion and accretion. During the summer of 2015 there was modest accretion of around 0.5m overall. The erosion at the top of the beach persisted from the previous full measures survey. There were also patches of erosion on the mid beach and in the east of the study area. **Long Term Topographic Trends Autumn 2008 to Autumn 2015:** The plot of the change over the last seven years (Appendix B – Map 4c) shows a clear pattern, with two areas of change. East of the mouth of Skelton Beck there has been accretion of up to 0.75m. West of the mouth of the beck the majority of the beach has eroded by up to 0.75m There is a small strip of accretion along the top of the beach and up to 1m gain at the mouth of the beck.	The beach stayed stable at profile 1cRC9 between April and October 2015 with some small bars forming. The difference plot for 2015 shows modest change across much of the beach. There is limited erosion across much of the upper beach. **Longer term trends**: the October 2015 beach level was still one of the lowest recorded profile since 2008, showing progressive erosion. **Autumn 2008 to Autumn 2015 trends** Long term net change shows the frontage has eroded west of Skelton Beck and accreted to the east, at the margins of the bay. The accretion of 0.5m occurs in the in the shadow of Saltburn Scar where the wave climate is less severe. Erosion rarely exceeds 0.75m dominates across much of the frontage particularly in the west.

3.5 Cattersty Sands

Survey Date	Description of Changes Since Last Survey	Interpretation
28th Nov 2015	**Topographic Survey:** Cattersty Sands is covered by a six-monthly topographic survey. The surveyor noted that construction works still ongoing on promenade although survey area not affected. It is understood that the council have been undertaking works to the beach control structures and repairs to the jetty. Data have been used to create a DGM (Appendix B – Map 5a) using a GIS package. The beach is steeper to the west of the breakwater than the east, but in both areas the gradient is relatively smooth. East of the breakwater the beach is punctuated by Kilton Beck and the harbour so the gradient is shallower. Immediately east of the fishtail groyne, the stream has cut a channel, which is most deeply incised at its landward extent. The GIS has also been used to calculate the differences between Spring 2015 and Autumn 2015 topographic surveys and is presented as DGM (as shown in Appendix B – Map 5b), to identify areas of net erosion and accretion. The difference plot shows an almost equal distribution of accretion and erosion. East of the breakwater the lower and mid beach has eroded by around 0.5m over the summer. There is a region of up to 4m of accretion on the landward side of the beach which is considered to be due to the storage of material to be used in the addition of rock armour either side of the jetty. East of the jetty there was erosion close to the jetty, in the centre of the bay and over the rocks in the east. The rest of the eastern part of the bay is covered in modest accretion of 0.25m. **Long Term Topographic Trends Autumn 2008 to Autumn 2015:** The Autumn 2008 to Autumn 2015 plot (Appendix B – Map 5c) of elevation difference shows a different pattern of change to that seen over the past year. West of the breakwater, erosion is prevalent at the back of the beach where lowering >1m has occurred in places, but the lower beach and foreshore have accreted. East of the breakwater accretion is proportionally more widespread, although a narrow strip of erosion surrounds the boat storage area (defended by rock armour) adjacent to Kilton Beck.	The topographic change data shows Cattersty Sands is very dynamic, influenced by both coastal and fluvial processes and the breakwater. Short term change, over the preceding six-monthly shows a marked difference in beach behaviour either side of the breakwater. The east side showed erosion immediately east of the breakwater and more mixed erosion and accretion further east, and west of the breakwater there were shore parallel strips of erosion and accretion indicating bar migration. **Longer term trends**: Previous short term change plots show very similar patterns change suggesting the summers of 2014 and 2015 had a comparable effect on the beach. The works being carried out on the beach and to the fishtail groyne and jetty are likely to impact on the beach behaviour in the future. **Autumn 2008 to Autumn 2015 trends** The difference plot for previous seven years clearly highlights the differences on either side of the breakwater, with the west side showing erosion at the back of the beach and the base of the cliff (where over 1m of sediment has been eroded in some areas), and the east side showing much more widespread accretion of up to 1m.

3.6 Staithes

Survey Date	Description of Changes Since Last Survey	Interpretation
14th Sept 2015	**Cliff-top Survey:** Twenty ground control points have been established at Cowbar and Staithes for biannual cliff top monitoring. Locations 12 to 20 are in the Scarborough Borough Council area. The separation between any two points is around 100 m. Data collection involves a distance offset measurement from the ground control point to the cliff edge along a fixed bearing. Between March 2015 and September 2015 nine of the 20 posts showed change within a range of ±0.1m, which is not considered significant given the error of the technique. Posts 3, 5, 9, 18, 19, and 20 showed the largest erosion with 0.3 to 0.8m cliff recession recorded. Calculation of longer-term erosion rates based on the recorded change between 2008 and 2015 indicates that fourteen posts on the frontage recorded a change rate within a range of ±0.1m/yr, which is considered to be within the error of the measurement. Post 13 (near the eastern breakwater) shows consistent erosion through the surveys at 0.3m/yr. Posts 17,18, 19 and 20 all show recession (0.2-0.8m) over the summer of 2015, this event means that the rate for those locations is now 0.1m/yr. The changes were observed on the bay east of Staithes. Appendix C provides results from the October 2014 survey, showing the distance from the ground control point to the edge of the cliff top along the defined bearing and changes in position since the November 2008 baseline survey.	Eight stations showed erosion of between 0.2 and 0.8m over the summer of 2015. There was a series of cliff losses on stations 17 and 20 inclusive, which may be due to cliff erosion in that part of the bay, possibly due to a cluster of failures. The photographs show a stable cliff with no evidence of recent failures and it is possible that the monitoring data are inaccurate. **Longer term trends**: Table C1 shows that survey location 13 has shown the greatest total erosion with a loss of 2.2m (±0.3m) between the November 2008 baseline and September 2015, resulting in a long term average recession rate of 0.4m/yr. This area is above the eastern breakwater and is known to have experienced rock falls previously.

4. Problems Encountered and Uncertainty in Analysis

Individual Surveys

At Skinningrove construction works still ongoing on promenade although survey area not affected. A new revetment has been installed on northern side of pier. Existing revetment to south of pier has been partially removed/reshaped.

Cliff Top Surveys

The cliff top surveys at Staithes are assumed to have a limit of accuracy of ± 0.1m due to the techniques used. One of the previous survey station has been buried under a newly installed man made embankment. New survey station 4 has been installed.

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

The aim of cliff monitoring data is to gain a reliable record of the frequency and magnitude of cliff top failures. Data are collected every six months, but previous surveys have had a low accuracy, meaning that survey error is typically greater than any measured short term change. It is likely that a more reliable pattern of change will be determined over the longer term. In addition, cliff recession data are available from the analysis of aerial survey data collected in 2010 and 2012-13 that was undertaken in 2013.

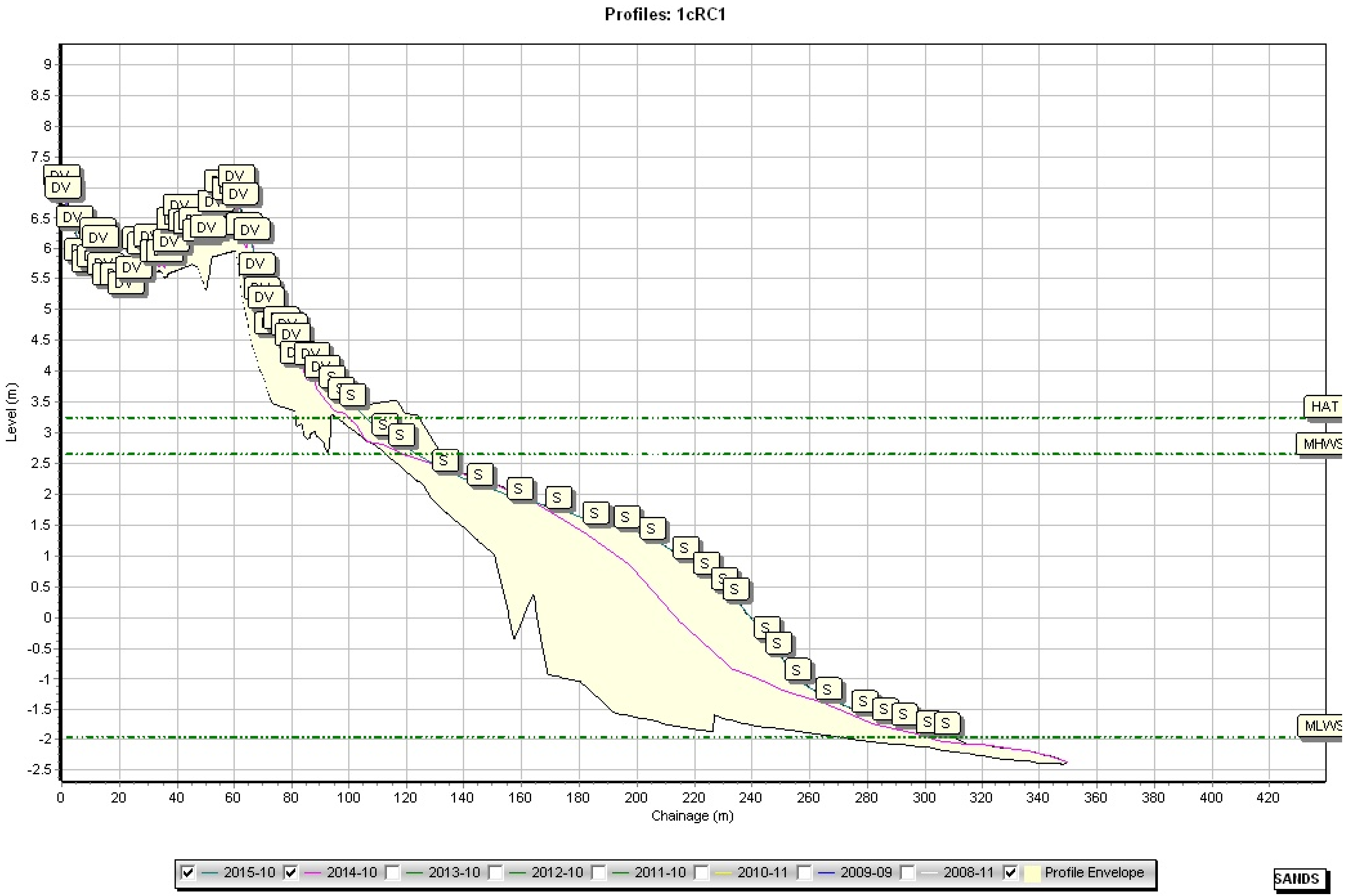
6. Conclusions and Areas of Concern

- At Coatham Sands, the October 2015 profiles in the north of the survey area are near the top of the range of profiles seen over the monitoring period. The long term difference plot shows a broad pattern of accretion in the north, little change in the middle of the plot and erosion in the south.
- At Redcar Sands the topographic change plot reflects the pattern of modest accretion shown in the beach profiles with some accretion on the eastern third of the difference plots. More accretion has occurred on the north east facing section, which is likely to be due to the wave environment.
- At Marske Sands the 2015 beach profiles show stability, with the formation of berms being the main change on the beach. The short term topographic change plot reflects this with evidence of the migration of beach berms. The long term difference plot shows accretion in the west and erosion in the east with patchy change in the centre of the beach.
- The beach at Saltburn Sands has remained stable between April and October 2015. However the profiles show a pattern of progressive erosion. The long term difference plot shows accretion in the west and erosion in the east, fronting the till cliffs and sheltered by Saltburn Scar.
- The Cattersty Sands difference model shows that the changes in the summer of 2014 were similar to those in 2015. The long term difference plot shows the differences on either side of the breakwater, with the west side showing erosion at the back of the beach and the base of the cliff (where over 1m of sediment has been eroded in some areas), and the east side showing much more widespread accretion.
- The measurements of the Cowbar and Staithes cliff top shows stability over the summer of 2015. There was a cluster of failures between stations 17 and 20 but looking at the photographs there appears not to have been a failure. The rest of the cliff has modest recession rates which will become more accurate as more data is collected.

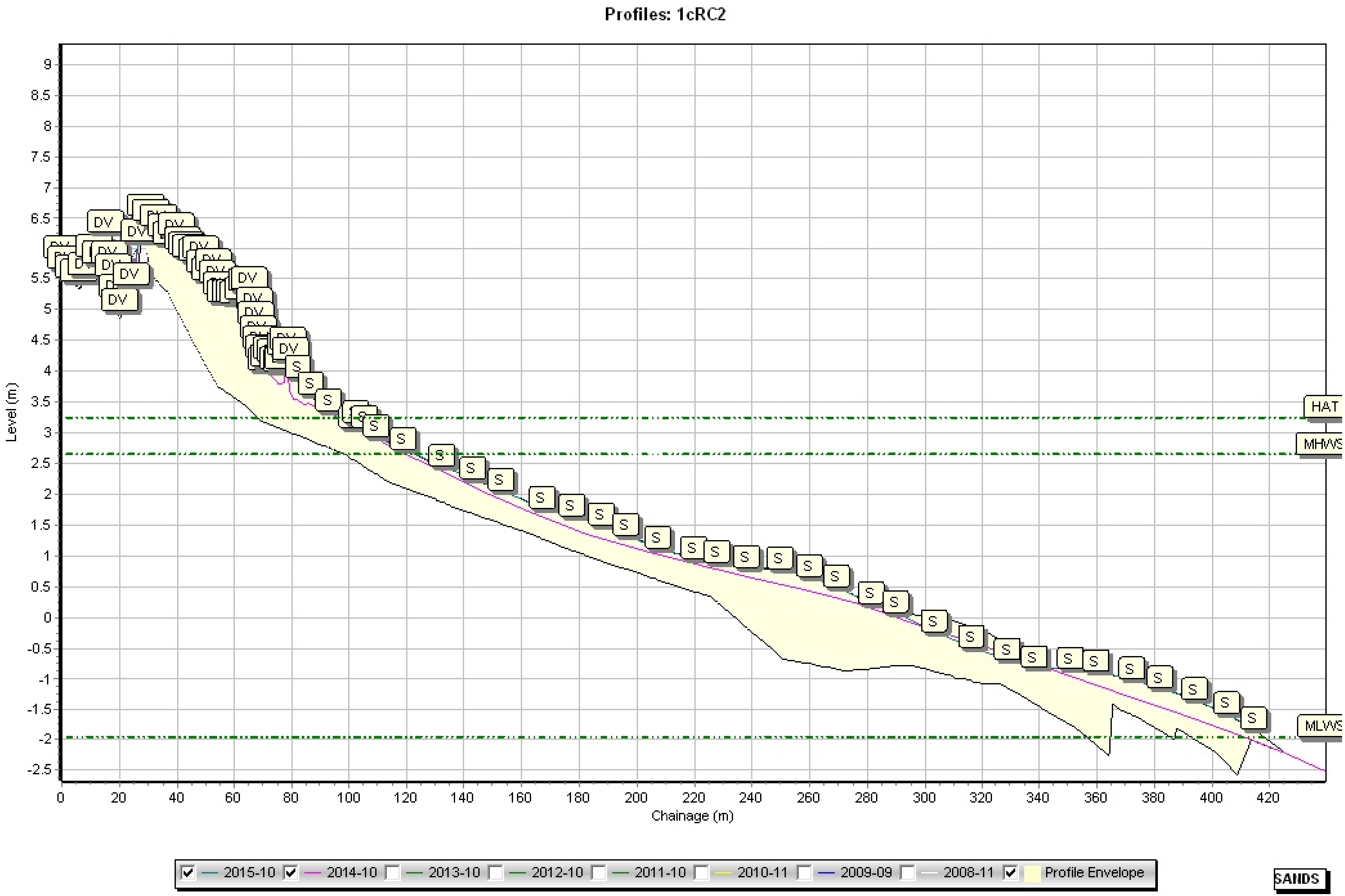
Appendices

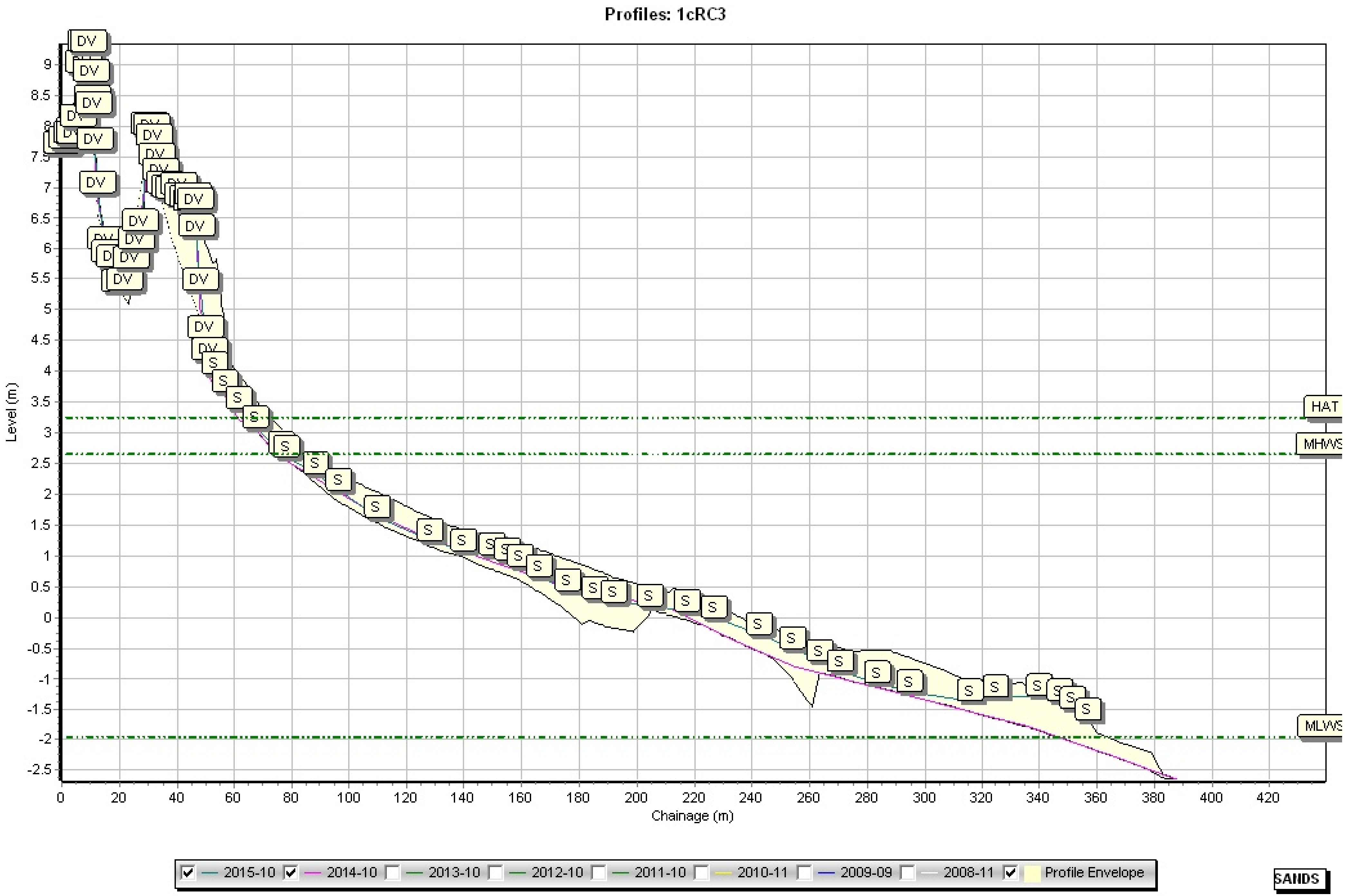
Appendix A

Beach Profiles

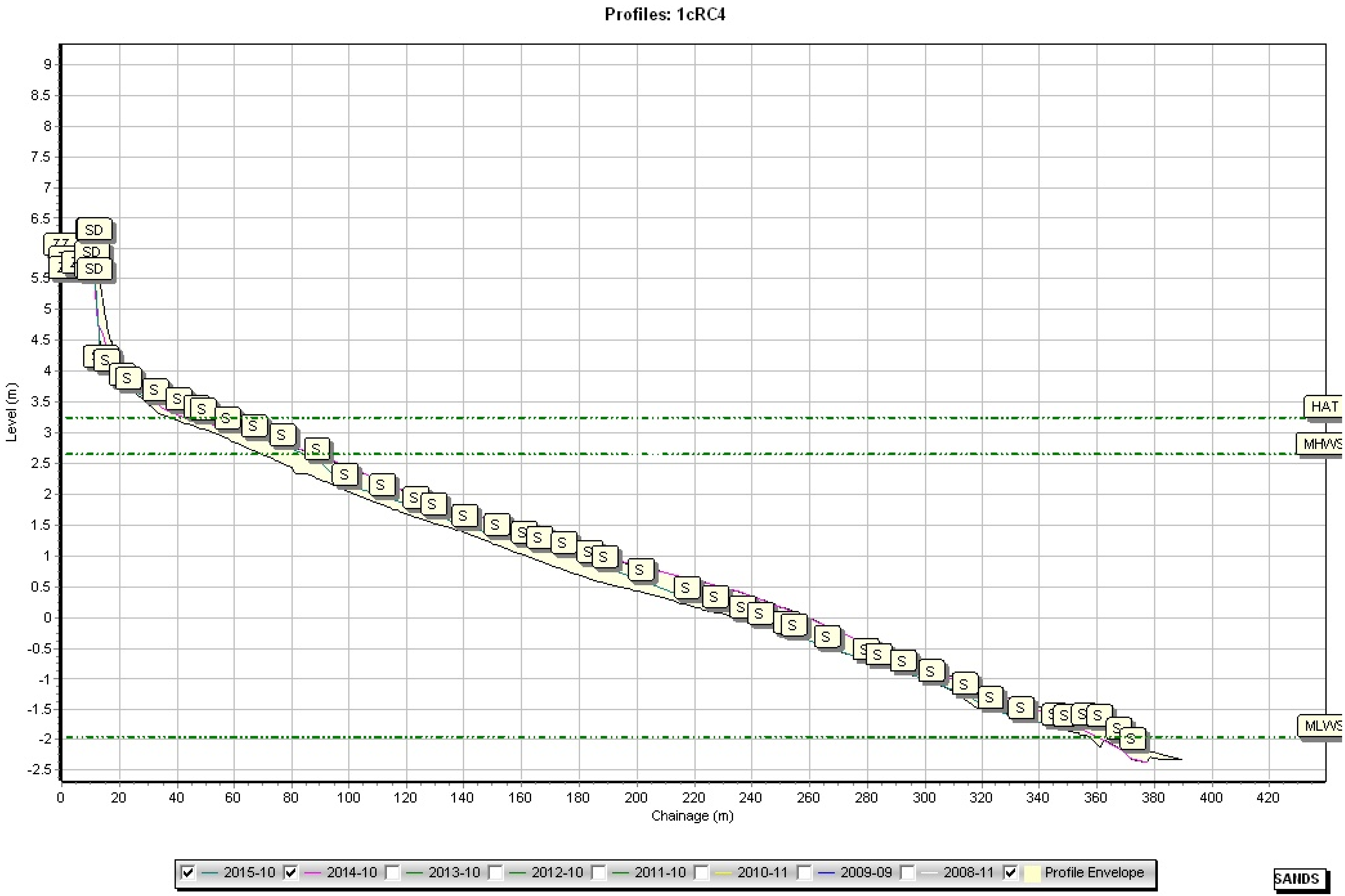


Profiles: 1cRC1
Level (m)
Chainage (m)
HAT
MHWS
MLWS
2015-10
2014-10
2013-10
2012-10
2011-10
2010-11
2009-09
2008-11
Profile Envelope
SANDS


Profiles: 1cRC2
Level (m)
Chainage (m)
HAT
MHWS
MLWS
2015-10
2014-10
2013-10
2012-10
2011-10
2010-11
2009-09
2008-11
Profile Envelope
SANDS

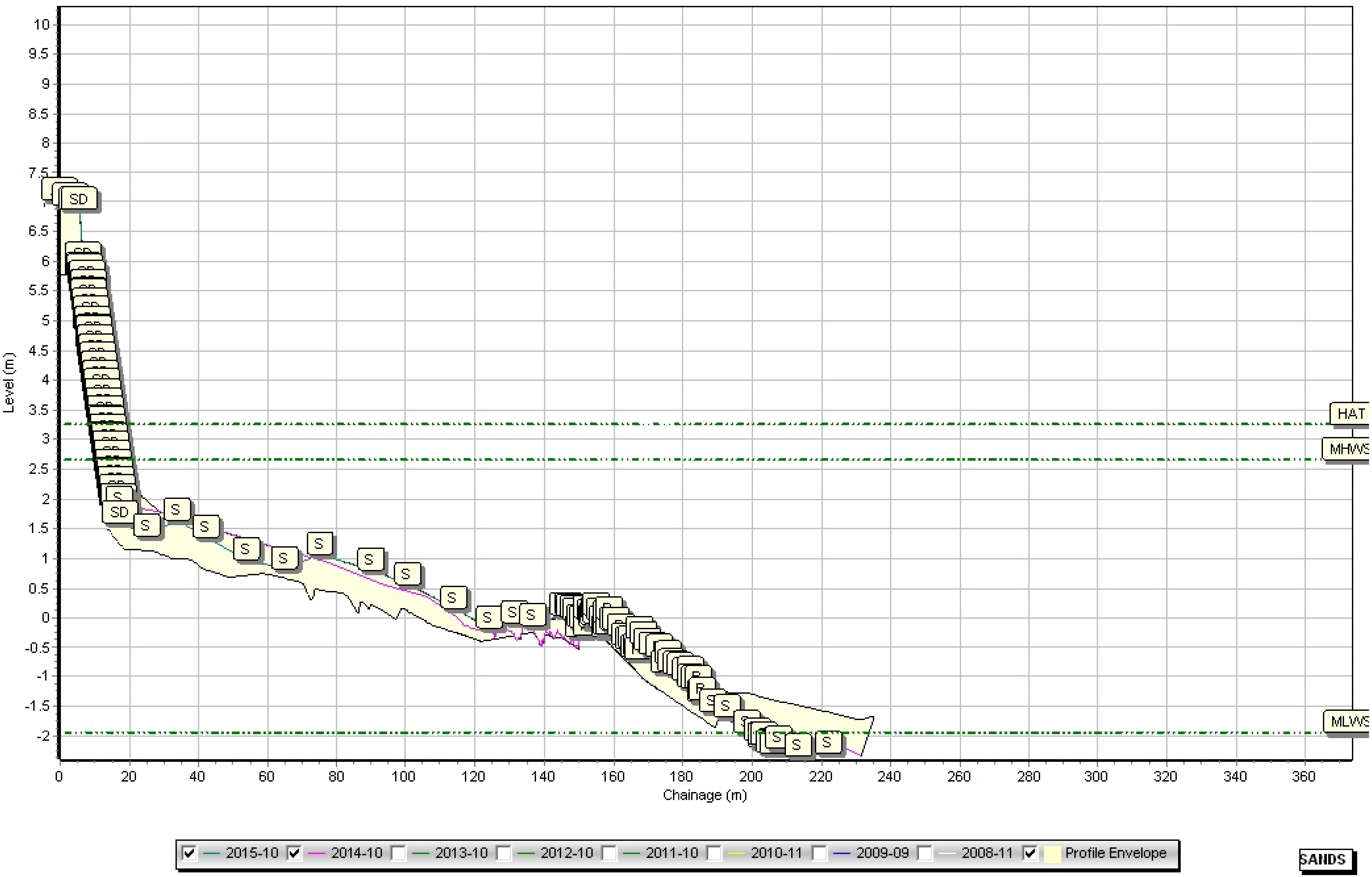


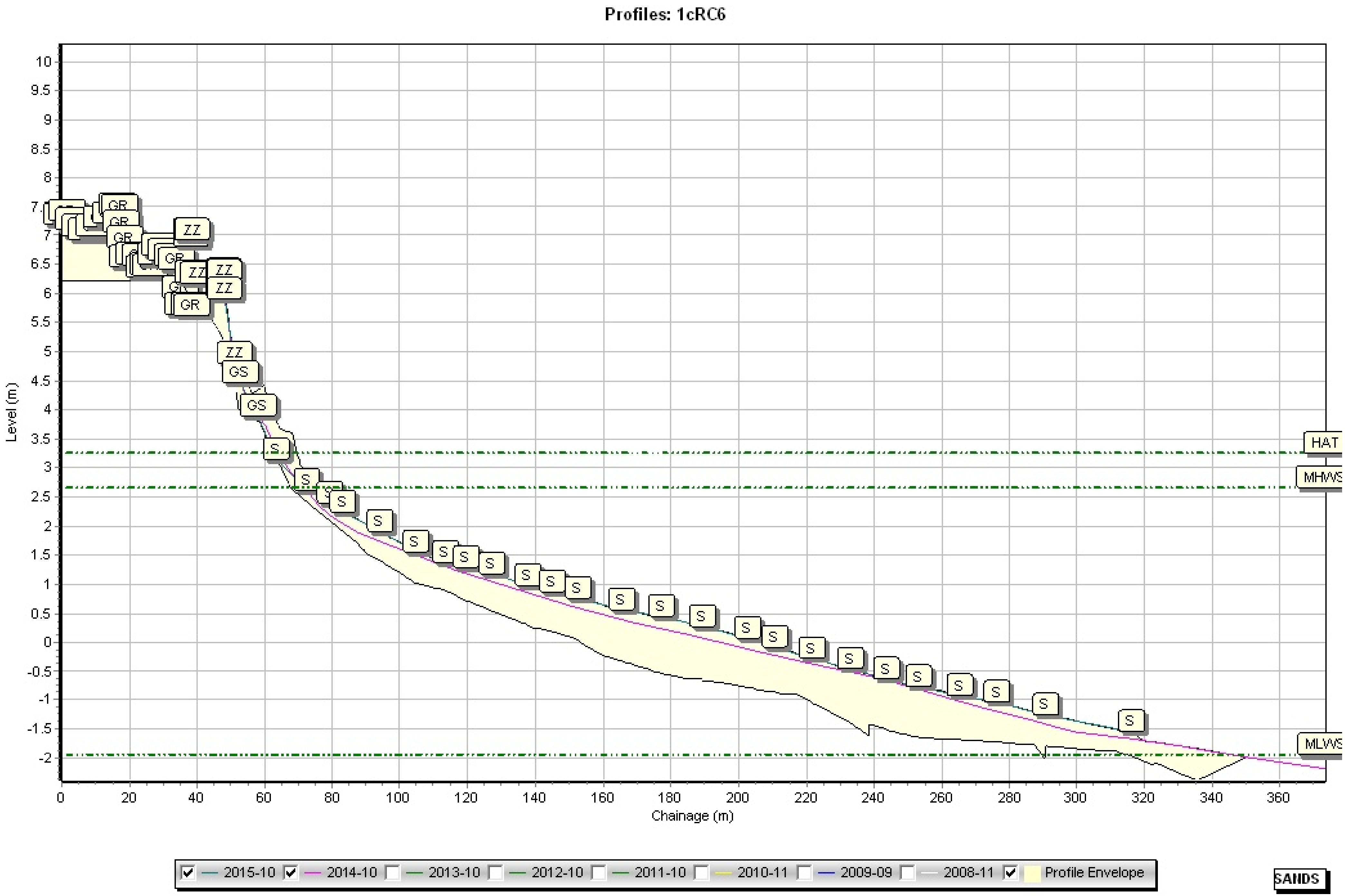
Profiles: 1cRC3
Level (m)
Chainage (m)
HAT
MHWS
MLWS
2015-10
2014-10
2013-10
2012-10
2011-10
2010-11
2009-09
2008-11
Profile Envelope
SANDS



Profiles: 1cRC4
Level (m)
Chainage (m)
HAT
MHWS
MLWS
2015-10
2014-10
2013-10
2012-10
2011-10
2010-11
2009-09
2008-11
Profile Envelope
SANDS

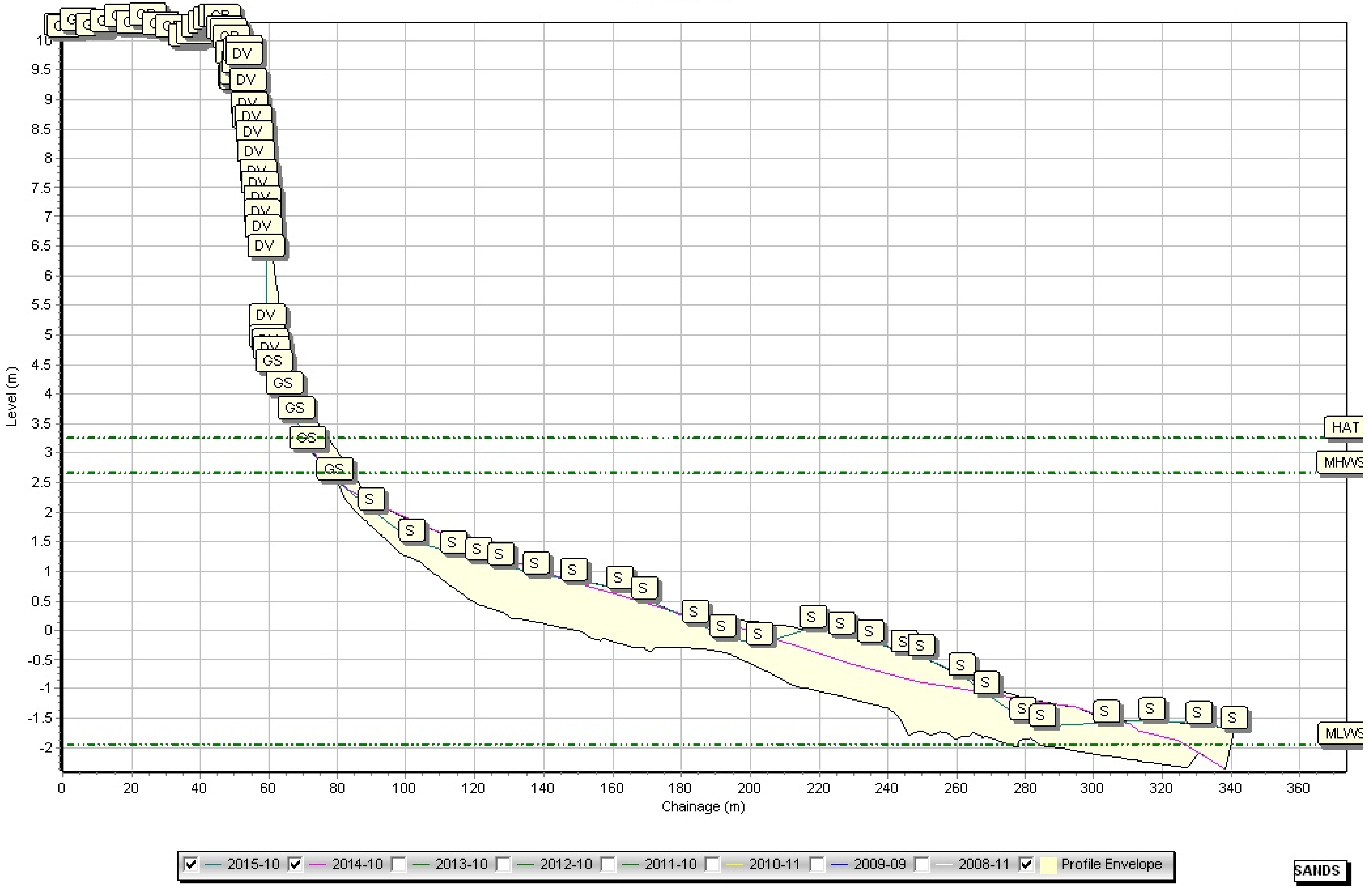
Profiles: 1cRC5

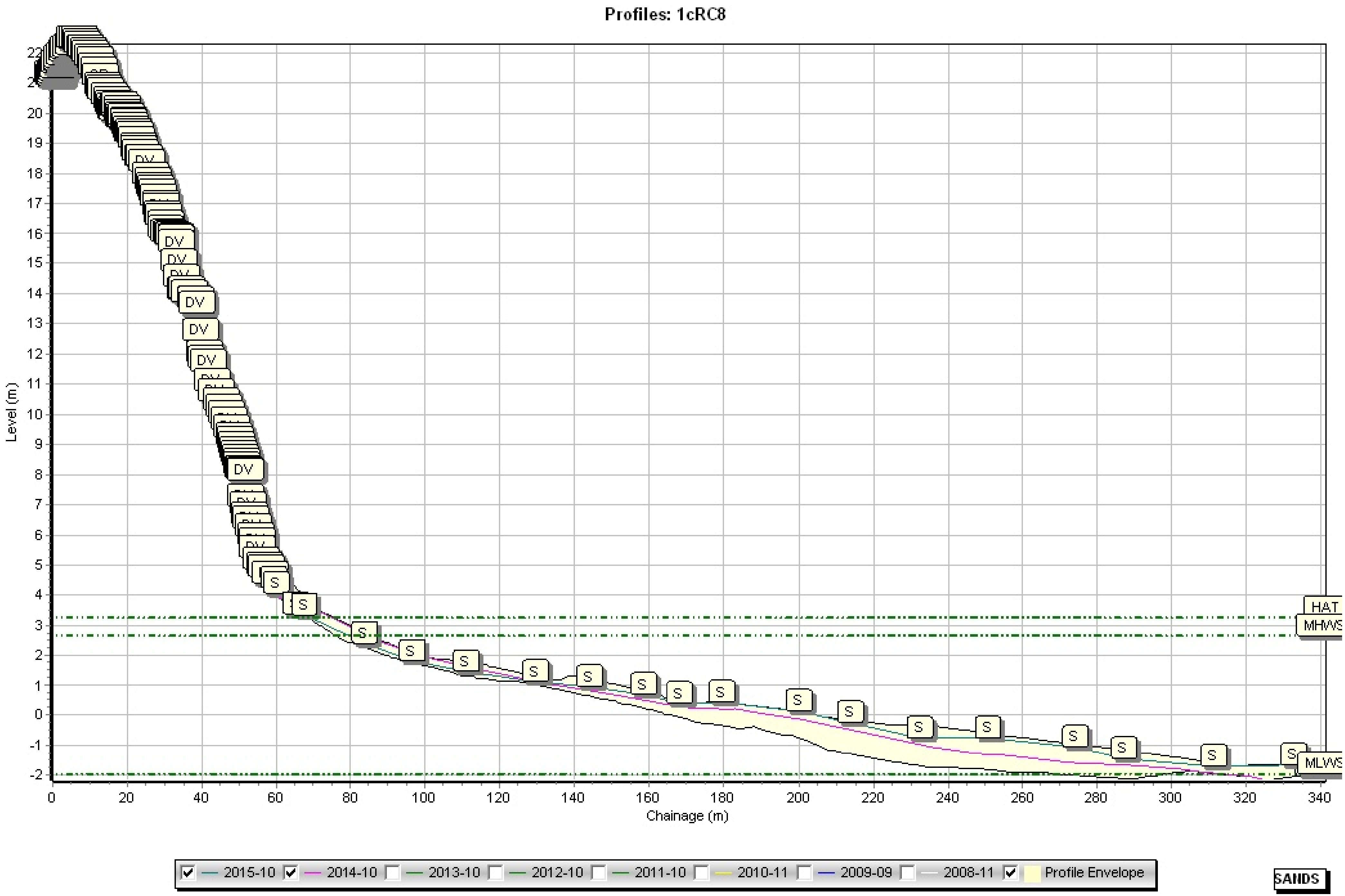




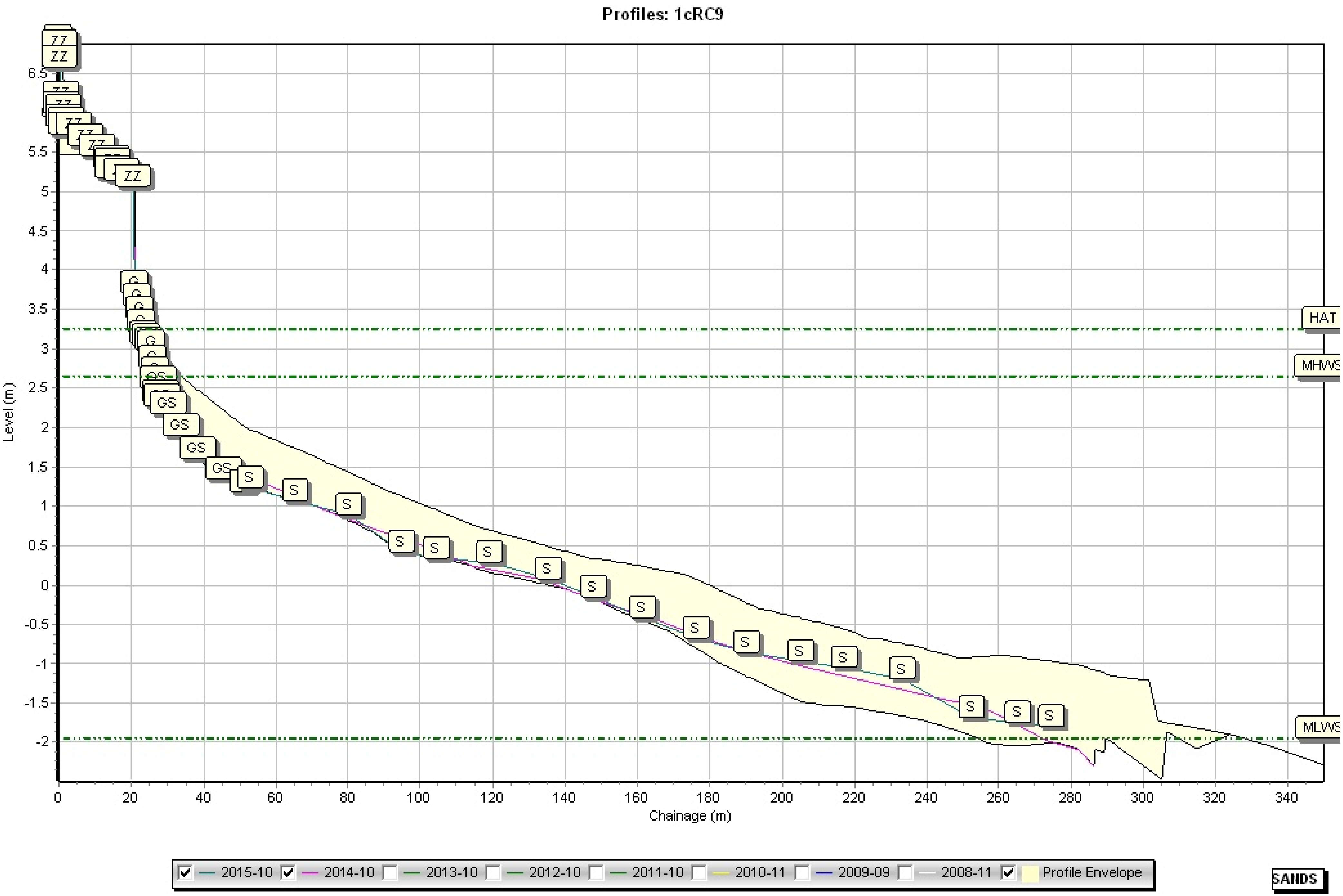
Profiles: 1cRC6
Level (m)
Chainage (m)
HAT
MHWS
MLWS
2015-10
2014-10
2013-10
2012-10
2011-10
2010-11
2009-09
2008-11
Profile Envelope
SANDS

Profiles: 1cRC7





Profiles: 1cRC8
Level (m)
Chainage (m)
HAT
MHWS
MLWS
2015-10
2014-10
2013-10
2012-10
2011-10
2010-11
2009-09
2008-11
Profile Envelope
SANDS

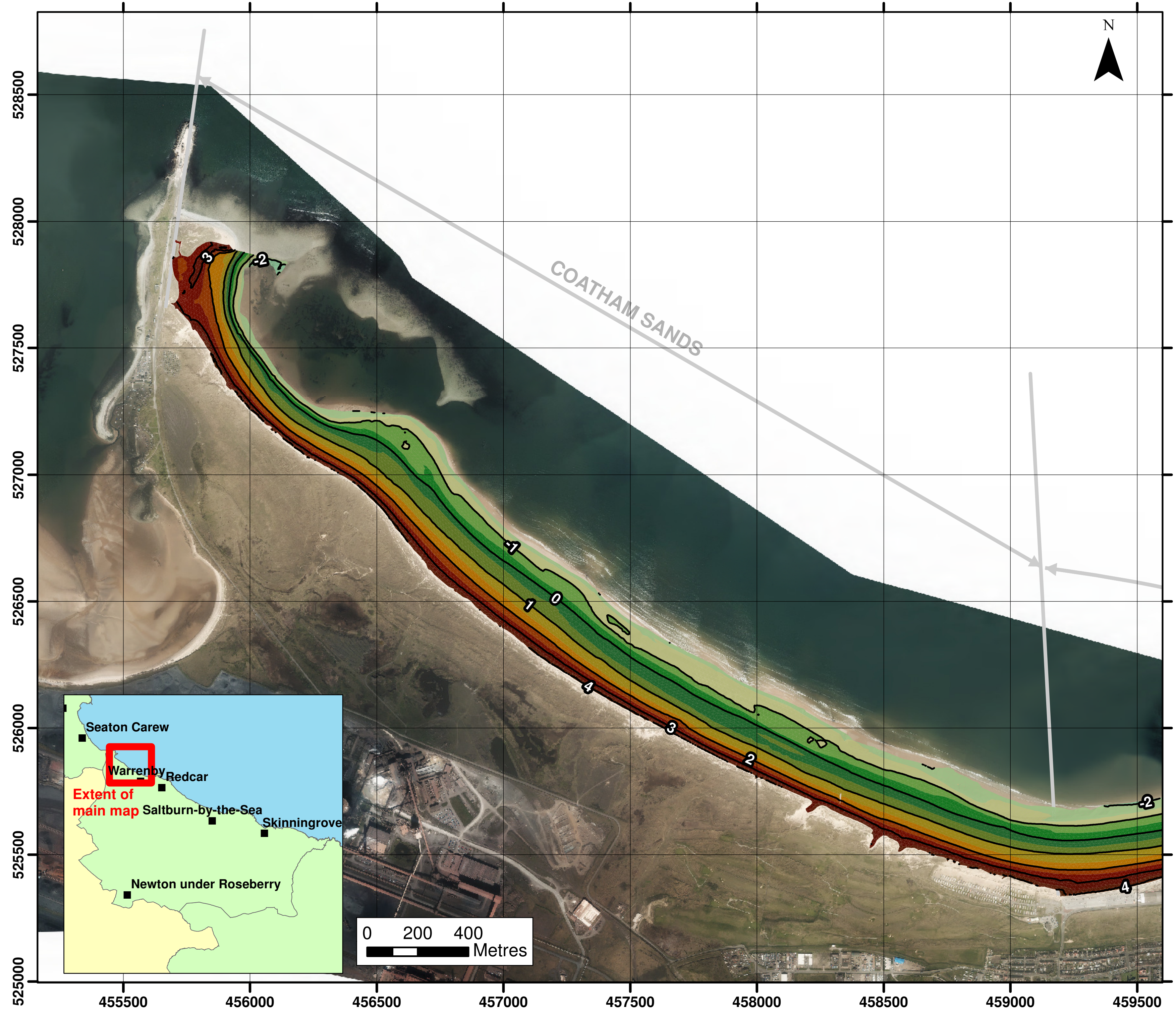

Profiles: 1cRC9
Level (m)
Chainage (m)
HAT
MHWS
MLWS
ZZ
G
GS
S
2015-10
2014-10
2013-10
2012-10
2011-10
2010-11
2009-09
2008-11
Profile Envelope
SANDS

The following sediment feature codes are used on some profile plots:

Code	Description
S	Sand
M	Mud
G	Gravel
GS	Gravel & Sand
MS	Mud & Sand
B	Boulders
R	Rock
SD	Sea Defence
SM	Saltmarsh
W	Water Body
GM	Gravel & Mud
GR	Grass
D	Dune (non-vegetated)
DV	Dune (vegetated)
F	Forested
X	Mixture
FB	Obstruction
CT	Cliff Top
CE	Cliff Edge
CF	Cliff Face
SH	Shell
ZZ	Unknown

Appendix B

Topographic Survey



KEY

Elevation (m OD)

- 7 - 7.5
- 6.5 - 7
- 6 - 6.5
- 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 1a
Topographic Survey
Coatham Sands
Redcar & Cleveland
Borough Council

Analytical Report 8
Full Measures Survey
Autumn 2015

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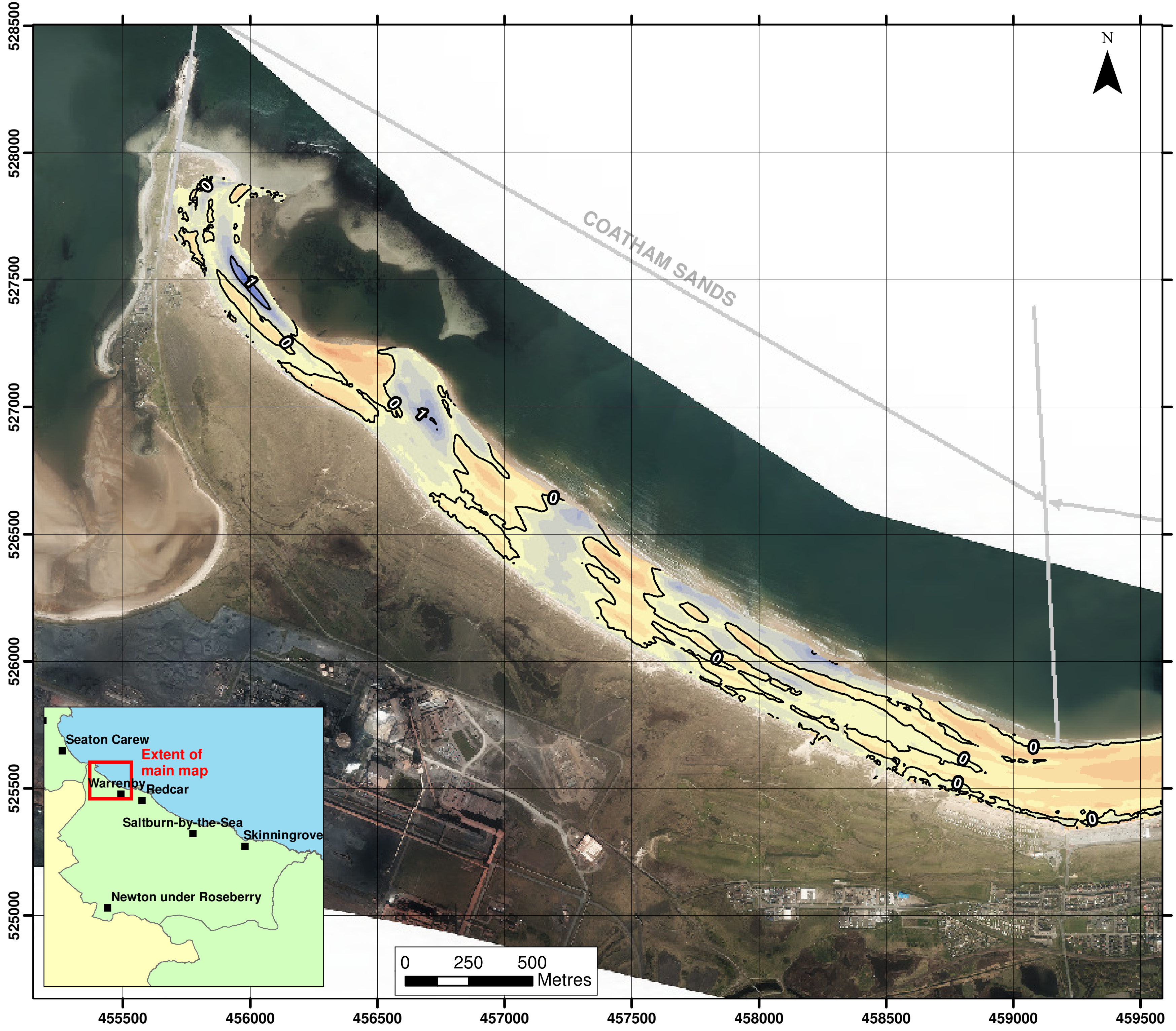

KEY Autumn 2014 and Autumn 2015
Change in elevation (m)

<-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 1b
Short-term Elevation Change Coatham Sands Redcar & Cleveland Borough Council

Analytical Report 8
Full Measures Survey
Autumn 2015

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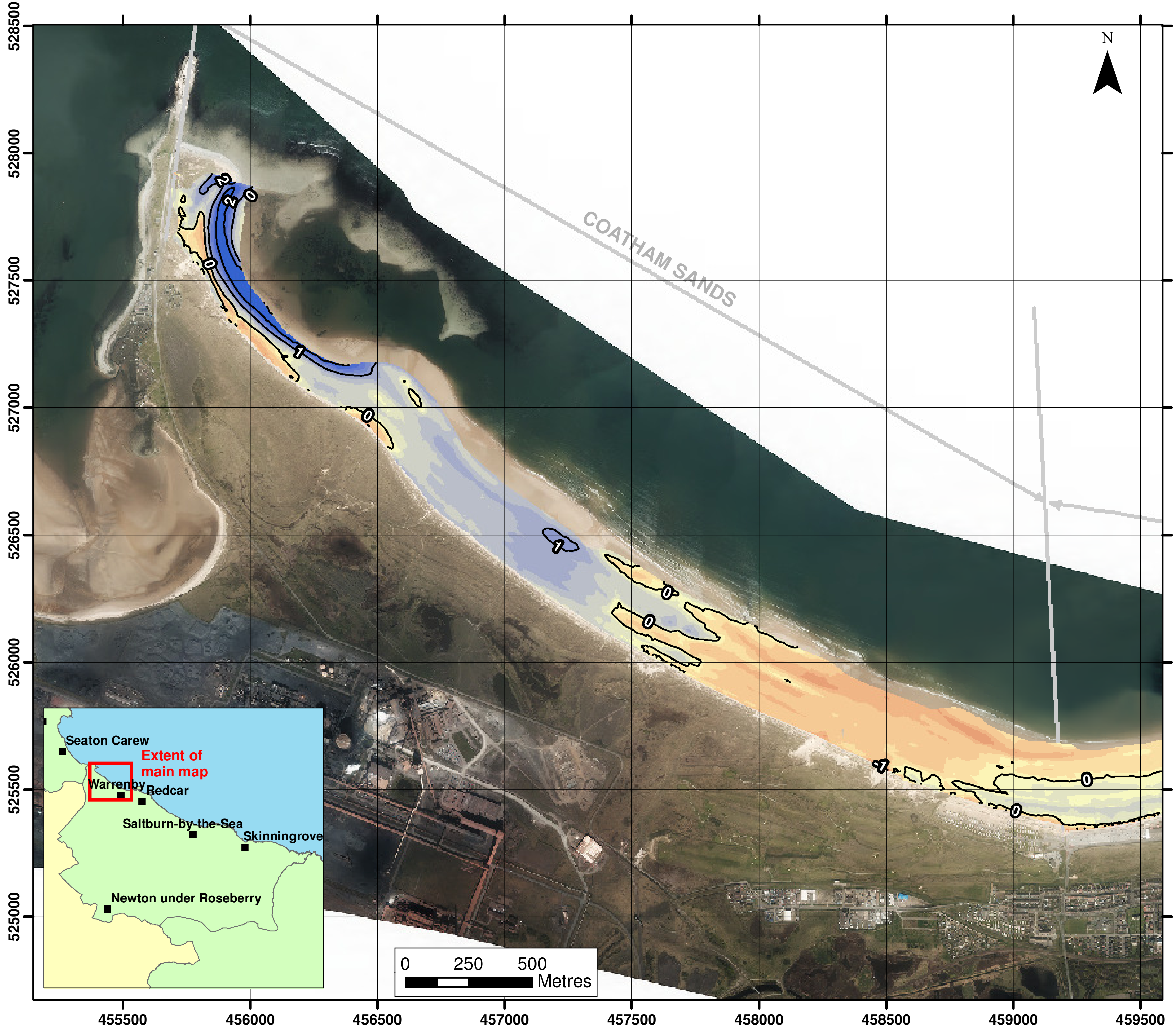

KEY Autumn 2008 and Autumn 2015
Change in elevation (m)

- <-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
Long-term Elevation Change Coatham Sands Redcar & Cleveland Borough Council

Analytical Report 8
Full Measures Survey
Autumn 2015

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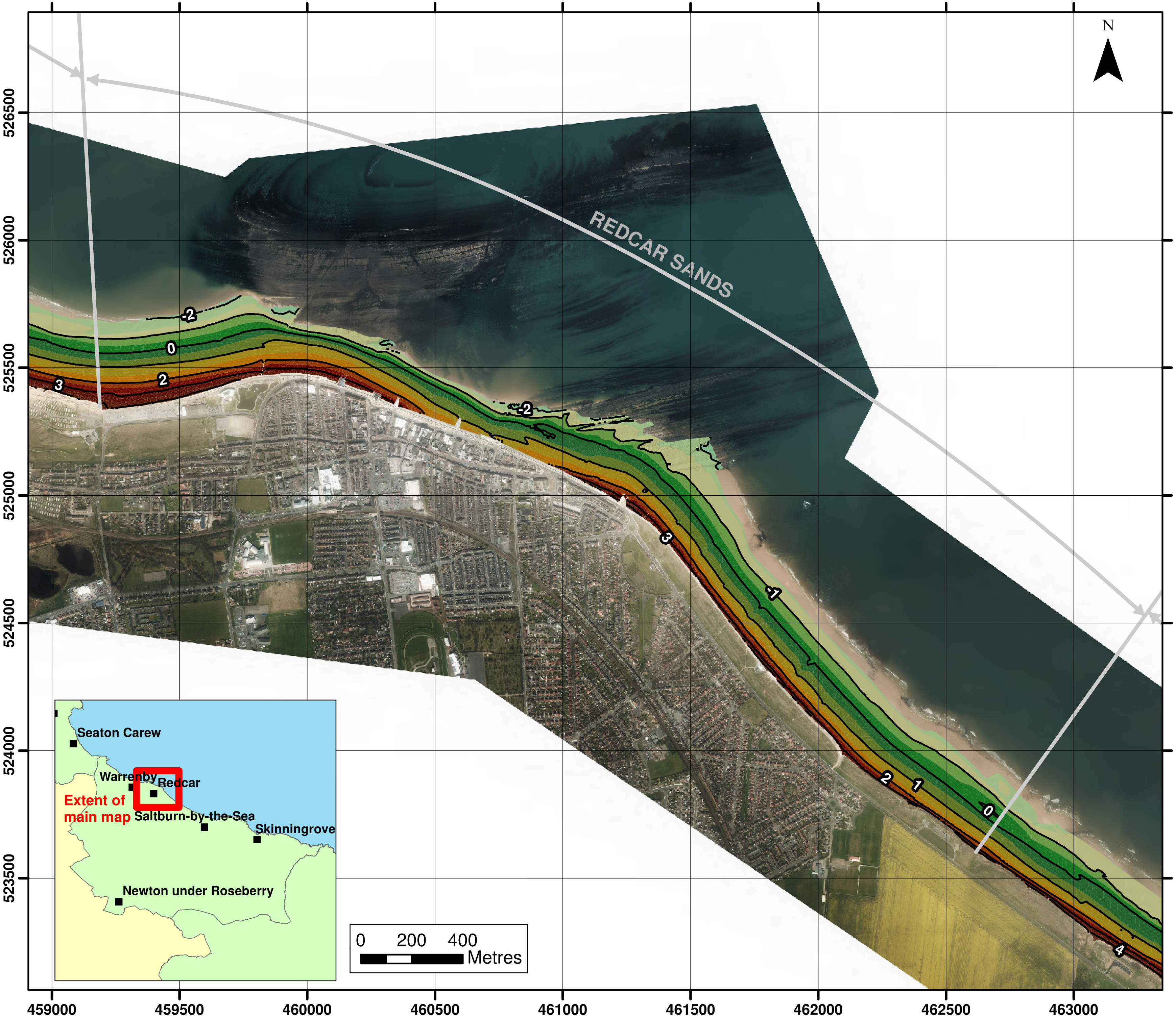

KEY

Elevation (m OD)

- 7 - 7.5
- 6.5 - 7
- 6 - 6.5
- 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 2a
Topographic Survey
Redcar Sands
Redcar & Cleveland
Borough Council

Analytical Report 8
Full Measures Survey
Autumn 2015

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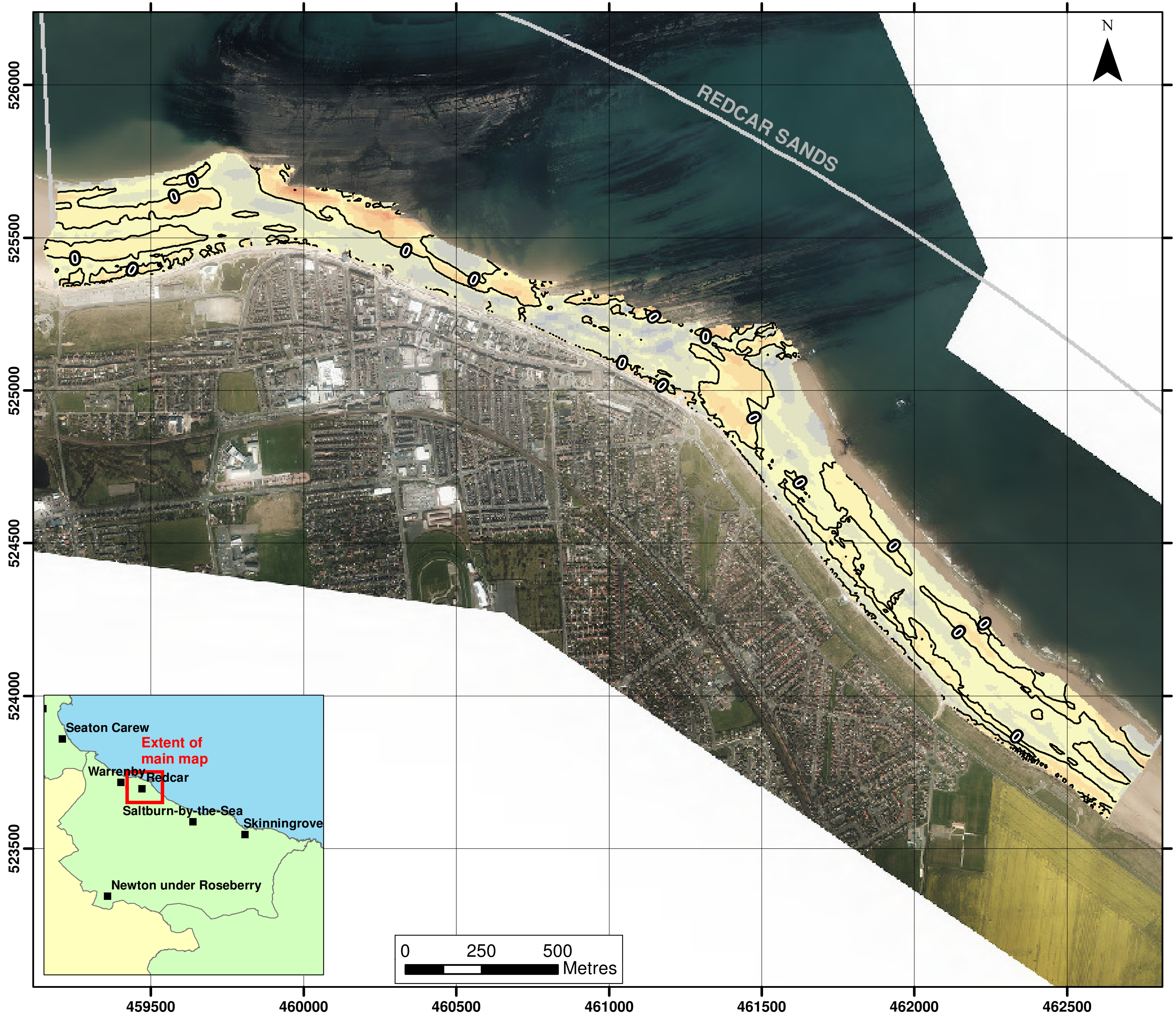

KEY Spring 2015 and Autumn 2015
Change in elevation (m)

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 2b
Short-term Elevation Change Redcar Sands Redcar & Cleveland Borough Council

Analytical Report 8
Full Measures Survey
Autumn 2015

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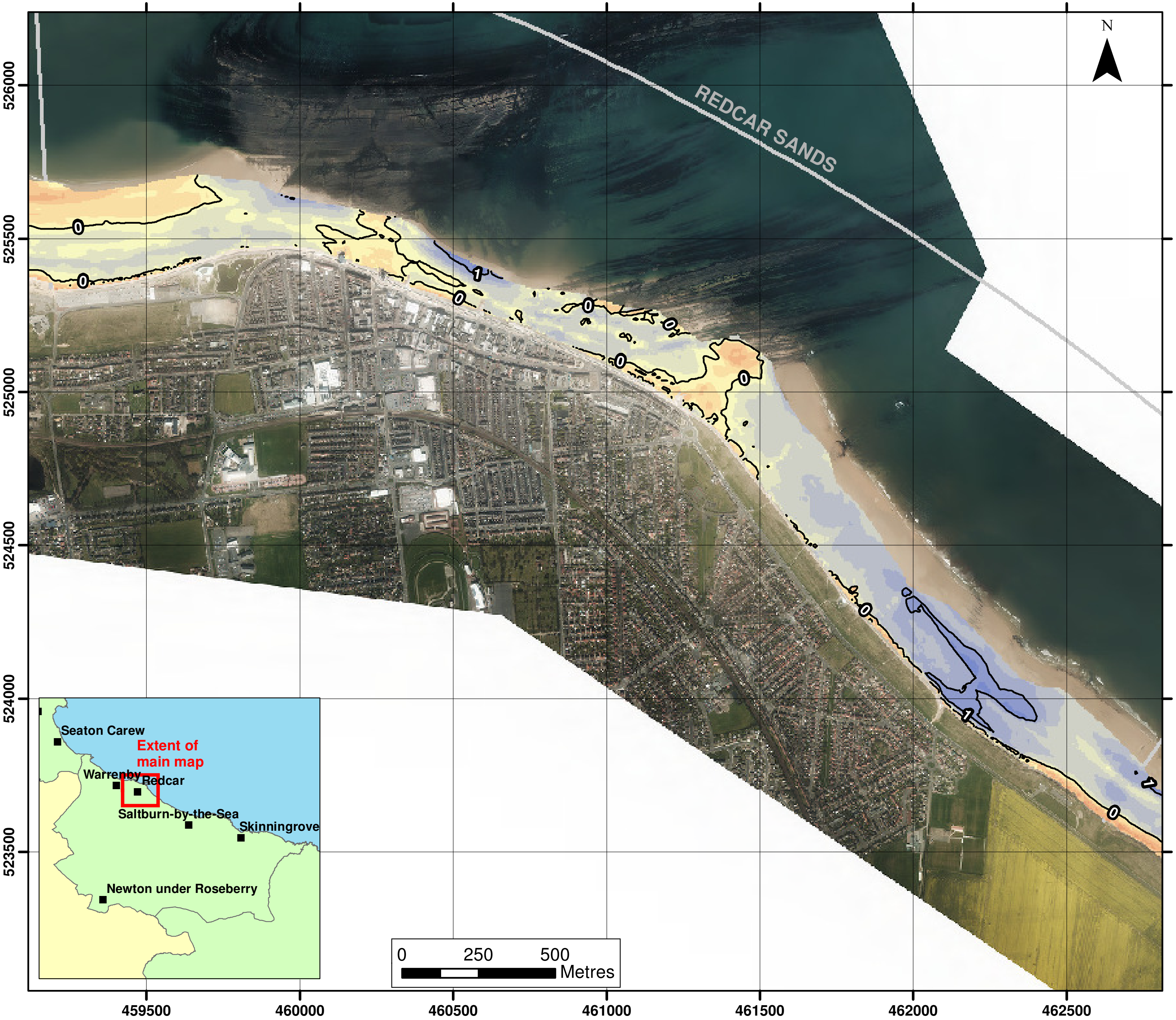

KEY Autumn 2008 and Autumn 2015
Change in elevation (m)

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 2c
Long-term Elevation Change Redcar Sands Redcar & Cleveland Borough Council

Analytical Report 8
Full Measures Survey
Autumn 2015

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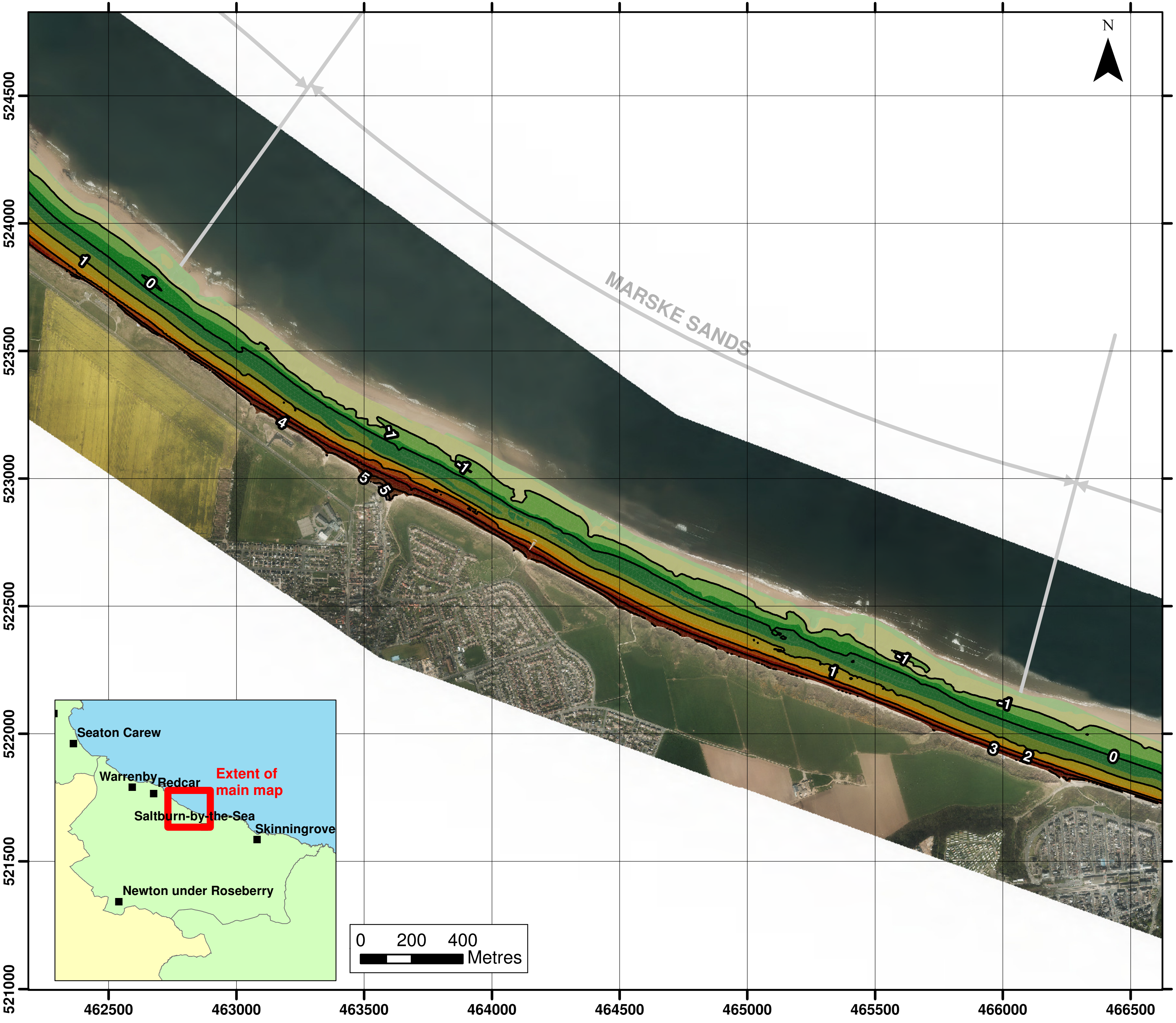

KEY

Elevation (m OD)

- 7 - 7.5
- 6.5 - 7
- 6 - 6.5
- 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
Marske Sands
Redcar & Cleveland
Borough Council

Analytical Report 8
Full Measures Survey
Autumn 2015

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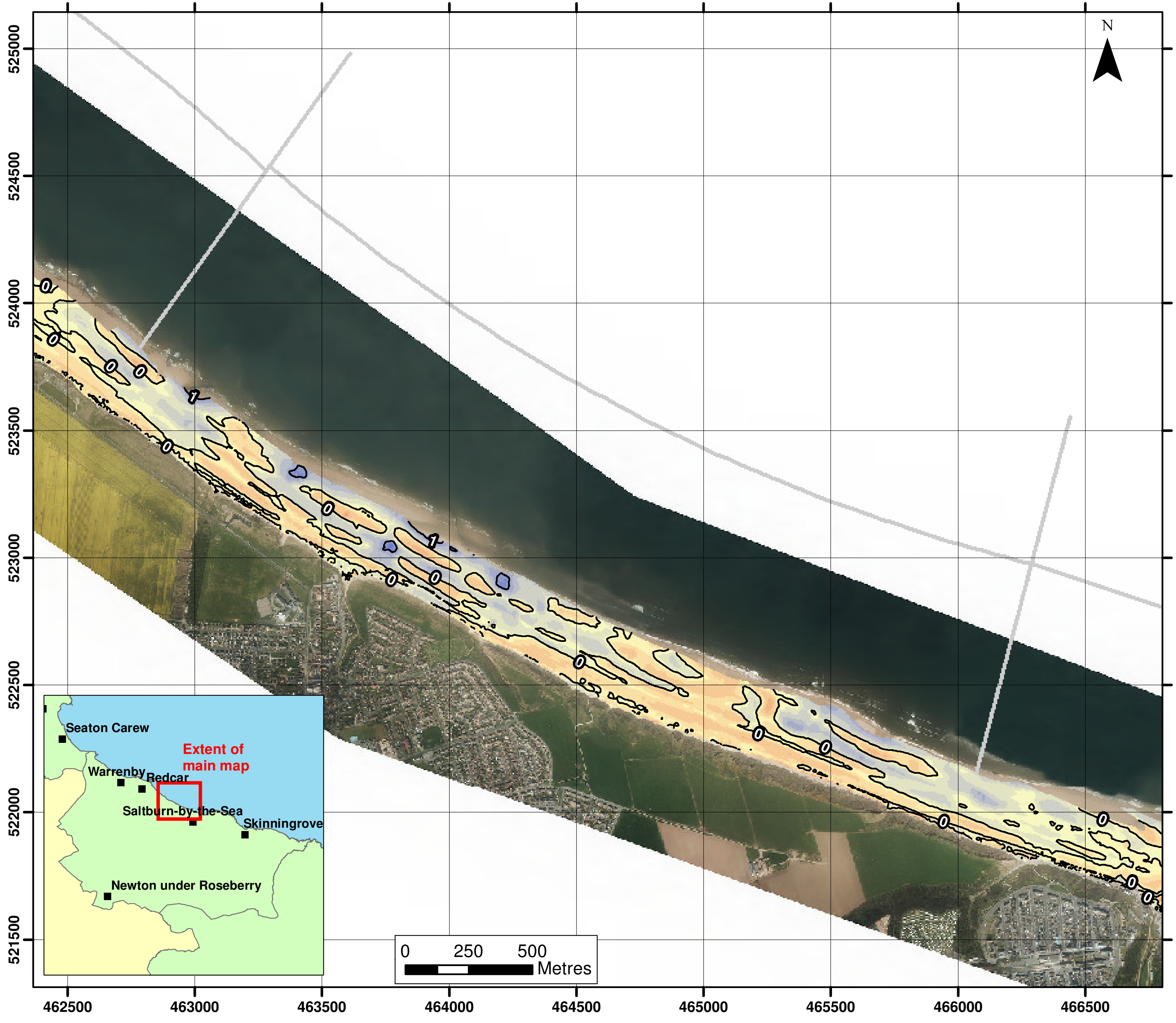

KEY Autumn 2014 and Autumn 2015

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
Marske Sands
Redcar & Cleveland Borough Council

Analytical Report 8
Full Measures Survey
Autumn 2015

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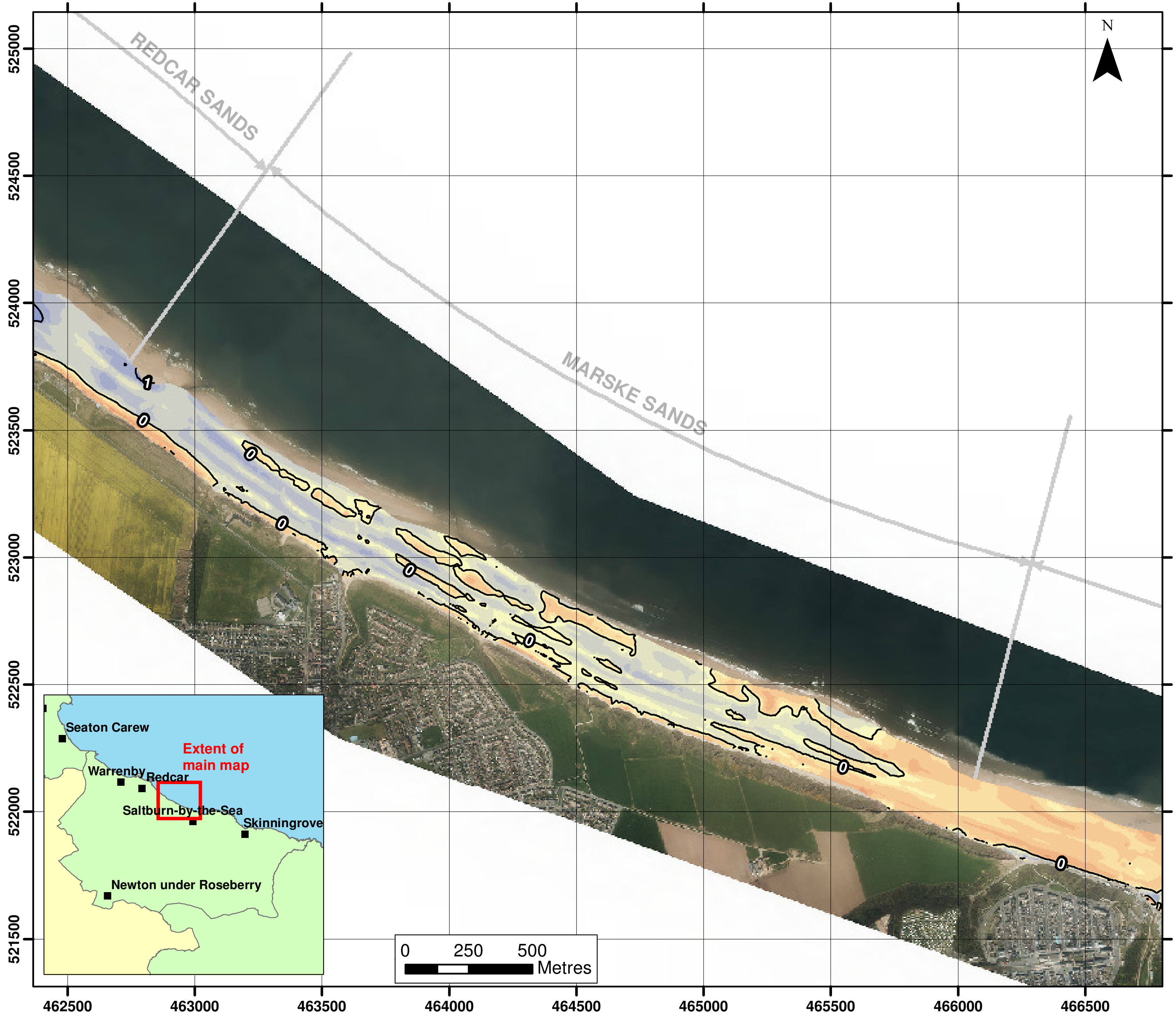

KEY Autumn 2008 and Autumn 2015
Change in elevation (m)

- <-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 3c
Long-term Elevation Change Marske Sands Redcar & Cleveland Borough Council

Analytical Report 8
Full Measures Survey
Autumn 2015

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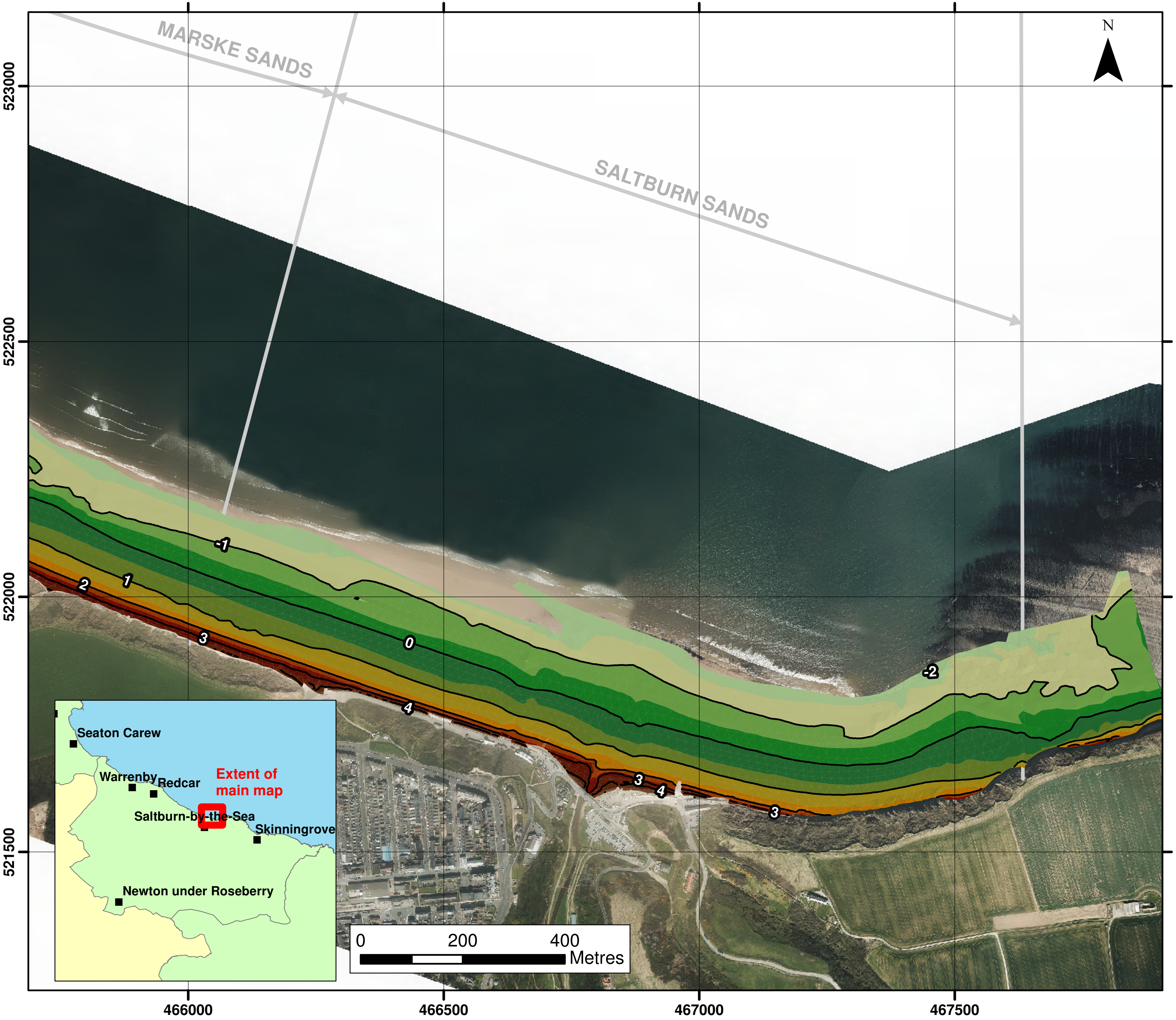

KEY

Elevation (m OD)

- 7 - 7.5
- 6.5 - 7
- 6 - 6.5
- 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
- -2.568 - -2.5
- Contour 1m

Client: North East Coastal Group

Project: Cell 1 Regional Coastal Monitoring Programme 2011 to 2016

Appendix B - Map 4a
Topographic Survey
Saltburn Sands
Redcar & Cleveland Borough Council

Analytical Report 8
FullMeasures Survey
Autumn 2015

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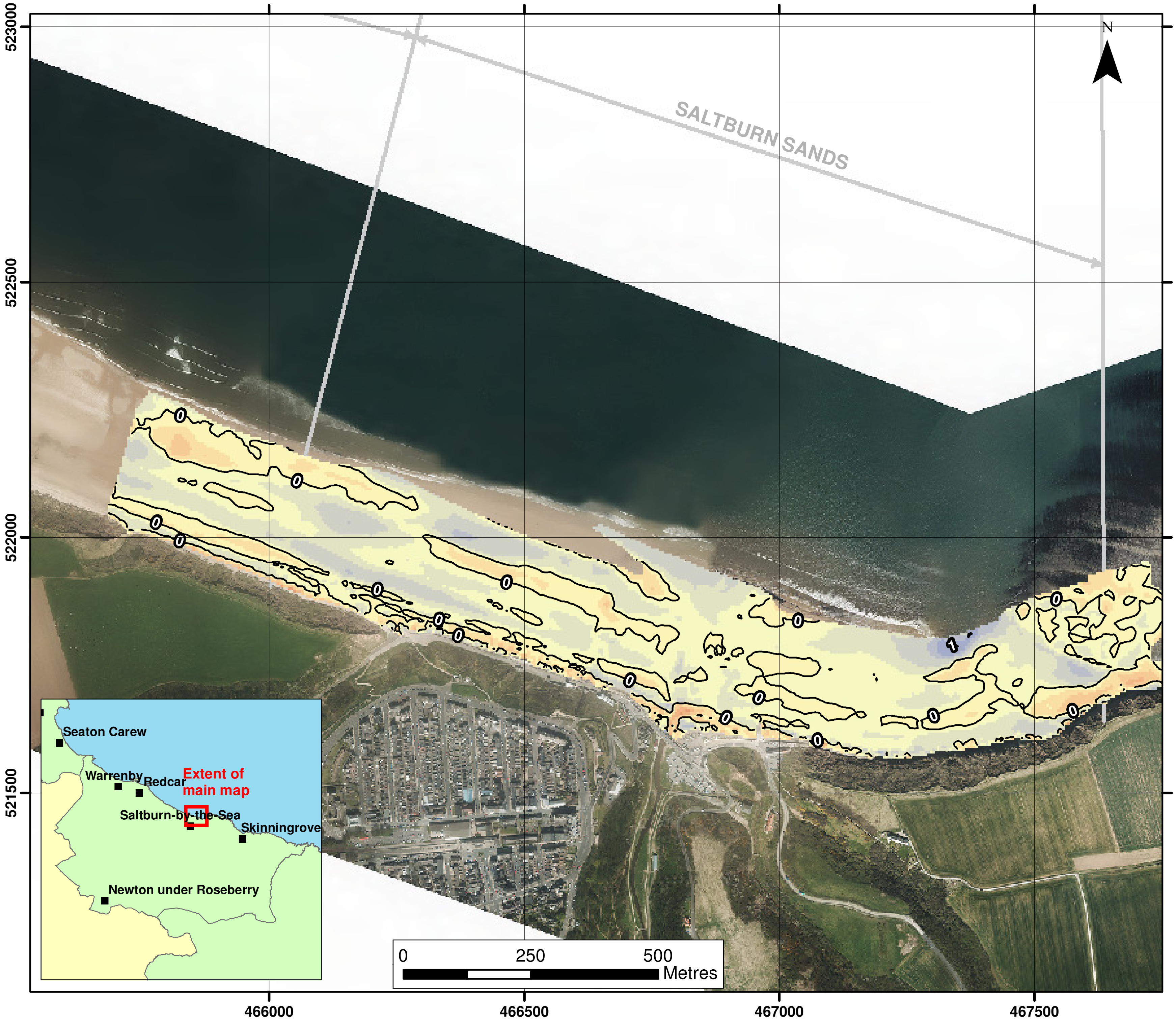

KEY Spring 2015 and Autumn 2015
Change in elevation (m)

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 4b
Short-term Elevation Change Saltburn Sands Redcar & Cleveland Borough Council

Analytical Report 8
Full Measures Survey
Autumn 2015

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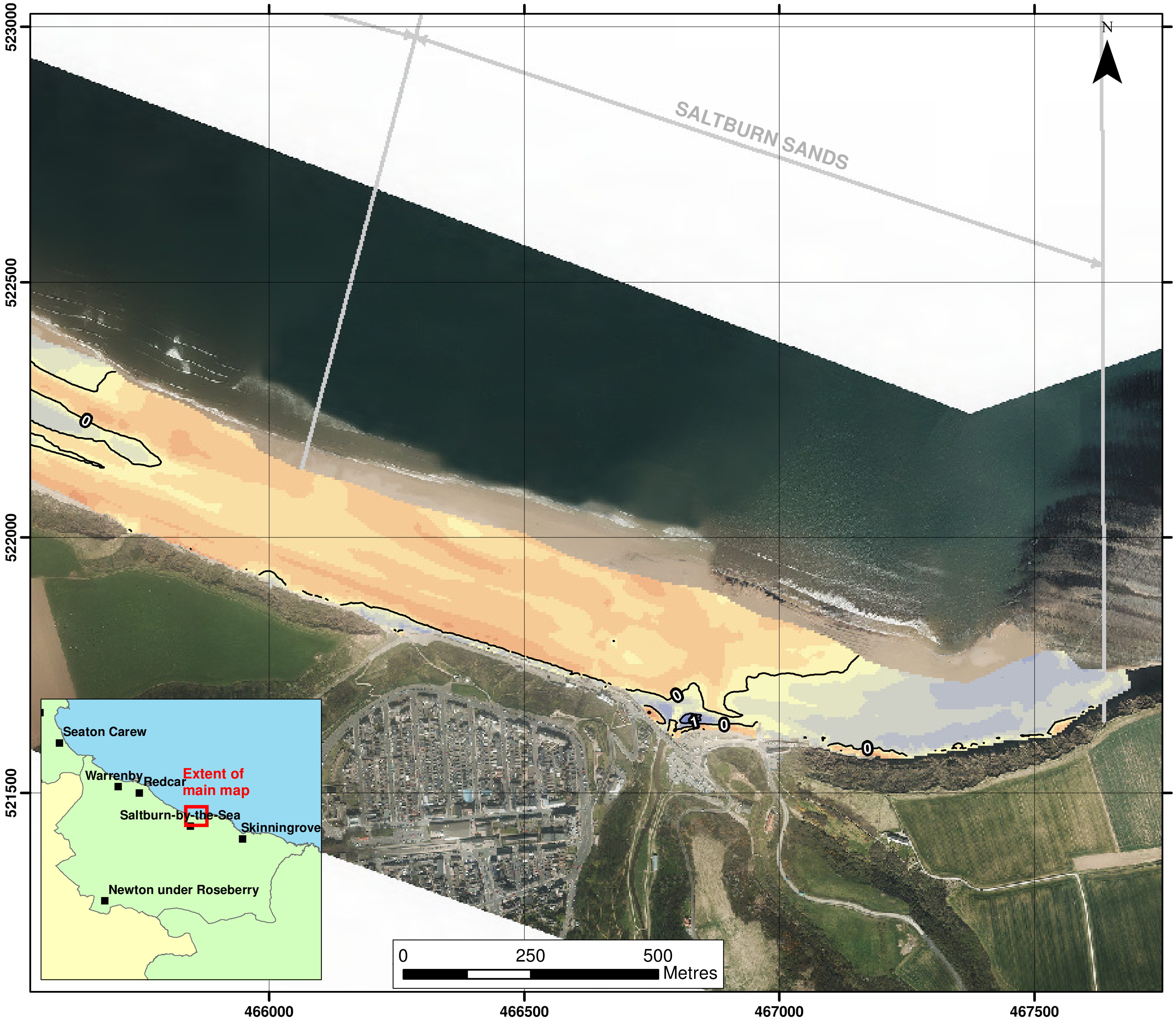

KEY Autumn 2008 and Autumn 2015
Change in elevation (m)

- <-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 4c
Long-term Elevation Change Saltburn Sands Redcar & Cleveland Borough Council

Analytical Report 8
Full Measures Survey
Autumn 2015

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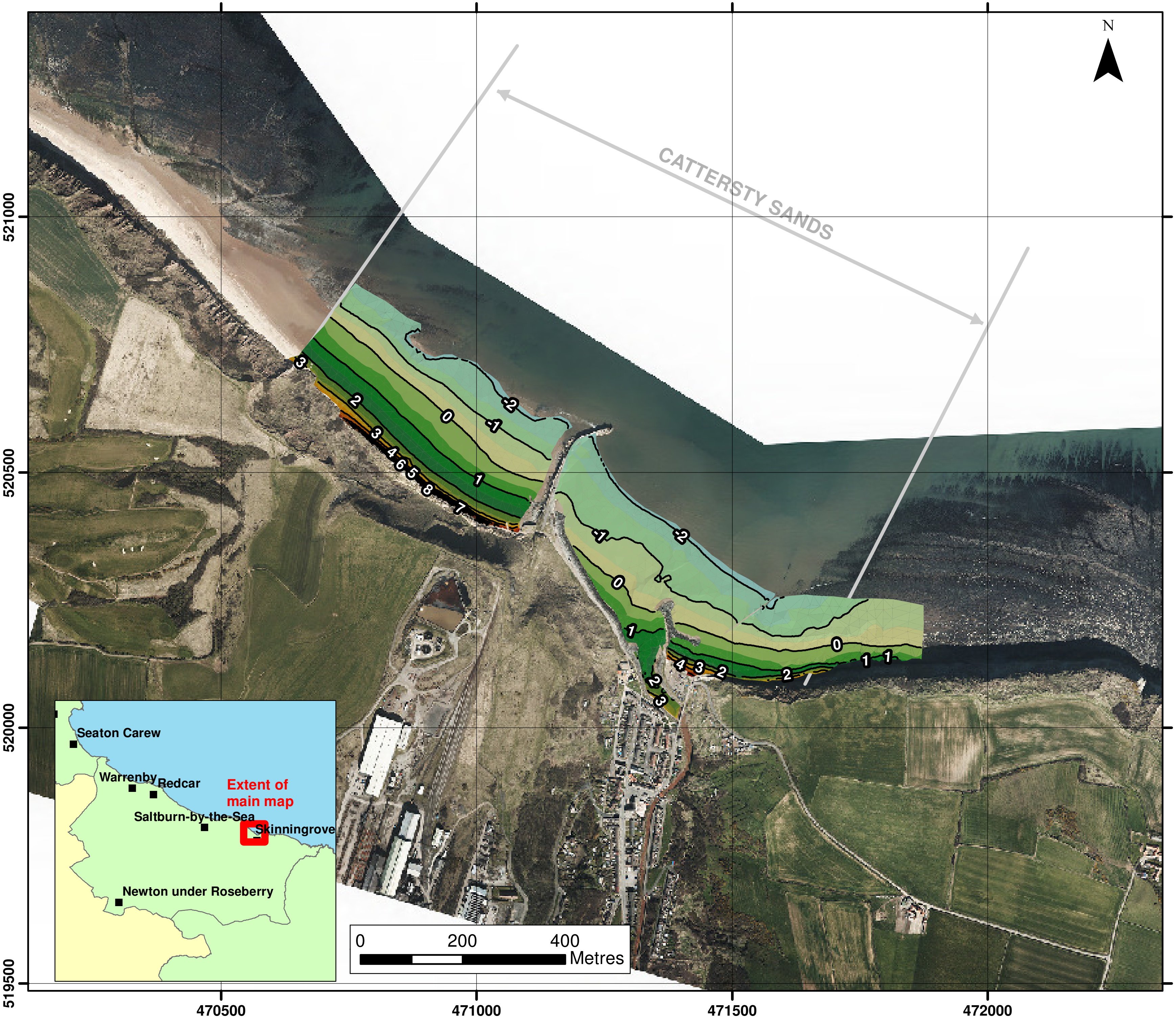

KEY

Elevation (m OD)

11 - 11.5	4 - 4.5
10.5 - 11	3.5 - 4
10 - 10.5	3 - 3.5
9.5 - 10	2.5 - 3
9 - 9.5	2 - 2.5
8.5 - 9	1.5 - 2
8 - 8.5	1 - 1.5
7.5 - 8	0.5 - 1
7 - 7.5	0 - 0.5
6.5 - 7	-0.5 - 0
6 - 6.5	-1 - -0.5
5.5 - 6	-1.5 - -1
5 - 5.5	-2 - -1.5
4.5 - 5	-2.5 - -2

Contour 1m

Client: North East Coastal Group

Project: Cell 1 Regional Coastal Monitoring Programme 2011 to 2016

Appendix B- Map 5a
Topographic Survey
Cattersty Sands
Redcar & Cleveland Borough Council

Analytical Report 8
Fulll Measures Survey
Autumn 2015

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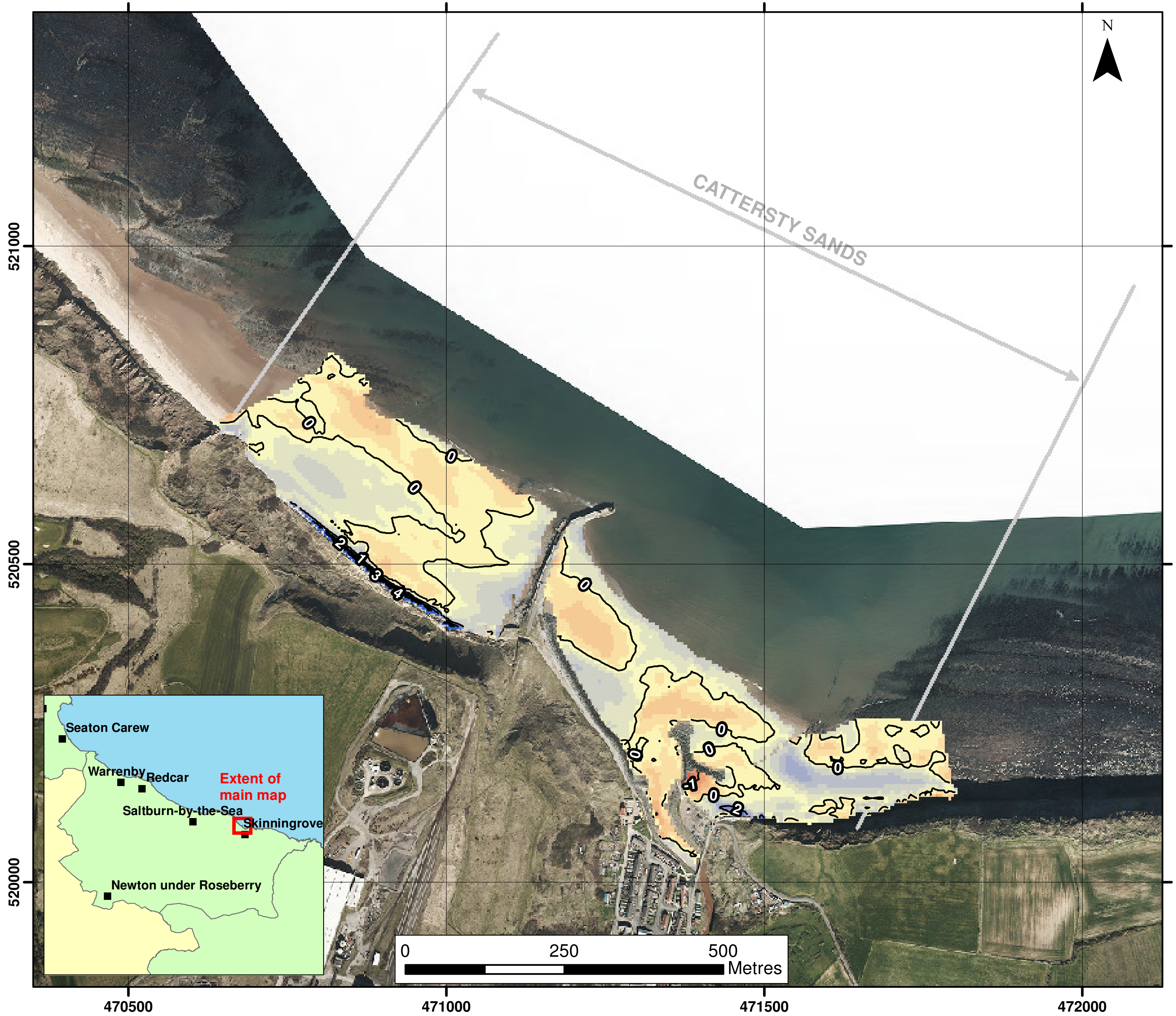

KEY Spring 15 and Autumn 15
Change in elevation (m)

<-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 5b
Short-term Elevation Change
Cattersty Sands
Redcar & Cleveland Borough Council

Analytical Report 8
Full Measures Survey
Autumn 2015

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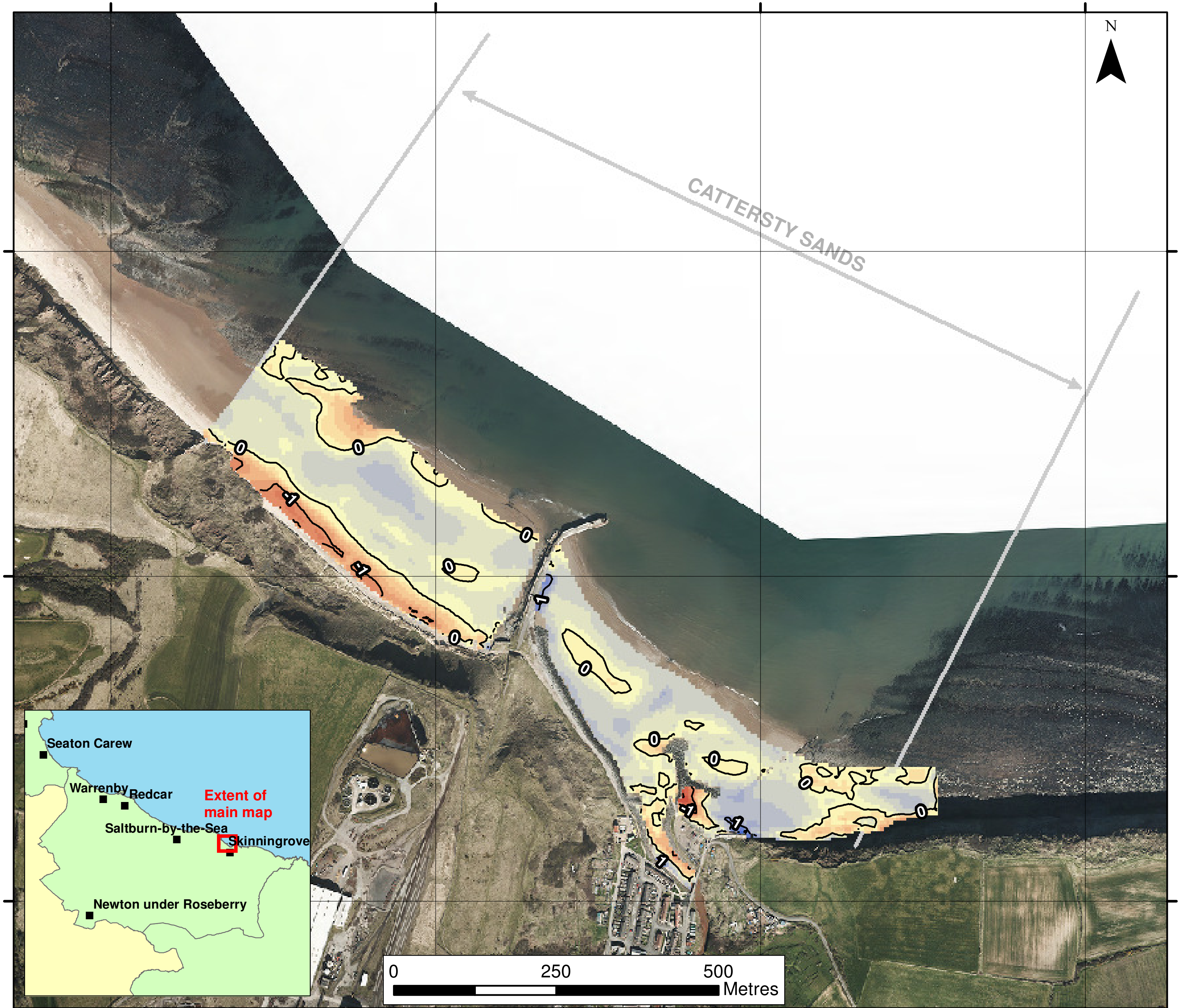

KEY Autumn 2008 and Autumn 15
Change in elevation (m)

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 5c
Long-term Elevation Change Cattersty Sands Redcar & Cleveland Borough Council

Analytical Report 8
Full Measures Survey
Autumn 2015

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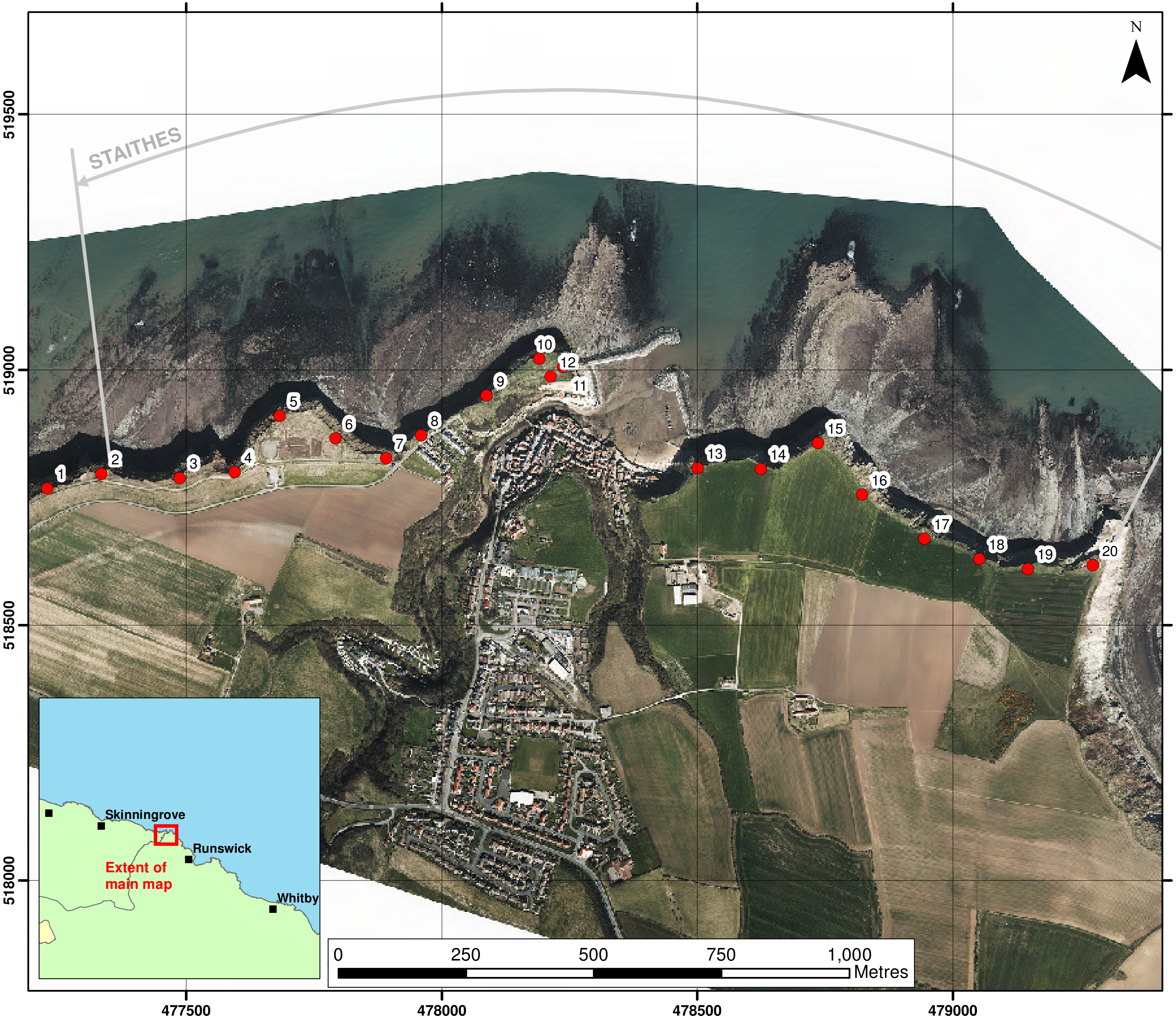
Appendix C

Cliff Top Survey



KEY

Ground Control Points

Client: North East Coastal Group

Project: Cell 1 Regional Coastal Monitoring Programme 2011 to 2016

Appendix C - Map 1
Ground Control Points
Staithes
Redcar & Cleveland Borough Council

Analytical Report 8
Full Measures Survey
Autumn 2015

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Cliff Top Survey

Staithes

Twenty ground control points have been established within Staithes (Figure C1). The maximum separation between any two points is nominally 100m.

The cliff top surveys at Staithes are undertaken bi-annually. Measurements are taken from a fixed ground control point along a fixed bearing to the edge of the cliff top.

Table C1 provides baseline information about these ground control points and results from the 2008 (baseline) survey showing the position from the ground control point to the edge of the cliff top along the defined bearing. Future reports will show results from subsequent surveys and provide a means of assessing erosion since the baseline survey.

Table C1 – Cliff Top Surveys at Staithes

Ground Control Point Details				Distance to Cliff Top (m)			Total Erosion (m)		Erosion Rate (m/year)
Ref	Easting	Northing	Bearing (º)	Baseline Survey (Nov 2008)	Previous Survey (Mar 2015)	Present Survey (Sept 2015)	Baseline (Nov 2008) to Present (Sept 2015)	Previous (Mar 2015) to Present (Sept 2015)	Baseline (Nov 2008) to Present (Sept 2015)
1	477228	518769	320	1.9	1.6	1.6	-0.3	0.0	0.0
2	477334	518798	0	10.9	10.8	10.7	-0.2	-0.1	0.0
3	477487	518789	350	7.1	8.3	7.9	0.8	-0.4	0.1
4	477594	518801	340	5.9	5.1	5.2	-0.8	0.1	-0.1
5	477683	518911	350	8.4	8.5	8.2	-0.2	-0.3	0.0
6	477792	518867	30	8.6	8.5	8.5	-0.1	0.0	0.0
7	477891	518828	60	7.7	7.3	7.6	-0.1	0.3	0.0
8	477959	518873	350	8.7	9.8	9.7	1.0	-0.1	0.2
9	478088	518950	350	7.6	8.3	7.9	0.3	-0.4	0.0
10	478191	519023	340	8.4	8.8	8.8	0.4	0.0	0.1
11	478237	519007	60	6.9	6.7	6.7	-0.2	0.0	0.0

12	478213	518988	150	6.1	6.5	7.4	1.3	0.9	0.2
13	478501	518809	15	11.4	9.1	9.2	-2.2	0.1	-0.3
14	478624	518807	20	7.5	7.5	7.5	0.0	0.0	0.0
15	478737	518858	60	6.1	6.4	6.3	0.2	-0.1	0.0
16	478823	518757	60	8	8.8	8.6	0.6	-0.2	0.1
17	478944	518671	30	9.3	9.0	8.8	-0.5	-0.2	-0.1
18	479052	518630	20	9.2	9.4	8.7	-0.5	-0.8	-0.1
19	479147	518610	0	14.2	14.4	13.8	-0.4	-0.5	-0.1
20	479274	518618	20	11.4	11.4	11.0	-0.4	-0.4	-0.1

Note: It is assumed that the accuracy of cliff top monitoring using this technique is ±0.1m. Therefore observed changes have been altered by this amount prior to calculation of an erosion rate. Erosion rates are not calculated where the cliff line shows advance. This is likely to be the product of differing survey interpretation, and far less likely to be a toppling cliff edge.