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

A great place to live, work & play

Scarborough Council
Final Report

February 2016

Contents

Appendices

List of Figures

List of Tables

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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**
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
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**
1 in 200 year	3.88	3.93	3.93	4.04
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 northeast England 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.

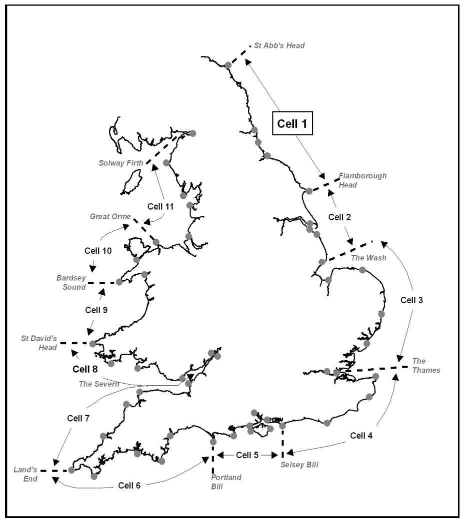


Figure 1 Sediment Cells in England and Wales

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 CH2M (formerly Halcrow).

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. A Cell 1 Overview Report is also produced regularly to provide 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	Sept 11	Aug 12	Mar-May 12	Feb 13	
5	2012/13	Sept 12	Mar 13	April-May 13	May 13	
6	2013/14	Sept 13	Feb 14	Mar-April 14	July 14	
7	2014/15	Sept 14	Feb 15	March 15	July 15	
8	2014/15	Sept 15	Feb 16 (*)			

(*) The present report is **Analytical Report 8** and provides an analysis of the autumn/winter 2015 Full Measures survey for Scarborough 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 Table 2. Areas covered in the current report are highlighted

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

Scarborough Borough Council's frontage extends from Staithes Harbour to Speeton, in Filey Bay. For the purposes of this report, the Scarborough frontage has been sub-divided into eight areas, namely:

- Staithes
- Runswick Bay
- Sandsend Beach, Upgang Beach and Whitby Sands
- Robin Hood's Bay
- Scarborough North Bay
- Scarborough South Bay
- Cayton Bay
- Filey Bay

1.2 Methodology

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

- Full Measures survey annually each autumn/early winter comprising:
    - Beach profile surveys along 20 transect lines
    - Topographic survey at Runswick Bay
    - Topographic survey along the Sandsend to Whitby frontage
    - Topographic survey at Robin Hood's Bay
    - Topographic survey at Scarborough North Bay
    - Topographic survey at Scarborough South Bay
    - Topographic survey at Cayton Bay
    - Topographic survey at Filey Bay

- Partial Measures survey annually each spring comprising:
    - Beach profile surveys along 20 transect lines
    - Topographic survey at Runswick Bay
    - Topographic survey at Robin Hood's Bay
    - Topographic survey at Filey Bay (Town coverage)

- Cliff top survey bi-annually at:
    - Staithes
    - Robin Hood's Bay (added Spring 2010)
    - Scarborough South Bay (added Spring 2010)
    - Cayton Bay
    - Filey

The location of these surveys is shown in Figure 2. Full Measures surveys were undertaken along this frontage between 14th September 2015 and 12th November 2015. The weather and sea state varied greatly in that time, for details of the survey conditions refer to the Academy Geomatics survey reports for each location. Information on wave monitoring that occurred over the analysis period are provided in Section 2 of this report.

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.
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.

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

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, just before the 2015 Full Measures survey data were collected.

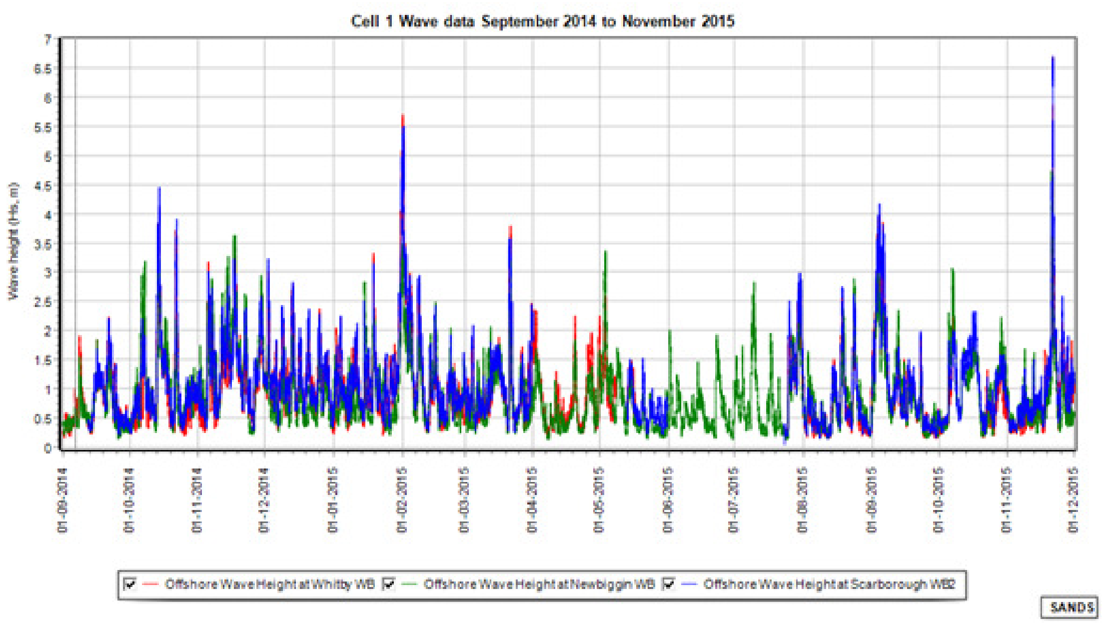


Figure 3 Wave monitoring data from the three Cell 1 wave buoys

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

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)**
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
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 beach profiles were taken before the storms, particularly Runswick, Robin Hoods Bay and Filey and as a result there was erosion at these beaches.

2.3 Wave data for the Scarborough Frontage

There are two local buoys on the Scarborough Borough Council frontage, at Whitby and Scarborough that were deployed in January 2013. Analysed storm data for these two buoys is presented in Tables 5 and 6.

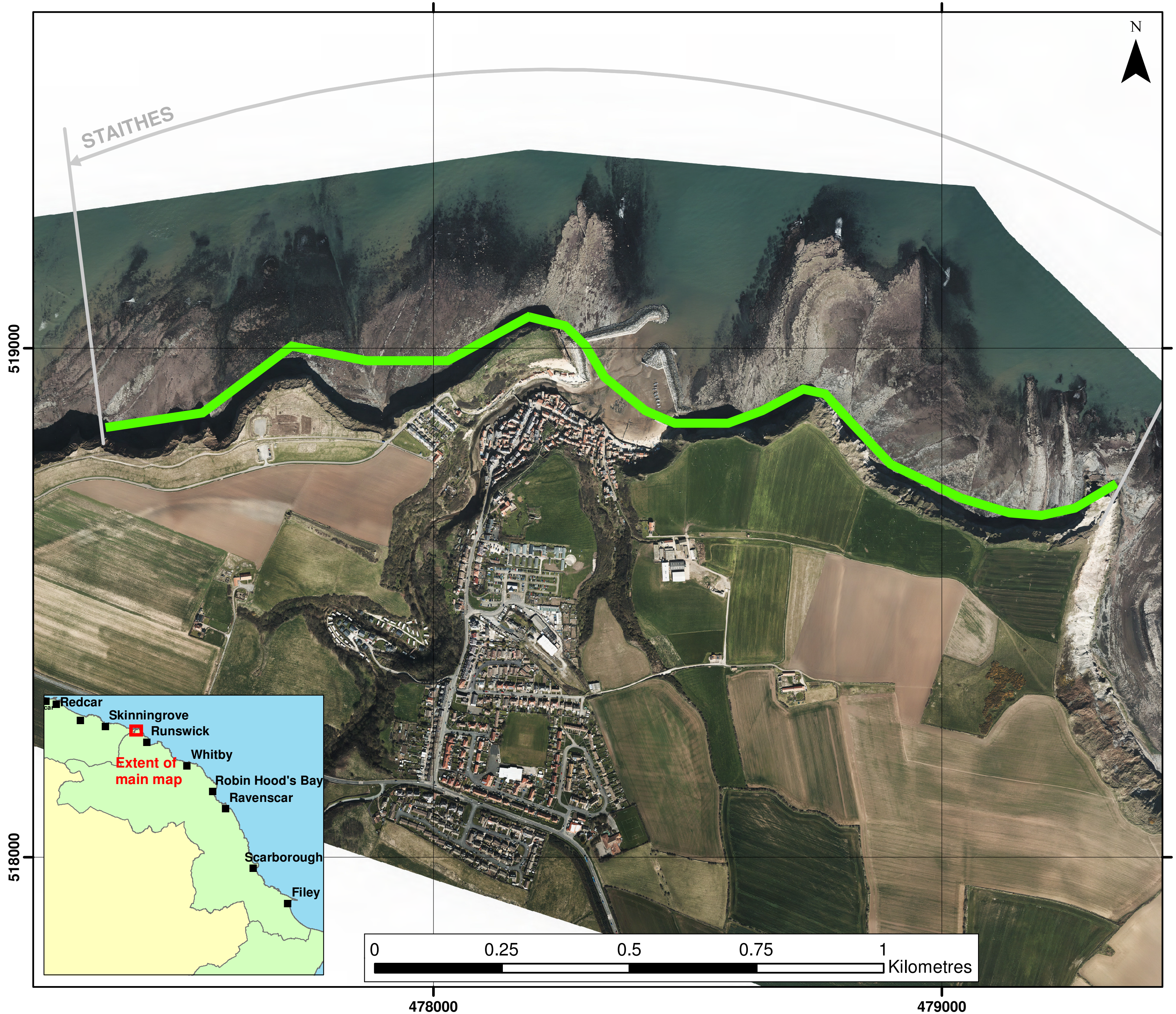
Overall the data for the storms recorded at Scarborough and Whitby are comparable in terms of wave height, period and energy. The highest energy storm recorded at Whitby was the 5th and 6th of December 2013 storm. The second most severe storm at Whitby in terms of wave height and energy was on the 10th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

Table 5: Storm analysis for Whitby WB (data 17/01/2013 to 30/11/2015)

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	21/01/13 14:30	64	38	26.7	5.0	11.1	8.2	61	6.0 E+3	5.0 E+6
06/02/2013 11:00	07/02/2013 04:00	17.0	06/02/13 18:30	17	35	73.5	4.8	11.8	7.1	16	6.4 E+3	4.3 E+6
08/03/2013 03:30	11/03/2013 05:30	74.0	11/03/13 04:00	58	12	35.5	4.3	10.0	7.1	45	3.7 E+3	1.1 E+6
18/03/2013 18:30	24/03/2013 17:30	143.0	23/03/13 13:00	70	95	20.3	5.2	11.1	8.2	72	6.6 E+3	1.2 E+7
23/05/2013 21:00	**24/05/2013 12:30**	**15.5**	**24/05/13 00:00**	**20**	**27**	**70.3**	**5.8**	12.5	**8.3**	**24**	**1.0 E+4**	**5.0 E+6**
10/09/2013 14:00	10/09/2013 22:30	8.5	10/09/13 16:00	19	17	71.5	4.4	11.1	6.9	24	4.6 E+3	1.8 E+6
10/10/2013 01:30	11/10/2013 06:30	29.0	11/10/13 00:00	30	57	69.2	5.7	13.3	8.3	31	1.1 E+4	1.1 E+7
30/11/2013 00:00	30/11/2013 06:30	6.5	30/11/13 03:30	16	13	74.8	4.8	12.5	7.4	20	7.1 E+3	2.1 E+6
05/12/2013 20:00	06/12/2013 22:00	26.0	06/12/13 19:30	20	45	70.6	4.7	16.7	9.1	32	**1.2 E+4**	8.2 E+6
14/10/2014 04:30	**14/10/2014 05:30**	**1.0**	**14/10/14 05:30**	**52**	**2**	**40.3**	**4.1**	8.3	**6.5**	**53**	**2.3 E+3**	**1.2 E+5**
31/01/2015 10:30	01/02/2015 18:00	31.5	01/02/15 02:30	14	60	79.1	**5.7**	11.8	7.8	11	8.9 E+3	9.0 E+6
03/09/2015 18:30:00	04/09/2015 07:00:00	12.5	03/09/2015 18:30:00	26	3	64.9	3.9	10.5	6.5	27	3.3 E+3	2.6 E+5
21/11/2015 07:00:00	21/11/2015 15:30:00	8.5	21/11/2015 07:30:00	16	14	75.3	6.7	12.5	8.3	14	1.4 E+4	2.7 E+6

Table 6: Storm analysis for Scarborough WB (data 17/01/2013 to 30/11/2015)

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	11.1	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	11.1	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	11.8	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	11.8	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	10.0	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**	12.5	**8.0**	**21**	**1.1E+04**	**1.1E+07**
Data missing for 5th / 6th December 2013 storm as buoy was off station from 21st November 2013 until 17th December 2013												
14/10/2014 03:00	14/10/2014 06:00	3	14/10/2014 04:30	61	4	33	4.4	9.1	6.7	61	3.2E+03	3.2E+05
31/01/2015 14:30	01/02/2015 18:30	28	31/01/15 23:30	20	57	76.74	4.8	13.3	7.5	25	8.0 E+3	8.2 E+6
Large gaps in data between April and July, 4th September 2015 storm had a max Hs of 3.6m, and was below the 4.0m analysis threshold.												
21/11/2015 04:30:00	**21/11/2015 16:30:00**	**12**	**21/11/2015 09:30:00**	**11**	**22**	**79.6**	**6.2**	**11.8**	**8.0**	**11**	**1.1 E+4**	**4.2 E+6**



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 Staithes Scarborough Borough Council

Analytical Report 8
Full Measures Survey
Autumn 2015

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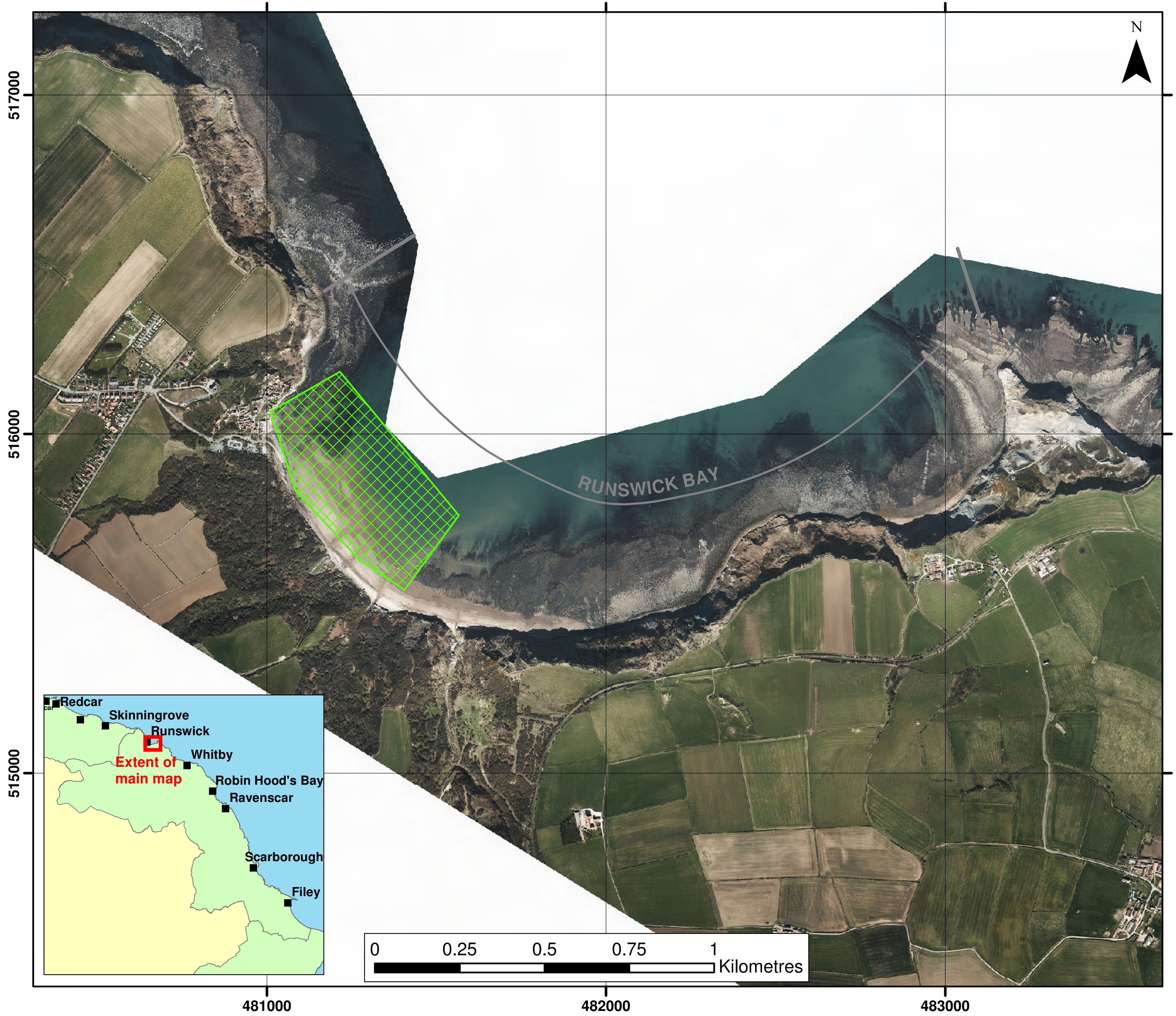

KEY

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 2
Survey Locations
Runswick Bay
Scarborough
Borough Council

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Full Measures Survey
Autumn 2015

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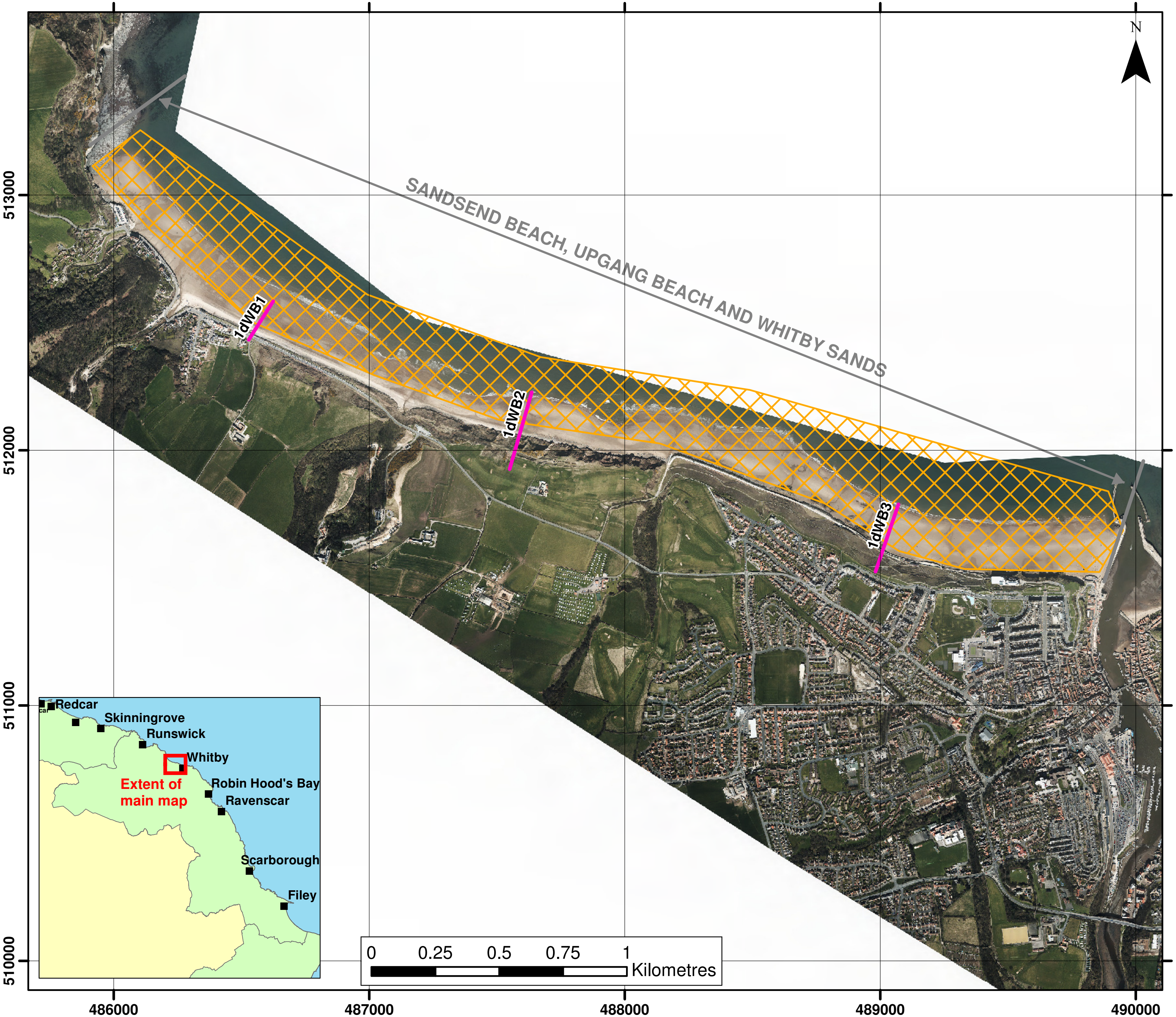

KEY

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 3 Survey Locations Sandsend to Whitby Scarborough Borough Council

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Partial Measures Survey
Autumn 2015

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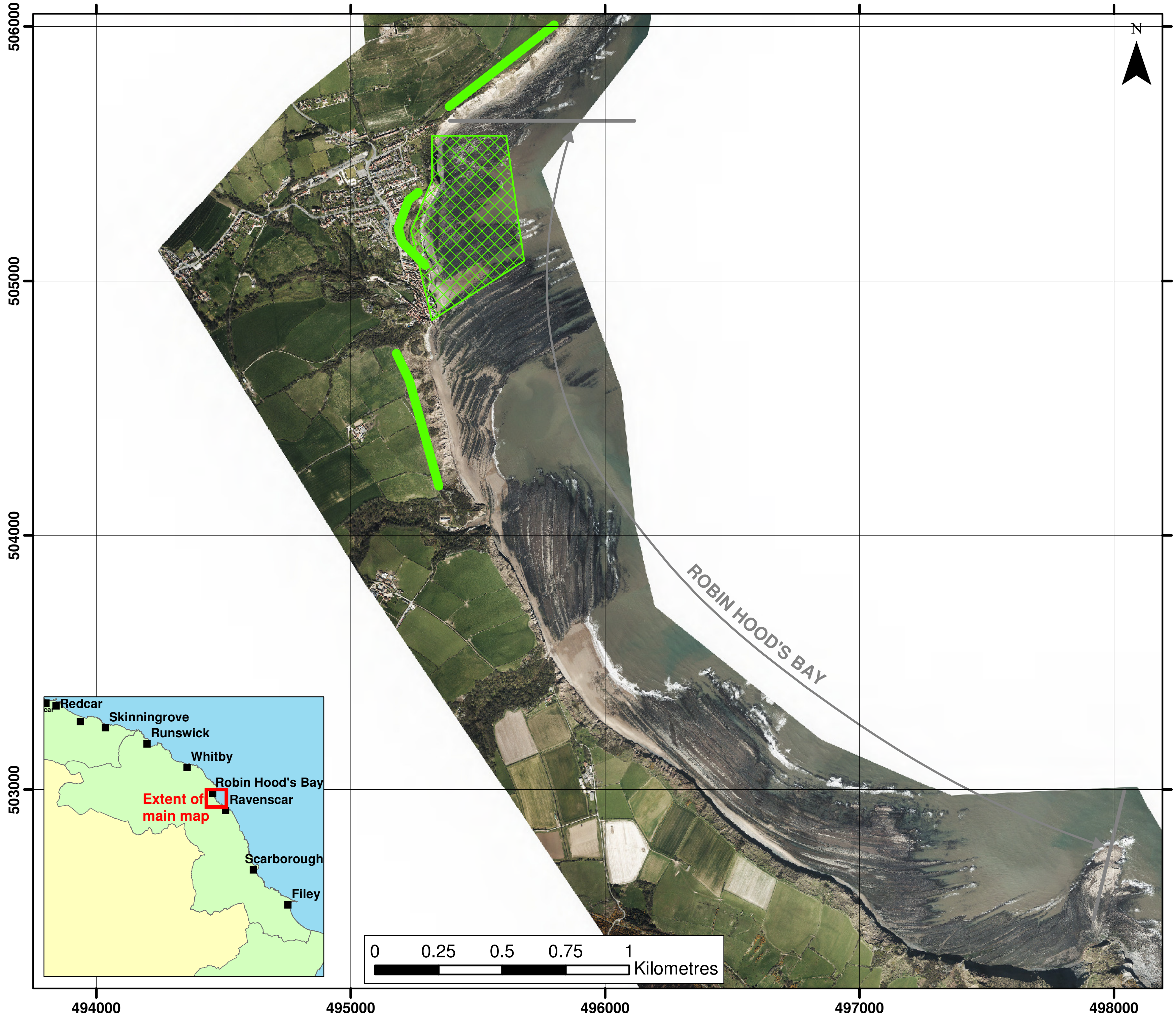

KEY

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
Robin Hood's Bay
Scarborough
Borough Council

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Full Measures Survey
Full 2015

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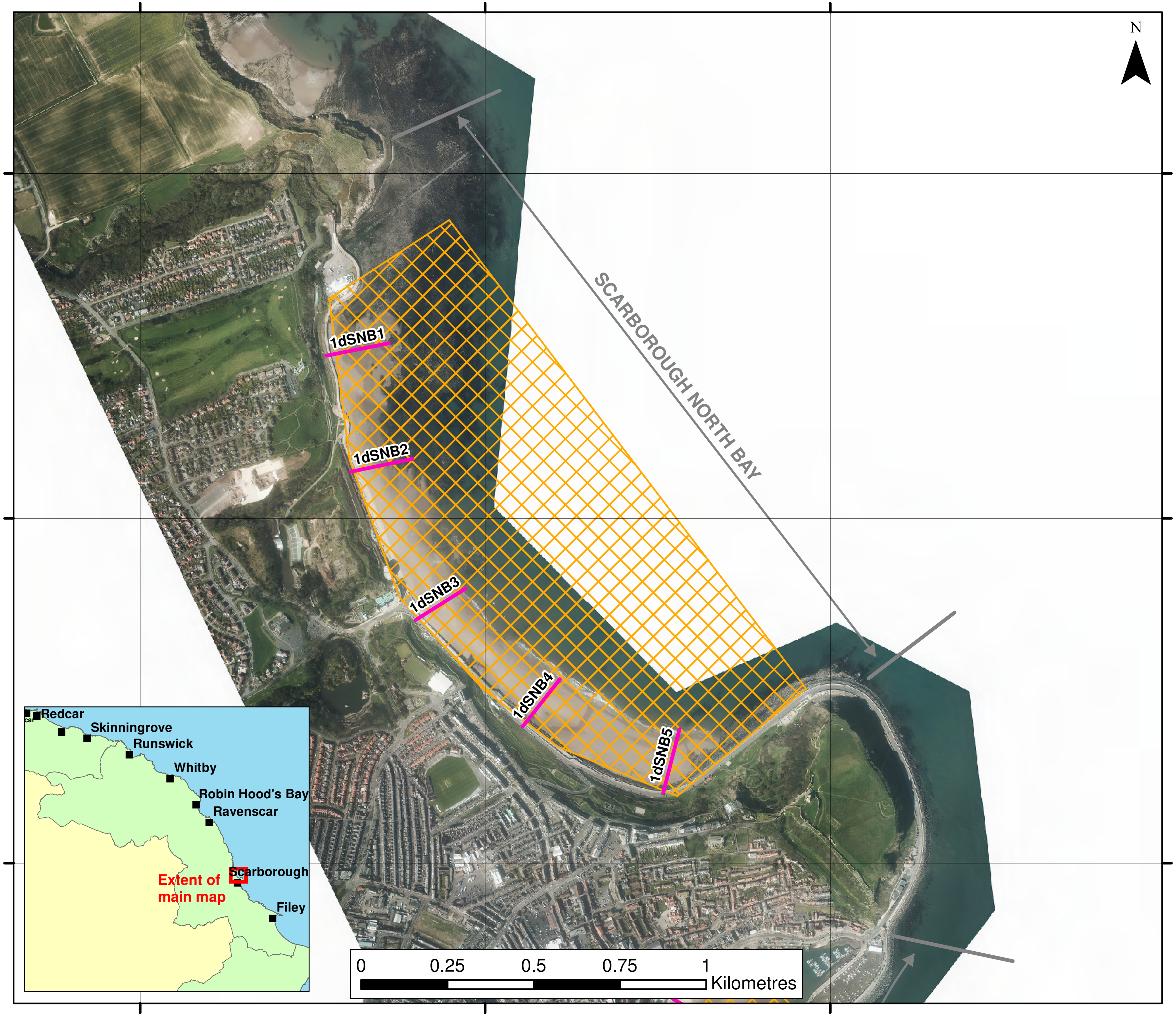

KEY

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
Scarborough North Bay
Scarborough
Borough Council

Analytical Report 8
Full Measures Survey
Autumn 2015

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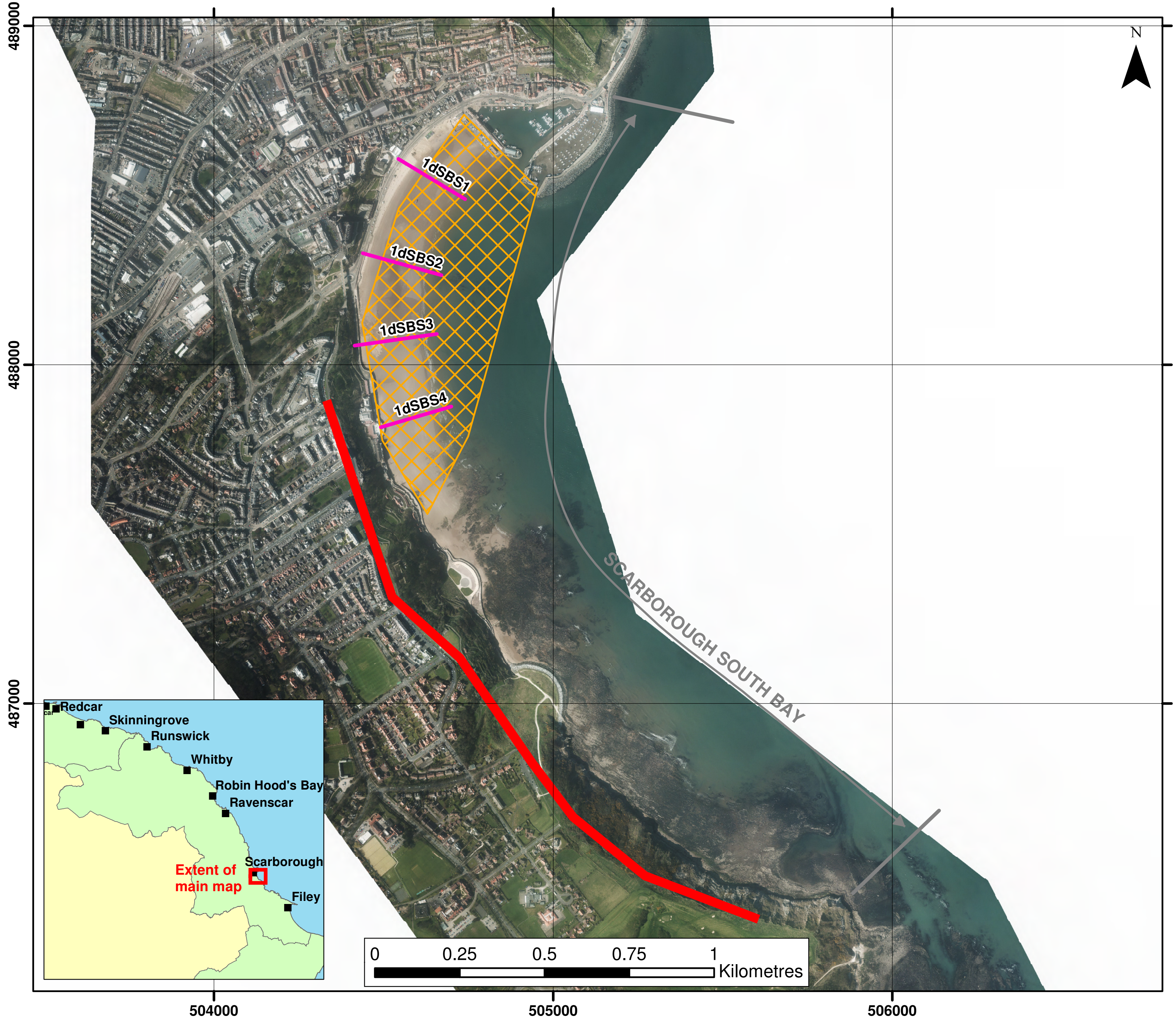

KEY

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
Scarborough South Bay
Scarborough
Borough Council

Analytical Report 8
Full Measures Survey
Autumn 2015

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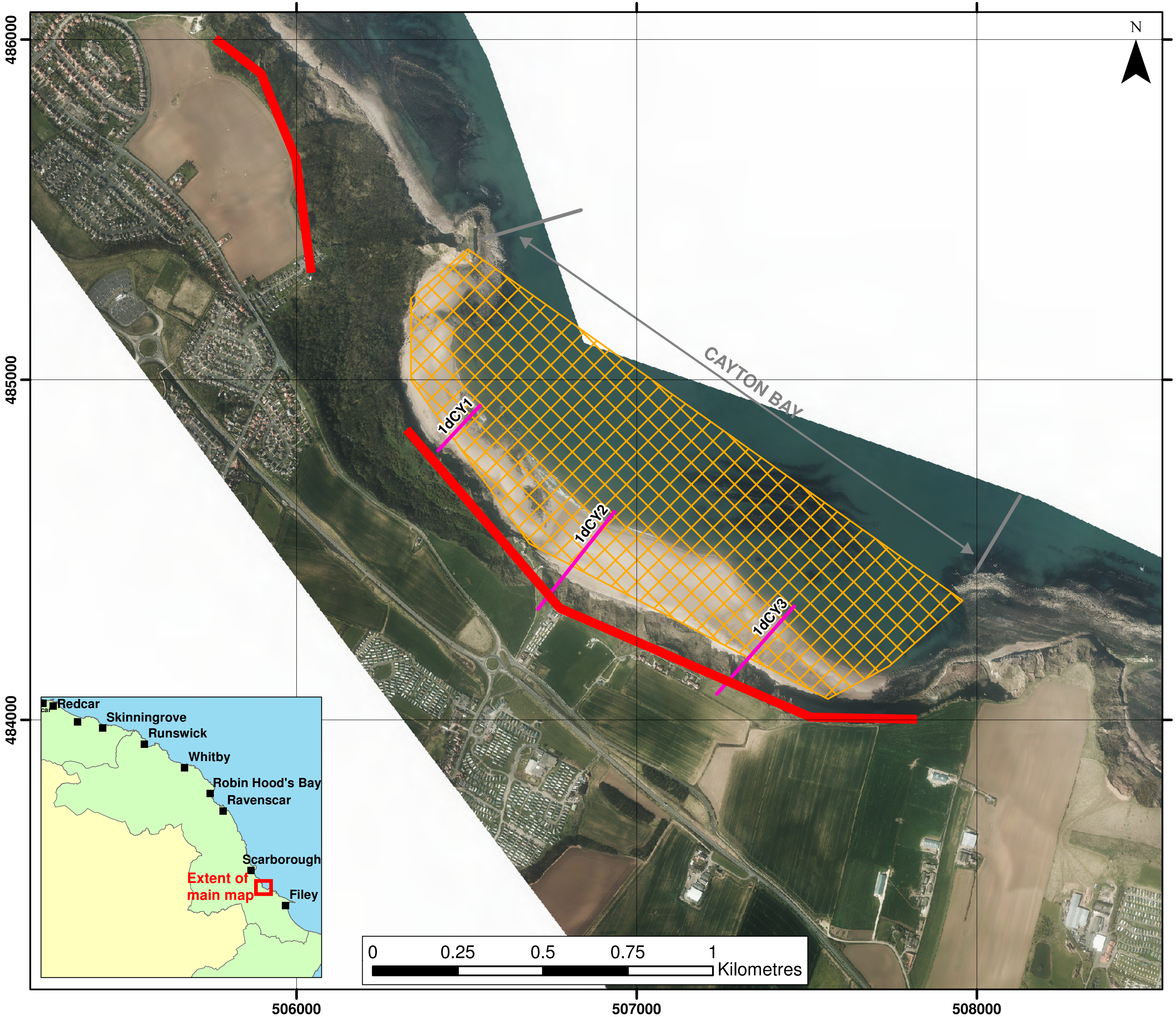

KEY

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 7
Survey Locations
Cayton Bay
Scarborough
Borough Council

Analytical Report 8
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Autumn 2015

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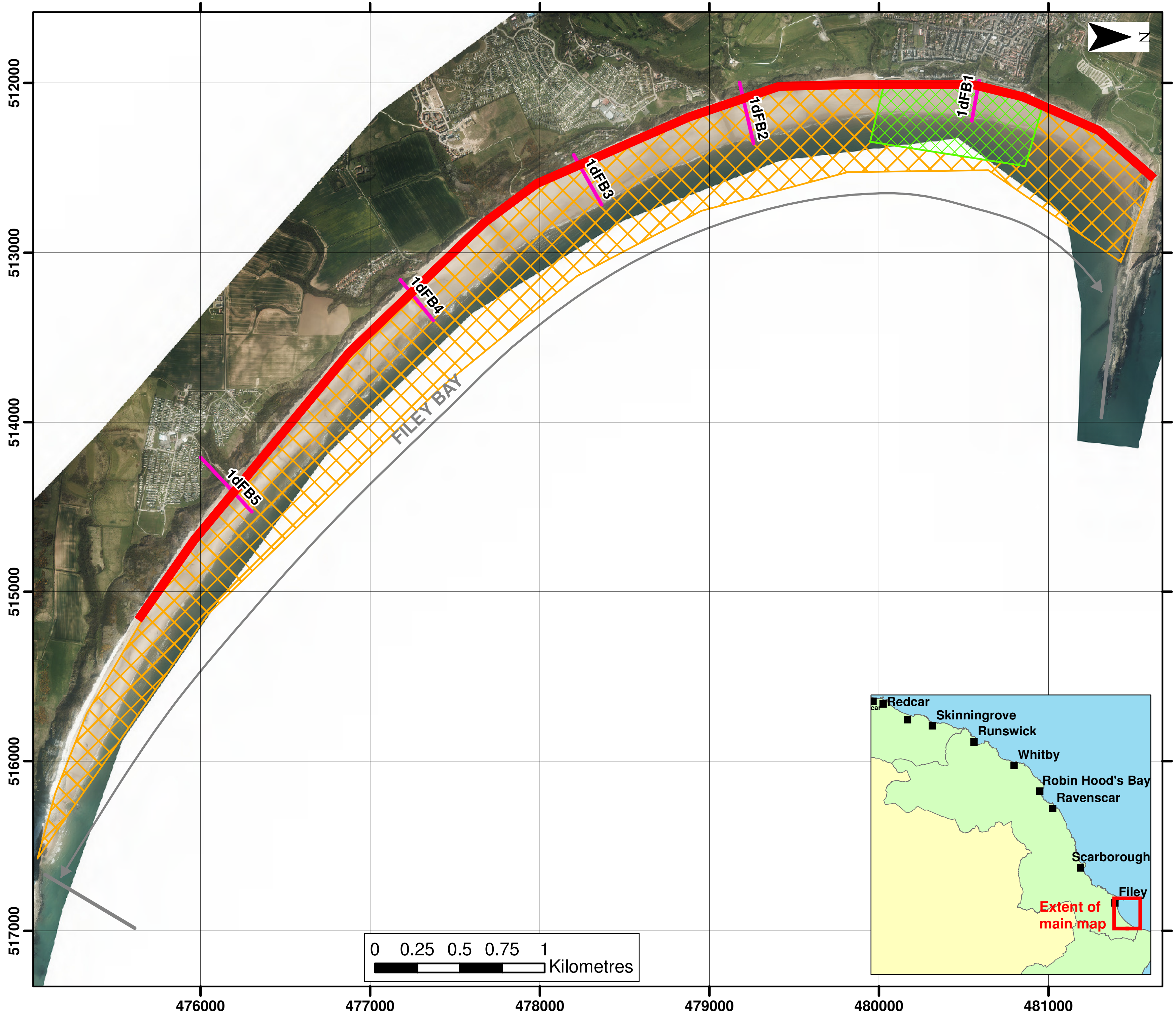

KEY

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 8
Survey Locations
Filey
Scarborough
Borough Council

Analytical Report 8
Full Measures Survey
Autumn 2015

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3. Analysis of Survey Data

3.1 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, with losses recorded at monitoring stations 17 to 20. However, site photographs do not support this evidence suggesting there may have been problems accurately recording the cliff edge. **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.

3.2 Runswick Bay

Survey Date	Description of Changes Since Last Survey	Interpretation
14th Sept 2015	**Topographic Survey:** Runswick Bay is covered by a 6-monthly topographic survey. A consistently applied GIS processing routine has been used to create a digital ground model (DGM) (Appendix B - Map 1a) and to calculate the differences between the current topographic survey (Autumn 2015) and the previous survey (Spring 2015) to highlight areas and amounts of erosion and deposition. In all cases, a 5m resolution raster grid has been used to identify areas of erosion and accretion. (Appendix B – Map 1b). Appendix B - Map 1b shows shore parallel bands of change on the beach at Runswick Bay. In the north west there is predominantly accretion of around 0.5m. There was erosion of up to 0.75m in the centre and south east of the Runswick plot. The surveyor noted that large areas of shale bedrock were exposed at the foot of the cliffs, which had previously been unseen. **Long Term Topographic Trends Autumn 2008 to Autumn 2015:** Appendix B - Map 1c shows a clear pattern of change with accretion of up to 1m in the centre of the bay, on the mid and lower beach. There were also areas of up to 1m of erosion on the upper beach, particularly in front of the village. In the centre of the bay there is an area of zero change over the rocks.	Between March and September 2015 Runswick Bay showed a mixed pattern of erosion and accretion in two to three shore parallel bands which show modest change of less than ±0.75m. **Longer term trends**: The changes in the bay have been no more than ±0.75m, but the pattern of erosion in front of the village has continued in 2015. **Autumn 2008 to Autumn 2015 trends:** The long term difference plots show a clear zone of accretion in the centre of the bay and erosion in the upper beach. In the northern part of the bay, fronting the northern end of the village, there has been up to 1m of erosion, which causes greater exposure of the sea defences.

3.3 Sandsend Beach, Upgang Beach and Whitby 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:

The frontage spanning Sandsend Beach, Upgang Beach, and Whitby Sands is covered by three beach profile lines, spaced between Sandsend and Whitby West Cliff (Appendix A).

Profile **1dWB1** was stable until 30m chainage. Between 30m and 40m chainage the toe of the cliff had eroded by 0.2m. The upper beach has gained a high berm between 40m and 90m where 0.8m has accreted since March 2015. From 90m to 155m the beach level has dropped by up to 0.6m. The beach profile is high in the upper beach and in the middle of the range of profiles in the lower beach.

At **1dWB2** the profile to 140m chainage has not changed significantly. The beach between 140m and 170m chainage has accreted by 0.5m. From 170m to 230m chainage the beach has eroded by 0.5m as the upper beach has steepened since March 2015. The lower part of the beach from 230m to 280m chainage has changed little. Overall the beach is low compared with previous profiles.

At profile **1dWB3** fronting the stabilised face of Whitby West Cliff, no change has occurred as far as 90m chainage. At the bottom of the seawall at 90m chainage 1m has been gained since March 2015, the accretion continues to 160m chainage. Between 160m and 210m chainage there was 0.3m of erosion. From 210m to 270m chainage the beach has accreted by 0.5m. Overall the two berms have formed on the upper and lower beach.

</td><td rowspan="2">

The October 2015 profiles tended to be near the mid-point of the previous range but all have been subject to accretion on the upper beach.

The topographic difference plots show a complex spatial pattern. The areas of accretion and erosion are approximately the same, but the amount of erosion tends to be greater than accretion, suggesting overall beach erosion. The erosion at the back of the beach suggests reworking of cliff fall debris.

The cliffs of Upgang Beach in the central part of the study area are undefended and erosion provides an important source of material to the beach. It is likely that sediment released by erosion over the winter months is subsequently redistributed across the beach as migrating sand bars.

Longer term trends: the beach profiles show seasonal variation but no linear trend of accretion or erosion. The six-monthly topographic difference plots show similar patterns of accretion and erosion in the all surveys although the magnitude of change is modest.

Autumn 2008 to Autumn 2015 trends: The long term difference plot for the Whitby to Sandsend frontage shows accretion of up to 1m at the margins of the bay and erosion in the middle of the bay. The middle of the bay is also the focus of cliff erosion, and shows active mudslides. Fine grained sediment supplied by

</td></tr>
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Topographic Survey:

The Sandsend to Whitby frontage is covered by an annual topographic survey, providing continuous data for Sandsend Beach, Upgang Beach, and Whitby Sands. Data have been used to create a DGM (Appendix B – Maps 2a and 3a) using GIS.

The GIS has also been used to calculate the differences between the current topographic survey DGM (Autumn 2014) and the earlier topographic survey DGM (Autumn 2014), with 5m resolution raster grids (as shown in Appendix B – Maps 2b and 3b), to identify areas of erosion and accretion.

Appendix B – Maps 2b and 3b show a varied picture of erosion and accretion. There are four main areas which show differing behaviour on the plots. Between Sandsend and Whitby Golf Course there is

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Survey Date	Description of Changes Since Last Survey	Interpretation
	a pattern of erosion of up to 0.75m on the upper and lower beach, there was accretion of up to 1m on the mid beach and on the east of the plot. In front of the golf club there was up to 1m of erosion on the upper half of the beach and around 0.5m of accretion on the lower beach over 2015. The North-east facing section of frontage near west Whitby has eroded in the middle of the beach by around 0.5m there is also one area of 1m of erosion close to the toe of the cliff, the rest has remained reasonably stable with around 0.25m of accretion. The beach immediately east of West Pier has eroded by up to 0.75m, there was little change or accretion on the lower beach but this area has eroded overall. **Long Term Topographic Trends Autumn 2008 to Autumn 2015:** The long term difference plot shows accretion on each end of the bay, with around 1m gained at Sandsend and up to 0.5m on the beach in front of Whitby. In the centre of the bay, in front of the golf course, there has been erosion of around 1m. There is also an isolated area of 1m of loss in front of the Whitby defences.	mudslides will be lost offshore while coarser materials will transported to the east and western margins of the bay.

3.4 Robin Hood's Bay

Survey Date	Description of Changes Since Last Survey	Interpretation
18th Sept 2015	**Topographic Survey:** Robin Hood's Bay is covered by a six-monthly topographic survey. Data have been used to create a DGM (Appendix B - Map 4a) using GIS. The GIS has also been used to calculate the differences between the current topographic survey DGM (Autumn 2015) and the earlier topographic survey DGM (Spring 2015), with 5m resolution raster grids (as shown in Appendix B – Map 4b), to identify areas of erosion and accretion. Appendix B - Map 4b shows a very patchy distribution of areas of accretion and erosion over the summer of 2015. Accretion of around 0.5m was more common on the upper beach, while there was erosion of up to 0.75m in the lower beach and the rocks. The largest change was 1m of accretion at the toe of the undefended cliff in the centre of the bay. Overall, accretion is slightly more dominant and is up to 0.75m across the majority of the bay. However, there are also notable areas of erosion, most notably at Dungeon Hole where there is a linear strip of up to 1m erosion at the base of the cliffs. **Long Term Topographic Trends Autumn 2008 to Autumn 2015:** The plot of difference between 2008 and 2014 (Appendix B - Map 4c) shows a patchy distribution of accretion at the back of the beach and erosion towards MLW, but with no clear net change.	The topographic change plot shows erosion dominated the frontage over the summer of 2015. This atypical change probably relates to the severe storm in early September that lowered beach levels and eroded the cliff causing around 1m of material being deposited at the back of the beach. This material is likely to have been reworked by the next survey. Cliff top monitoring shows little or no erosion since March 2015. **Longer term trends:** The limited change recorded in Robin Hoods Bay is due to the resistant rock platforms and thin, patchy cover of sand. The change recorded in the topographic survey was mainly erosion, which may have been due to a storm in early September. The erosion of the cliff in the middle of the bay, which lead to the accretion of the beach by 1m, was not recorded by the cliff monitoring, suggesting failures of

Survey Date	Description of Changes Since Last Survey	Interpretation
	Cliff-top Survey: Thirteen ground control points have been established at Robin Hood's Bay since March 2010 to monitor cliff recession. The separation between any two points is around 200m. Table C2 shows that four locations showed erosion between March and September 2015, with markers 3, 10, 11 and 12 retreating by more than 0.1m. However, inspection of the survey photos indicates this is due to difficulty locating the cliff edge precisely as the break in slope is covered by vegetation. Using data recorded between March 2010 and November 2014, calculated erosion rates show little change in all markers except Marker 1 which shows recession of 0.7m/yr. However, this marker has showed very little change since March 2012.	the cliff face did not result in cliff top recession. **Autumn 2008 to Autumn 2015 trends** Although the long term plot shows patches of accretion and erosion over the past year, only limited change has been observed across much of the bay in the long term. This is because of the thin veneer beach and rocky foreshore. Accretion was recorded on the upper beach close to the northern limit of the survey.

3.5 Scarborough North Bay

Survey Date	Description of Changes Since Last Survey	Interpretation
26th Oct 2015	**Beach Profiles:** Scarborough North Bay is covered by five beach profile lines, distributed between the Sealife Centre at Scalby Mills and Clarence Gardens (Appendix A). Profile **1dSBN1** remains stable at the defended, upper part of the profile. From 10m to 30m chainage, minor accretion of 0.2m of material has occurred since March 2015. Between 30m to 120m chainage the beach is very similar to the March 2015 profile. From 120m to 180m chainage the beach level has increased by 0.8m infilling a low point in the March 2015 profile. Between 180 and 210m chainage the rocks at the bottom of the beach are exposed in both 2015 profiles. At **1dSBN2** the beach is characterised by a shifting berm in the profile, which can form on the upper or lower beach. In October 2015 much of the seawall at 10m chainage was visible as the upper beach level has dropped by 1m since March 2015. Between 10m and 50m chainage the beach level has dropped by around 0.6m. From 50m to 110m the beach level has risen by 0.7m as a lower beach berm has formed. From 110 to 17m the rocks at the bottom of the beach are exposed to the end of the survey. The beach at profile **1dSBN3** has experienced up to 1.2m erosion at the base of the seawall at 15m chainage since March 2015. At around 20m chainage there is a flat part of the profile which reflects the part of the beach at the bottom of the slipway that has tyre marks on in the photographs. From 20m to 70m chainage the beach has reduced by 0.6m chainage. Form 70m to 100m chainage there has been little variation in beach level. From 100m to 160m chainage the beach level has increased by 0.7m while the lower beach has accreted a berm. The profile at **1dSBN4** has accreted by 0.6m between 25m and 35m chainage since March 2014, to infill the trough at the base off the sea wall, which is a seasonal occurrence. Between 35m chainage and 60m the rocks at the top of the beach are exposed as they were in the March 2015 survey. From 60m to 110m chainage the top of the beach has remained stable with little change over summer 2015. From 110 to the end of the profile at 180m the beach level has increased by 0.4m where a low beach berm has formed.	Profiles SBN2, 3, 4 and 5 have gained berms on the lower beach while remaining stable in the mid beach since March 2015. The lower beach berms reflect beach building processes have dominated over the summer months The pattern of erosion on the upper parts of the beach and accretion in the centre of the beach indicates draw-down of sediment, which is more typical of winter months. This atypical response is probably related to a storm in early September that occurred prior to the survey in late October. **Longer term trends:** The observed trends in the topographic plots and beach profiles point to overall stability with seasonal fluctuations. **Autumn 2008 to Autumn 2015 trends:** The pattern of change suggests net accretion and transport of material northwards.

Survey Date	Description of Changes Since Last Survey	Interpretation
	On profile **1dSBN5** a small berm has accreted at the base of the seawall between 30m and 50m chainage. From 50m to 100m chainage the beach has remained stable since March 2015. Between 100m and 200m a berm has accreted on a lower beach due to an increase of 0.5m.	
	Topographic Survey: Scarborough North Bay is covered by an annual topographic survey. Data have been used to create a DGM (Appendix B - Map 5a (i)) with GIS. The GIS has also been used to calculate the differences between the current topographic survey DGM (Autumn 2015) and the earlier topographic survey DGM (Autumn 2014), with 5m resolution raster grids (as shown in Appendix B – Map 5b (i)), to identify areas of erosion and accretion. Appendix B - Map 5b shows three part of the beach. The southern third was subject to modest erosion of around 0.25 in the upper beach and a similar quantity of accretion on the lower beach. The central third of the bay had accretion of up to 1m through 2015. In the northern third of the bay the dominant process was erosion of up to 1m. **Long Term Topographic Trends Autumn 2008 to Autumn 2015:** The long term topographic plots in Appendix B – Map 5c shows accretion overall with the largest change of over 1m in the north of the bay and the centre where accretion was noted in 2015. There southern half of the bay also had accretion, but it was around 0.5m so less than in the north. There is one main area of erosion in the middle of the bay on the upper beach where 1m of material was lost.	

3.6 Scarborough South Bay

Survey Date	Description of Changes Since Last Survey	Interpretation
27th Oct 2015	**Beach Profiles:** Scarborough South Bay is monitored by four beach profiles, between the harbour in the north and the Spa Complex in the south (Appendix A). Sediment recycling took place in April 2015 to address an accumulation of sediment at the north end of the bay and very low beach levels in front of Scarborough Spa. As such, comparisons of short-term change are between May and September 2015. At profile **1dSBS1** up to 0.3m of sediment has accumulated against the sea wall from 15m to 25m chainage since May 2015. The upper beach between 25m and 70m chainage has remained the same between May and October 2015 although it was 0.2m higher than in September 2014. From 70m to 100m chainage the beach is 0.2m higher than in May 2015. From 100m to 170m chainage the beach level has dropped by up to 0.4m since May 2015 and 0.6m since September 2014. Between 170m and 200m chainage the October 2015 beach level is similar to the May 2015 and September 2014 profiles. The October profile is steep overall with a comparatively high upper beach and low lower beach. The beach at profile at **1dSBS2** has remained stable at the seawall and its toe. From 10m to 45m chainage the October 2015 profile is 0.1m higher than the May profile. Between 45m and 100m chainage the beach is up to 0.2m higher then September 2014 and 0.4m higher than May 2015. From 100m to 160m chainage the beach has changed little since September 2014 and May 2015. Between 160m and 180m chainage the beach level has dropped by 0.2m since May 2015. Overall the profile is steep with a high upper beach and a low lower beach. At profile **1dSBS3** the 0.3m material which was placed between 15m and 35m chainage in April had been removed by natural processes by October 2015. From 35m to 24m chainage there has been little change. Between 45m and 140m chainage the beach level is around 0.4m higher than the September 2014 and May 2015 profiles. From 140m to 160m chainage the beach level in May 2014 is very similar to October 2015. Between 160m and 190m the beach is similar to the May 2015 profile, and up to 0.5m higher than the September 2014 level. Overall the mid beach is comparatively high but the upper and lower beach are comparable with the previous profiles Profile **1dSBS4** shows erosion at the base of the seawall, between 5m and 25m chainage, where 0.8m	The level of the beach in the profiles is high compared to previous years. Much of the beach recycling material that had been placed in April 2015 had been moved by October 2015. The material is likely to have moved onto the mid beach where the profiles are high, which is reflected in the difference plot for May to October 2015. The short term change plot also shows variable erosion and accretion. The accumulation in the mid-beach is likely to be due to the action of constructive waves through the summer. The cliff top change markers have indicated negligible change at most locations markers, with, 0.1m loss recorded at three locations. However, photographs suggest this apparent change is likely to be due to survey error. **Longer term trends**: The beach was re-profiled in April 2015 as sediment was moved from near the harbour to the frontage of The Spa, but sediment is already being moved back towards the harbour. **Autumn 2008 to Autumn 2015 trends:** The long term difference plot shows erosion in the centre of the bay as material is apparently moved to the edges of the bay. However it is difficult to assess the long term trends because the beach is frequently re-profiled early in the summer.

<table>
<tr><th>Survey Date</th><th>Description of Changes Since Last Survey</th><th>Interpretation</th></tr>
<tr><td rowspan="3"></td><td>has been lost since September 2014 and May 2015. From 25m to 160m chainage the October profile is up to 0.3m higher than the September 2014 and May 2015 profiles. Between 160m chainage and the end of the profile at 210m the beach level has remained the same. Overall the profile is high compared to previous years, with the exception of the area directly fronting the seawall.</td><td rowspan="3">Table C3 shows that since March 2010 the majority of the cliff erosion profiles have shown negligible recession. Profiles 11 and 12 show erosion of 0.6 and 0.4 m/year respectively. These points are at the rear of a mudslide system which experiences periodic reactivation or headscarp collapse.</td></tr>
<tr><td>Topographic Survey:

Scarborough South Bay is covered by an annual topographic survey. Data have been used to create a DGM (Appendix B - Map 6a) using GIS. The GIS has also been used to calculate the differences between the current topographic survey DGM (Autumn 2015) and the earlier topographic survey DGM (after sediment recycling in May 2015), with 5m resolution raster grids (as shown in Appendix B – Map 6b), to identify areas of erosion and accretion.

Appendix B - Map 6b shows an almost continuous band of around 0.25m of accretion along the middle of the beach. The upper and lower beach had eroded by up to 0.5m

Long Term Topographic Trends Autumn 2008 to Autumn 2015:

The long term plot of change (Appendix B Map 6c) shows that Scarborough South Bay has erosion in the centre of the bay of up to 1m. The two ends of the bay have a patchy of accretion and erosion, with the upper beach having more accretion. The changes observed are not entirely natural because of the beach reprofiling works which are carried out each year to improve the amenity value of the beach. As a result the long term trends of the beach are obscured by the management approach.</td></tr>
<tr><td>Cliff-top Survey:

Thirteen ground control points have been established at Scarborough South Bay, extending from South Bay to Cayton Bay for the purposes of cliff top monitoring. The separation between any two points is around 300 m. The cliff top surveys at Scarborough South Bay are undertaken bi-annually. Data collection involves a distance offset measurement from the ground control point to the cliff edge along a fixed bearing.

Between March and October 2015 ten of the thirteen locations showed change of less than ±0.1m. Three markers, numbers 6, 8 and 10 all had erosion of 0.1m over the summer of 2015. The photographs show dense vegetation at the cliff edge, rather than a fresh failure.</td></tr>
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Survey Date	Description of Changes Since Last Survey	Interpretation
	The recession rates calculated for the period from March 2010 to October 2015 give a picture of the change over the longer term. Ten of the markers have a recession rate of less than 0.1m/yr. Marker 9 has a rate of 0.1m/yr while a larger change was observed at markers 11 and 12 have been a rate of 0.6m/yr and 0.4m/yr respectively. Appendix C provides results from the October 2015 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 March 2010 baseline survey. Short-term and long term average recession rates are also provided.	

3.7 Cayton Bay

Survey Date	Description of Changes Since Last Survey	Interpretation
12th Nov 2015	**Beach Profiles:** Cayton Bay is covered by three beach profile lines, distributed between Tenants' Cliff and the south of Cayton Sands (Appendix A). The surveyor noted that due to poor weather and equipment failure, the sections and VMPs were not measured on the same day (12/11/15) the topographical survey (28/10/15) was measured. The cliff face at profile **1dCY1** is vegetated and was difficult for the surveyors to access resulting in poor data in the top of the profile. In the rest of the profile, there was little change as far as 20m chainage between March and November 2015. From 20m to 80m chainage the beach level has dropped by up to 0.4m. Between 80m and 100m chainage a small berm has accreted with 0.1m rise in beach levels since March 2015. From 100m to the end of the survey at 140m the lower beach and rocky exposure have remained stable. Overall the profile November 2015 is among the highest recorded levels. The centre of cliff profile **1dCY2** could not be accessed, so there is low confidence in this part of the data. The survey indicates that there has been little change to 120m chainage. Three berms have accreted in the beach, from 120m to 190m chainage, between 190m and 270m change and from 270m to 340m chainage. The largest berm is on the upper beach 0.3m accretion, the mid berm saw 0.2m accretion while the lower beach berm had only accumulated 0.1m of material since March 2015. Overall the profile November 2015 is among the highest recorded levels. The centre of cliff profile **1dCY3** profile could also not be accessed, so there is low confidence in that part of the data. From 125m to 140m chainage the rocks which were exposed in the top of the beach have been covered by 0.4m of beach material. Between 140 and 190m chainage the beach has remained similar. From 190m to 290m the beach berm present in March 2015 has moved seawards, with the biggest change being a drop of 0.5m.	The beach profiles have been stable overall with evidence of the formation of beach berms. CY1 and CY2 are among the highest on record. The plot of difference between Autumn 2014 to Autumn 2015 surveys shows variability in the erosion and accretion in the bay. The main change was erosion on the upper beach. The cliff top survey data shows no change during the summer of 2015. **Longer term trends:** The pattern of migrating sand bars has remained consistent since 2010 indicating seasonal variation in beach level with no net change. **Autumn 2008 to Autumn 2015 trends:** The distribution of change on the long term difference plot reflects sediment redistribution northwards and rather than net erosion or accretion in the bay.
	Topographic Survey: Cayton Bay is covered by an annual topographic survey. Data have been used to create a DGM (Appendix B - Map 7a) using GIS. The GIS has also been used to calculate the differences between the	

Survey Date	Description of Changes Since Last Survey	Interpretation
	current topographic survey DGM (Autumn 2015) and the earlier topographic survey DGM (Autumn 2014), with 5m raster grids (as shown in Appendix B – Map 6b), to identify areas of erosion and accretion. Appendix B - Map 7b shows that the observed changes are weakly shore parallel. During 2015 there was erosion of around 0.5m at the top of the beach and accretion of up to 1m on the lower and mid-beach. The distribution is patchy so the patterns of change varies across the beach. **Long Term Topographic Trends Autumn 2008 to Autumn 2015:** The long term difference plot in Appendix B – Map 7c indicates that in the long term there has been more erosion at the distal ends of the bay (particularly of the northern limit of the survey and the foreshore in the south) and greater accretion in the centre and the north. The largest change was over 1m of accretion in the northern third of the beach, although there was also an isolated patch of 1m of erosion at the southern end of the bay.	
	Cliff-top Survey: Eight ground control points have been established within Cayton Bay for the purposes of cliff top monitoring. The separation between any two points is typically around 200 m. The cliff top surveys at Cayton Bay are undertaken bi-annually. Data collection involves a distance offset measurement from the ground control point to the cliff edge along a fixed bearing. The results of the cliff top survey are shown in Table C4. Between March and November 2015 seven of the eight profiles showed no discernible change (within the ±0.1m accuracy of the survey). Only marker 8 shows erosion, but the thick vegetation on this cliff means the result could be error. Long-term erosion rates calculated using data collected since November 2008 show change either within the margin of error or advance, indicating survey difficulties, at most points. Markers 2, 4 and 6 show erosion rates >0.1m per year. Appendix C provides results from the November 2015 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.	

3.8 Filey Bay

Survey Date	Description of Changes Since Last Survey	Interpretation
17th Sept 2015	**Beach Profiles:** Filey Bay is covered by five beach profiles between Filey Sands and Speeton Sands (Appendix A). At profile **1dFB1** fronting Filey seawall, the upper beach between 20m and 140m chainage has accreted uniformly by 0.1m. From 140m and 240m chainage there was little change since March 2015. The profile is among the highest recorded and is similar to the September 2014 and March 2015 profiles. The changes observed at profile **1dFB2** since March 2015 are very small. The main difference is the small berm which has developed between 140 and 230m chainage, with the accretion of 0.2m. The profile is among the highest recorded and is similar to the September 2014 and March 2015 profiles. At profile **1dFB3**, near Flat Cliffs, the March and September 2015 profiles are very similar, with a small berm forming between 110m and 280m chainage. Overall the profile similar to the September 2014 and March 2015 profiles and is among one of the highest recorded. Profile **1dFB4** at Hunmanby Gap, has remained stable overall since March 2015 with small changes on the profile. From 30m to 120m chainage the beach level has dropped by 0.2m. Between 120 and 170m chainage the beach level has increased by 0.2m. Between 170m and 220m chainage the beach has dropped by 0.3m. The largest difference is from 220m to 280m chainage where a lower beach berm has accreted by up to 0.8m over the summer of 2015. similar to the September 2014 and March 2015 profiles At profile **1dFB5** there has been little change to 240m chainage since March 2015. Overall the two berms on the beach profile has move seaward between March 2015 and September 2015. From 240m to 270m chainage the beach level has increased by 0.2m. Between 270m and 300m chainage the beach level has dropped by 0.3m From 300m to 340m chainage the beach level has increased by 0.9m. Between 340m to 400m chainage the beach level has dropped by 0.5m. From 400m to the end of the survey at 450m chainage the beach level has increased by 0.5m. The profile is in the mid-range of profiles previously recorded for this area and is a similar level to the September 2014 and March 2015 profiles.	Most of the profiles (FB1, 2, 3 and 4) show very little change since March 2015. The profiles are among the highest recorded for those locations. Profile FB5 also shows modest change with the two berms on the beach moving seaward. The topographic change map shows Filey Bay has shore parallel bands of accretion and erosion in the south and accretion in the north associated with migrating berms. The difference plot for Filey Town shows accretion of up to 0.5m in the upper beach and a similar amount of erosion in the lower beach. The cliff top survey data provided in Table C5 shows erosion at several monitoring points. The largest change was at marker 12 where 0.8m was lost over the summer of 2015. **Longer term trends**: Past trends dominated by migrating sand bars continue to the present day. **Autumn 2008 to Autumn 2015 trends:** The overall trend in Filey Bay over the last seven years is of erosion of up to 0.75 in the margins of the bay and accretion of up to 1m in the centre of the bay. The southern part of the bay, which shows net loss of sediment is closely associated with the area of wide and active mudsliding between Hunmanby and

Survey Date	Description of Changes Since Last Survey	Interpretation
	Topographic Survey (Filey Bay): Filey Bay is covered by an annual topographic survey. Data have been used to create a DGM (Appendix B - Maps 8a and 9a) using GIS. The GIS has also been used to calculate the differences between the current topographic survey DGM (Autumn 2015) and the earlier topographic survey DGM (Autumn 2014), with 5m resolution raster grids (as shown in Appendix B – Maps 8b, 9b and 10a) to identify areas of erosion and accretion. Appendix B - Map 8b and 9b shows the bay can be divided into two parts. In the northern half of the bay the change plot is dominated by up to 0.5m of accretion with limited erosion at the top of the each and also at the northern extent on the bottom of the beach. In the southern half of the bay there is a clear pattern of shore parallel bands with up to 1m of accretion common on the lower beach and erosion of around 0.5m on the upper beach. **Topographic Survey (Filey Town):** In addition to the annual survey of Filey Bay, a smaller area fronting Filey Town is re-surveyed every six months to document seasonal patterns. The GIS has been used to calculate the differences between the current (full measures) topographic survey DGM (Autumn 2015) and the earlier (partial measures) topographic survey DGM (spring 2015), with 5m resolution raster grids (as shown in Appendix B – Map 10a), to identify areas of erosion and accretion during the previous six months. Appendix B - Map 10a shows shore parallel strips of change throughout the survey area, with accretion on the upper beach and erosion on the lower beach. The changes observed are within a range of ±0.5m, although there was an isolated area where 1m was lost on the upper beach. **Long Term Topographic Trends Autumn 2008 to Autumn 2015:** The long term trends of change in Filey Bay are shown in Appendix B – Maps 8c and 9c. These show widespread accretion in the central half of the bay of up to 1m and erosion at each end. The erosion in the north of the bay is smaller and less severe at around 0.25m. The southern end has been subject to widespread erosion of up to 0.75m	Reighton. The pattern of more muted changes at Filey Sands indicates this area is more influenced by seasonal bar migrations than larger scale transfer of sediment throughout the bay.

Survey Date	Description of Changes Since Last Survey	Interpretation
	Filey Town Long Term Trends: The long term difference plot for the Filey town frontage is in Appendix B Map 10b. The plot shows stability overall. There was modest accretion of up to 0.5m on the upper half of the beach close to the defence. The most significant erosion, which was limited to 0.25m over the past seven years, was in the lower beach of the southern half of the plot.	
	Cliff-top Survey: Twenty-eight ground control points have been established within Filey Bay for the purposes of cliff top monitoring. This includes the installation of three additional locations in September 2010: points 12A (as a replacement for point 13 which can no longer be accessed due to vegetation growth), 24 & 25 (to the north of Filey Bay at Filey Brigg). A further replacement for monitoring point 13, 13A, has been added in 2014. The maximum separation between any two points is nominally 300 m. The cliff top surveys at Filey Bay are undertaken every six months. Data collection involves a distance offset measurement from the ground control point to the cliff edge along a fixed bearing. Between March and September 2015 ten of the ground control points showed recession of ≥0.1m. Two of the remaining points had shown apparent recession of -0.2. Marker 12 showed recession of 0.8m, the photograph also shows evidence of a recent failure. Long term rates of change show only six markers have erosion, with rates between 0.1m/yr and 0.9m/yr. The largest erosion rate recorded is at control point 5, to the south of the Filey Town defences. Appendix C provides results from the September 2015 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 baseline survey.	

4. Problems Encountered and Uncertainty in Analysis

Survey accuracy of beach/ cliff profiles

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 possible that a more reliable pattern of change will be determined over the longer term. However, in the short term, more reliable assessments of cliff recession can be derived from analysis of time-series remote sensing data. Under this programme a high quality baseline survey, comprising LiDAR and aerial photography, was collected in 2010, a repeat survey was completed in 2012/13 and a second repeat survey is planned for 2015. These data will be analysed to give more accurate information on the behaviour of the cliffs in a separate report. More accurate estimates of long term cliff top change would be possible by comparing results from the current programme to historical aerial photography over the last 50 years.

A previous survey station has been buried under a newly installed man made embankment at Staithes A new survey station 4 has been installed. At Robin Hoods Bay there was a large increase in VMP 5 due to deposited garden waste.

At Whitby profile 2 measured as far as possible, despite the unsafe, soft ground.

The sections and VMPs were not measured on the same day the topographical survey was measured at Cayton due to poor weather and equipment failure. The top of profile 1, the middle of profiles 2 and 3 couldn’t be measured due to the ground conditions.

At Filey the surveyor was unable to measure the start of profile 2 due to vegetation, the middle of profile 5 was not measured from chainage 63m to approx 206m, due to vegetation. The topographic survey shorter at south end of beach than usual, due to the contribution of poorer tide levels and shape of beach, leading to sand not being uncovered at low tide.

Cliff top erosion errors & data capture techniques

The cliff top surveys are in general assumed to have a limit of accuracy of ± 0.1m due to the techniques used and problems have been experienced in precisely locating the cliff edge, due to vegetation growth and the convex profile. Most profiles have now been monitored for six years, and a more reliable picture of change is now emerging that indicates very low rates of erosion, with only occasional and localised examples of erosion exceeding 0.5m/yr.

5. Recommendations for ‘Fine-tuning’ the Monitoring Programme

At Robin Hoods Bay there is a thin and narrow veneer beach over a rocky shore platform that is currently surveyed every six months. The shore platform dominates the behaviour of the bay and little change in the beach has been recorded since 2008. Therefore, the frequency of beach surveys could be reduced to an annual basis.

6. Conclusions and Areas of Concern

The following points have been observed:

- The measurements of the Cowbar and Staithes cliff top shows stability over the summer of 2015. There was a cluster of results indicating failure between Station 17 and 20 but the photographs show a stable cliff top so it is considered likely that there was no recession.
- At Runswick Bay the long term difference plot shows accretion of up to 1m in the centre of the bay, on the mid and lower beach. There were also areas of up to 1m of erosion on the upper beach, particularly in front of the village.
- At Sandsend Beach, Upgang Beach and Whitby Sands the long term topographic difference plots show accretion of up to 1m at the margins of the bay and erosion in the middle of the bay. The middle of the bay is also the focus of cliff erosion, and shows

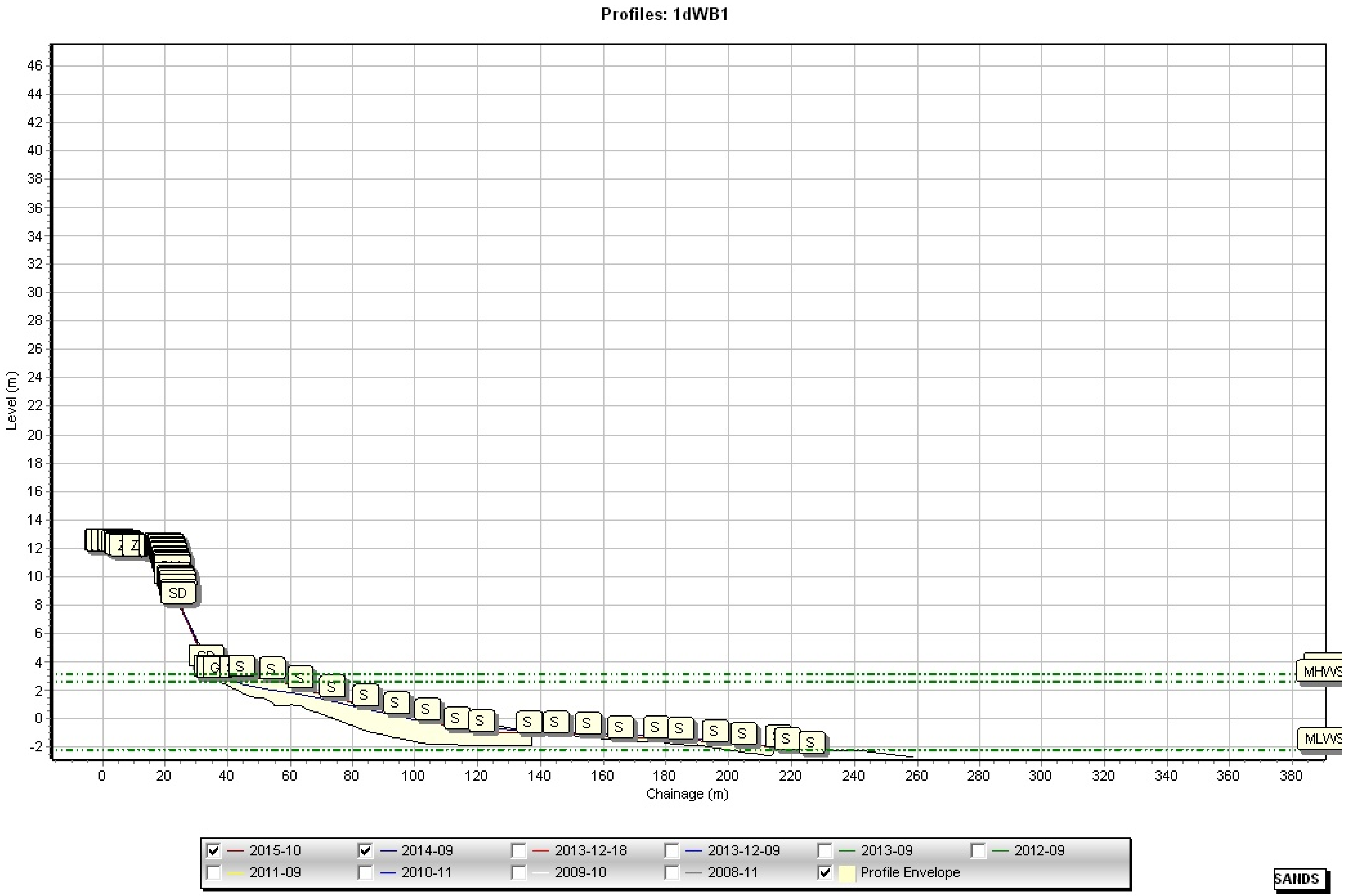
active mudslides. The sediment supplied by mudslides must either be lost offshore or transported to the east and western margins of the bay.

- At Robin Hoods Bay the topographic change plots show that the Bay as a whole appears to have been subject to slight accretion. There was apparent accretion in the centre of the bay where material from the cliff had fallen onto the beach. The long term difference plot shows very little change. No discernible change is has been registered by the cliff top markers and only one cliff recession marker shows substantial change in the long term record, and the majority of this change occurred in 2011.
- For Scarborough North Bay the beach profiles show stability in the mid beach and accretion of a lower beach berm. The short term difference plot shows that the pattern of erosion on the upper parts of the beach and accretion in the centre of the bay. The pattern which emerges over the long term is accretion in the north and erosion in the south, which is likely due to be due to northward sediment transport.
- At Scarborough South Bay the beach profiles are high compared to the previous profiles, especially in the mid beach, which also shows accretion in the short term difference plots. The long term difference plot shows erosion in the centre of the bay, particularly in front of the seawall, although this pattern may not be entirely natural due to the annual reprofiling of the beach.
- The Cayton Bay beach profiles show stability overall with evidence of the formation of beach berms. The pattern of migrating sand bars has remained consistent since 2010 indicating seasonal variation in beach level with no net change. The cliff monitoring showed no erosion.
- The profiles at Filey Bay show stability overall. Most of the profiles (FB1, 2, 3 and 4) show very little change since March 2015. The profiles are among the highest recorded for those locations. Profile FB5 shows modest change with the two berms on the beach moving seaward. The long term difference plot shows accretion in the central half of the bay with erosion at the ends. In the south the area of erosion is associated with the most active landsliding.

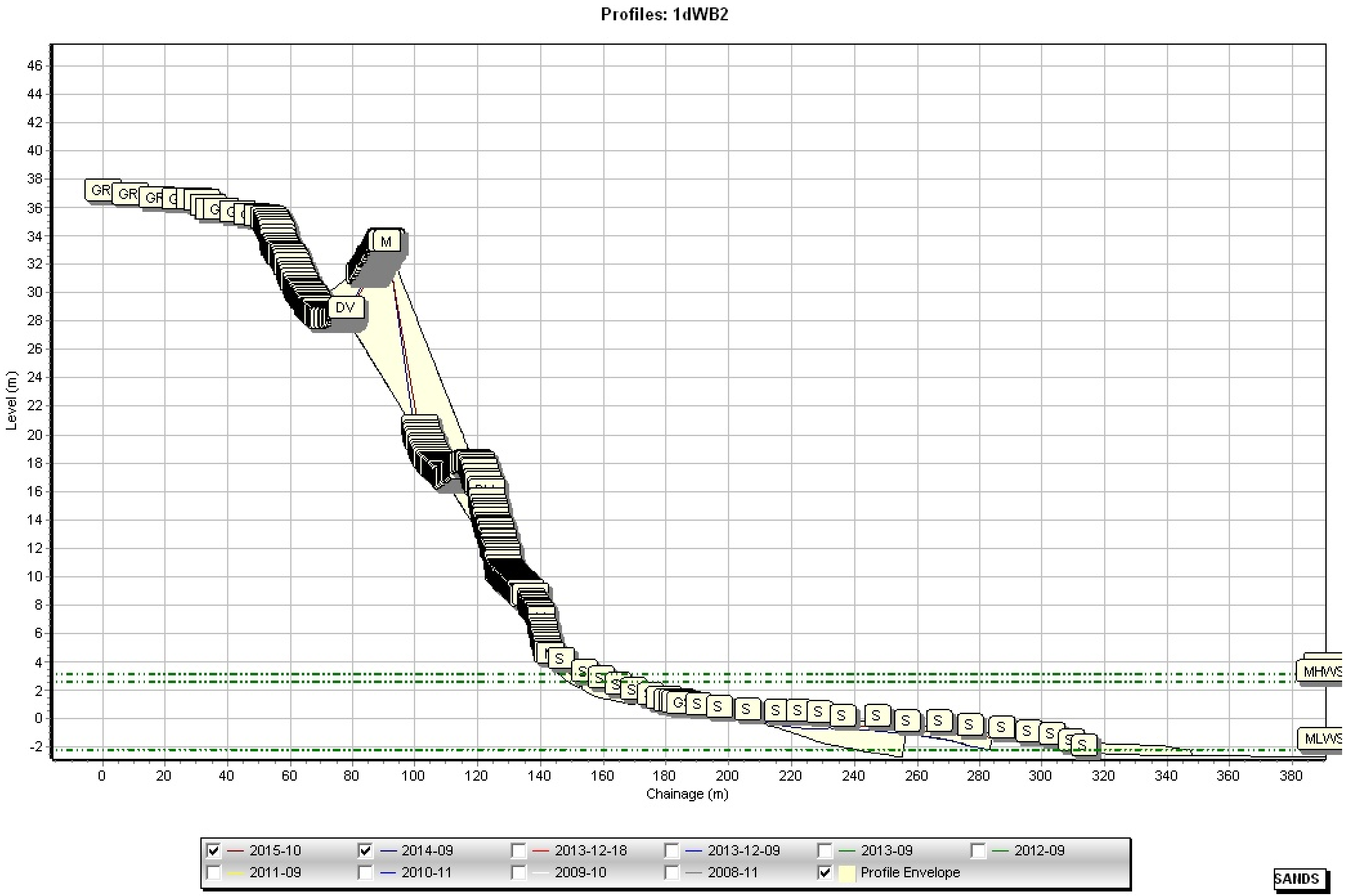
Appendices

Appendix A

Beach Profiles

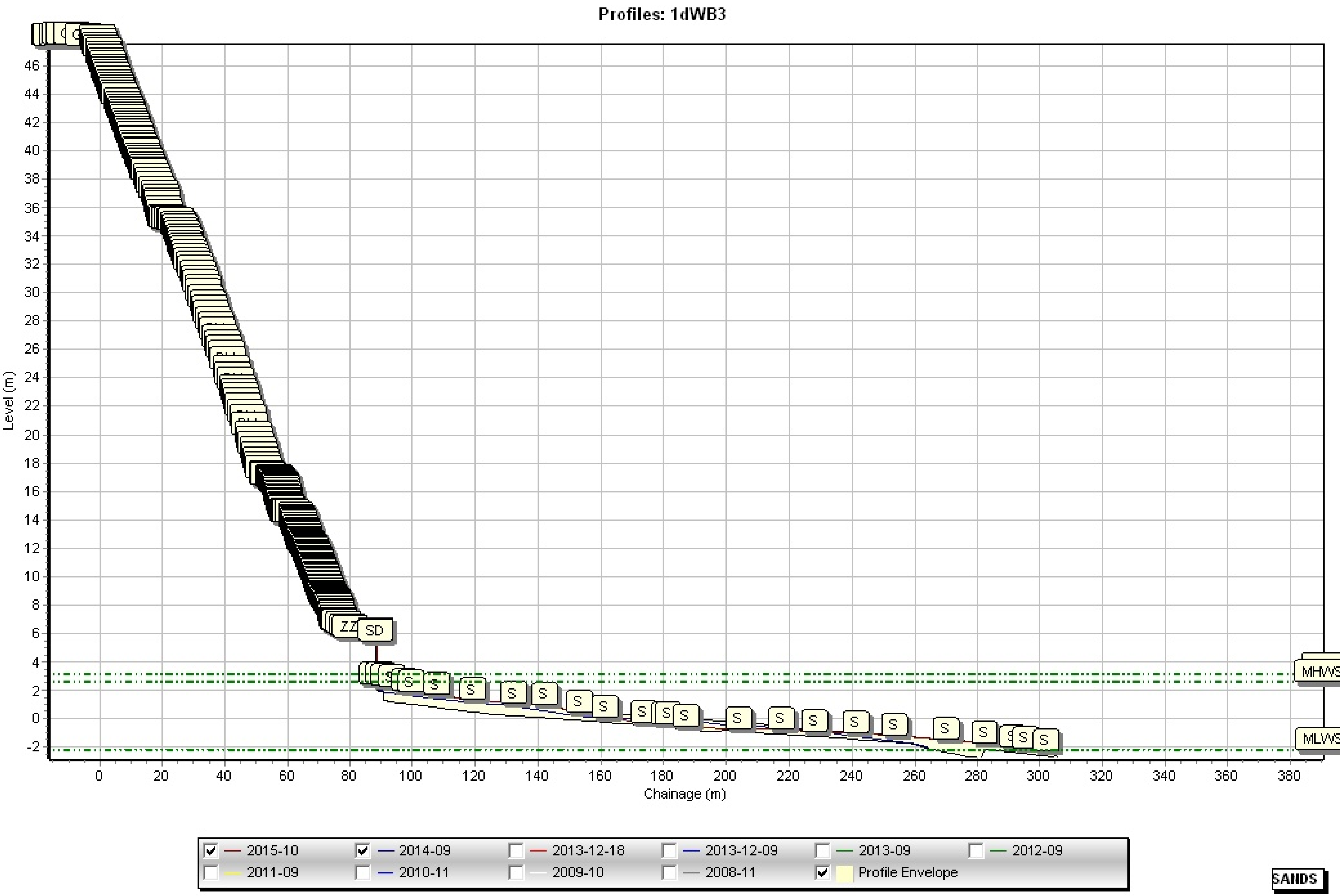


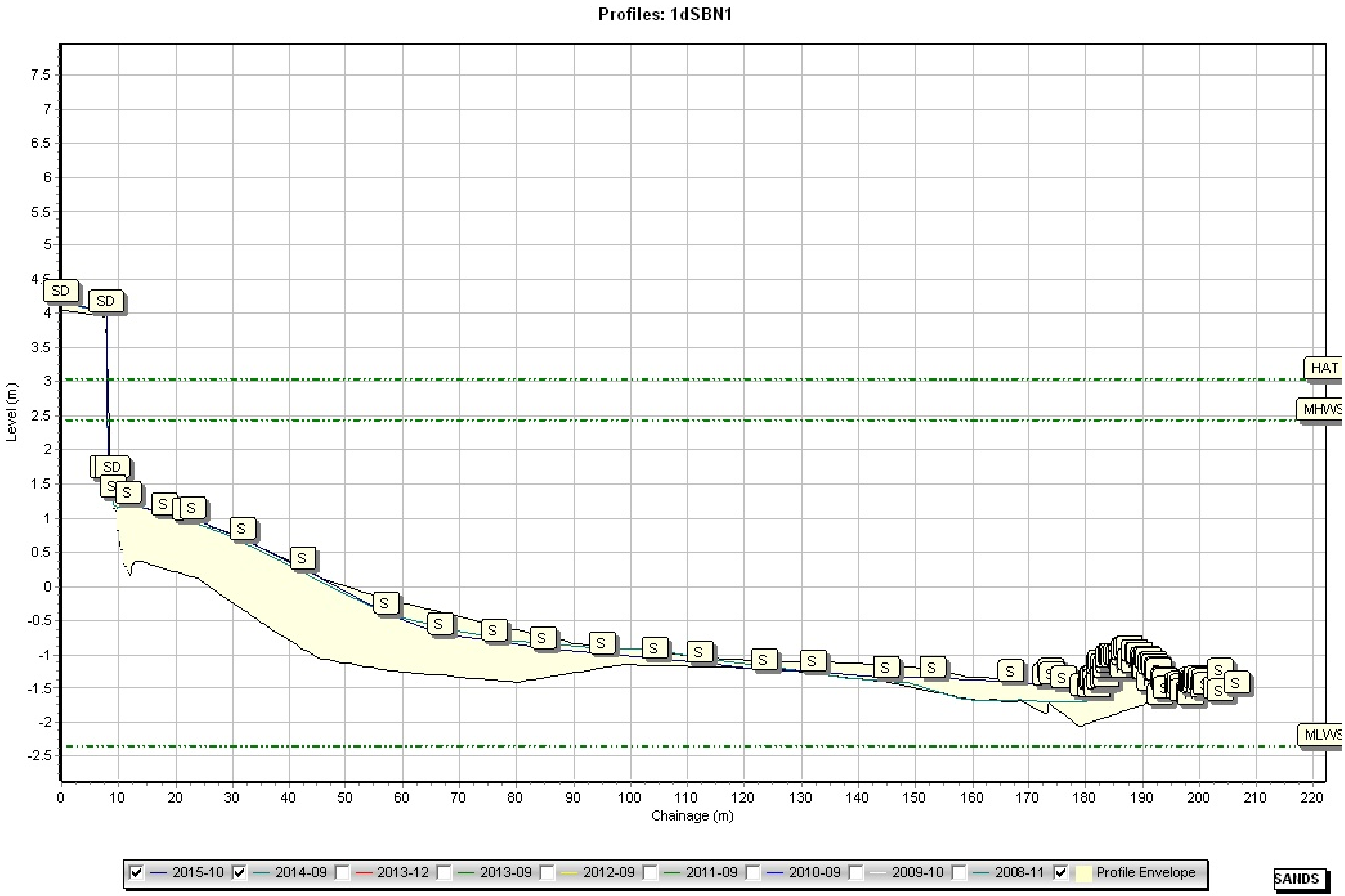
Profiles: 1dWB1
Level (m)
Chainage (m)
MHWS
MLWS
2015-10
2014-09
2013-12-18
2013-12-09
2013-09
2012-09
2011-09
2010-11
2009-10
2008-11
Profile Envelope
SANDS



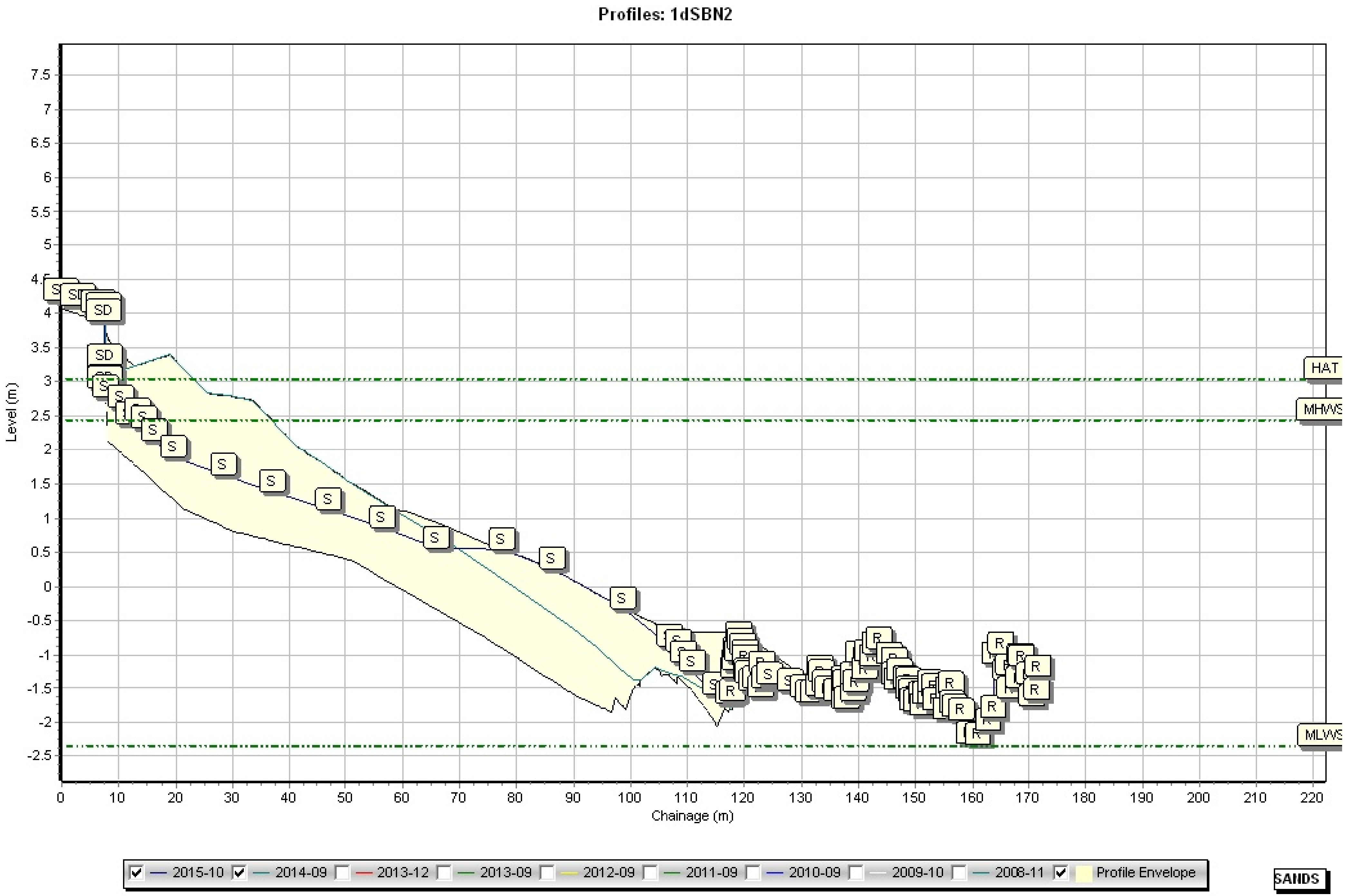
Profiles: 1dWB2
Level (m)
Chainage (m)
46
44
42
40
38
36
34
32
30
28
26
24
22
20
18
16
14
12
10
8
6
4
2
0
-2
0
20
40
60
80
100
120
140
160
180
200
220
240
260
280
300
320
340
360
380
GR
DV
M
S
MHWS
MLWS
2015-10
2014-09
2013-12-18
2013-12-09
2013-09
2012-09
2011-09
2010-11
2009-10
2008-11
Profile Envelope
SANDS

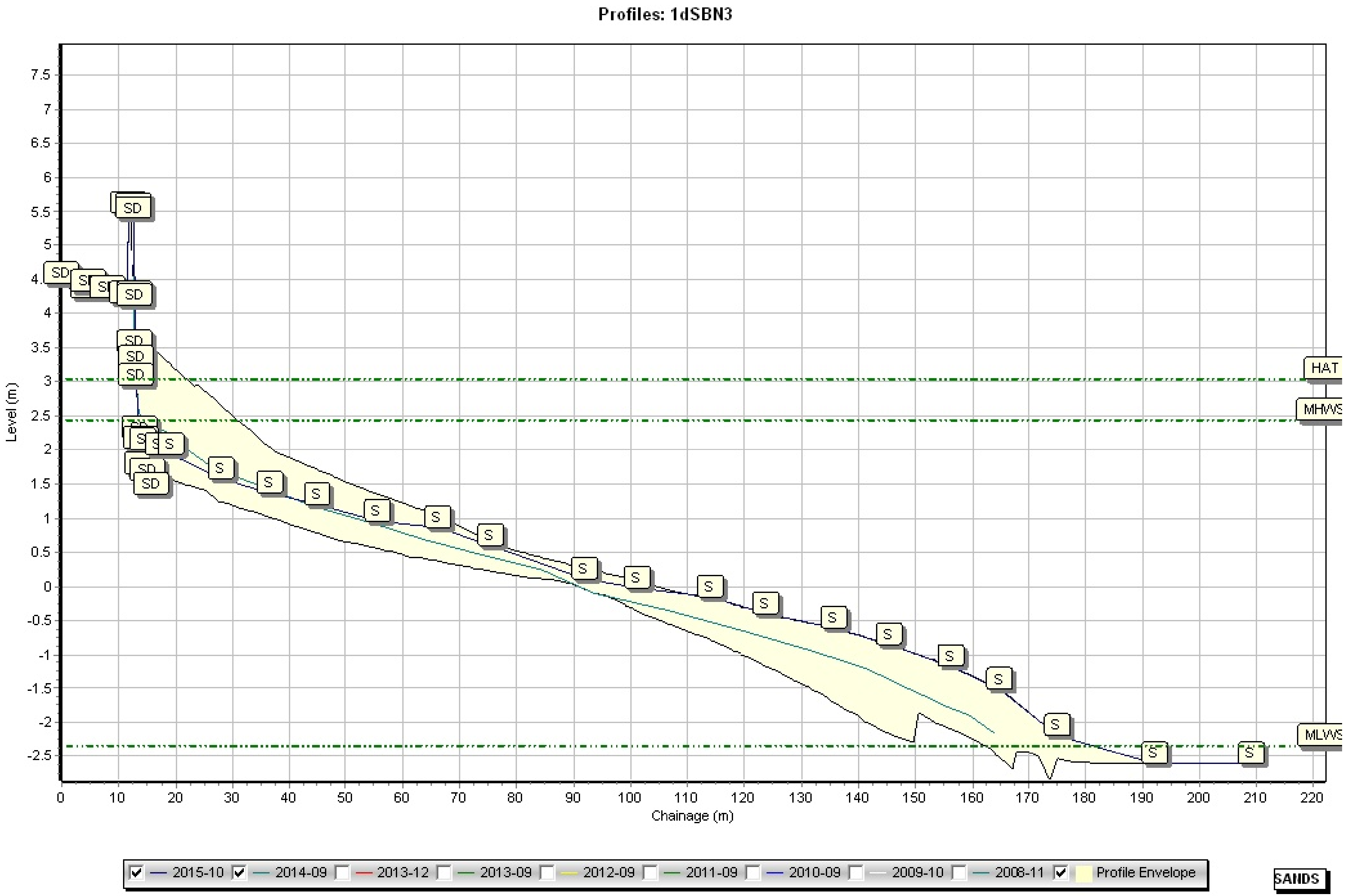
Profiles: 1dWB3

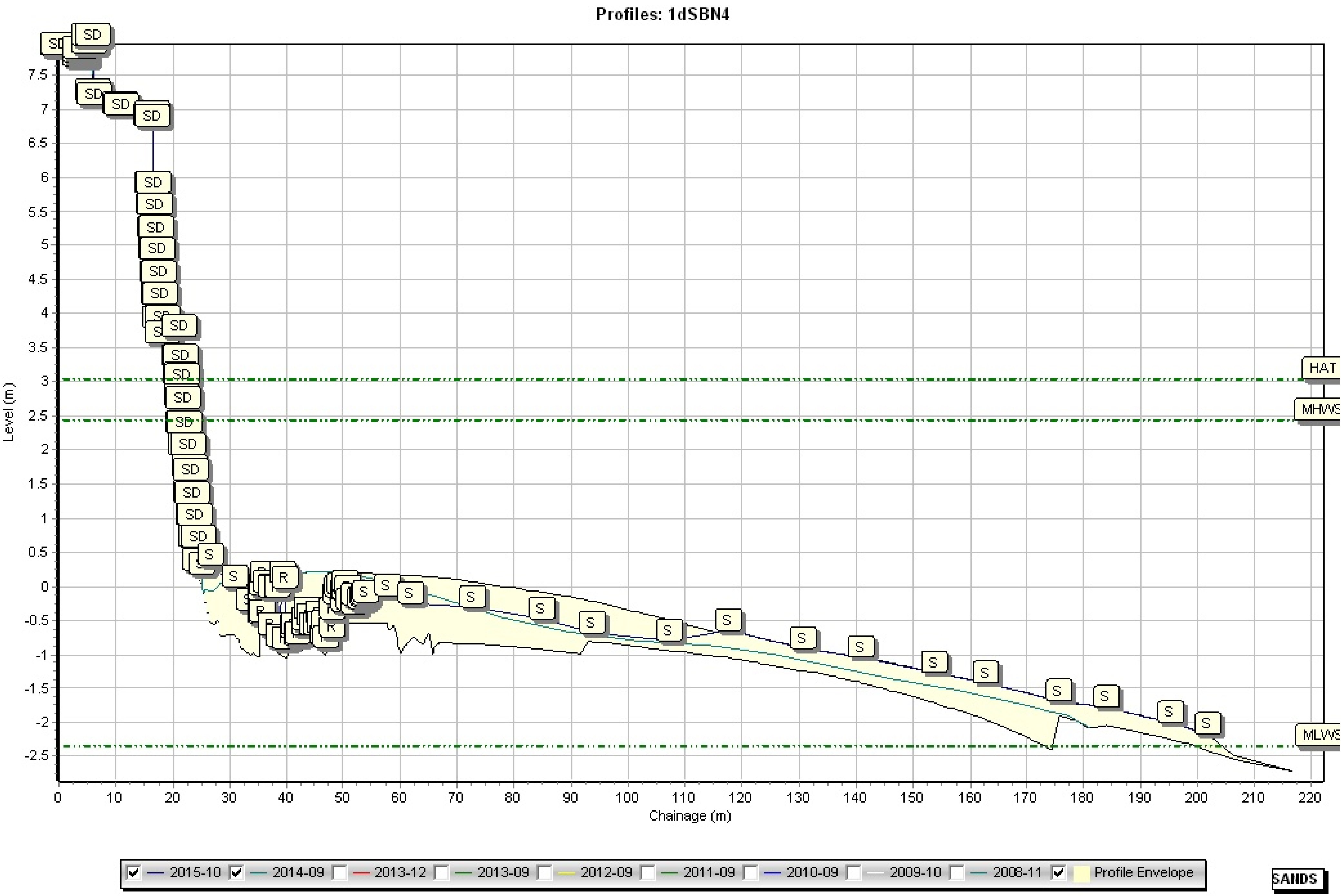




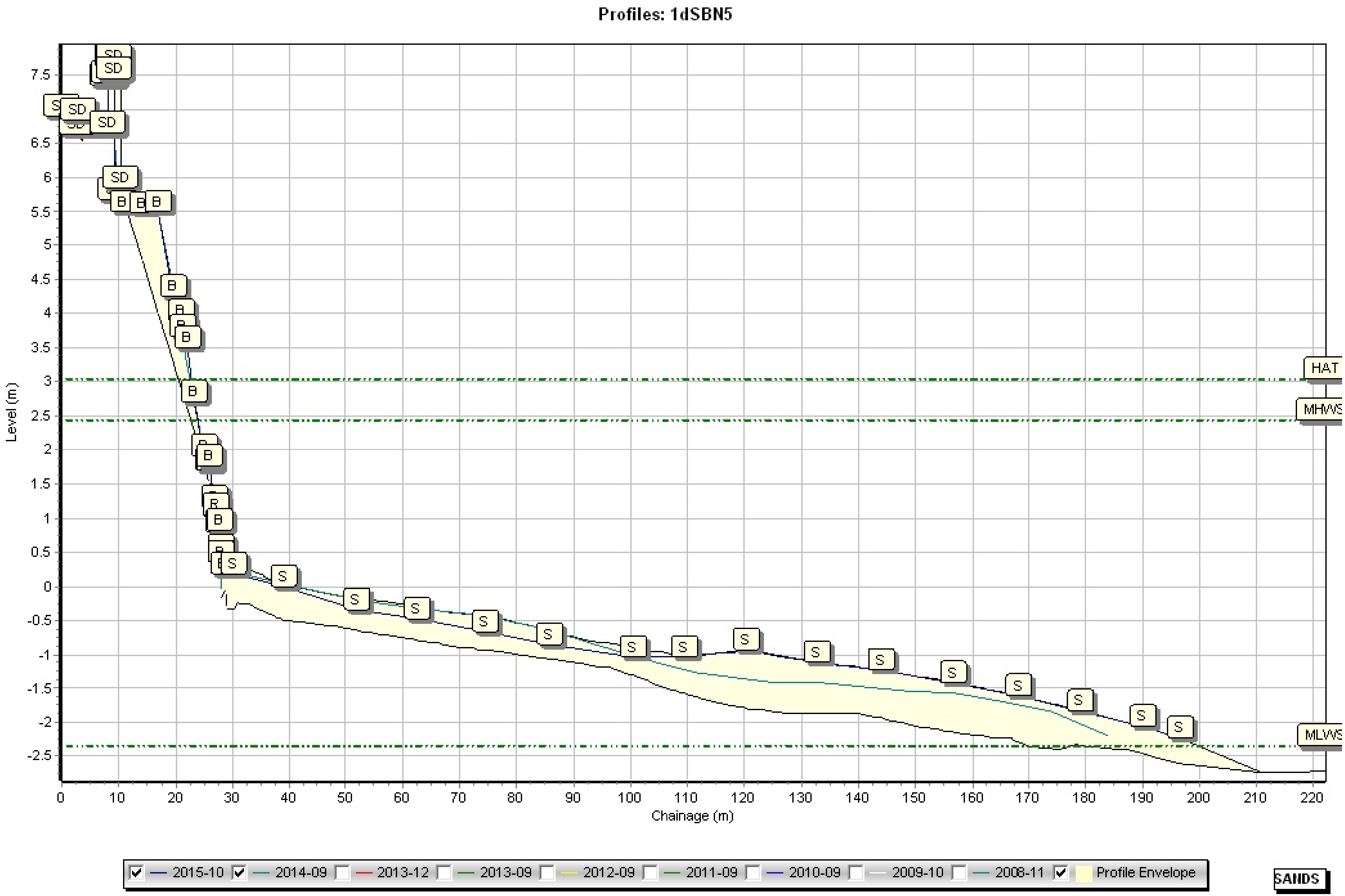
Profiles: 1dSBN1
Level (m)
Chainage (m)
HAT
MHWS
MLWS
SD
S
2015-10
2014-09
2013-12
2013-09
2012-09
2011-09
2010-09
2009-10
2008-11
Profile Envelope
SANDS


Profiles: 1dSBN2
Level (m)
Chainage (m)
HAT
MHWS
MLWS
2015-10
2014-09
2013-12
2013-09
2012-09
2011-09
2010-09
2009-10
2008-11
Profile Envelope
SANDS


Profiles: 1dSBN3
Level (m)
Chainage (m)
HAT
MHWS
MLWS
SD
S
2015-10
2014-09
2013-12
2013-09
2012-09
2011-09
2010-09
2009-10
2008-11
Profile Envelope
SANDS

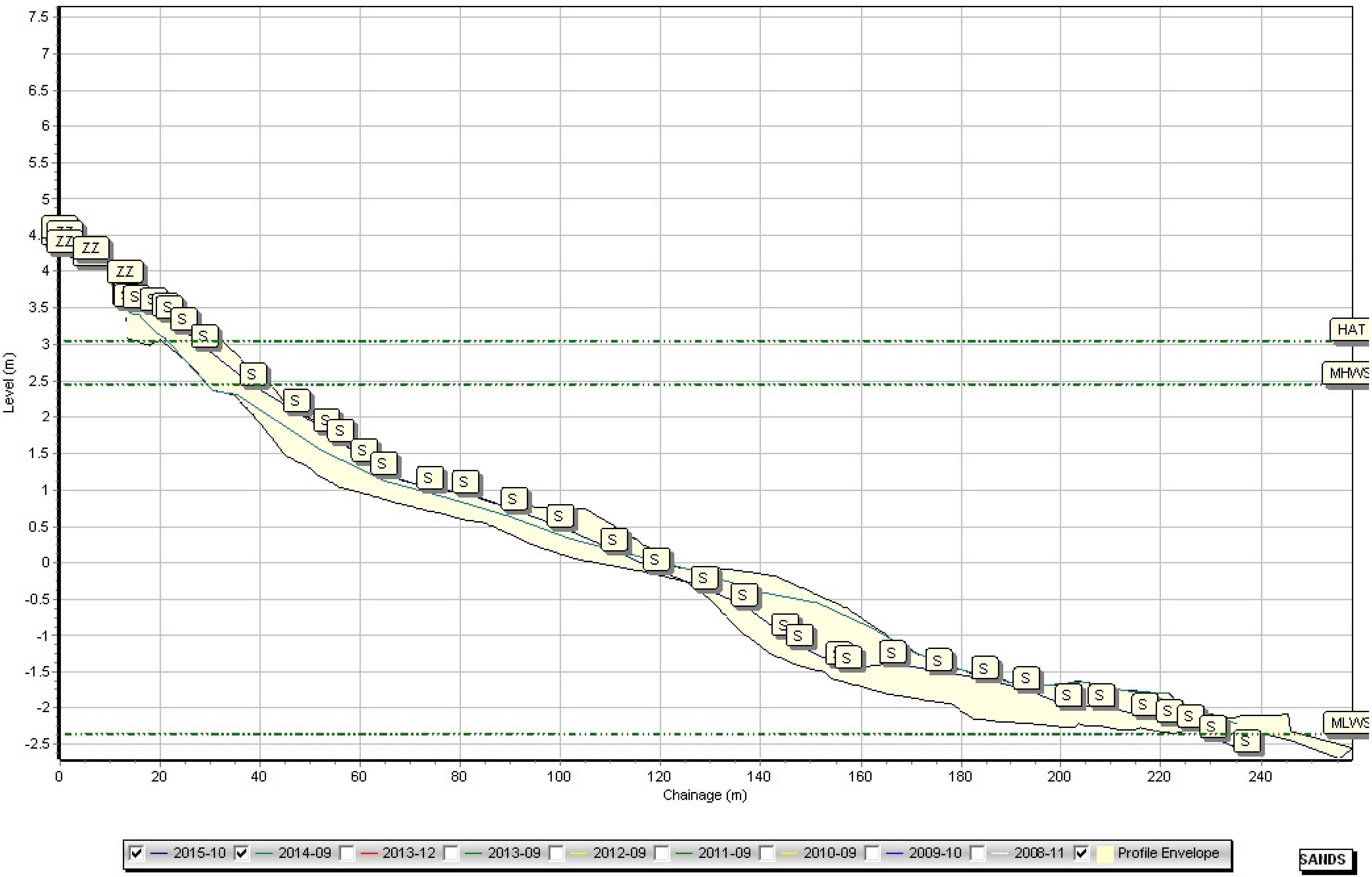


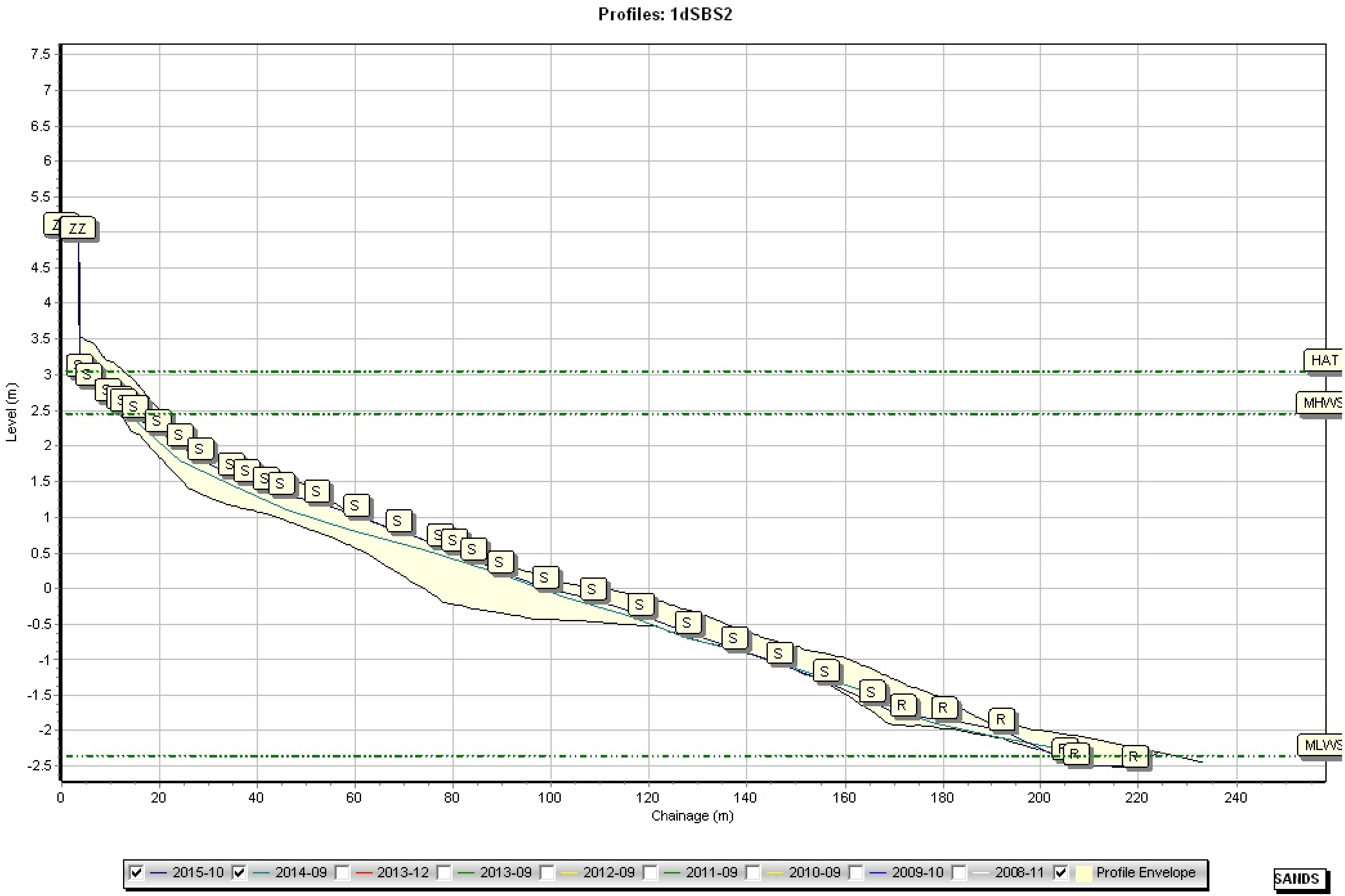
Profiles: 1dSBN4
Level (m)
Chainage (m)
HAT
MHWS
MLWS
2015-10
2014-09
2013-12
2013-09
2012-09
2011-09
2010-09
2009-10
2008-11
Profile Envelope
SANDS



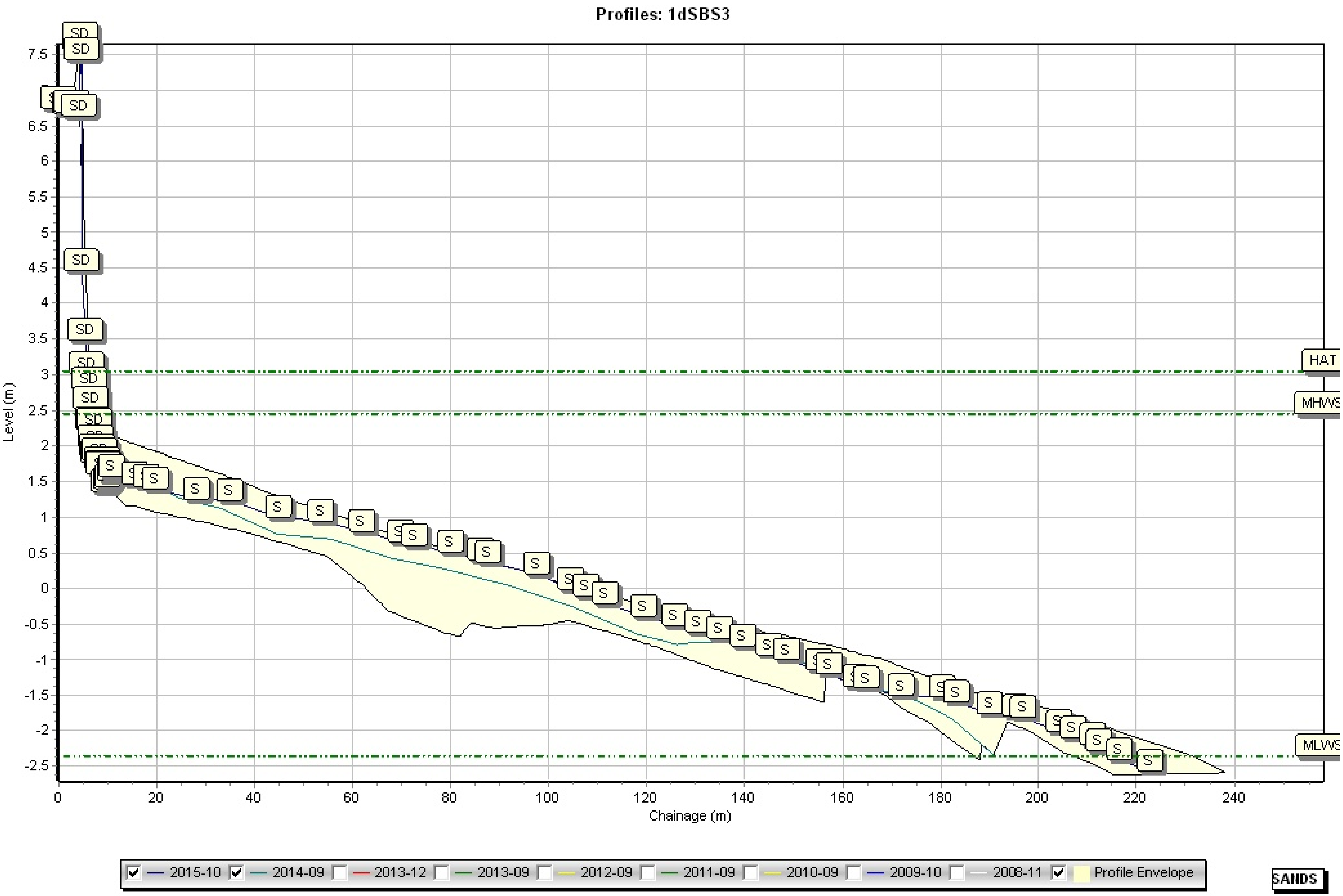
Profiles: 1dSBN5
Level (m)
Chainage (m)
HAT
MHWS
MLWS
SD
B
S
2015-10
2014-09
2013-12
2013-09
2012-09
2011-09
2010-09
2009-10
2008-11
Profile Envelope
SANDS

Profiles: 1dSBS1

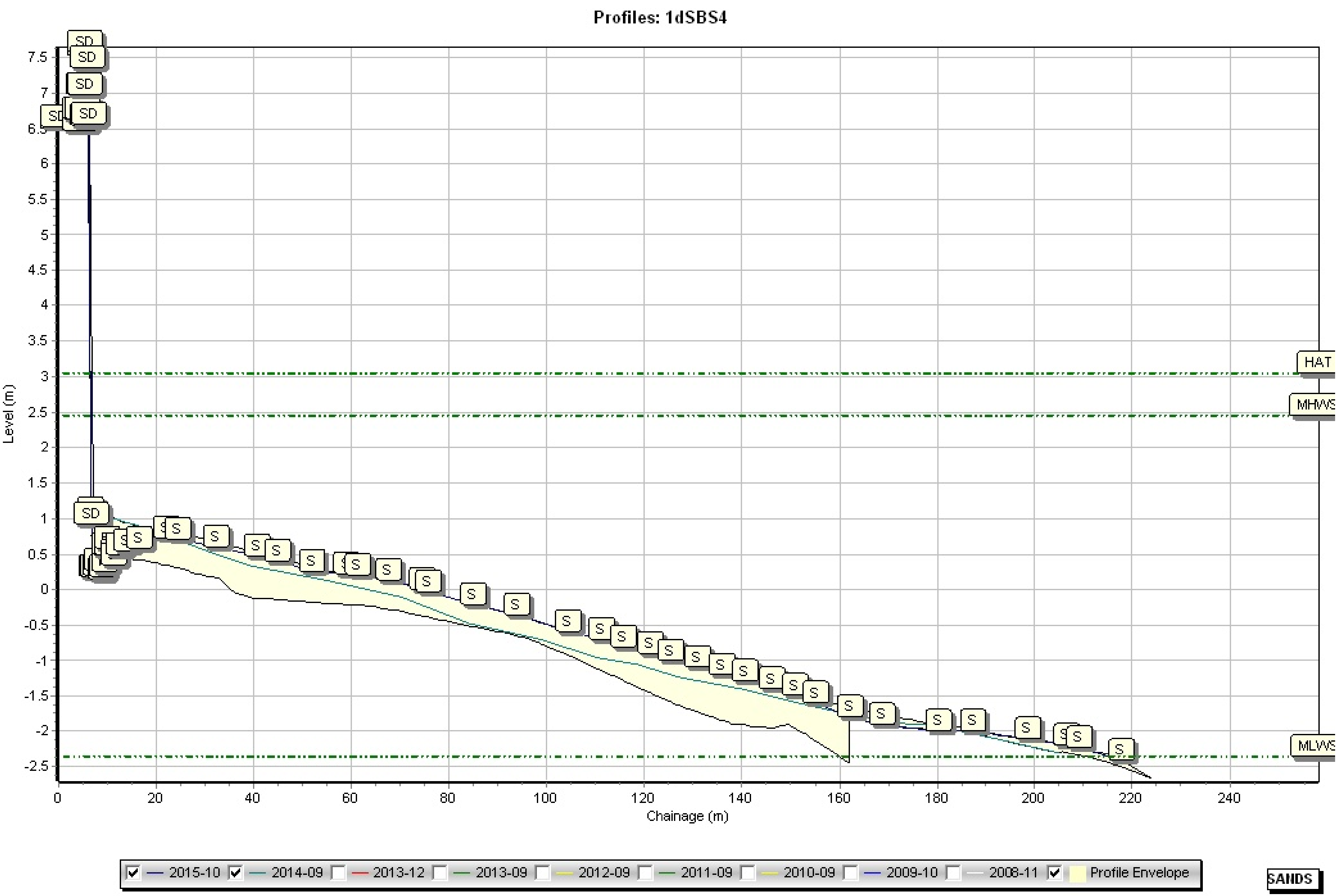




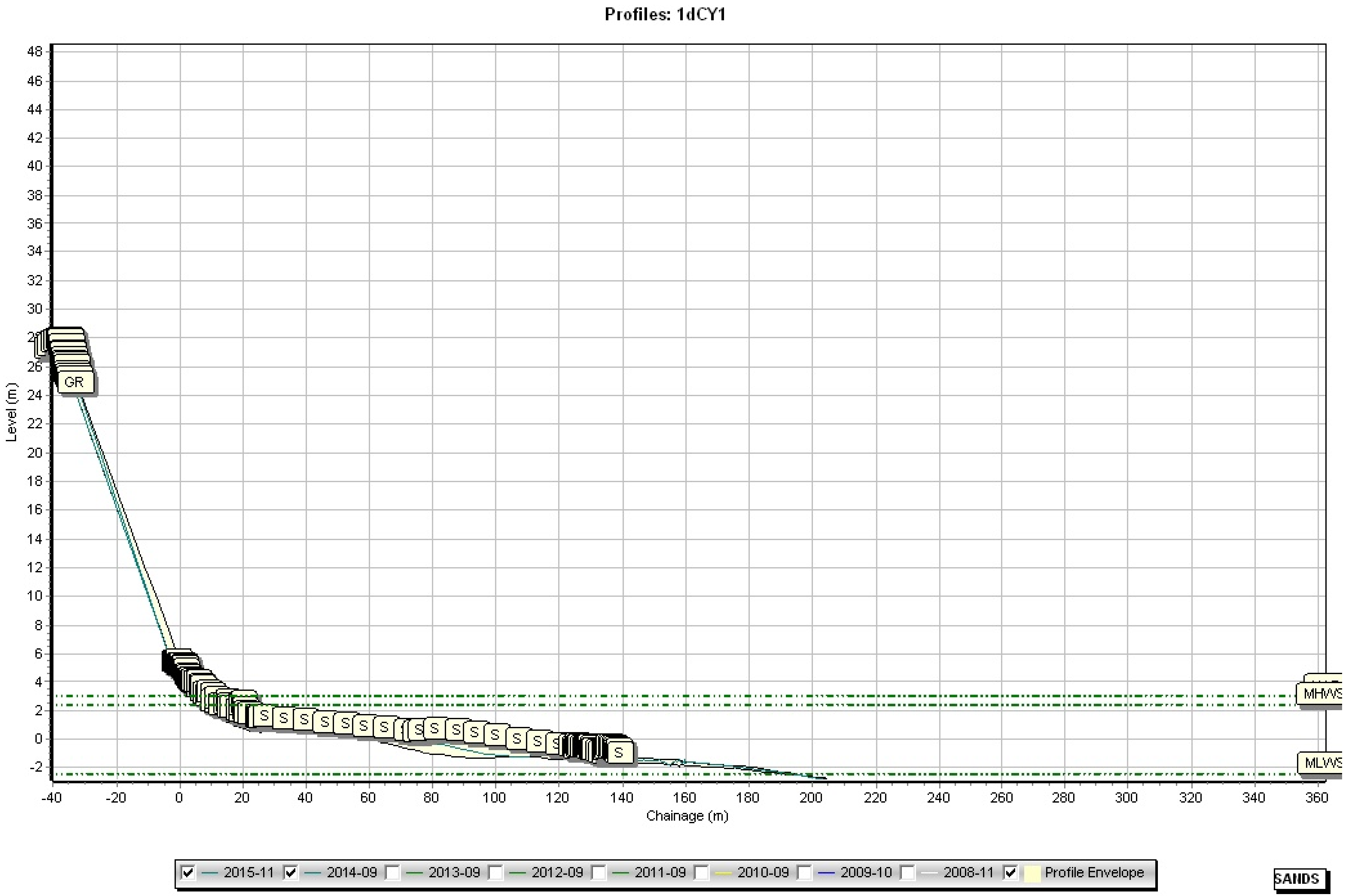
Profiles: 1dSBS2
Level (m)
Chainage (m)
HAT
MHWS
MLWS
2015-10
2014-09
2013-12
2013-09
2012-09
2011-09
2010-09
2009-10
2008-11
Profile Envelope
SANDS

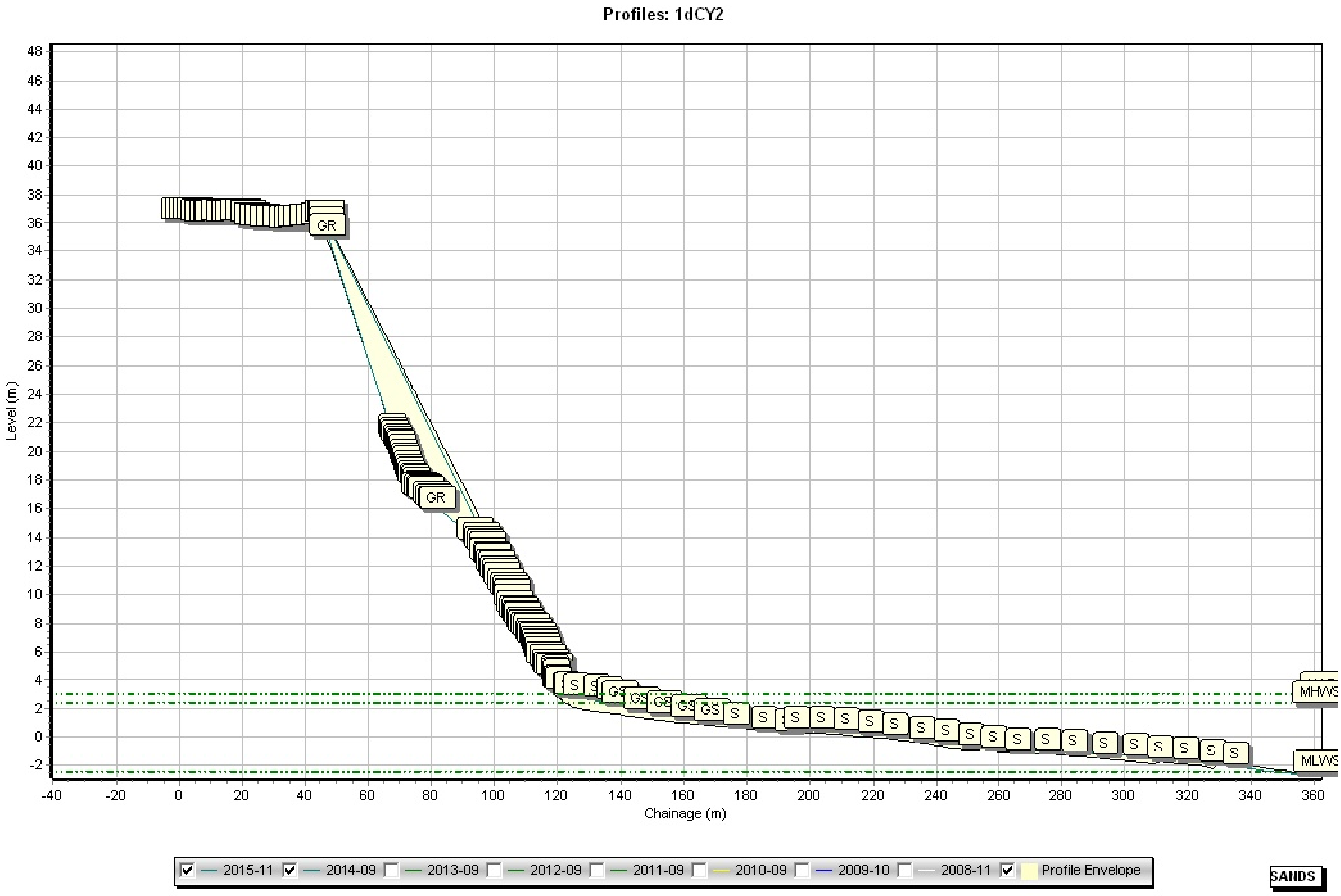


Profiles: 1dSBS3
Level (m)
Chainage (m)
HAT
MHWS
MLWS
2015-10
2014-09
2013-12
2013-09
2012-09
2011-09
2010-09
2009-10
2008-11
Profile Envelope
SANDS

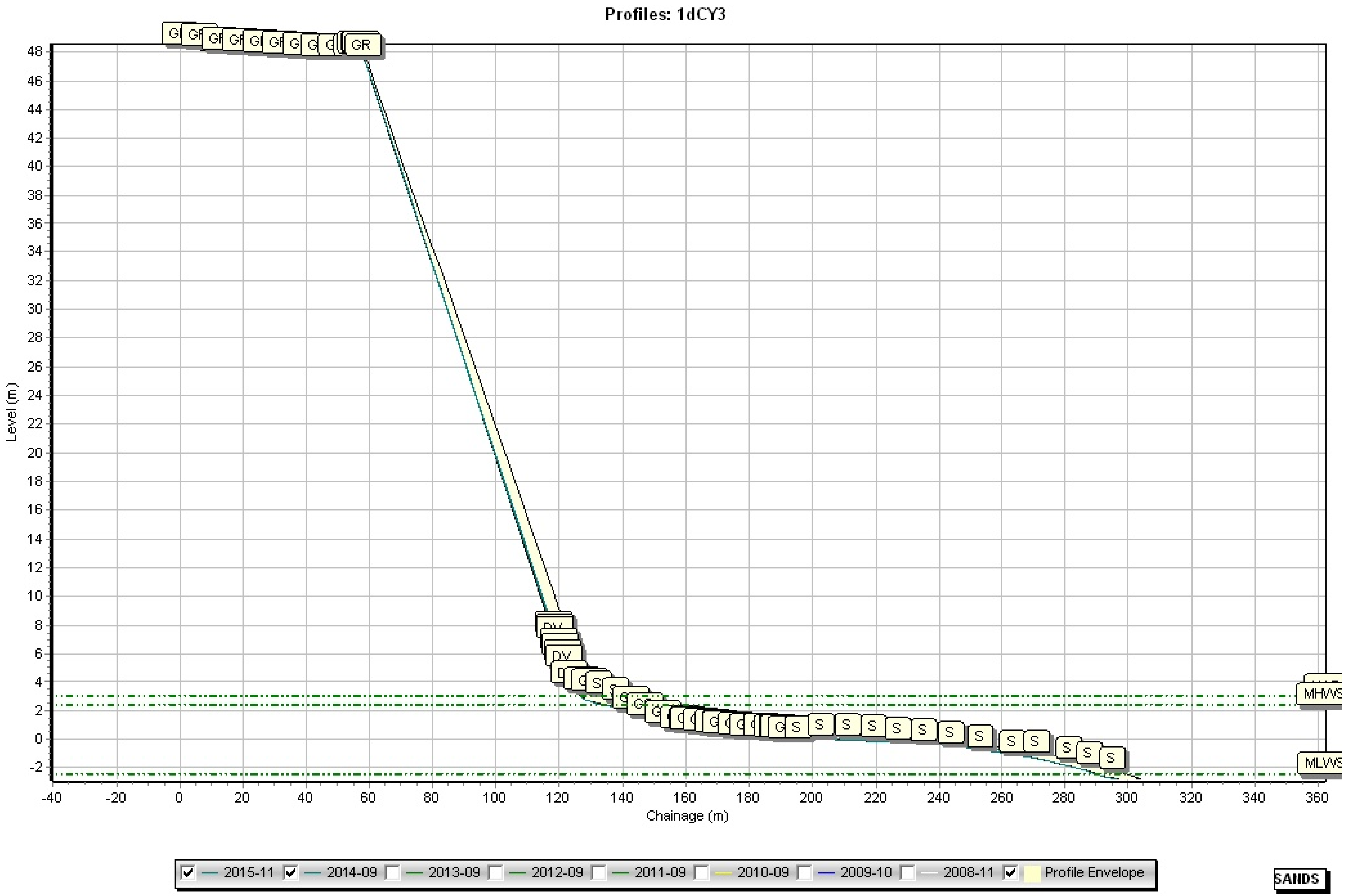


Profiles: 1dSBS4
Level (m)
Chainage (m)
7.5
7
6.5
6
5.5
5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
-0.5
-1
-1.5
-2
-2.5
0
20
40
60
80
100
120
140
160
180
200
220
240
SD
S
HAT
MHWS
MLWS
2015-10
2014-09
2013-12
2013-09
2012-09
2011-09
2010-09
2009-10
2008-11
Profile Envelope
SANDS

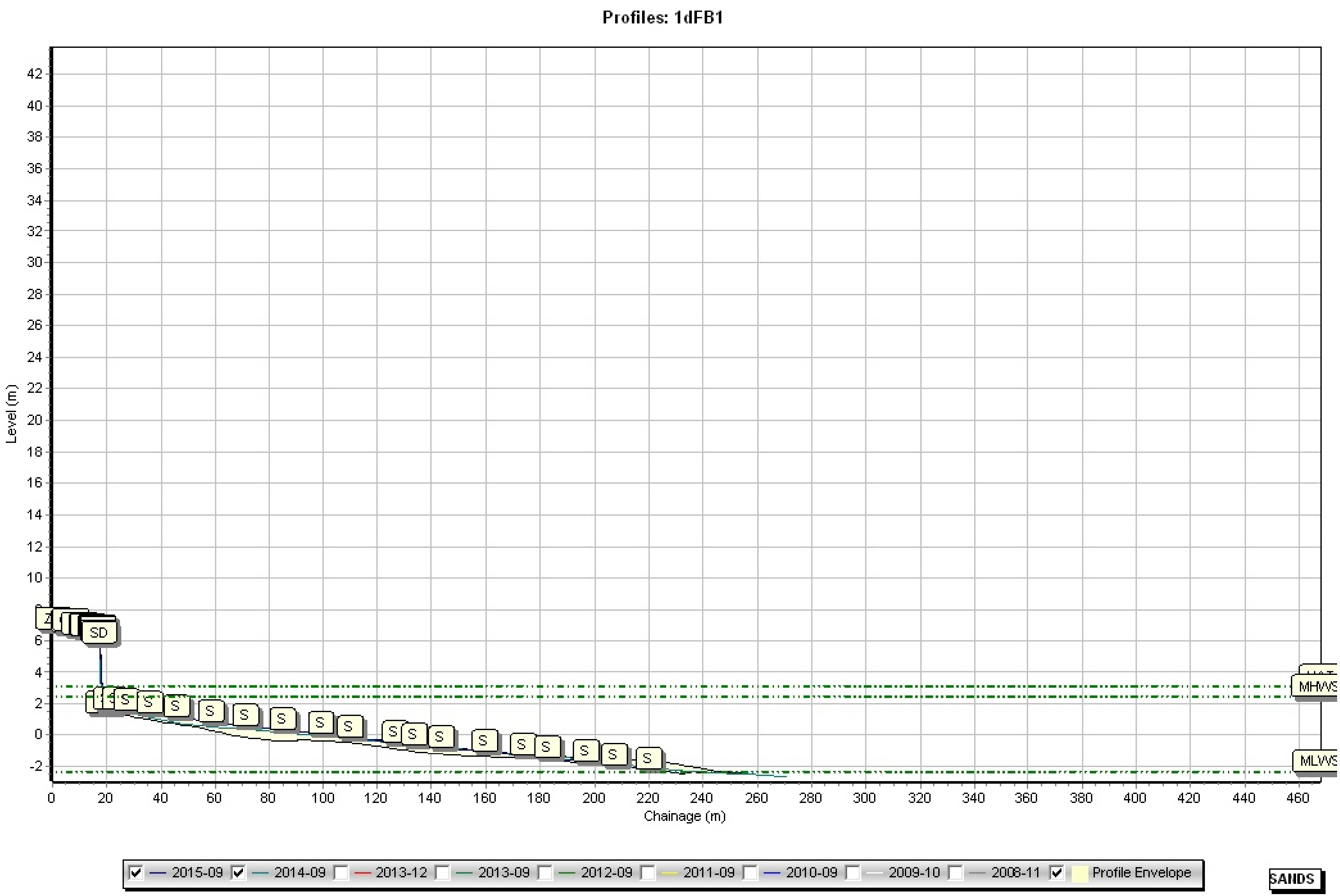

Profiles: 1dCY1
Level (m)
Chainage (m)
GR
S
MHWS
MLWS
2015-11
2014-09
2013-09
2012-09
2011-09
2010-09
2009-10
2008-11
Profile Envelope
SANDS



Profiles: 1dCY2
Level (m)
Chainage (m)
GR
GR
S
GS
MHWS
MLWS
2015-11
2014-09
2013-09
2012-09
2011-09
2010-09
2009-10
2008-11
Profile Envelope
SANDS

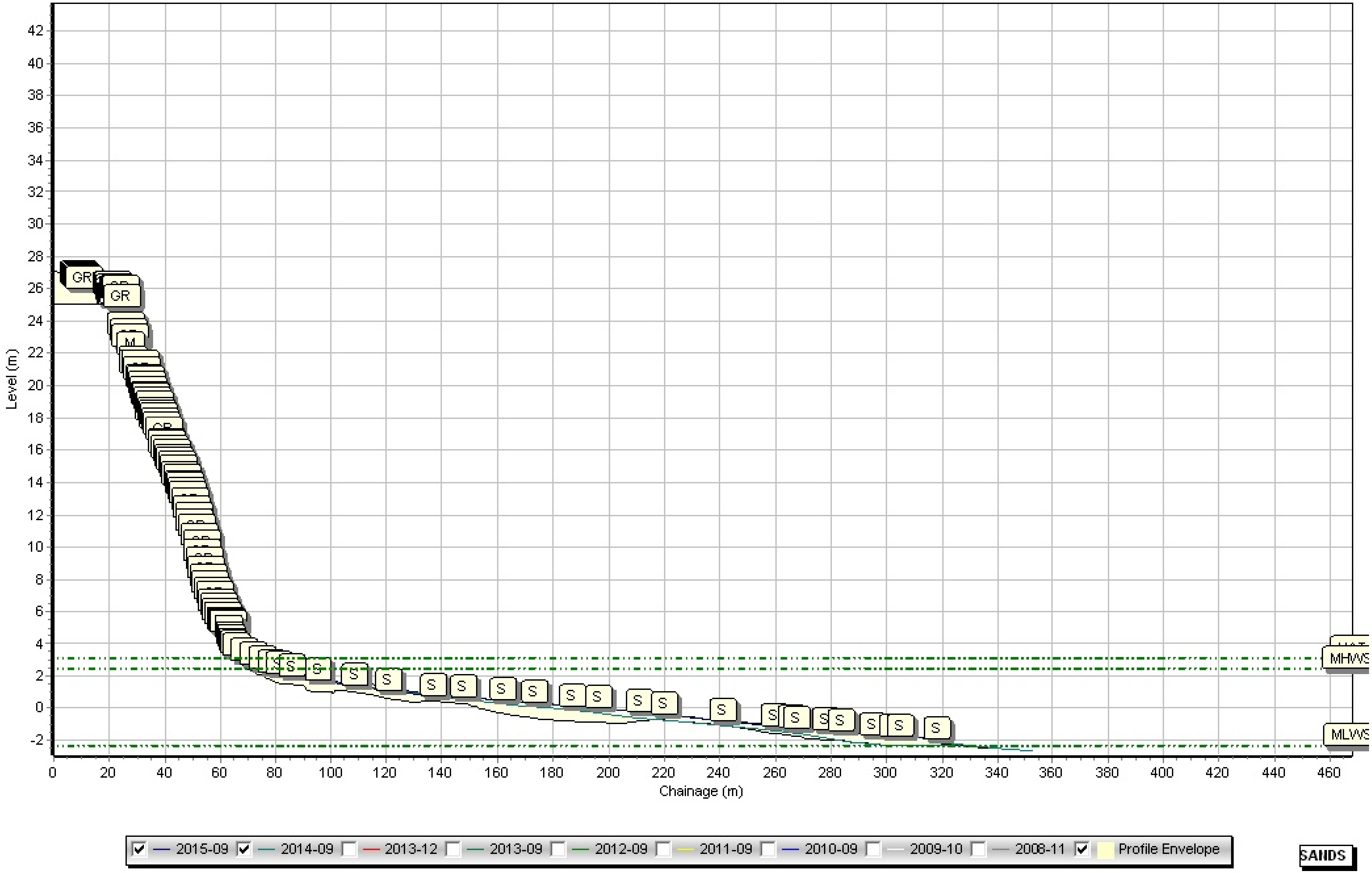


Profiles: 1dCY3
Level (m)
Chainage (m)
MHWS
MLWS
2015-11
2014-09
2013-09
2012-09
2011-09
2010-09
2009-10
2008-11
Profile Envelope
SANDS

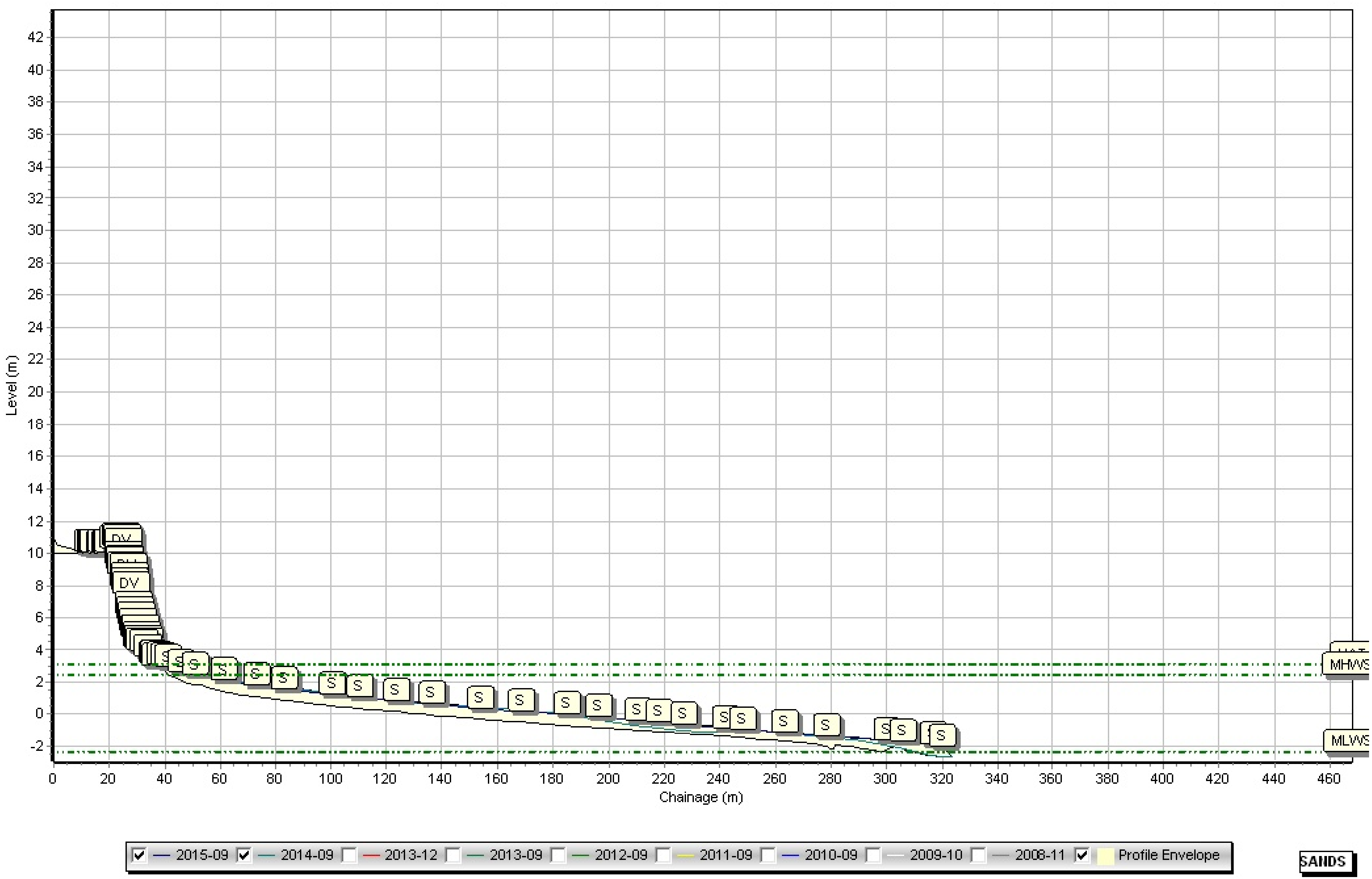


Profiles: 1dFB1
Level (m)
Chainage (m)
SD
MHWS
MLWS
2015-09
2014-09
2013-12
2013-09
2012-09
2011-09
2010-09
2009-10
2008-11
Profile Envelope
SANDS

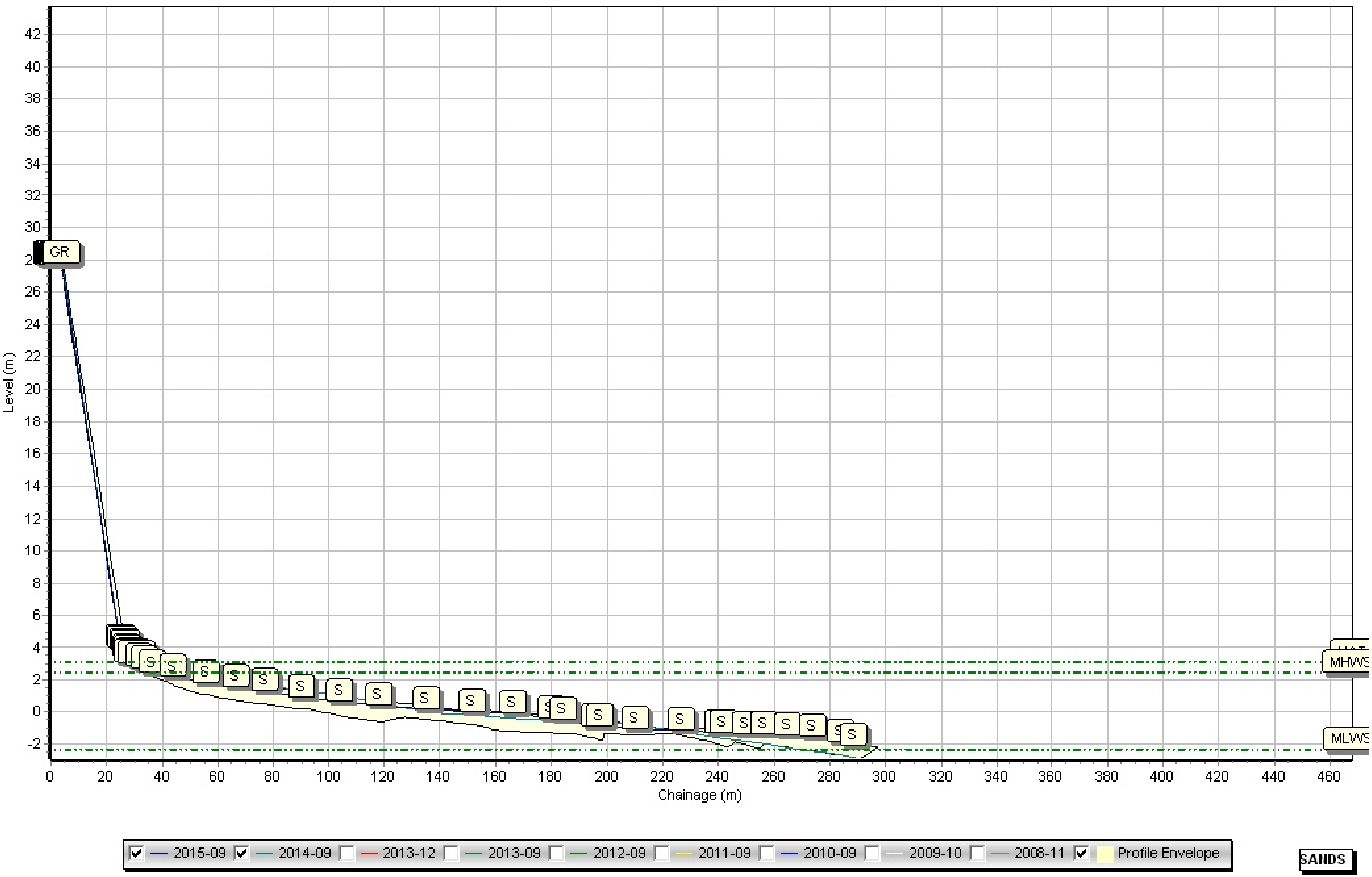
Profiles: 1dFB2

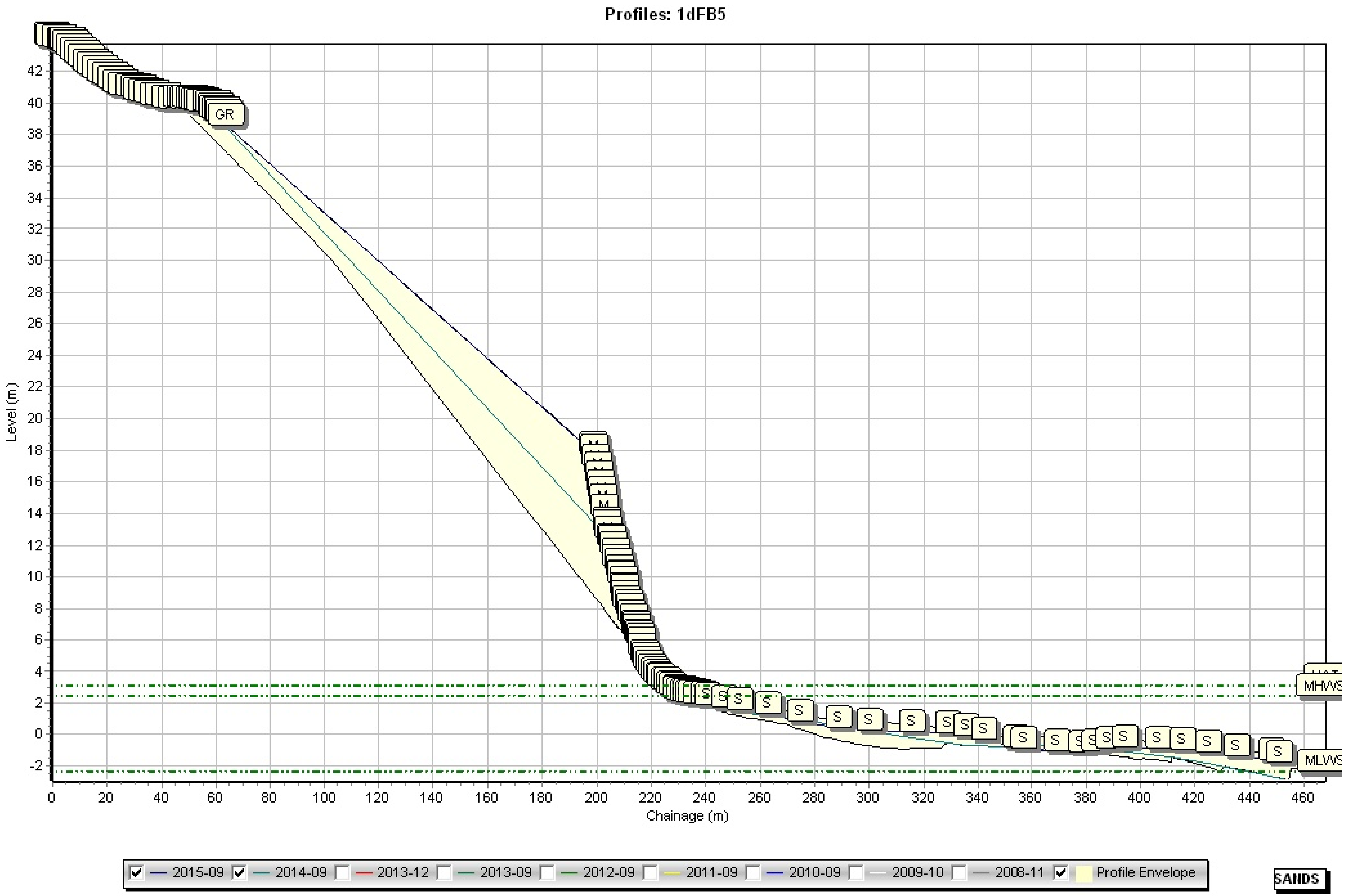


Profiles: 1dFB3



Profiles: 1dFB4





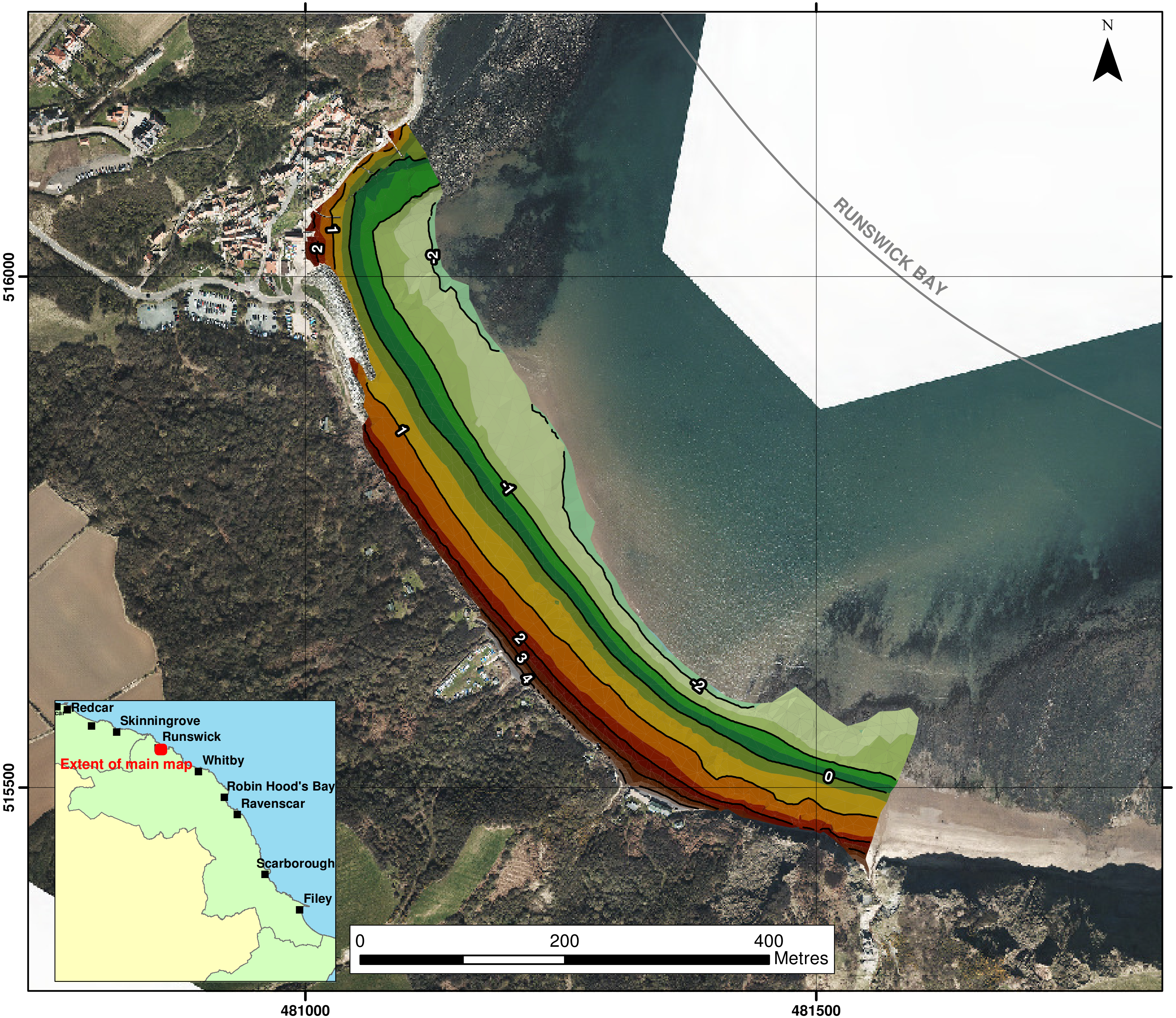
Profiles: 1dFB5
Level (m)
Chainage (m)
GR
M
S
MHWS
MLWS
2015-09
2014-09
2013-12
2013-09
2012-09
2011-09
2010-09
2009-10
2008-11
Profile Envelope
SANDS

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)

- 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 Runswick Scarborough Borough Council

Analytical Report 8
Full Measures Survey
Autumn 2015

ch2m

Halcrow Group Ltd, Lyndon House, 62 Hagley Road, Edgbaston, Birmingham, B16 8PE

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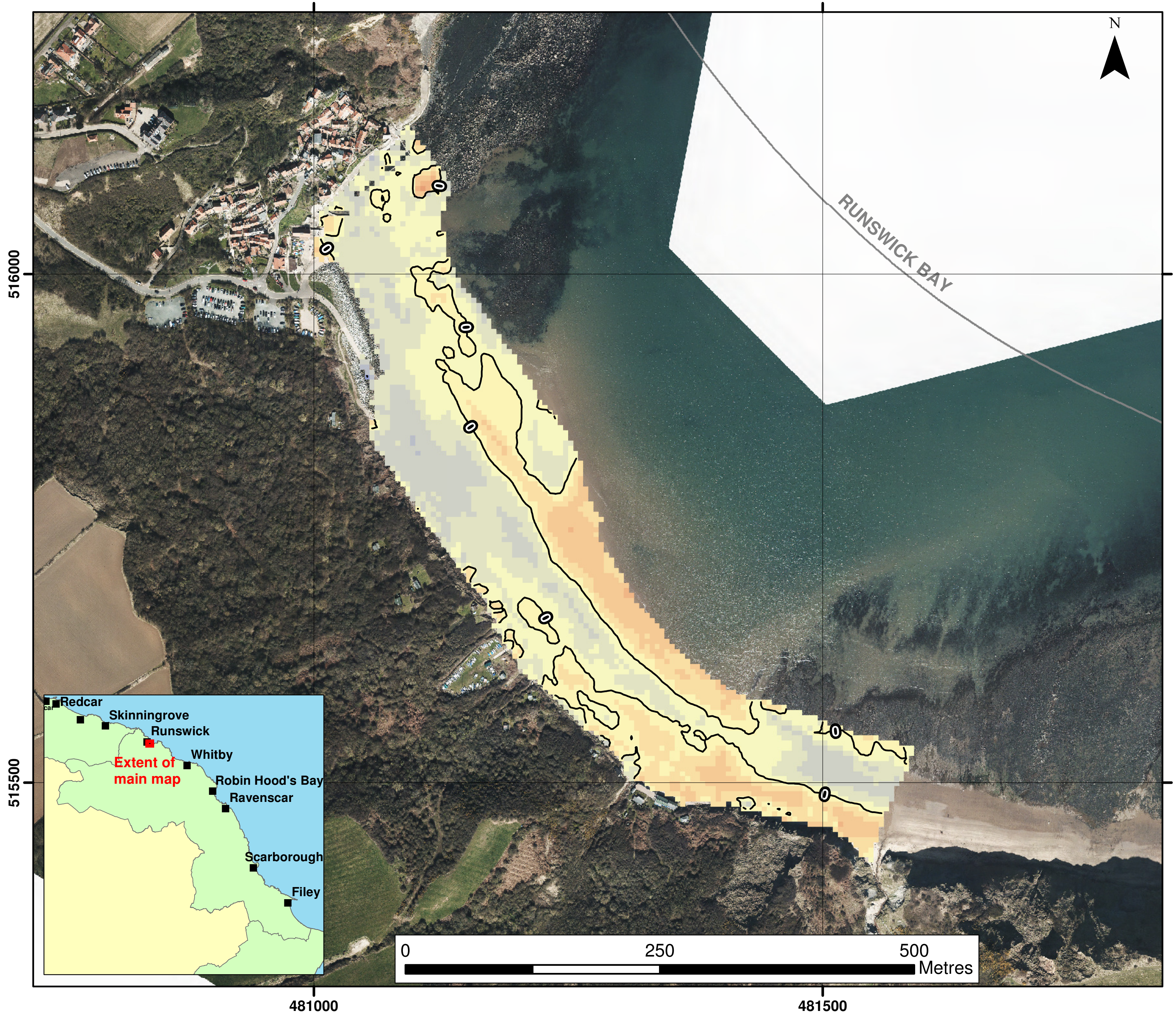
Fax: +44(0)121 456 1569
www.ch2m.com

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



KEY Spring 2015 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 Runswick
Scarborough Borough Council

Analytical Report 8
Full Measures Survey
Autumn 2015

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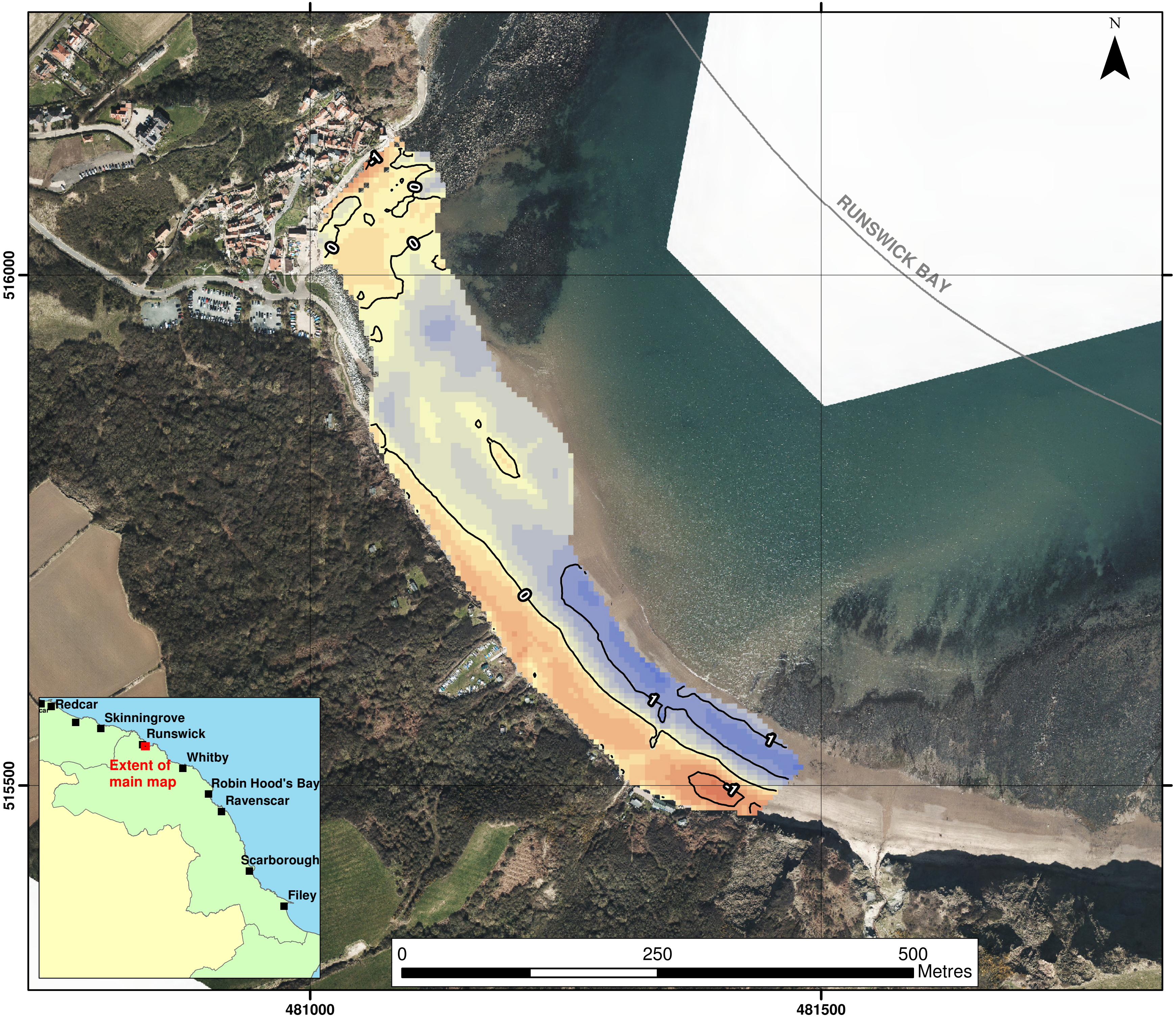

KEY Autumn 2008 Autumn 2015
Change in elevation (m)

<-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 1c
Long-term Elevation Change
Runswick
Scarborough Borough Council

Analytical Report 8
Full Measures Survey
Autumn 2015

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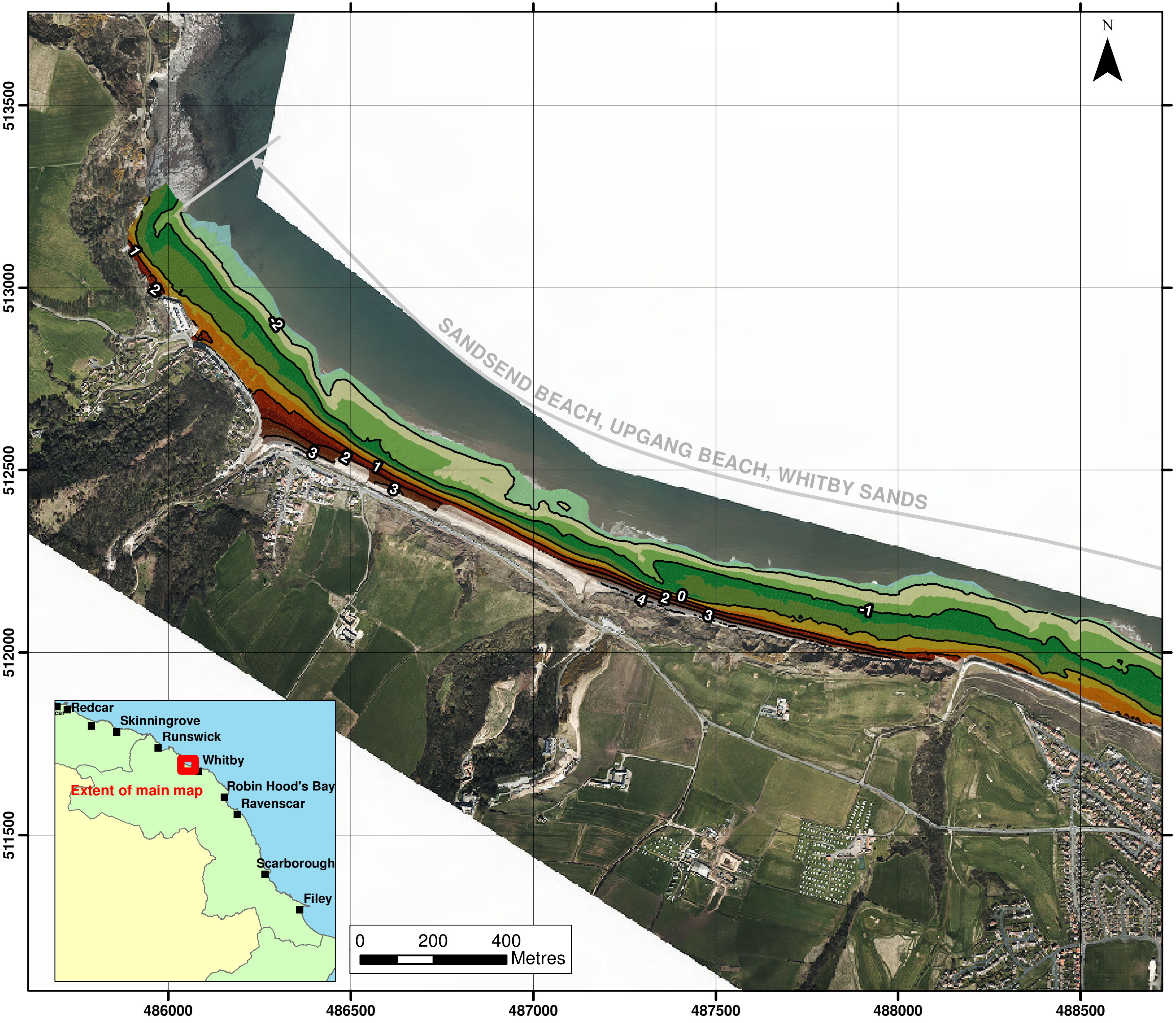

KEY

Elevation (m OD)

- 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
Whitby
Scarborough Borough Council

Analytical Report 8
Full Measures Survey
Autumn 2015

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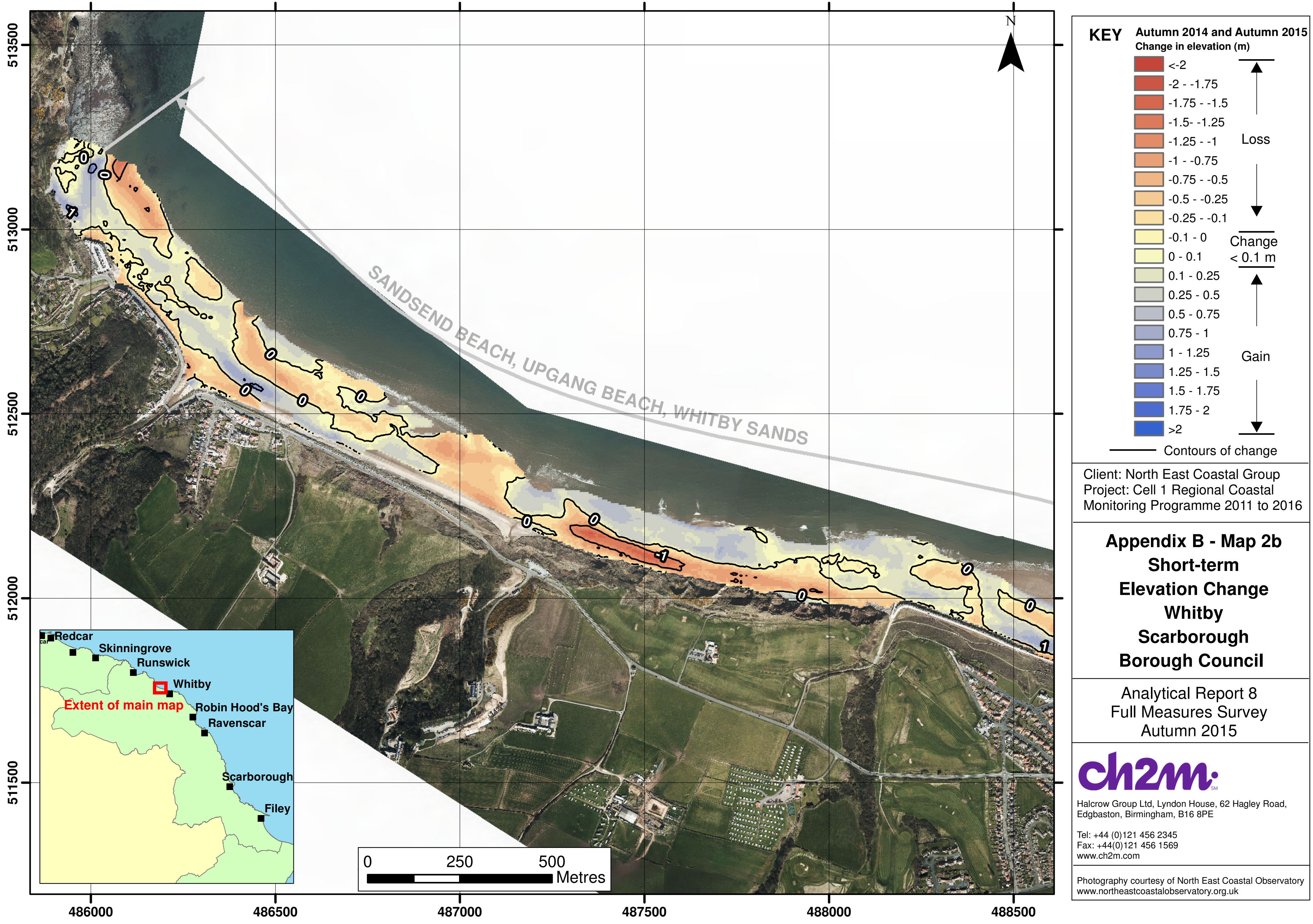

Client: North East Coastal Group
Project: Cell 1 Regional Coastal Monitoring Programme 2011 to 2016

Appendix B - Map 2b
Short-term Elevation Change Whitby Scarborough Borough Council

Analytical Report 8
Full Measures Survey
Autumn 2015

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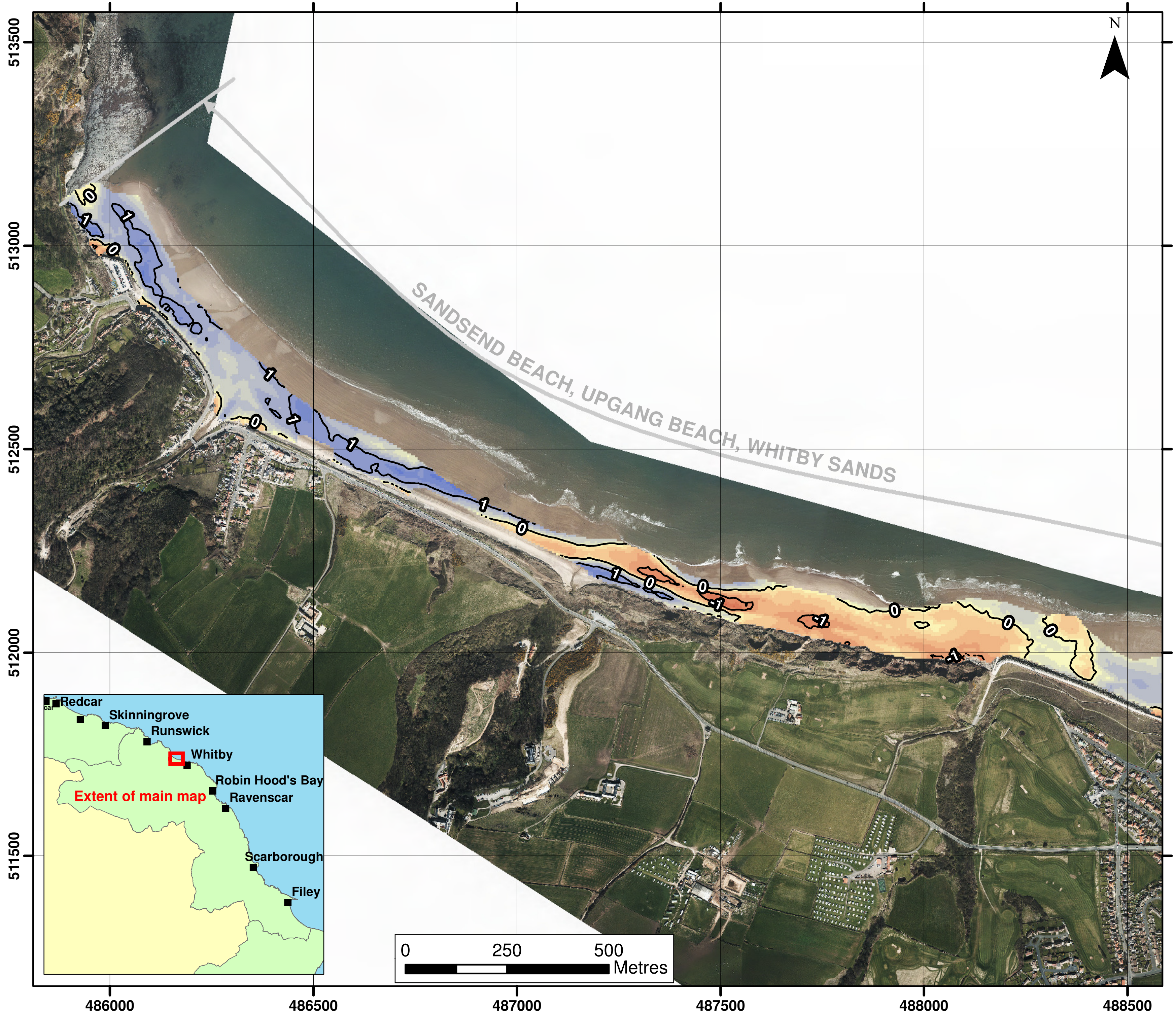

KEY Autumn 2008 and Autumn 2015
Change in elevation (m)

- <-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 2c
Long-term Elevation Change Whitby Scarborough Borough Council

Analytical Report 8
Full Measures Survey
Autumn 2015

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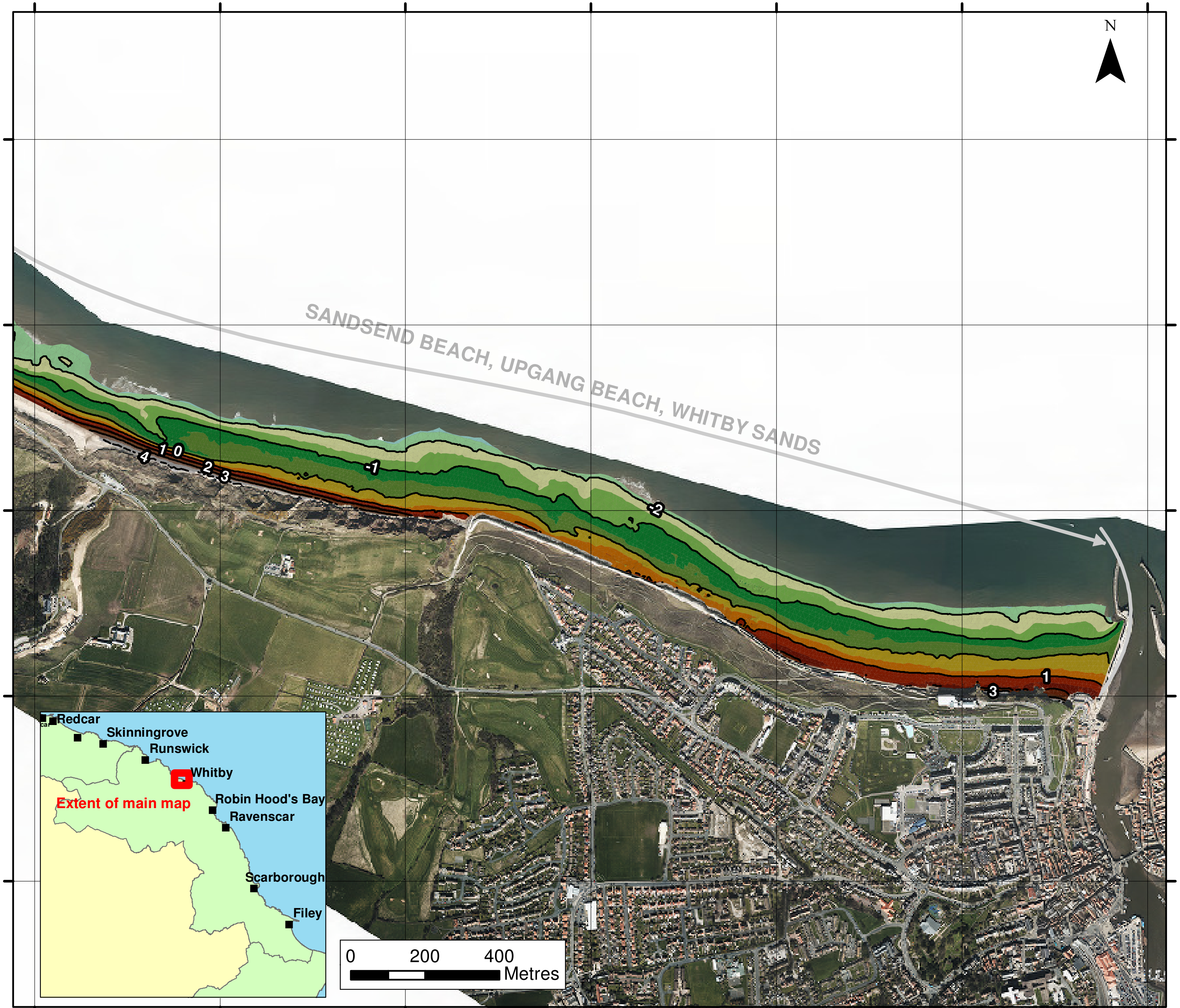

KEY

Elevation (m OD)

- 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
Whitby
Scarborough Borough Council

Analytical Report 8
Full Measures Survey
Autumn 2015

ch2m

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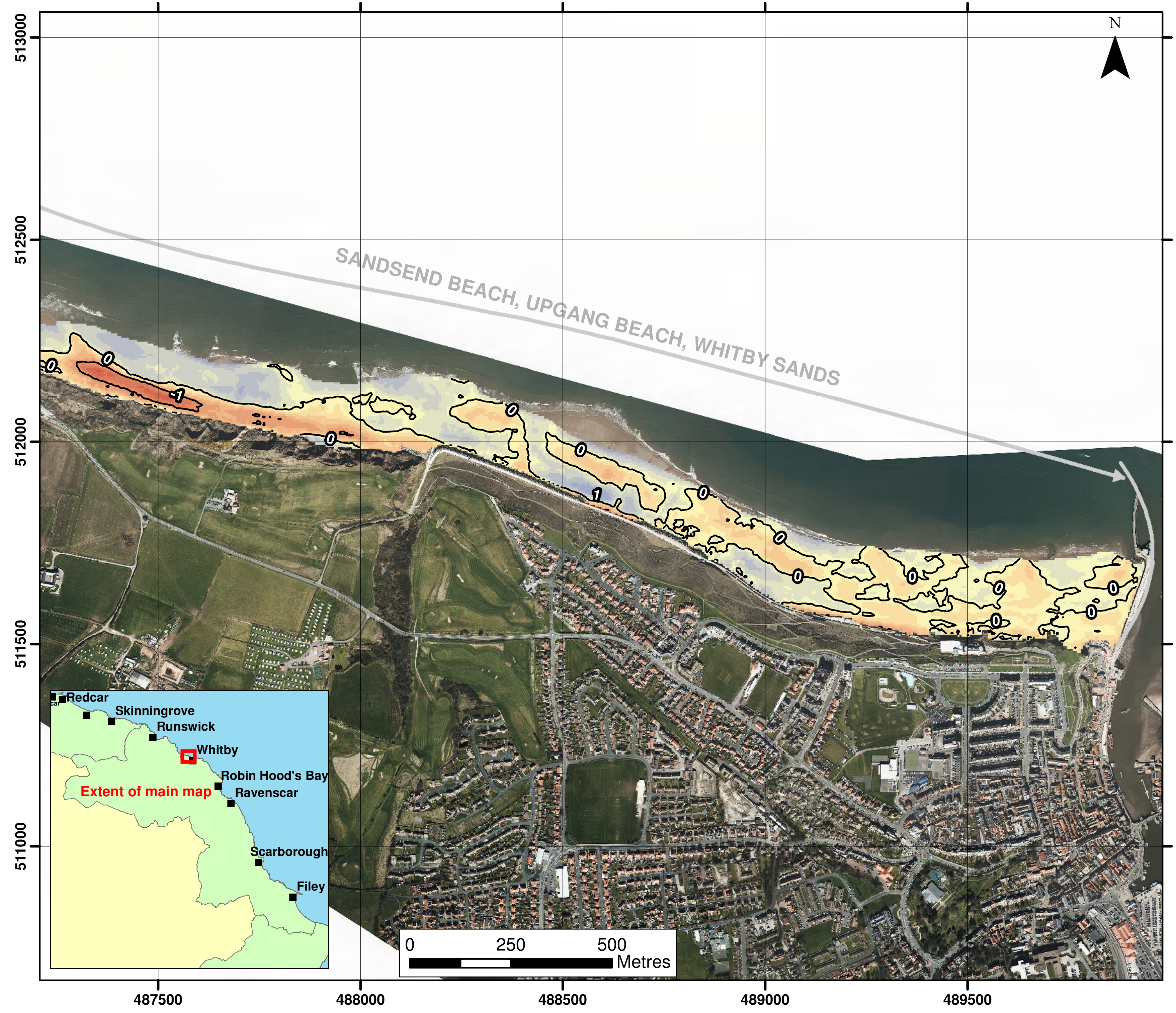

KEY Autumn 2014 and Autumn 2015

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 3b
Short-term Elevation Change
Whitby
Scarborough Borough Council

Analytical Report 8
Full Measures Survey
Autumn 2015

ch2m

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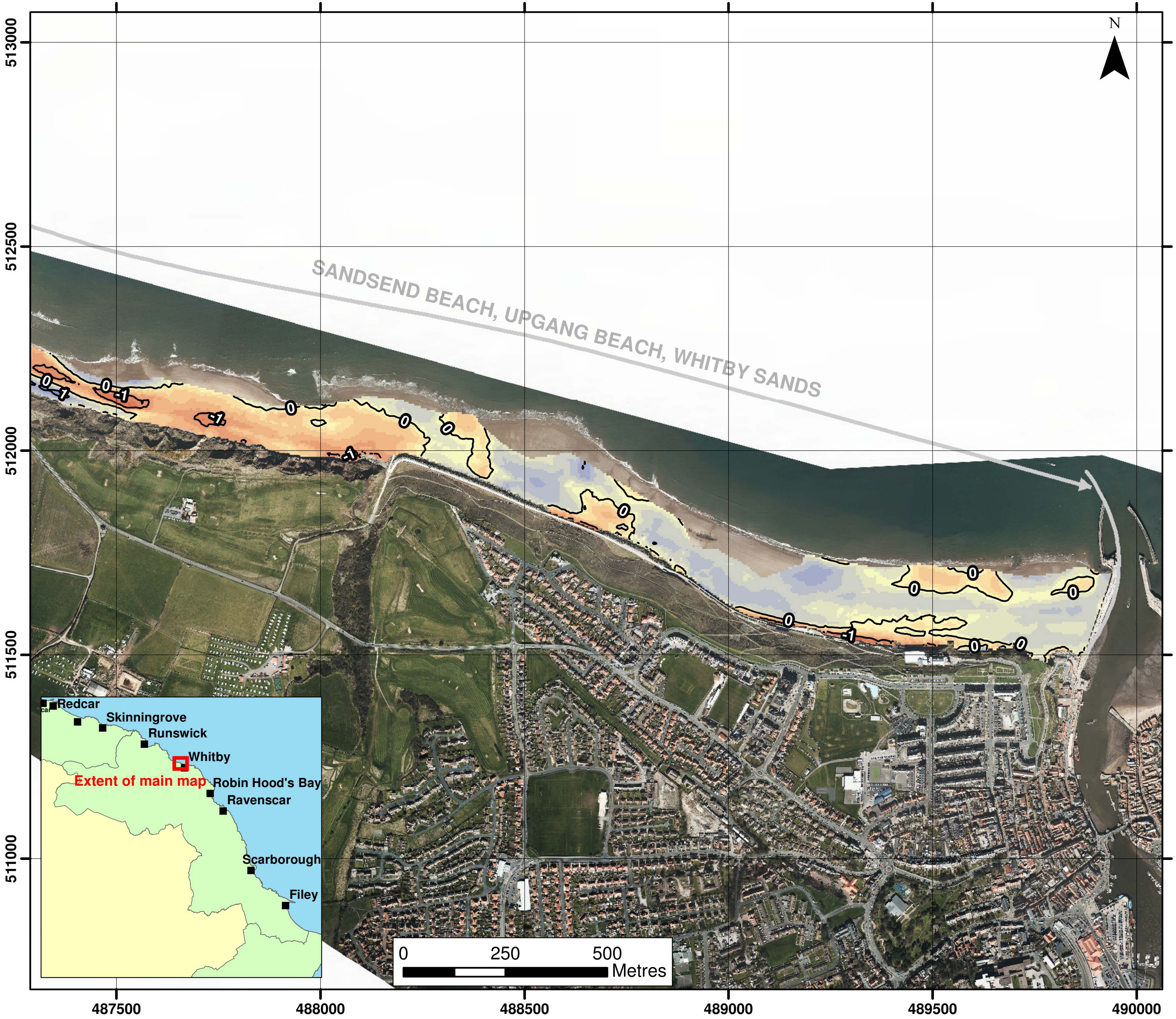

KEY Autumn 2008 and Autumn 2015

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 3c
Long-term Elevation Change
Whitby
Scarborough 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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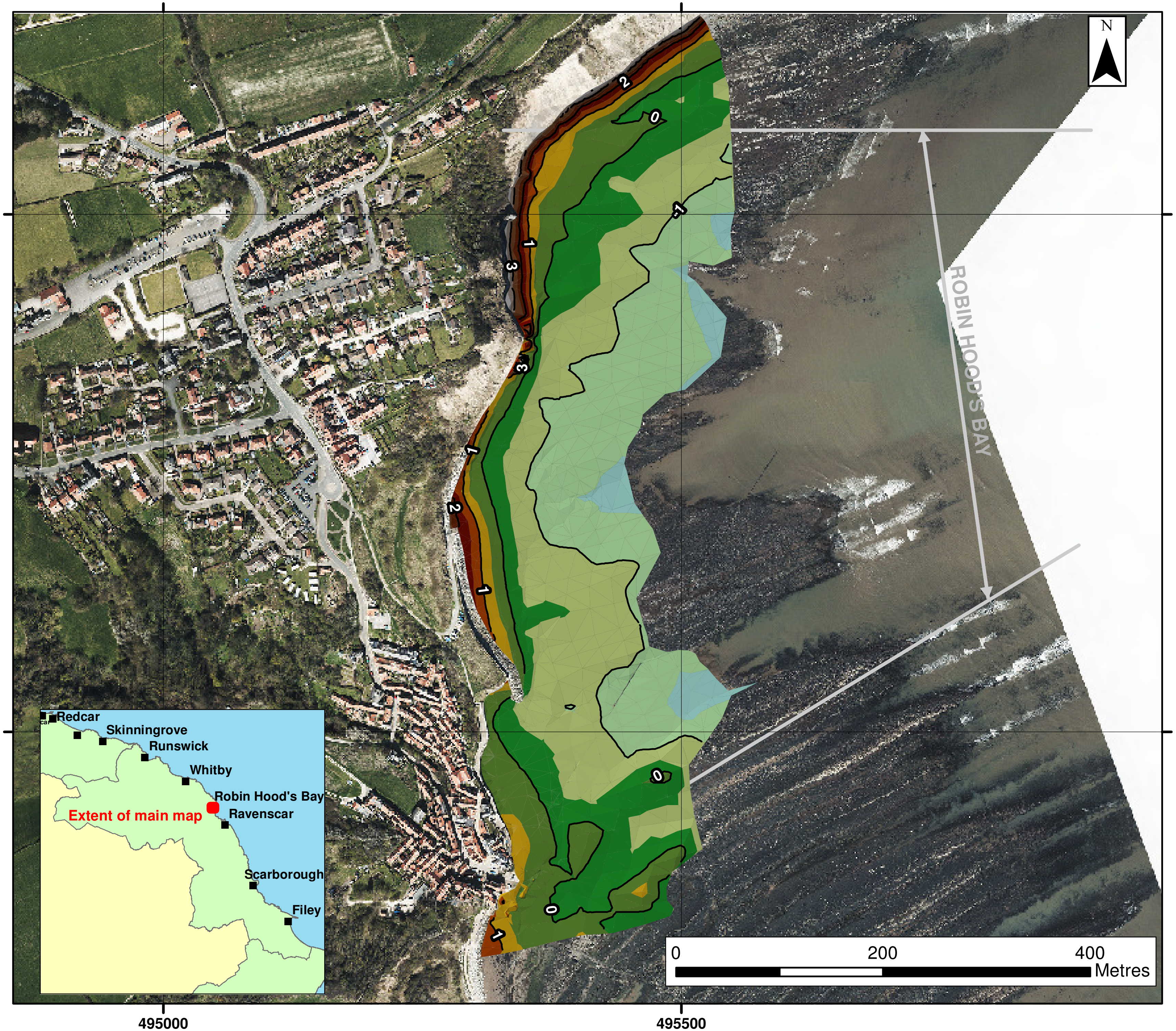

KEY

Elevation (m OD)

- 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 4a
Topographic Survey
Robin Hood's Bay
Scarborough
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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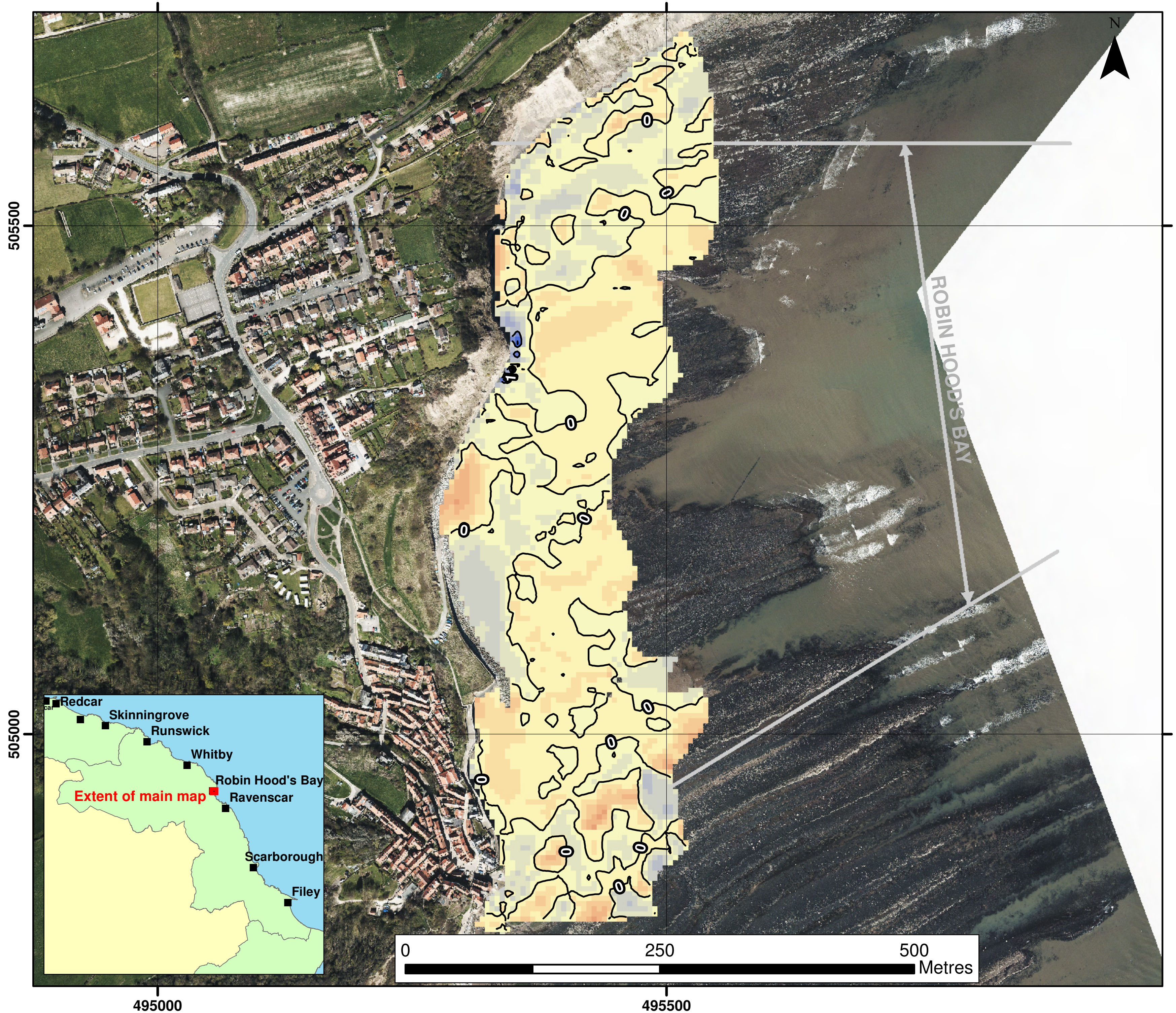

KEY Spring 2015 and Autumn 2015
Change in elevation (m)

- <-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 4b
Short-term Elevation Change
Robin Hood's Bay
Scarborough Borough Council

Analytical Report 8
Full Measures Survey
Autumn 2015

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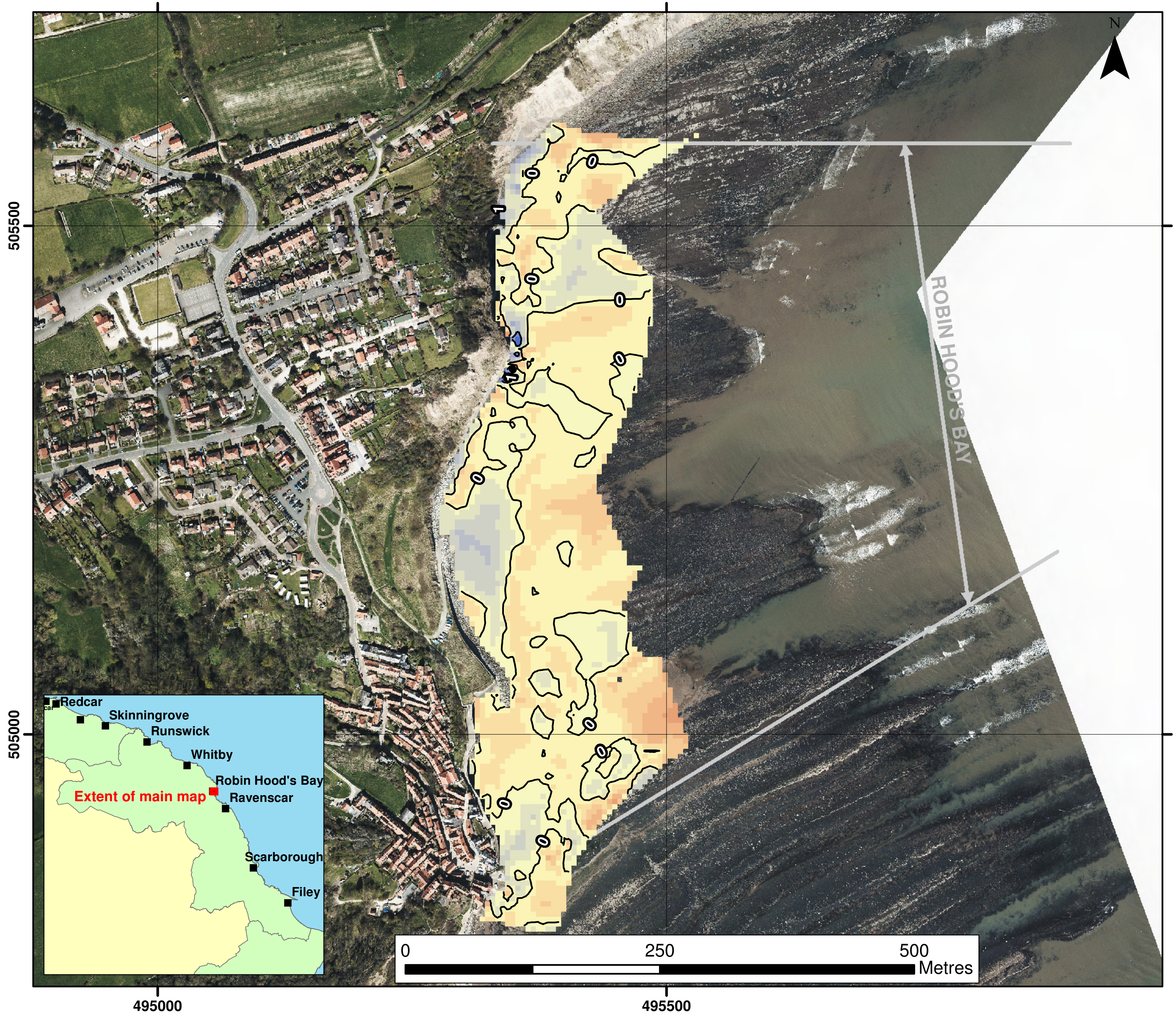

KEY Autumn 2008 and Autumn 2015
Change in elevation (m)

- <-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
Robin Hood's Bay
Scarborough Borough Council

Analytical Report 8
Full Measures Survey
Autumn 2015

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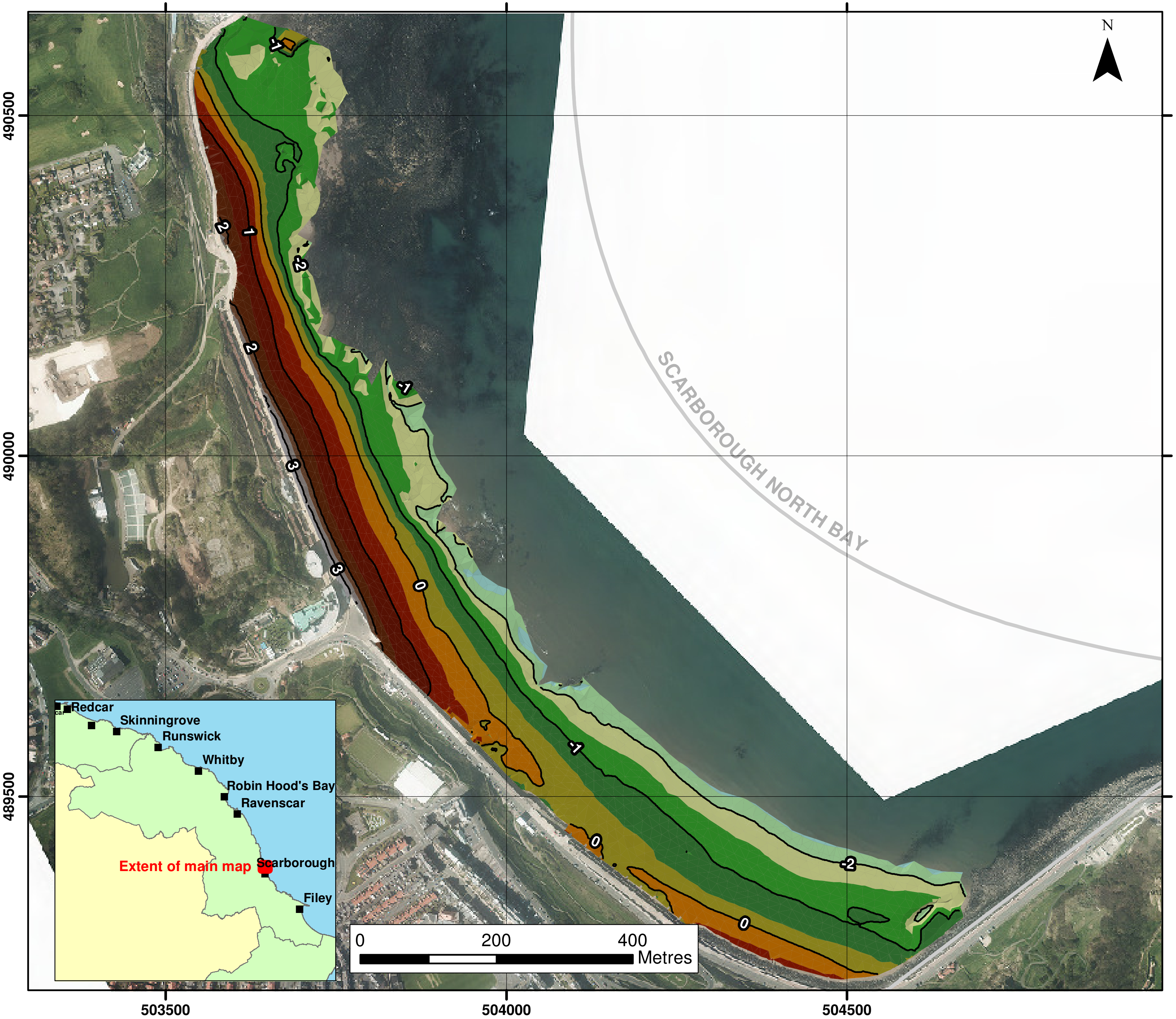

KEY

Elevation (m OD)

- 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 5a
Topographic Survey
Scarborough North
Scarborough Borough Council

Analytical Report 8
Full Measures Survey
Autumn 2015

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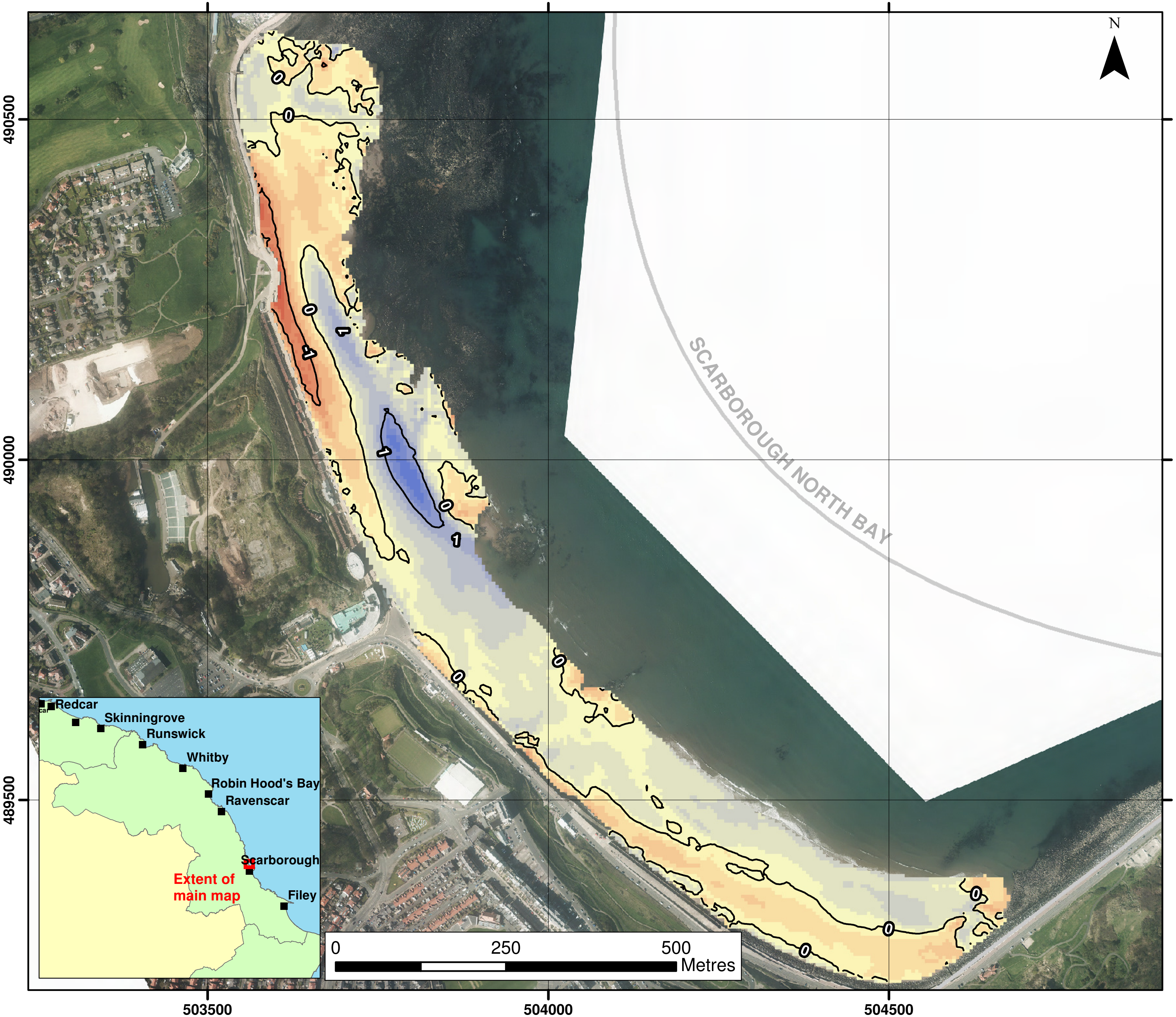

KEY Autumn 2014 and Autumn 2015
Change in elevation (m)

- <-2
- -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 5b
Short-term Elevation Change
Scarborough North
Scarborough Borough Council

Analytical Report 8
Full Measures Survey
Autumn 2015

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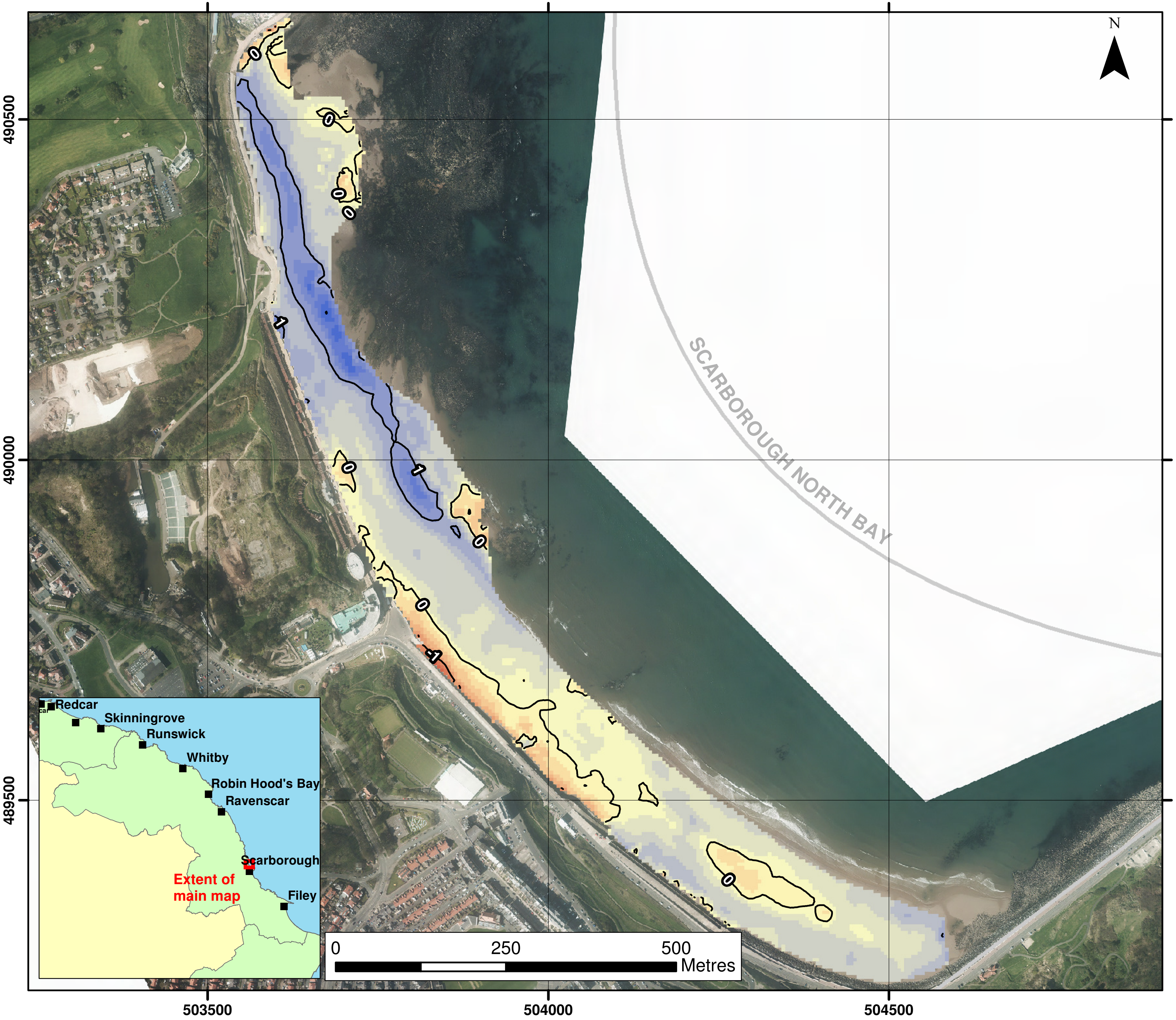

KEY Autumn 2008 and Autumn 2015
Change in elevation (m)

- <-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 5c
Long-term Elevation Change Scarborough North Scarborough Borough Council

Analytical Report 8
Full Measures Survey
Autumn 2015

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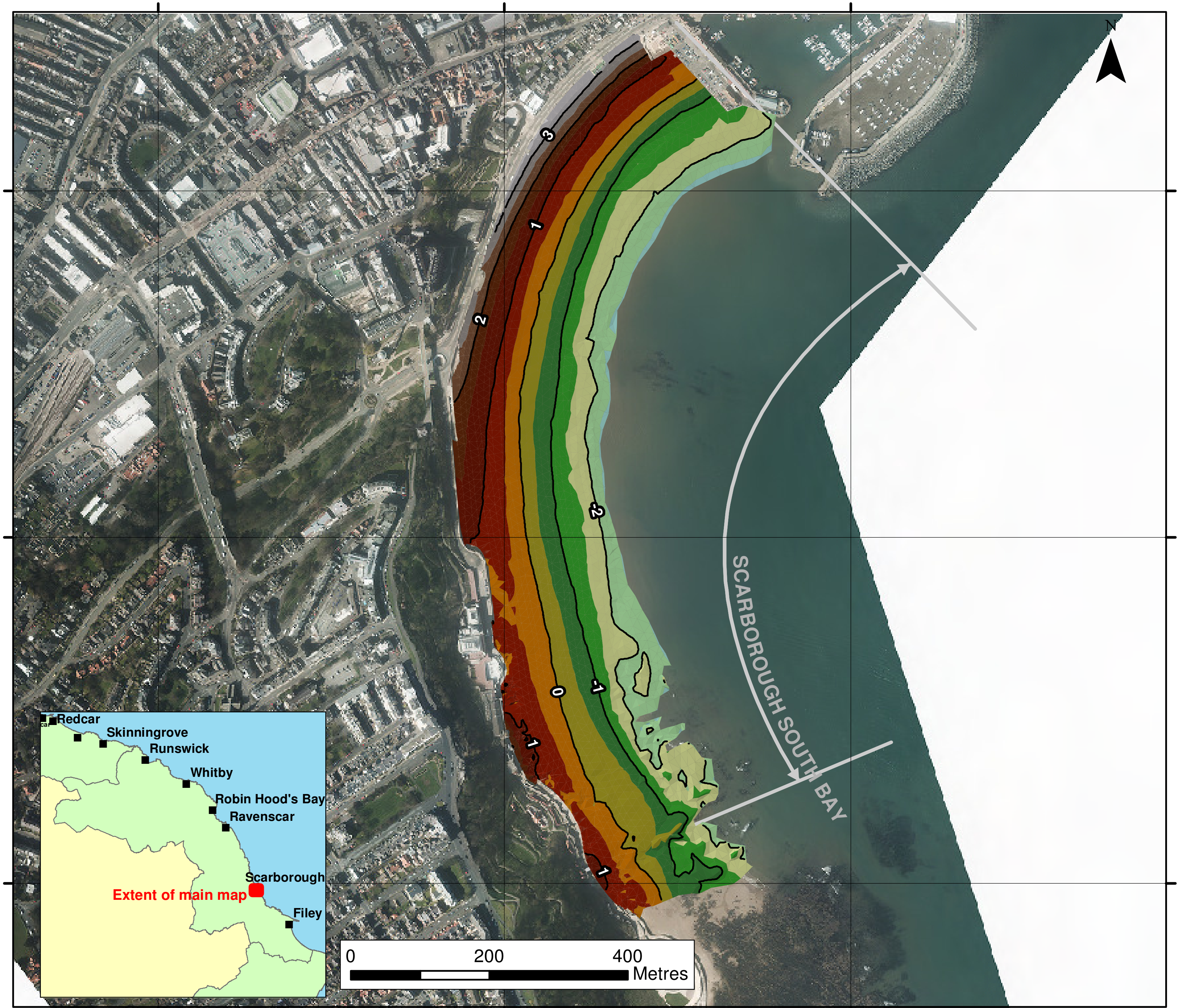

KEY

Elevation (m OD)

- 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 6a
Topographic Survey
Scarborough South
Scarborough Borough Council

Analytical Report 8
Full Measures Survey
Autumn 2015

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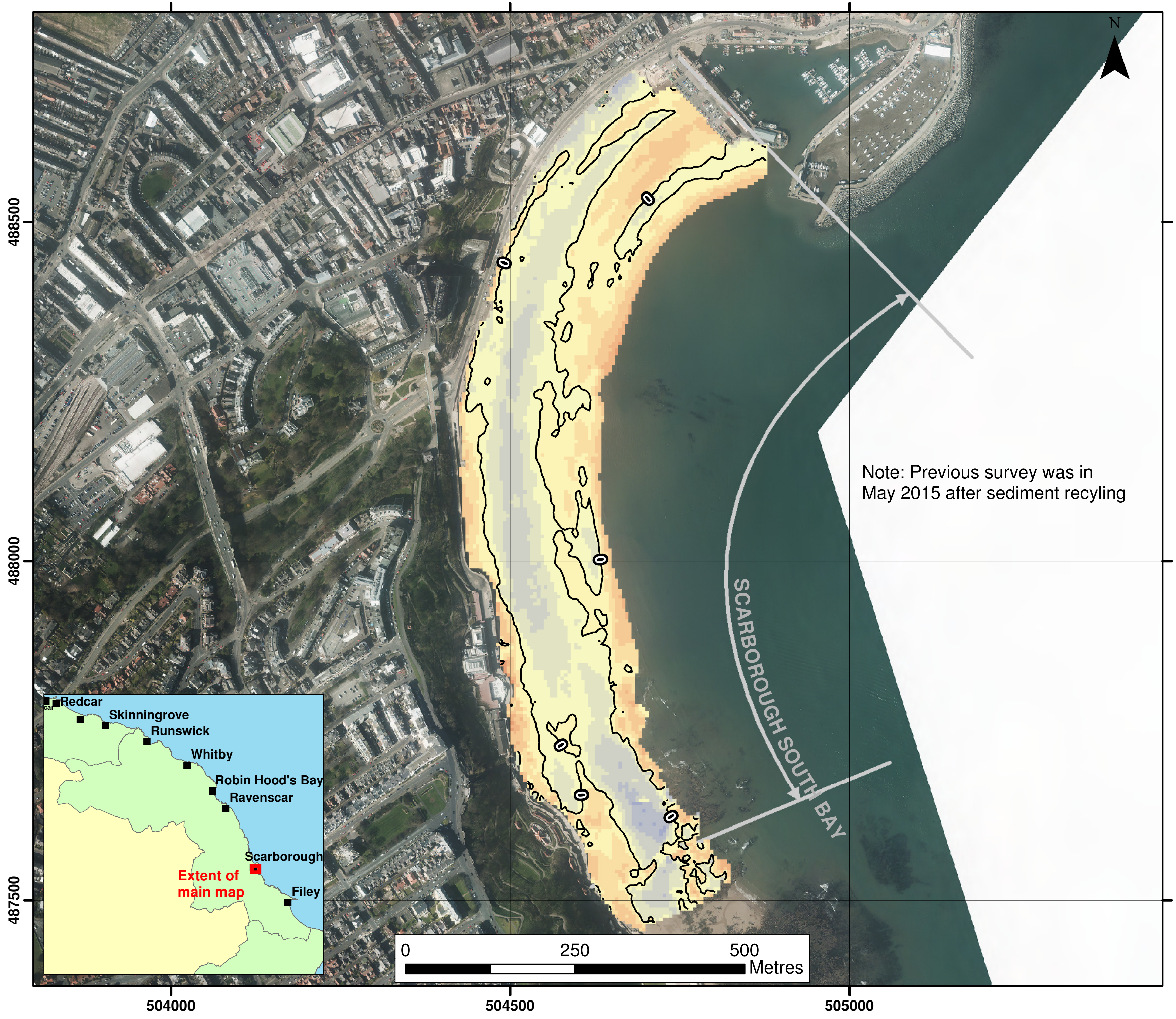

KEY Spring 2014 and Autumn 2015
Change in elevation (m)

- <-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 6b
Short-term Elevation Change Scarborough South Scarborough Borough Council

Analytical Report 8
Full Measures Survey
Autumn 2015

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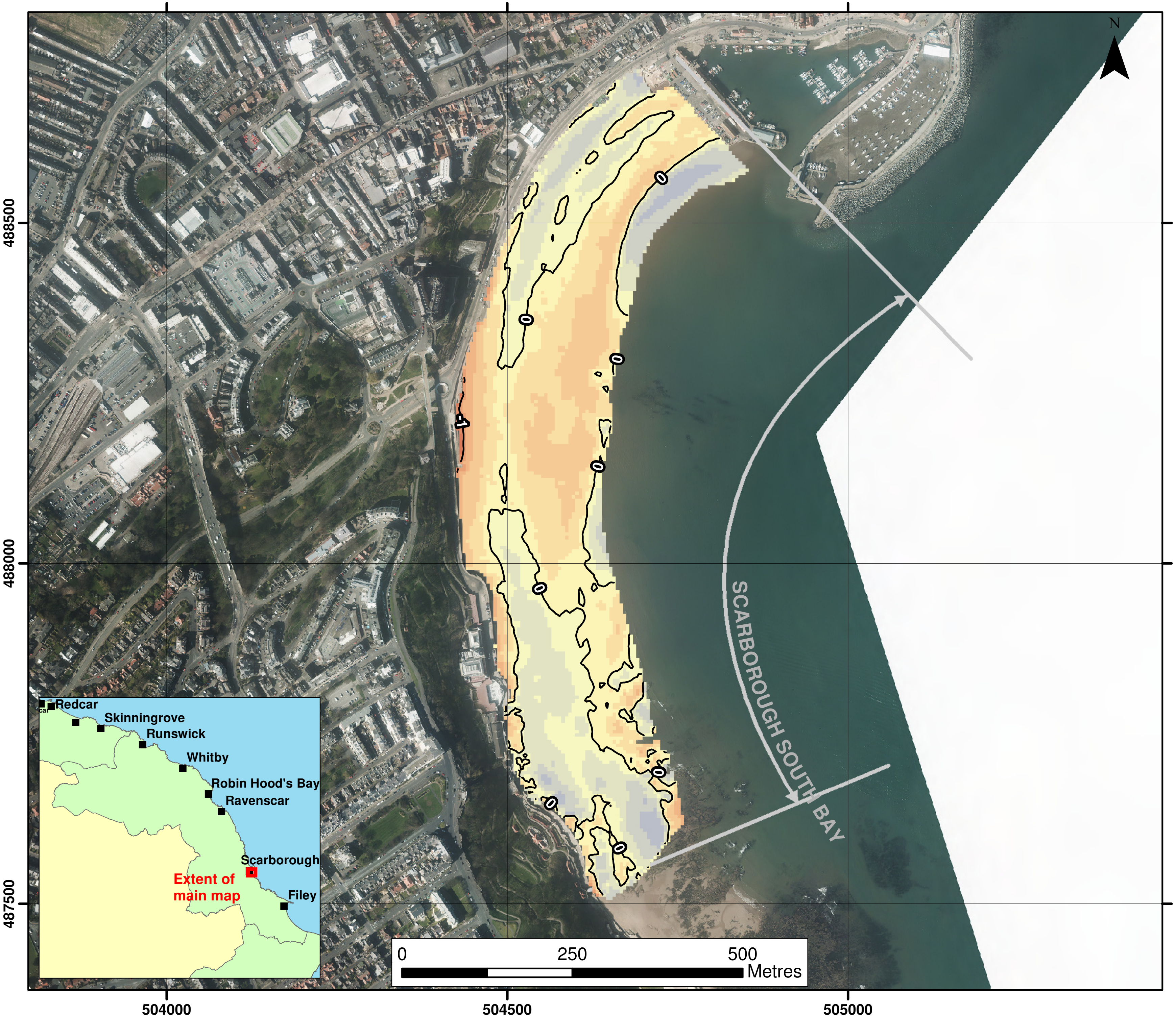

KEY Autumn 2008 and Autumn 2015
Change in elevation (m)

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 6c
Long-term Elevation Change
Scarborough South
Scarborough Borough Council

Analytical Report 8
Full Measures Survey
Autumn 2015

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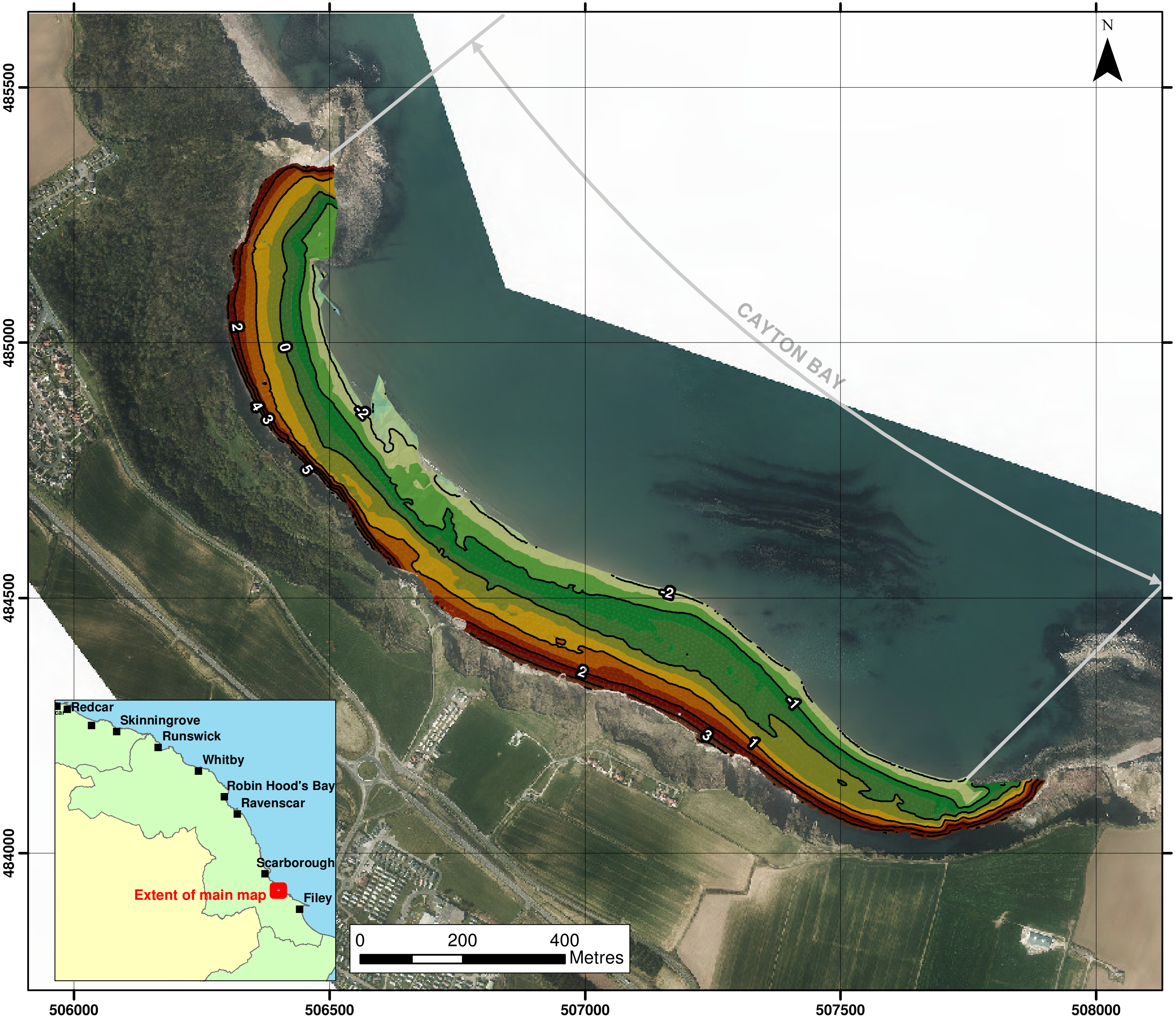

KEY

Elevation (m OD)

- 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
- -3.5 - -3
- Contour 1m

Client: North East Coastal Group

Project: Cell 1 Regional Coastal Monitoring Programme 2011 to 2016

Appendix B - Map 7a
Topographic Survey
Cayton Bay
Scarborough
Borough Council

Analytical Report 8
Full Measures Survey
Autumn 2015

ch2m

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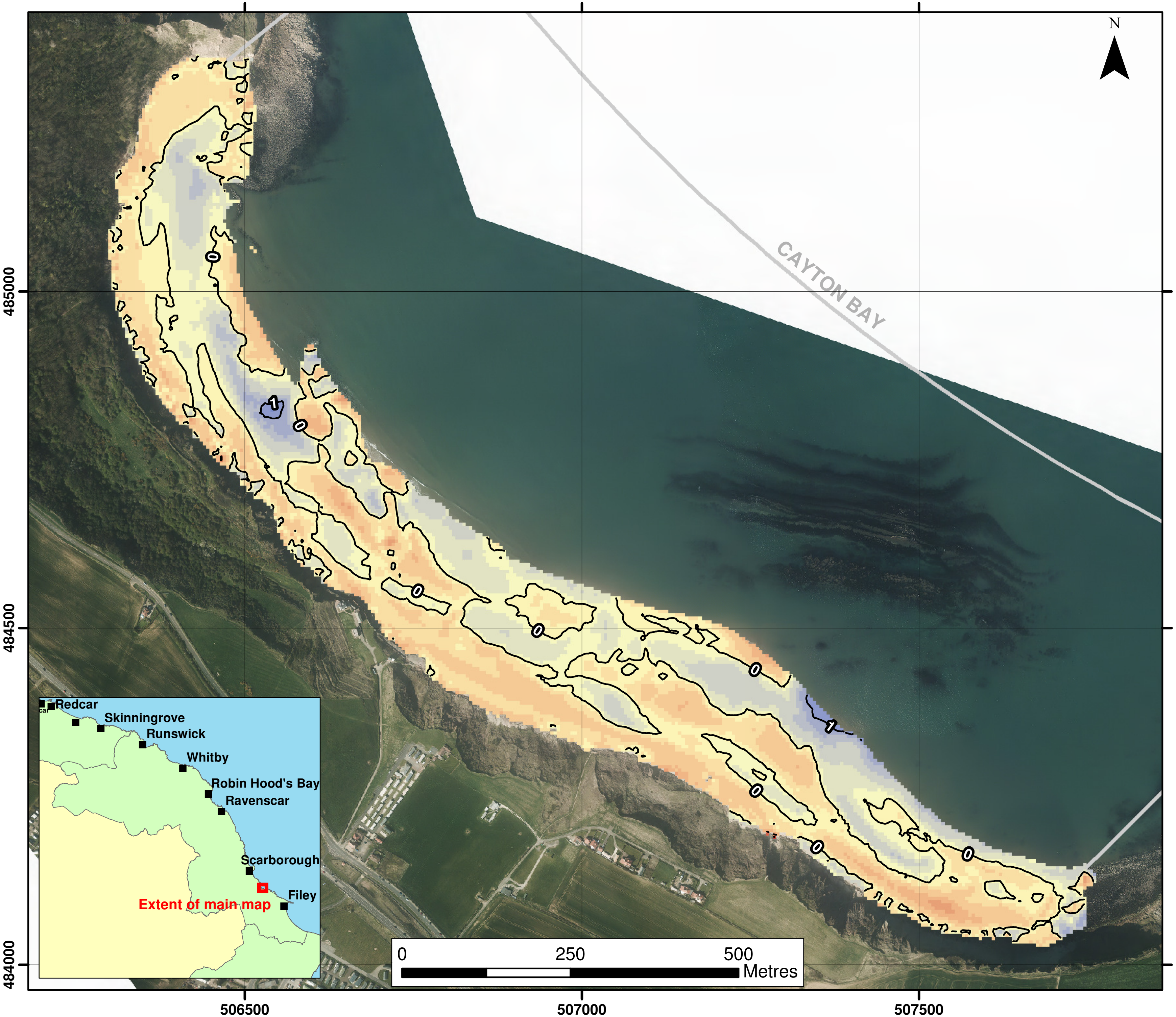

KEY Autumn 2014 and Autumn 2015
Change in elevation (m)

<-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 7b Short-term Elevation Change Cayton Scarborough Borough Council

Analytical Report 8
Full Measures Surveys
Autumn 2015

ch2m

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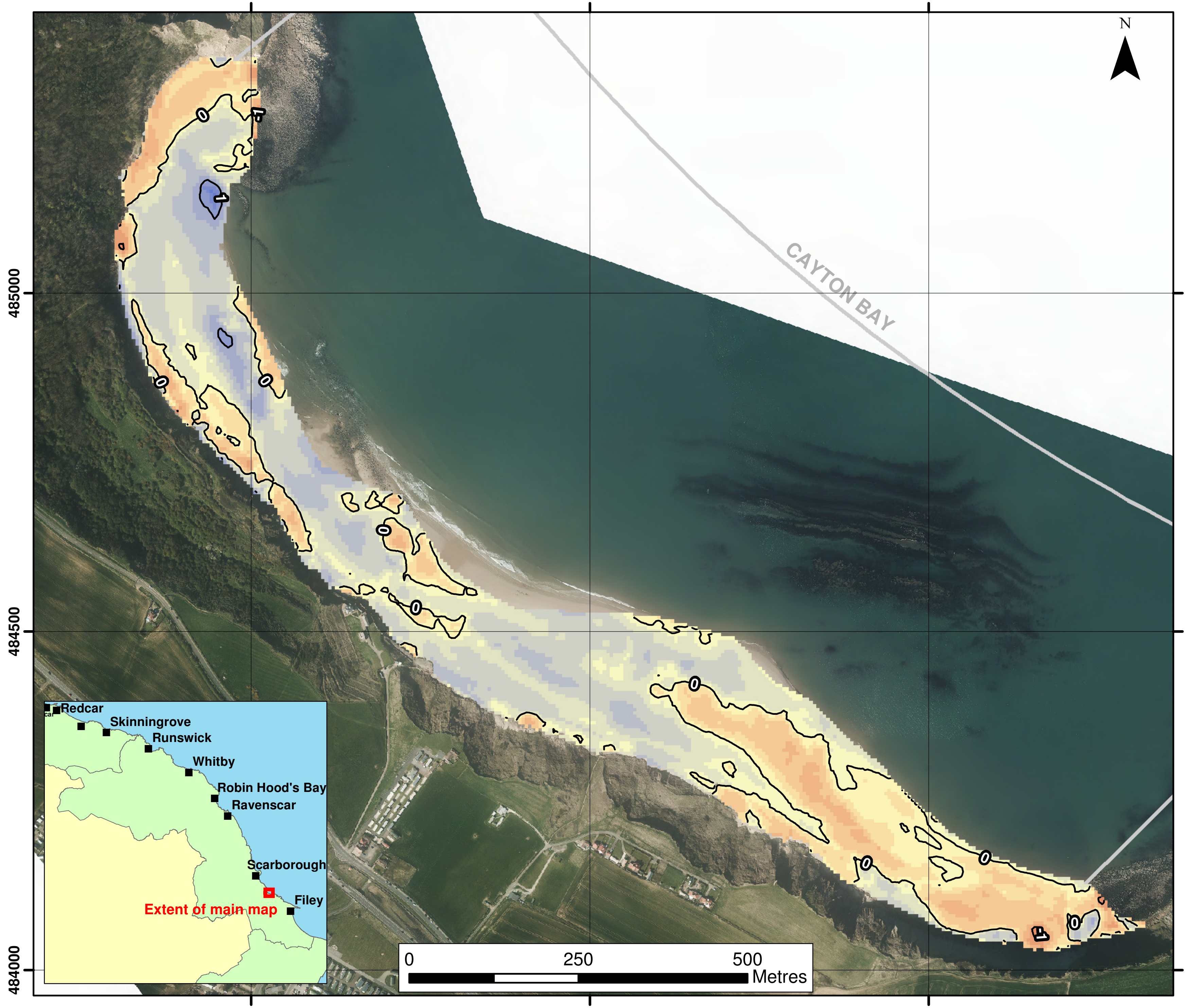

KEY Autumn 2008 and Autumn 2015
Change in elevation (m)

<-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 7c
Long-term Elevation Change
Cayton
Scarborough Borough Council

Analytical Report 8
Full Measures Survey
Autumn 2015

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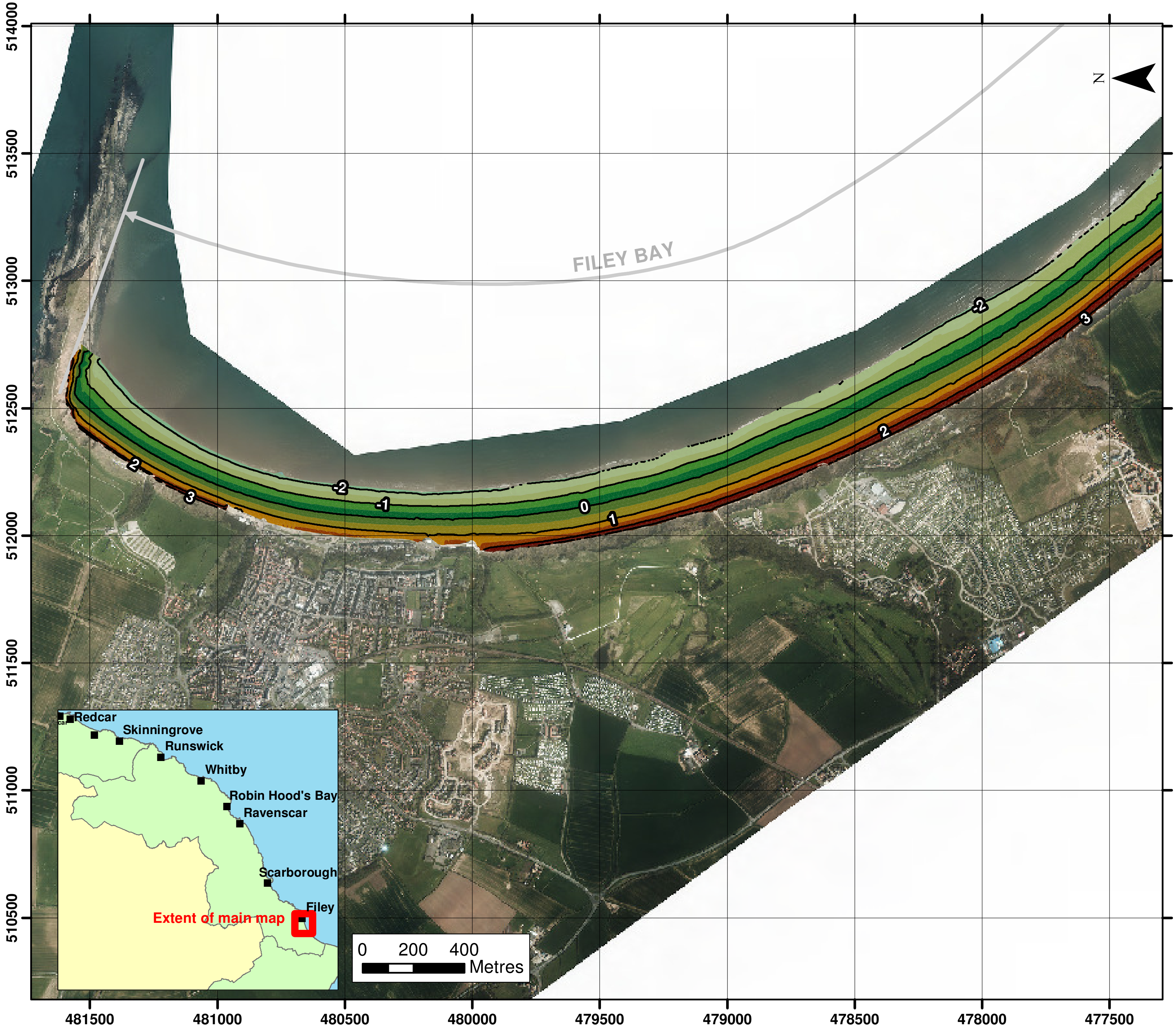

KEY

Elevation (m OD)

- 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 8a Topographic Survey Filey Bay a Scarborough Borough Council

Analytical Report 8
Full Measures Survey
Autumn 2015

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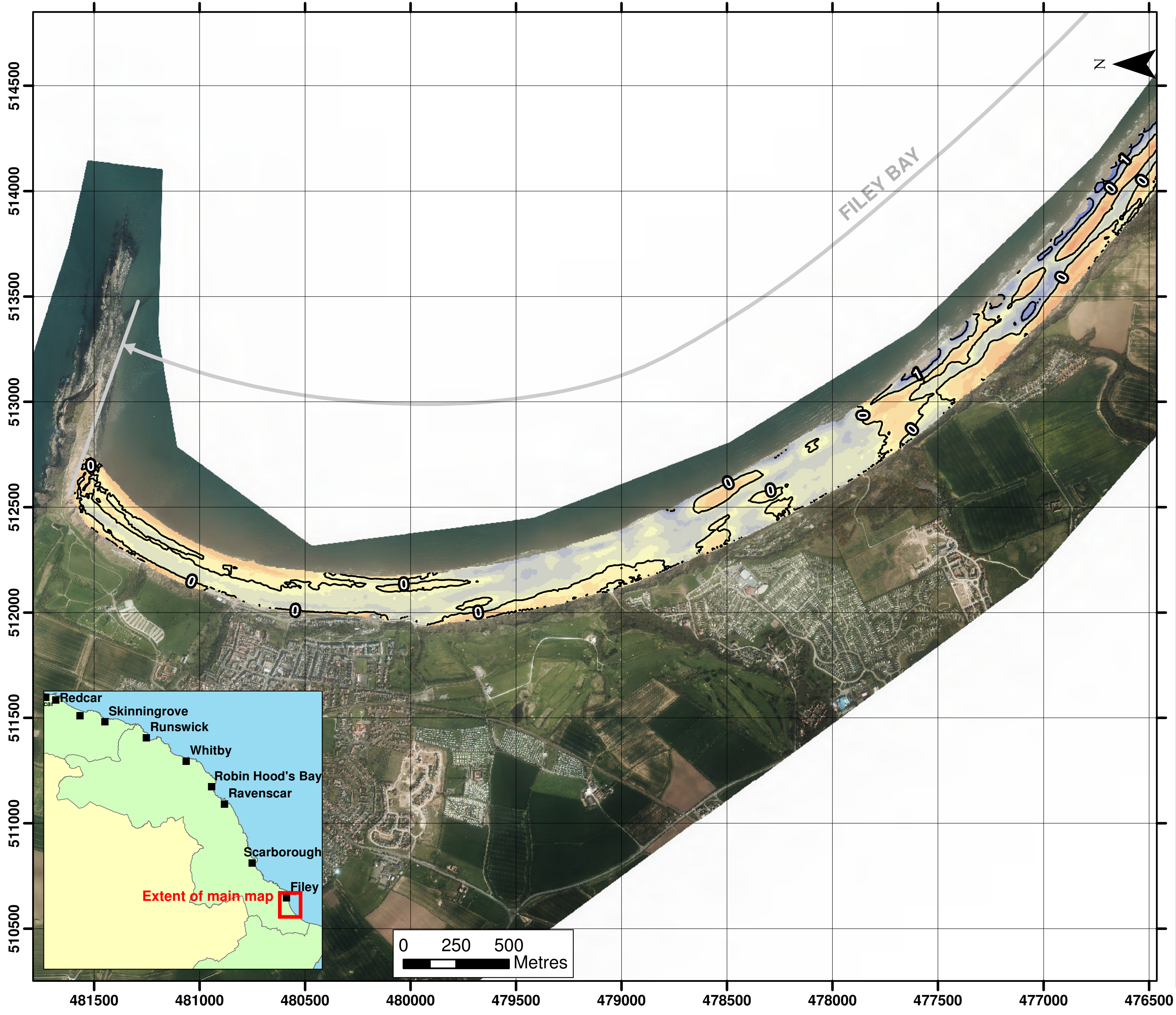

KEY Autumn 2014 and Autumn 2015

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 8b
Short-term Elevation Change
Filey a
Scarborough Borough Council

Analytical Report 8
Full Measures Survey
Autumn 2015

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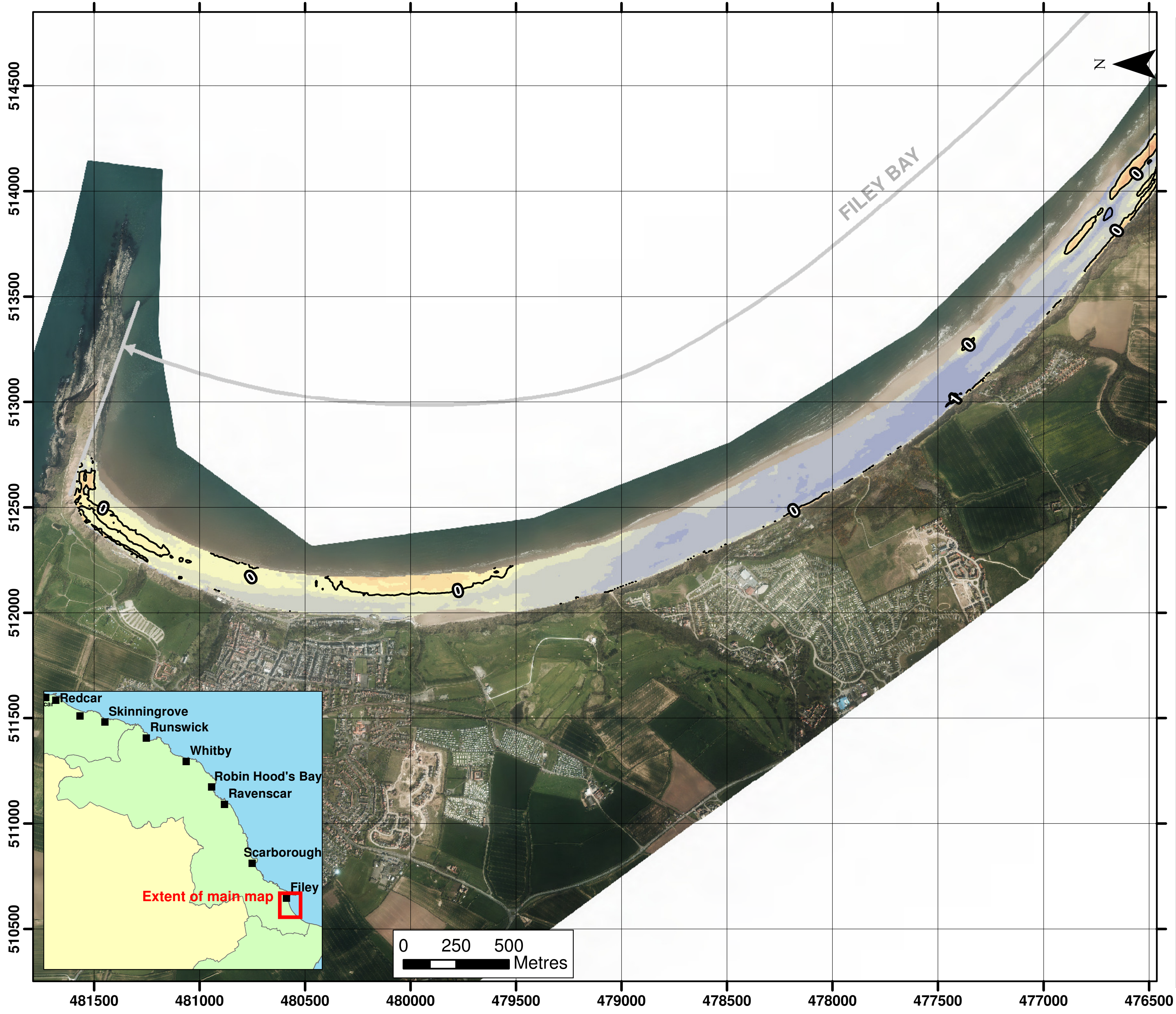

KEY Autumn 2008 and Autumn 2015
Change in elevation (m)

- <-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 8c
Long-term Elevation Change Filey a Scarborough Borough Council

Analytical Report 8
Full Measures Survey
Autumn 2015

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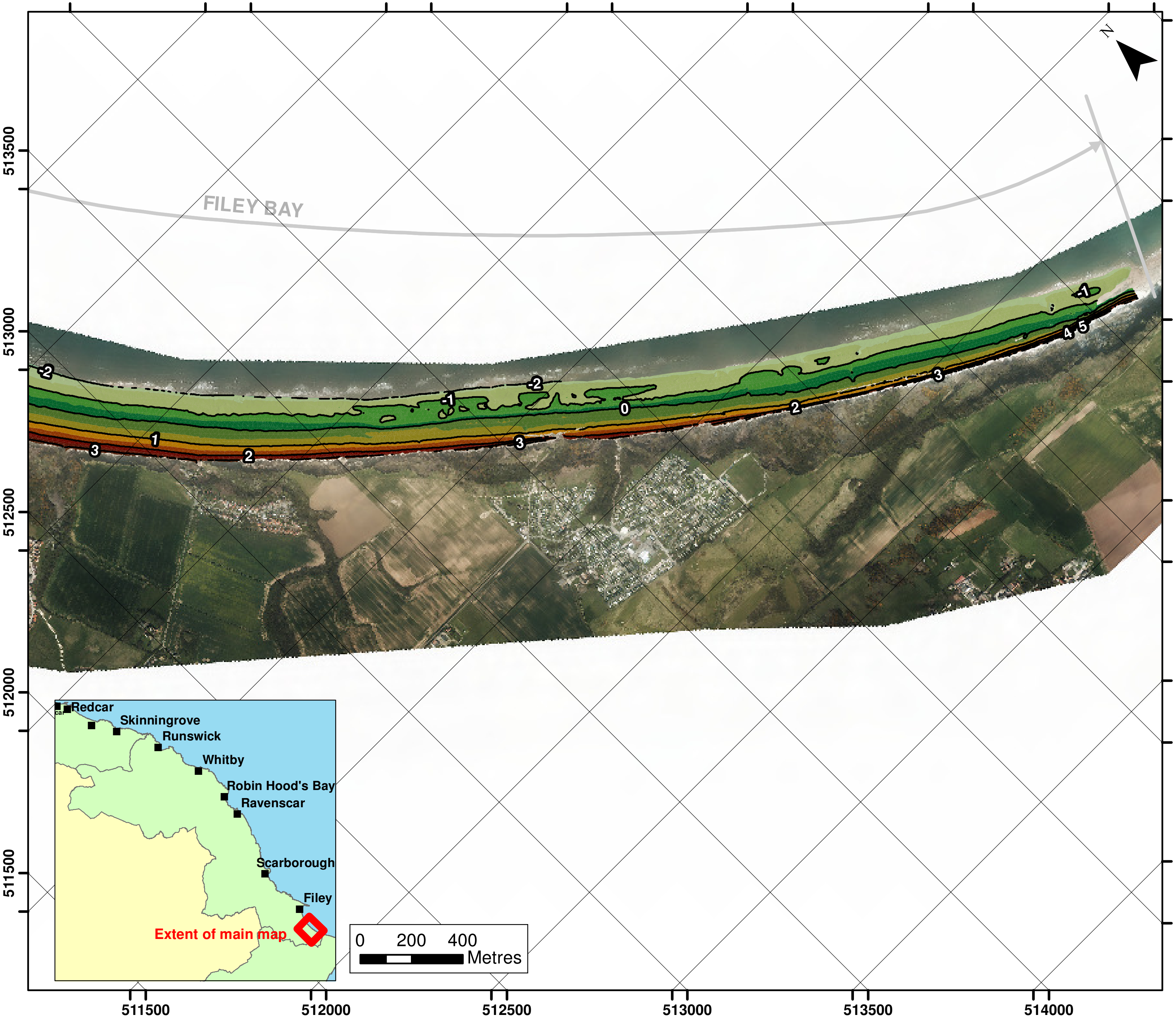

KEY

Elevation (m OD)

- 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 9a
Topographic Survey
Filey Bay b
Scarborough Borough Council

Analytical Report 8
Full Measures Survey
Autumn 2015

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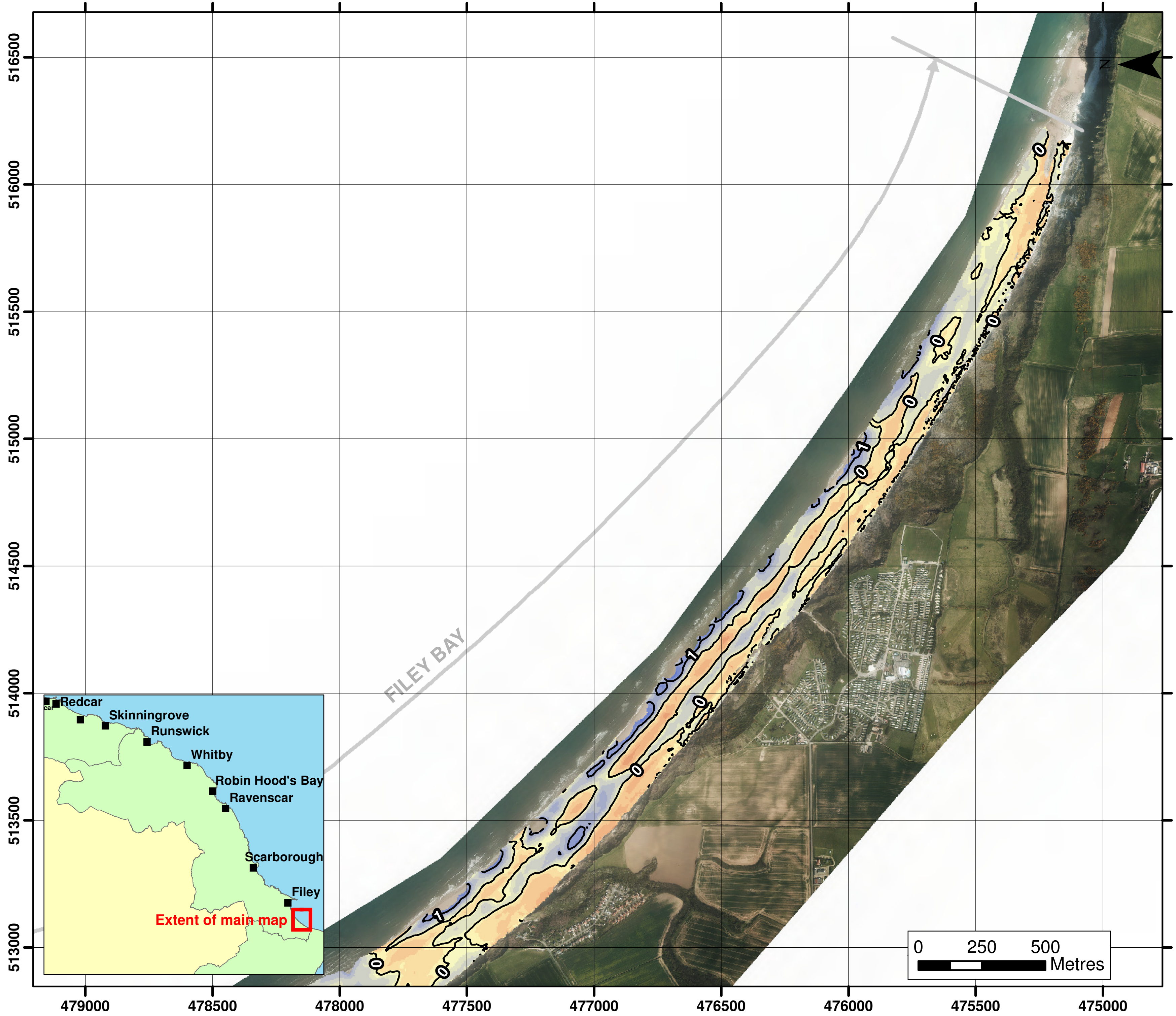

KEY Autumn 2014 and Autumn 2015
Change in elevation (m)

<-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 9b Short-term Elevation Change Filey b Scarborough Borough Council

Analytical Report 8
Full Measures Survey
Autumn 2015

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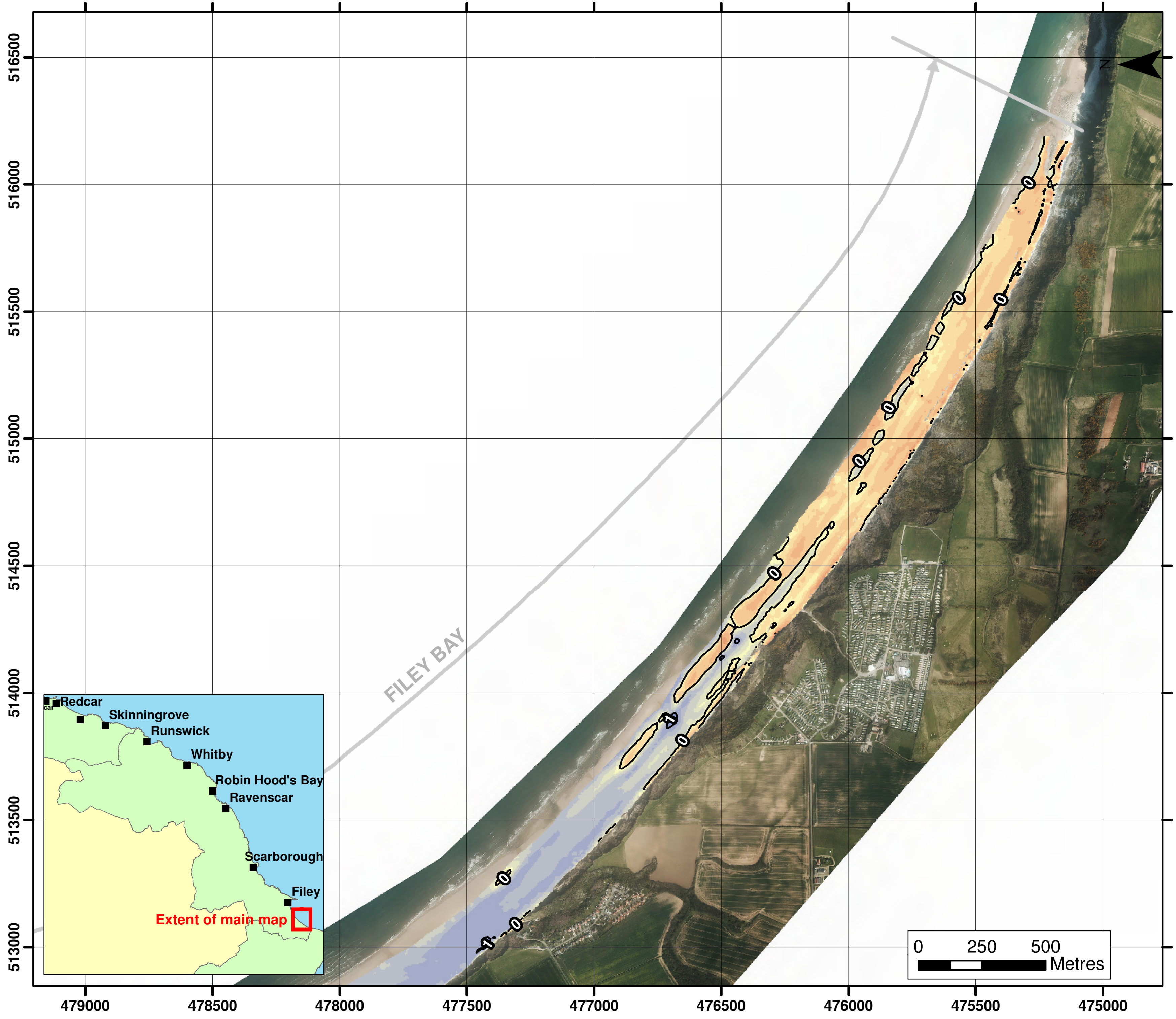

KEY Autumn 2008 and Autumn 2015
Change in elevation (m)

- <-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 9c
Long-term Elevation Change Filey b
Scarborough Borough Council

Analytical Report 8
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Autumn 2015

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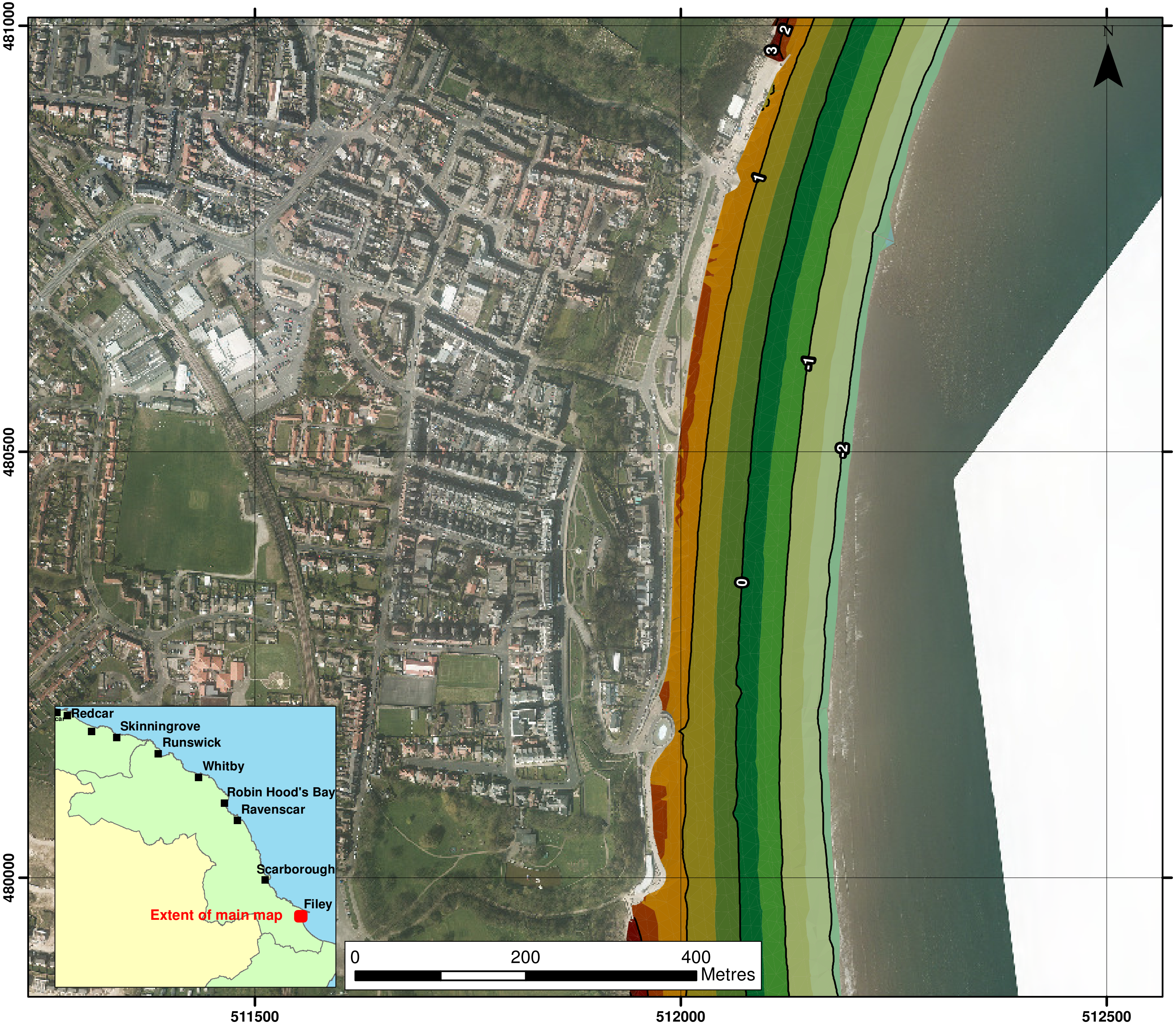

KEY

Elevation (m OD)

- 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 10a
Topographic Survey
Filey Bay
Scarborough
Borough Council

Analytical Report 8
Full Measures Survey
Autumn 2015

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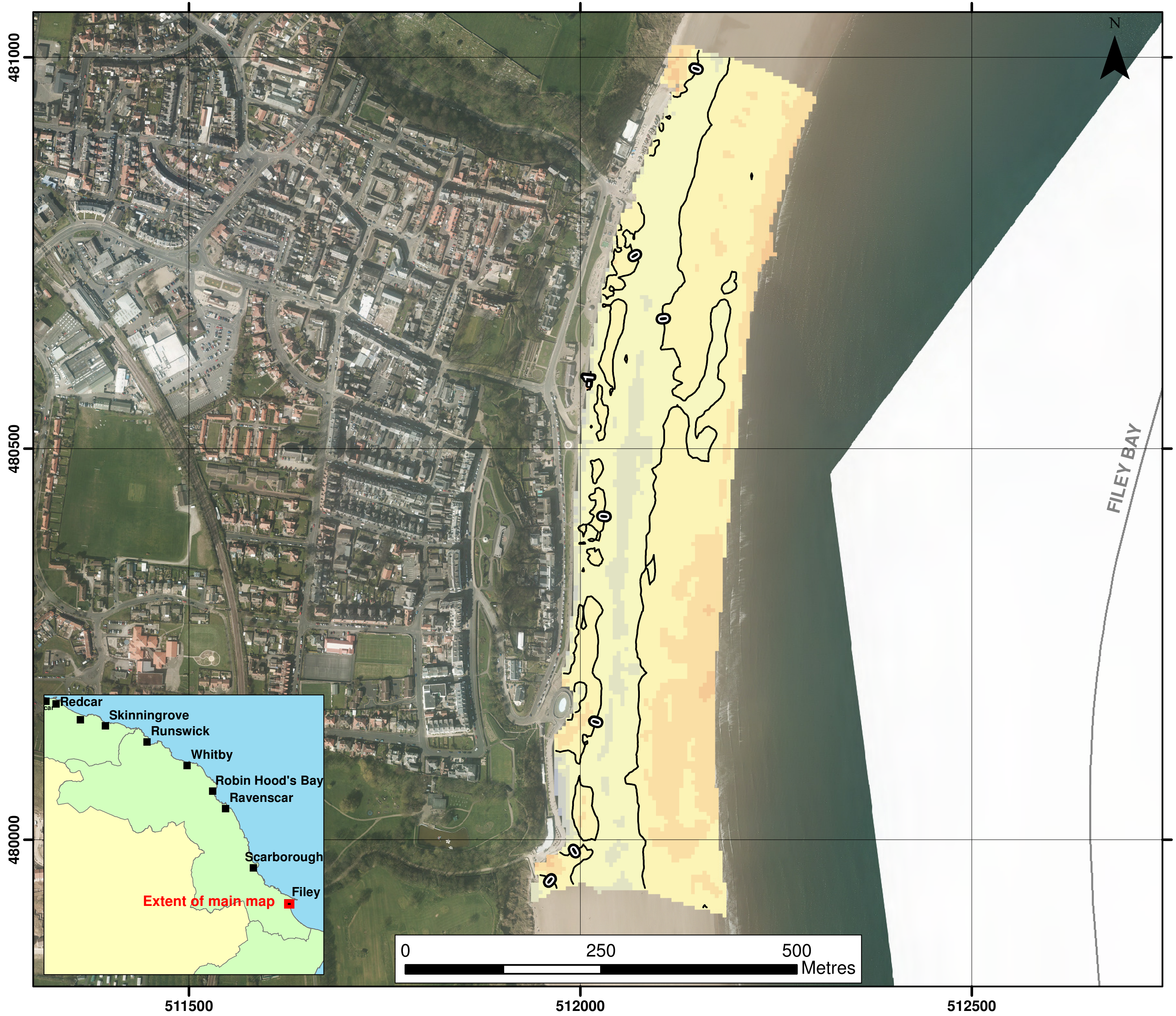

KEY Spring 2015 and Autumn 2015
Change in elevation (m)

<-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 10b
Short-term Elevation Change
Filey
Scarborough Borough Council

Analytical Report 8
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Autumn 2015

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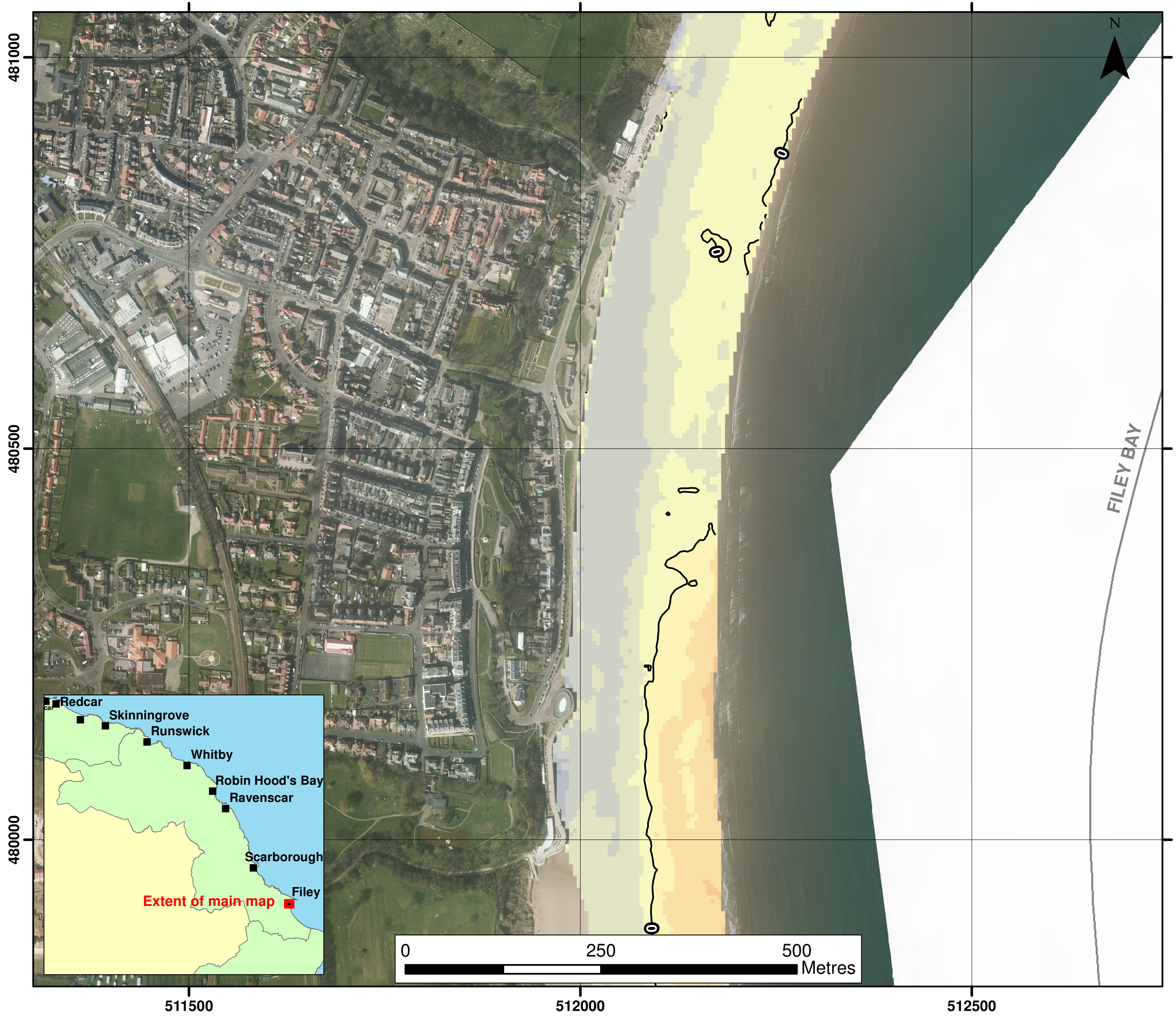

KEY Autumn 2008 and Autumn 2015
Change in elevation (m)

- <-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 10c
Long-term Elevation Change
Filey
Scarborough Borough Council

Analytical Report 8
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Appendix C

Cliff Top Survey

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 (Oct 2014)	Present Survey (Mar 2015)	Baseline (Nov 2008) to Present (Mar 2015)	Previous (Oct 2014) to Present (Mar 2015)	Baseline (Nov 2008) to Present (Mar 2015)
1	477228	518769	320	1.9	1.6	1.6	-0.3	0.0	-0.1
2	477334	518798	0	10.9	10.8	10.8	-0.1	0.0	0.0
3	477487	518789	350	7.1	8.3	8.3	1.2	0.0	0.2
4	477594	518801	340	5.9	5.1	5.1	-0.8	0.0	-0.1
5	477683	518911	350	8.4	9.1	8.5	0.1	-0.6	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	7.3	-0.4	0.0	-0.1
8	477959	518873	350	8.7	9.8	9.8	1.1	0.0	0.2
9	478088	518950	350	7.6	8.2	8.3	0.7	0.1	0.1
10	478191	519023	340	8.4	8.8	8.8	0.4	0.0	0.1
11	478237	519007	60	6.9	6.8	6.7	-0.2	0.0	0.0
12	478213	518988	150	6.1	6.5	6.5	0.4	0.0	0.1
13	478501	518809	15	11.4	9.2	9.1	-2.3	-0.1	-0.4

14	478624	518807	20	7.5	7.5	7.5	0.0	0.1	0.0
15	478737	518858	60	6.1	6.5	6.4	0.3	-0.1	0.0
16	478823	518757	60	8	8.9	8.8	0.8	-0.1	0.1
17	478944	518671	30	9.3	9.2	9.0	-0.3	-0.2	-0.1
18	479052	518630	20	9.2	9.5	9.4	0.2	-0.1	0.0
19	479147	518610	0	14.2	14.4	14.4	0.2	0.0	0.0
20	479274	518618	20	11.4	11.1	11.4	0.0	0.3	0.0

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.

Robin Hoods Bay

Thirteen ground control points have been established within Robin Hoods Bay (Figure C1). The maximum separation between any two points is nominally 200m.

The cliff top surveys at Robin Hoods Bay are undertaken annually. Measurements are taken from a fixed ground control point along a fixed bearing to the edge of the cliff top.

Table C2 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 C2 – Cliff Top Surveys at Robin Hoods Bay

Ground Control Point Details				Distance to Cliff Top (m)			Total Erosion (m)		Erosion Rate (m/year)
Ref	Easting	Northing	Bearing (º)	Baseline Survey (March 2010)	Previous Survey (March 2015)	Present Survey (Sept 2015)	Baseline (March 2010) to Present (Sept 2015)	Previous (March 2015) to Present (Sept 2015)	Baseline (March 2010) to Present (Sept 2015)
1	495799.5	506002.2	130	11.6	7.9	7.9	-3.7	0.0	-0.7
2	495549.2	505807.3	135	9.3	9.0	9.0	-0.3	0.0	-0.1
3	495456.3	505740	130	5	5.3	5.2	0.2	-0.1	0.0
4	495389.9	505683.7	140	6.3	6.1	6.4	0.1	0.3	0.0
5	495259.4	505342.5	130	11.3	10.0	10.0	-1.3	0.0	-0.2
6	495231.2	505315.7	95	5.9	5.8	5.8	-0.1	0.0	0.0
7	495184.8	505210.7	85	6.4	6.3	6.7	0.3	0.4	0.0
8	495206.5	505153	75	5	5.2	5.3	0.3	0.0	0.0
9	495287.8	505060.5	80	4.3	4.6	4.7	0.4	0.1	0.1
10	495187.8	504708.8	70	3.1	2.6	2.6	-0.6	-0.1	-0.1
11	495226.2	504615.7	120	3.8	4.0	3.2	-0.6	-0.8	-0.1
12	495297.5	504380.2	80	11	11.1	11.0	0.0	-0.1	0.0
13	495350.4	504193	55	3.7	3.8	3.8	0.1	0.1	0.0

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.

Scarborough South Bay

Thirteen ground control points have been established between Scarborough South Bay and Cayton Bay (Figure C1). The maximum separation between any two points is nominally 300m.

The cliff top surveys at Scarborough South Bay are undertaken annually. Measurements are taken from a fixed ground control point along a fixed bearing to the edge of the cliff top.

Table C3 provides baseline information about these ground control points and results from the 2010 (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 C3 – Cliff Top Surveys at Scarborough South

Ground Control Point Details				Distance to Cliff Top (m)			Total Erosion (m)		Erosion Rate (m/year)
Ref	Easting	Northing	Bearing (º)	Baseline Survey (March 2010)	Previous Survey (March 2015)	Present Survey (Oct 2015)	Baseline (March 2010) to Present (Oct 2015)	Previous (March 2015) to Present (Oct 2015)	Baseline (March 2010) to Present (Oct 2015)
1	504339.5	487887.3	70	7.0	7.0	7.0	0.0	0.0	0.0
2	504422.3	487603.7	80	4.8	4.8	4.8	0.0	0.0	0.0
3	504534.8	487318.3	40	15.1	15.1	15.2	0.1	0.0	0.0
4	504730.2	487137.9	55	9.6	9.6	9.6	0.0	0.0	0.0
5	504922.9	486837.8	60	8.8	8.6	8.8	0.0	0.1	0.0
6	505071.1	486652.1	75	3.8	3.8	3.7	-0.1	-0.1	0.0
7	505284.3	486480	35	7.0	6.9	6.9	-0.1	0.0	0.0
8	505597.9	486363.4	30	8.6	8.6	8.5	-0.1	-0.1	0.0
9	505758.6	486005.1	45	9.1	8.8	8.8	-0.3	0.0	-0.1
10	505896	485889.6	15	14.8	14.8	14.7	-0.1	-0.1	0.0
11	505990	485657.1	80	4.7	1.6	1.6	-3.1	0.0	-0.6
12	506024.9	485421.8	55	6.1	4.1	4.1	-2.0	0.0	-0.4
13	506036	485315.3	90	7.0	7.0	7.1	0.1	0.1	0.0

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.

Cayton Bay

Eight ground control points have been established within Cayton Bay (Figure C1). The maximum separation between any two points is nominally 300m.

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

Table C4 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 C4 – Cliff Top Surveys at Cayton Bay

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 (March 2015)	Present Survey (Nov 2015)	Baseline (Nov 2008) to Present (Nov 2015)	Previous (March 2015) to Present (Nov 2015)	Baseline (Nov 2008) to Present (Nov 2015)
1	506325.5	484849.7	50	4.0	3.5	3.7	-0.3	0.3	0.0
2	506459.4	484715.9	65	5.0	0.0	0.0	-5.0	0.1	-0.7
3	506597.4	484538.6	65	5.0	6.3	6.3	1.3	0.0	0.2
4	506778.1	484345.5	21	9.0	6.0	6.0	-3.0	0.0	-0.4
5	507018.6	484221.6	342	7.7	8.1	8.1	0.4	0.0	0.1
6	507242.3	484121.7	2	7.4	6.3	6.3	-1.1	0.0	-0.2
7	507518.2	484008.2	25	7.5	7.8	7.9	0.4	0.1	0.1
8	507818.7	484006	1	5.5	6.3	5.7	0.2	-0.6	0.0

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.

Filey Bay

Twenty-seven ground control points have been established within Filey Bay (Figure C1). The maximum separation between any two points is nominally 300m.

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

Table C5 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 C5 – Cliff Top Surveys at Filey Bay

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 (March 2015)	Present Survey (Sept 2015)	Baseline (Nov 2008) to Present (Sept 2015)	Previous (March 2015) to Present (Sept 2015)	Baseline (Nov 2008) to Present (Sept 2015)
1	512444.9	481630.9	130	8.7	8.8	8.8	0.1	0.0	0.0
2	512306.7	481490.3	144	7.6	7.8	7.8	0.2	0.0	0.0
3	512153.6	481234.6	122	8.3	8.4	8.3	0.0	-0.2	0.0
4	512029.2	480959.9	115	7.4	7.6	7.4	0.0	-0.1	0.0
5	511895.4	479888	89	7.1	0.8	0.7	-6.4	-0.1	-0.9
6	511908.5	479597.1	48	6.7	7.2	7.3	0.6	0.1	0.1
7	511991.4	479310.4	69	6.7	4.7	4.6	-2.1	-0.1	-0.3
8	512083.4	478981.5	66	10.2	10.4	10.3	0.1	-0.1	0.0
9	512121.3	478786.3	76	8.3	8.3	8.4	0.1	0.1	0.0
10	512226.2	478547.9	74	7.5	7.2	7.3	-0.2	0.0	0.0
11	512471.4	478153.5	53	6.6	7.8	7.9	1.3	0.1	0.2
12	512558.9	477901.9	66	7.7	7.7	6.9	-0.9	-0.8	-0.1
12A*	512655.8	477822.4	67	13.9	13.7	14.0	0.1	0.3	0.0

13**	512697.6	477719	34	4.2	No Data	No Data	No Data	No Data	No Data
13A*	512805.5	477572.1	32	13.42	13.5	13.5	0.0	0.0	0.0
14	512939.4	477400.9	66	8	7.0	7.0	-1.0	0.0	-0.1
15	513157	477192.7	51	5.2	4.6	4.6	-0.6	0.0	-0.1
16	513299.5	477024.6	30	7.7	7.2	7.1	-0.6	-0.1	-0.1
17	513507.7	476821.1	34	10.7	10.7	10.5	-0.2	-0.2	0.0
18	513721	476602.3	31	7.2	7.0	6.9	-0.3	-0.1	0.0
19	513916.6	476354.1	51	6.6	6.5	6.5	-0.1	-0.1	0.0
20	514174.8	476179.4	32	7	6.9	7.0	0.0	0.1	0.0
21	514471.5	475965.7	66	7.6	7.5	7.6	0.0	0.1	0.0
22	514656.2	475728.8	101	8.1	8.2	8.2	0.1	0.0	0.0
23	514889.5	475537.6	60	9.1	9.1	9.1	0.0	0.0	0.0
24*	512603.7	481665.9	14	19.9	19.8	19.8	-0.1	-0.1	0.0
25*	512607.1	481648.9	184	17.2	17.0	17.2	0.0	0.2	0.0
26*	512301.9	481825.5	18	11	10.9	10.9	-0.1	0.0	0.0
27*	512475.8	481712.1	20	11.6	11.36	11.47	-0.1	0.1	0.0

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.
*baseline for 12A and 24-27 is March 2011.

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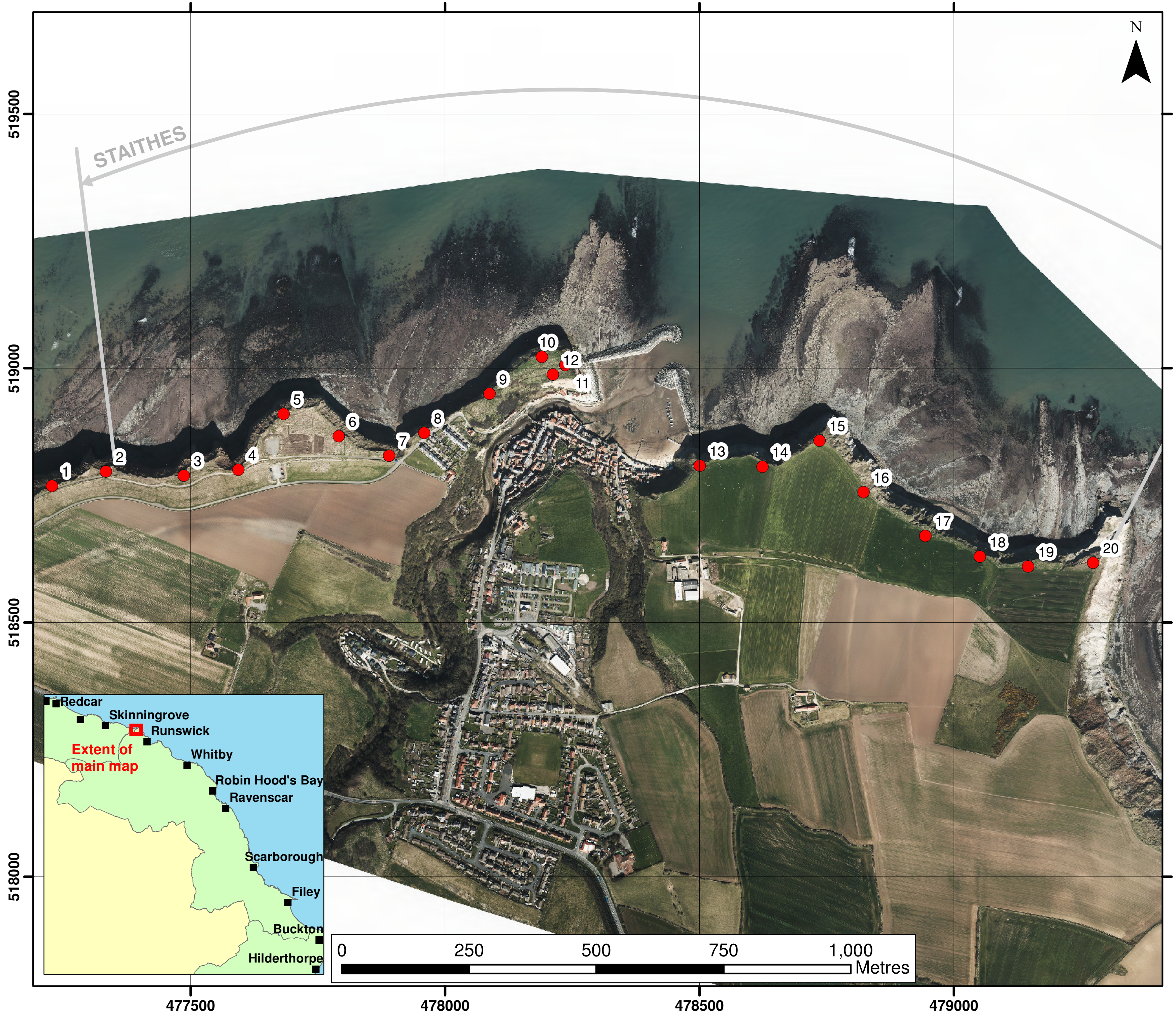

KEY

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
Scarborough
Borough Council

Analytical Report 8
Full Measures Survey
Autumn 2015

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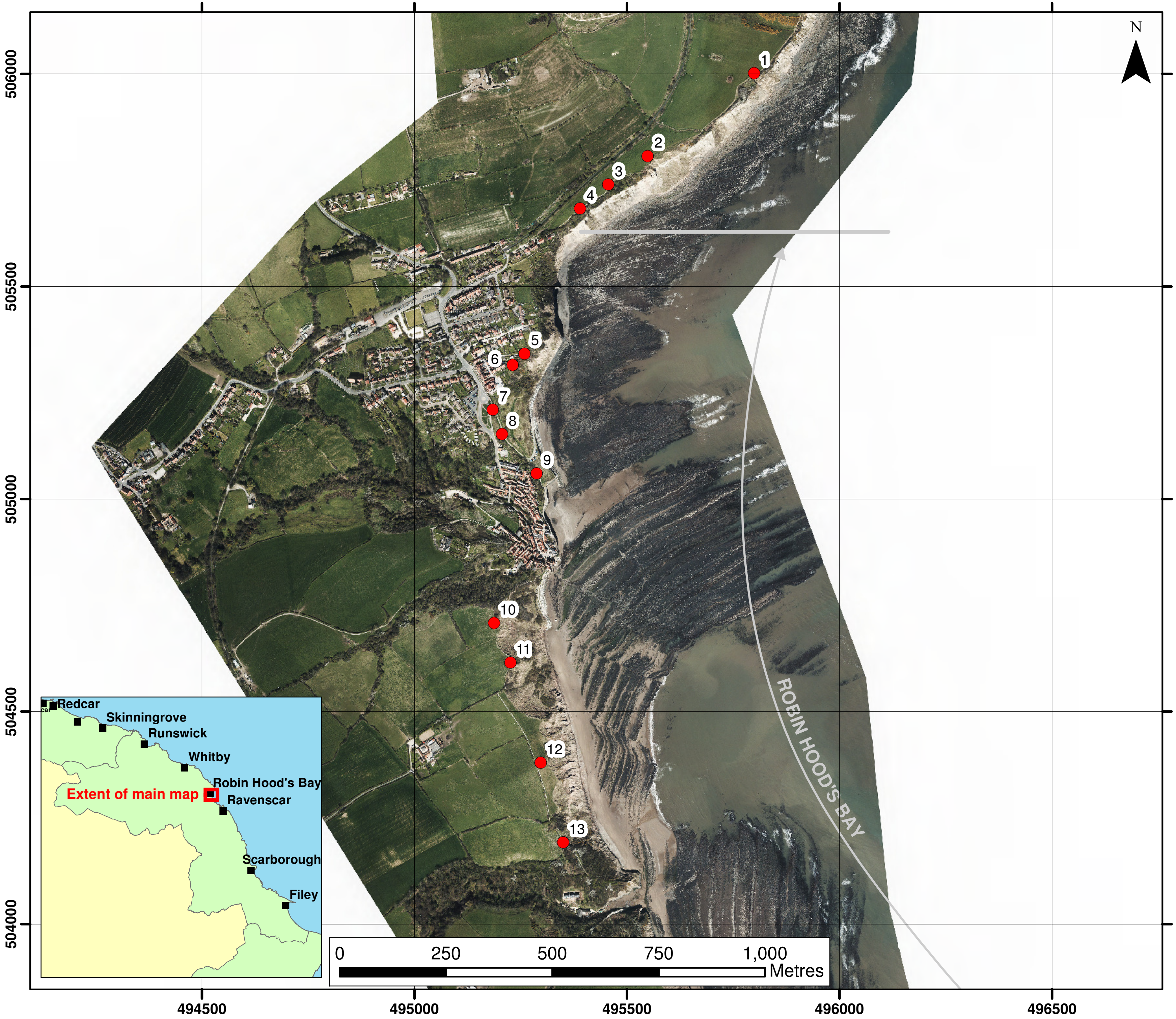

KEY

Ground Control Points

Client: North East Coastal Group

Project: Cell 1 Regional Coastal Monitoring Programme 2011 to 2016

Appendix C- Map 2
Ground Control Points
Robin Hood's Bay
Scarborough
Borough Council

Analytical Report 8
Full Measures Survey
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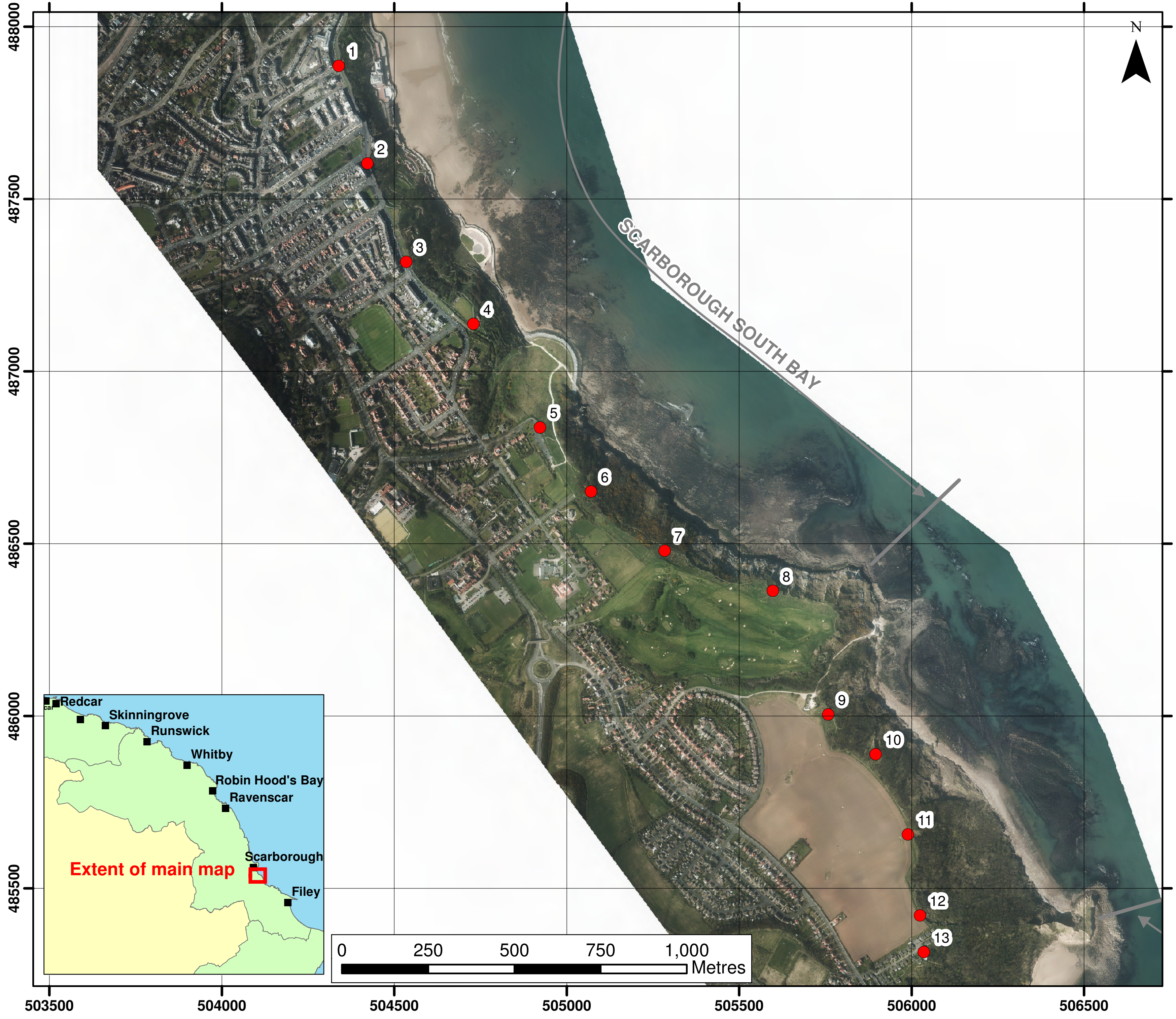

KEY

Ground Control Points

Client: North East Coastal Group

Project: Cell 1 Regional Coastal Monitoring Programme 2011 to 2016

Appendix C - Map 3
Ground Control Points
Scarborough South Bay
Scarborough
Borough Council

Analytical Report 8
Full Measures Survey
Autumn 2015

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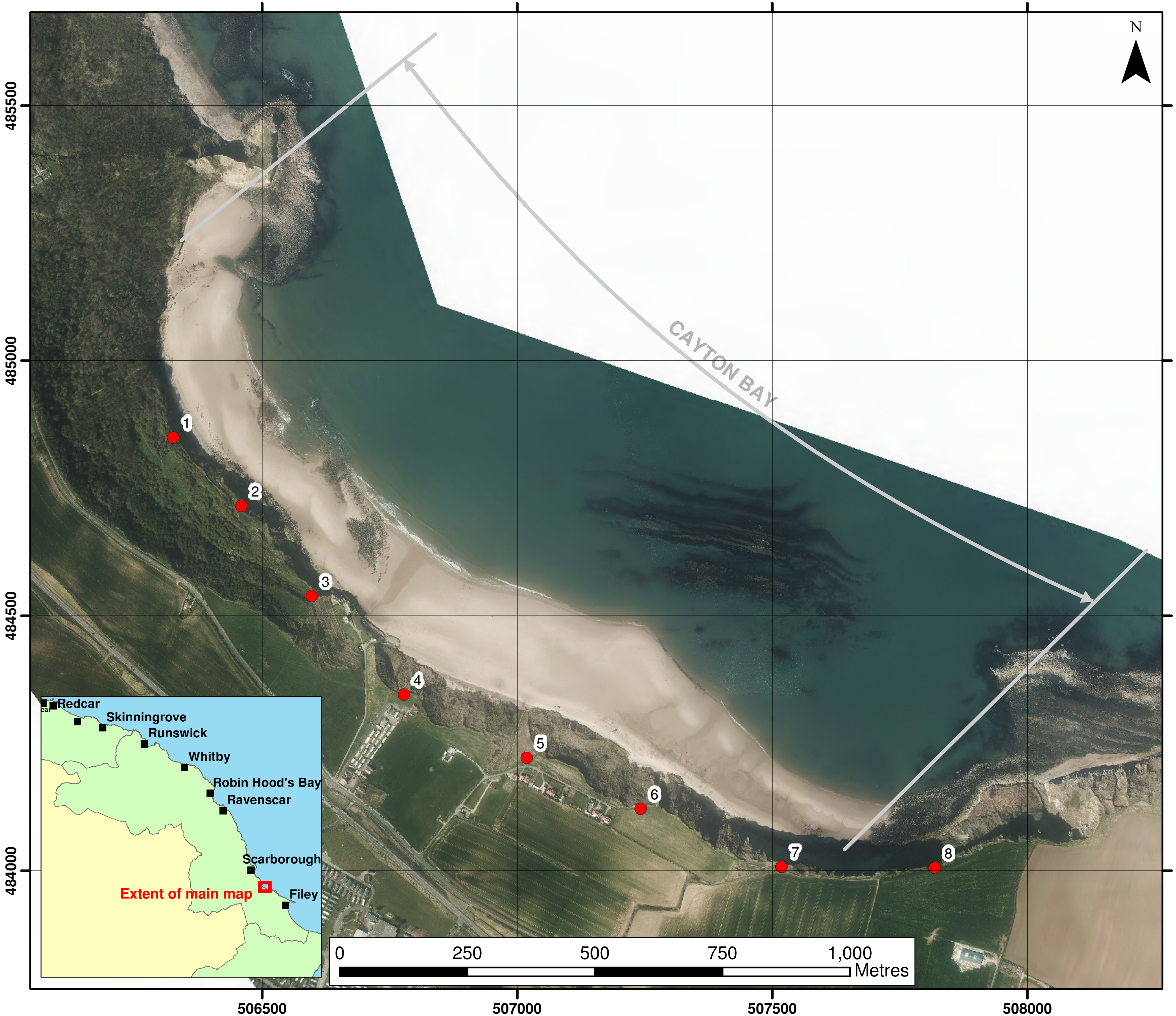

KEY

- Ground Control Points

Client: North East Coastal Group

Project: Cell 1 Regional Coastal Monitoring Programme 2011 to 2016

Appendix C - Map 4
Ground Control Points
Cayton Bay
Scarborough
Borough Council

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Full Measures Survey
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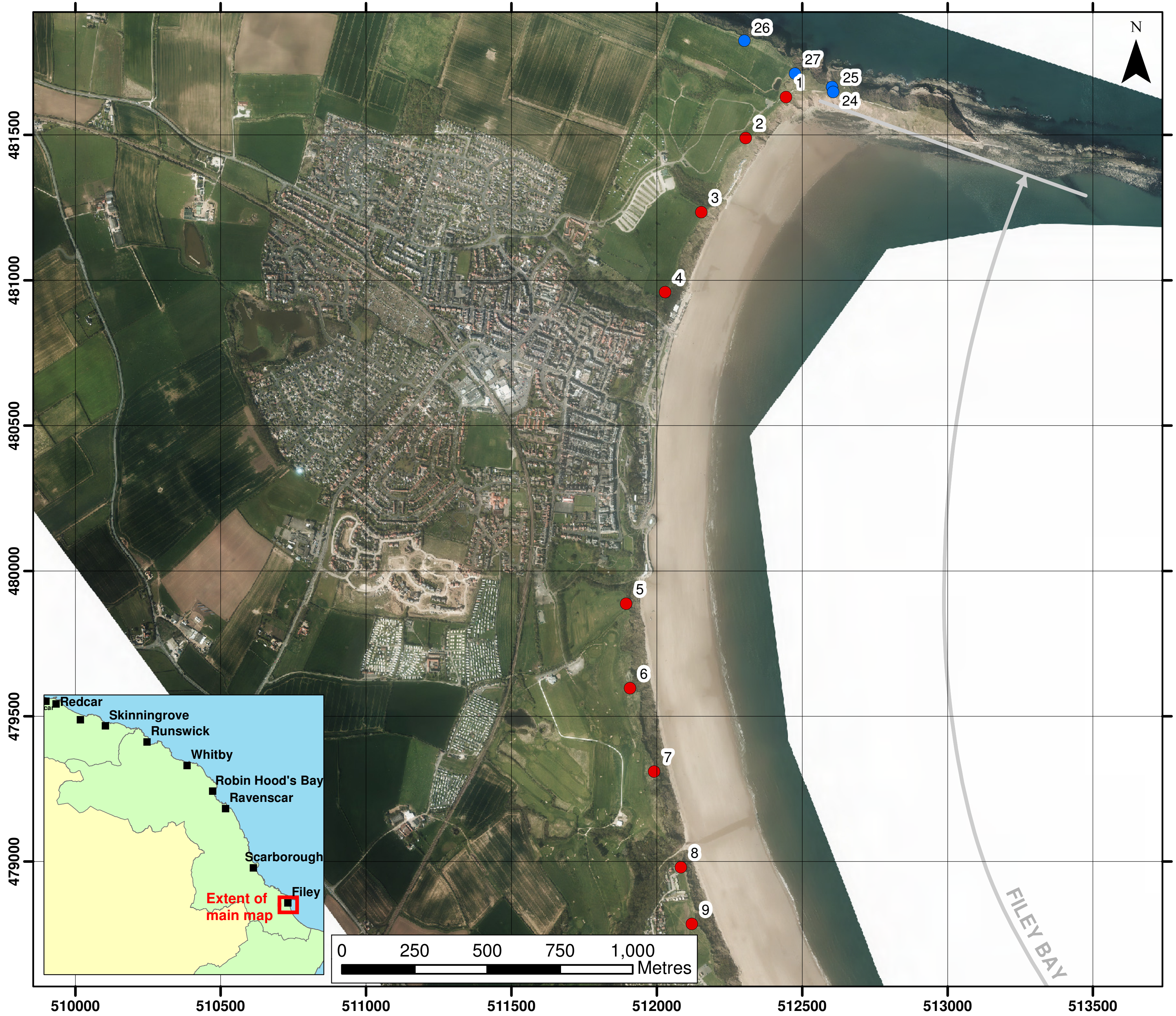

KEY

Ground Control Points

- Established Sep 2014
- Established Mar 2011
- Established Nov 2008

Client: North East Coastal Group

Project: Cell 1 Regional Coastal Monitoring Programme 2011 to 2016

Appendix C - Map 5
Ground Control Points
Filey Bay North
Scarborough
Borough Council

Analytical Report 8
Full Measures Survey
Autumn 2015

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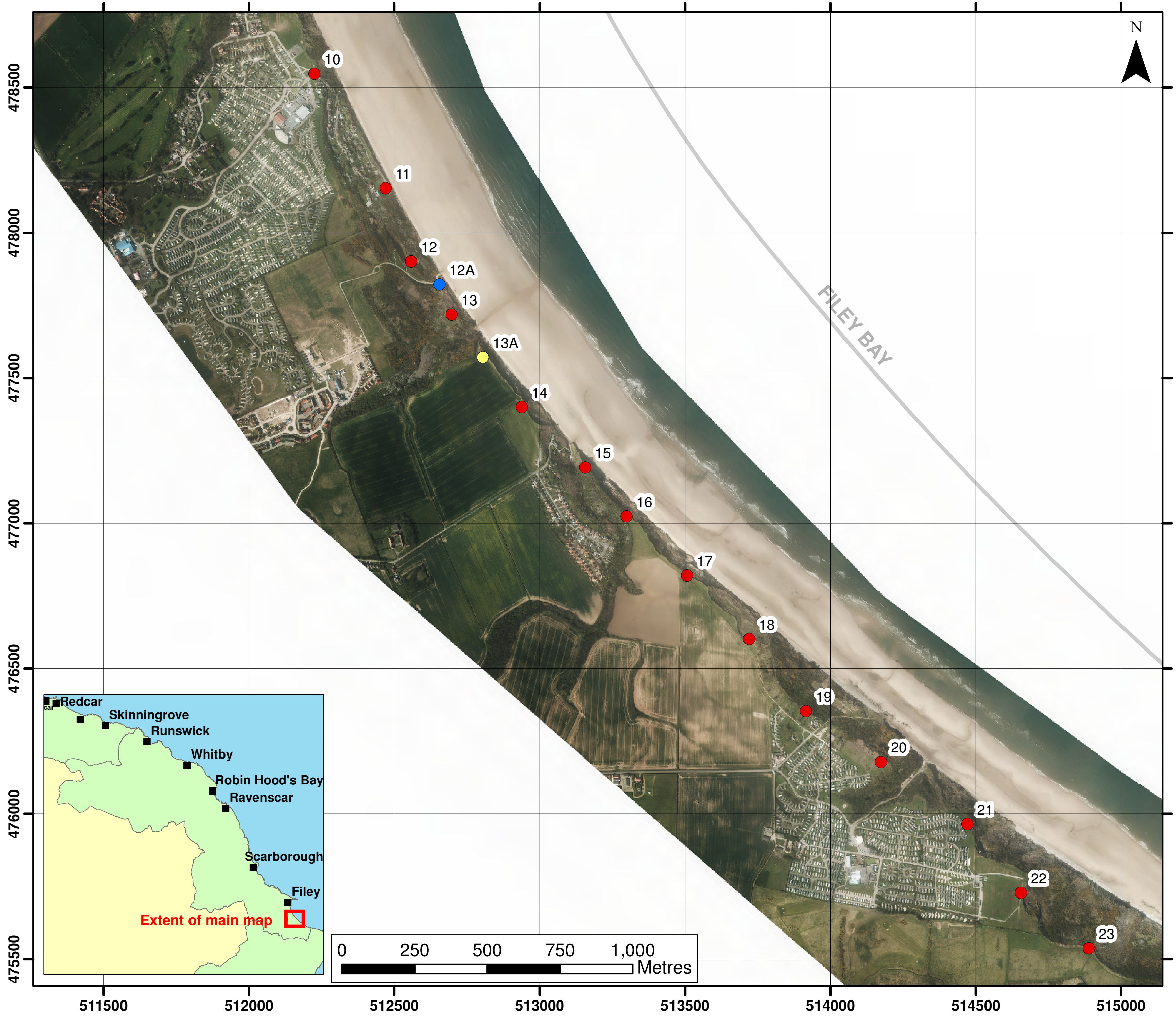

KEY

Ground Control Points

- Established Sep 2014
- Established Mar 2011
- Established Nov 2008

Client: North East Coastal Group

Project: Cell 1 Regional Coastal Monitoring Programme 2011 to 2016

Appendix C - Map 6
Ground Control Points
Filey Bay South
Scarborough Borough Council

Analytical Report 8
Full Measures Survey
Autumn 2015

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