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Cell 1 Regional Coastal Monitoring Programme
Analytical Report 6 Full Measures Survey 2013

Scarborough Council
Final Report

A great place to live, work & play

February 2014

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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.

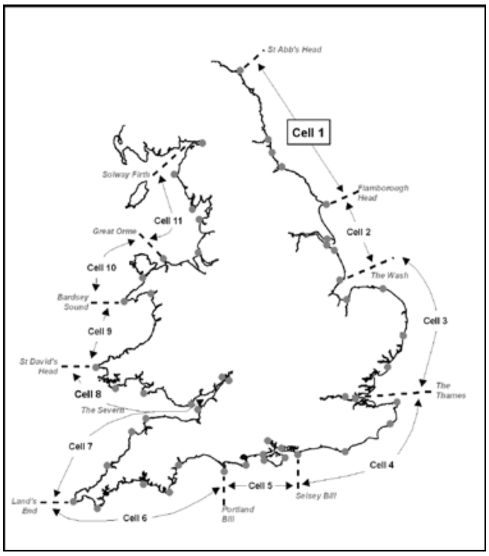


Figure 1 Sediment Cells in England and Wales

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

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

CH2MHILL Halcrow   academy geomatics

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(*)			

(*) The present report is **Analytical Report 6** and provides an analysis of the autumn/winter 2013 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 the 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 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 2nd and 20th September 2013. Work at Robin Hoods Bay was undertaken on 7th November. The weather was variable through this time. For details of the survey conditions refer to the Academy Geomatics survey reports for each location. Information on wave monitoring and the exceptional storms 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.

In addition to the typical analysis, this report includes additional work to review the impact on beach levels of the exceptional storms of the 5th and 6th December 2013. Additional beach surveys were undertaken at Filey, Runswick Bay, Scarborough North Bay, Scarborough South Bay and Whitby in December 2013 immediately following the storms. In addition to the beach surveys, cliff and asset inspections were undertaken at principal settlements to document the impacts of the storm. This information is provided as an update to the 2012 asset inspection report.

1.3 Uncertainties in data and analysis

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

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

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

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

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

Table 3. Error bands for long-term calculations of change.

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

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

2. Wave Data and Interpretation.

2.1 Introduction

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

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

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

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

Table 4: SANDS Storm Analysis at Tyne/Tees WaveNet Buoy

General Storm Information					At Peak			
Start Time	**End Time**	**Duration (Hours)**	**Peak of Storm**	**Mean Direction Vector (Degrees)**	**Hs (m)**	**Tp (s)**	**Direction (Degrees)**	**Energy @ Peak (KJ/m/s)**
19/03/2007 10:30	21/03/2007 05:30	43	20/03/2007 14:30	79.0	6.2	12.4	22	11759.3
25/06/2007 20:00	26/06/2007 13:30	17.5	26/06/2007 10:00	81.6	4.4	8.6	22	2832.6
26/09/2007 03:00	27/09/2007 05:00	26	26/09/2007 19:00	80.4	4.6	11.6	6	5488.7
08/11/2007 20:00	**12/11/2007 15:00**	**91**	**09/11/2007 08:30**	**78.7**	**6.2**	**13.4**	**6**	**13698.9**
19/11/2007 03:30	25/11/2007 21:30	162	23/11/2007 05:00	78.8	4.9	10.7	17	5353.7
08/12/2007 03:00	10/12/2007 14:30	59.5	08/12/2007 03:30	85.1	4.1	10.8	17	3816.4
03/01/2008 10:30	04/01/2008 01:30	15	03/01/2008 23:30	14.8	4.2	9.1	62	2964.9
01/02/2008 15:00	02/02/2008 09:30	18.5	02/02/2008	80.9	6.0	13.8	17	13641.7
10/03/2008 08:30	10/03/2008 12:30	4	10/03/2008 11:00	307.6	4.6	8.0	141	2631.9
17/03/2008 15:00	**25/03/2008 03:00**	**180**	**22/03/2008 05:00**	**83.8**	7.9	**12.4**	**6**	**19123.9**
05/04/2008 22:00	07/04/2008 05:00	31	06/04/2008 19:00	83.8	4.6	11.6	6	5520.5
20/07/2008 16:00	21/07/2008 09:30	17.5	20/07/2008 23:30	75.9	4.2	9.9	11	3492.5
03/10/2008 03:00	03/10/2008 20:30	17.5	03/10/2008 16:30	82.4	4.7	11.4	22	5728.4
21/11/2008 04:00	25/11/2008 12:30	104.5	22/11/2008 11:30	75.8	6.0	13.1	11	12267.5

General Storm Information					At Peak			
Start Time	End Time	Duration (Hours)	Peak of Storm	Mean Direction Vector (Degrees)	Hs (m)	Tp (s)	Direction (Degrees)	Energy @ Peak (KJ/m/s)
10/12/2008 12:00	13/12/2008 18:00	78	13/12/2008 08:00	331.9	4.9	8.3	129	3286.2
31/01/2009 16:30	03/02/2009 09:00	64.5	02/02/2009 22:00	7.1	5.8	9.5	84	6078.5
23/03/2009 20:30	28/03/2009 20:30	120	28/03/2009 18:30	89.7	4.9	9.3	0	4053.0
10/07/2009 01:30	10/07/2009 02:30	1	10/07/2009 01:30	78.8	4.2	9.9	11	3504.3
29/11/2009 20:00	**30/11/2009 15:00**	**19**	**30/11/2009 00:30**	**73.4**	**6.0**	**9.4**	**11**	**6331.4**
17/12/2009 10:30	18/12/2009 05:00	18.5	17/12/2009 19:30	26.4	5.4	10.6	68	**6549.5**
30/12/2009 09:00	30/12/2009 23:00	14	30/12/2009 12:30	7.7	5.1	7.5	90	2866.0
06/01/2010 05:30	06/01/2010 11:00	5.5	06/01/2010 06:30	63.7	4.2	10.7	11	4044.1
29/01/2010 10:30	30/01/2010 00:30	14	29/01/2010 22:30	83.9	5.4	8.6	6	4258.2
26/02/2010 22:30	27/02/2010 02:30	4	27/02/2010 01:00	72.6	4.6	8.5	17	2925.7
19/06/2010 07:00	20/06/2010 08:30	25.5	19/06/2010 20:00	69.4	5.4	10.7	22	**6611.8**
29/08/2010 14:00	30/08/2010 06:30	16.5	29/08/2010 22:30	91.8	4.9	8.9	0	3715.5
06/09/2010 22:30	07/09/2010 16:00	17.5	07/09/2010 15:30	353.3	4.6	8.8	90	3192.5
17/09/2010 07:00	17/09/2010 18:30	11.5	17/09/2010 08:30	80.8	4.7	11.0	11	5323.3
24/09/2010 03:00	26/09/2010	45	24/09/2010 10:00	73.1	5.3	10.1	11	5564.7
20/10/2010 02:00	24/10/2010 16:30	110.5	20/10/2010 10:00	78.3	4.2	11.3	17	4514.5
08/11/2010 14:00	**09/11/2010 20:30**	**30.5**	**09/11/2010 10:00**	**3.1**	**5.6**	**8.8**	**73**	**4870.6**
17/11/2010 11:00	17/11/2010 18:30	7.5	17/11/2010 12:00	322.2	4.7	7.8	129	2646.0
29/11/2010 19:30	02/12/2010 08:30	61	29/11/2010 21:00	11.8	5.1	9.4	56	4474.2
16/12/2010 15:00	17/12/2010 06:30	15.5	17/12/2010 03:30	80.2	4.6	10.5	17	4504.6
23/07/2011 14:00	**24/07/2011 11:00**	**21**	**24/07/2011 03:00**	**67.5**	**4.7**	**10.8**	**17**	**5082.6**
24/10/2011 18:30	25/10/2011 09:30	15	25/10/2011 09:30	348.5	4.1	9.5	79	2986.1
09/12/2011 08:30	09/12/2011 10:00	1.5	09/12/2011 08:30	84.4	4.1	11.9	6	4669.0
05/01/2012 15:30	06/01/2012 05:00	13.5	06/01/2012 00:30	81.4	4.5	9.9	14	3896.6
03/04/2012 13:30	04/04/2012 10:30	21	04/04/2012 03:00	26.5	5.7	8.4	90	4510.0
24/09/2012 07:30	25/09/2012 11:00	27.5	24/09/2012 17:30	17.2	5.3	9.3	77	4786.2
26/10/2012 12:00	27/10/2012 15:00	27	26/10/2012 23:00	78.9	4.9	12.9	11	**7839.9**
05/12/2012 15:00	**15/12/2012 01:30**	**226.5**	**14/12/2012 18:30**	**39.6**	**6.1**	**8.4**	**107**	**5080.9**
20/12/2012 06:00	21/12/2012 14:30	32.5	20/12/2012 23:30	347.3	6.0	8.8	103	5436.3
18/01/2013 17:30	22/01/2013 07:30	86	21/01/2013 09:30	7.6	6.8	9.3	83	7978.4
06/02/2013 08:00	07/02/2013 08:30	24.5	06/02/2013 12:30	82.6	5.6	9.9	11	6039.7
07/03/2013 21:00	11/03/2013 04:00	79	08/03/2013 04:00	24.3	5.1	8.4	82	3667.4
18/03/2013 07:00	**25/03/2013 02:00**	**163**	**23/03/2013 10:30**	**4.5**	**7.3**	**9.3**	**89**	**9164.3**

General Storm Information					At Peak			
Start Time	End Time	Duration (Hours)	Peak of Storm	Mean Direction Vector (Degrees)	Hs (m)	Tp (s)	Direction (Degrees)	Energy @ Peak (KJ/m/s)
23/05/2013 18:00	24/05/2013 12:00	18	23/05/2013 22:30	77.5	6.7	10.5	17	**9678.4**
10/09/2013 13:00	10/09/2013 19:30	6.5	10/09/2013 14:00	79.3	4.4	9.2	11	3237.0
29/11/2013 22:30	30/11/2013 05:30	7	30/11/2013 00:30	82.8	5.6	10.7	11	7071.5
05/12/2013 14:00	07/12/2013 04:30	38.5	06/12/2013 20:00	80.4	4.7	14.3	6	8937.4
27/12/2013 09:30	27/12/2013 12:30	3	27/12/2013 10:00	249.3	4.1	6.1	202	1237.4

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

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

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

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

The storm on the 5th to 7th December, 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. The combined high water levels and large waves causing significant damage to many coastal defences and beaches. The storm is discussed throughout the report and its effect on the beaches is considered through interpretation of post-storm beach surveys which were commissioned by SBC to capture the impacts of the event.

2.2 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, which is discussed throughout this report. The event is not part of the available Scarborough data record because the buoy was off-station during the event. 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.

Many of the beach profiles for the Full Measures 2013 were around the 5th September or the 18th September, with additional work done in October and November. The profiles captured soon after the 10th September storm show flattening or erosion of the mid and upper beach, which may be due to the storm.

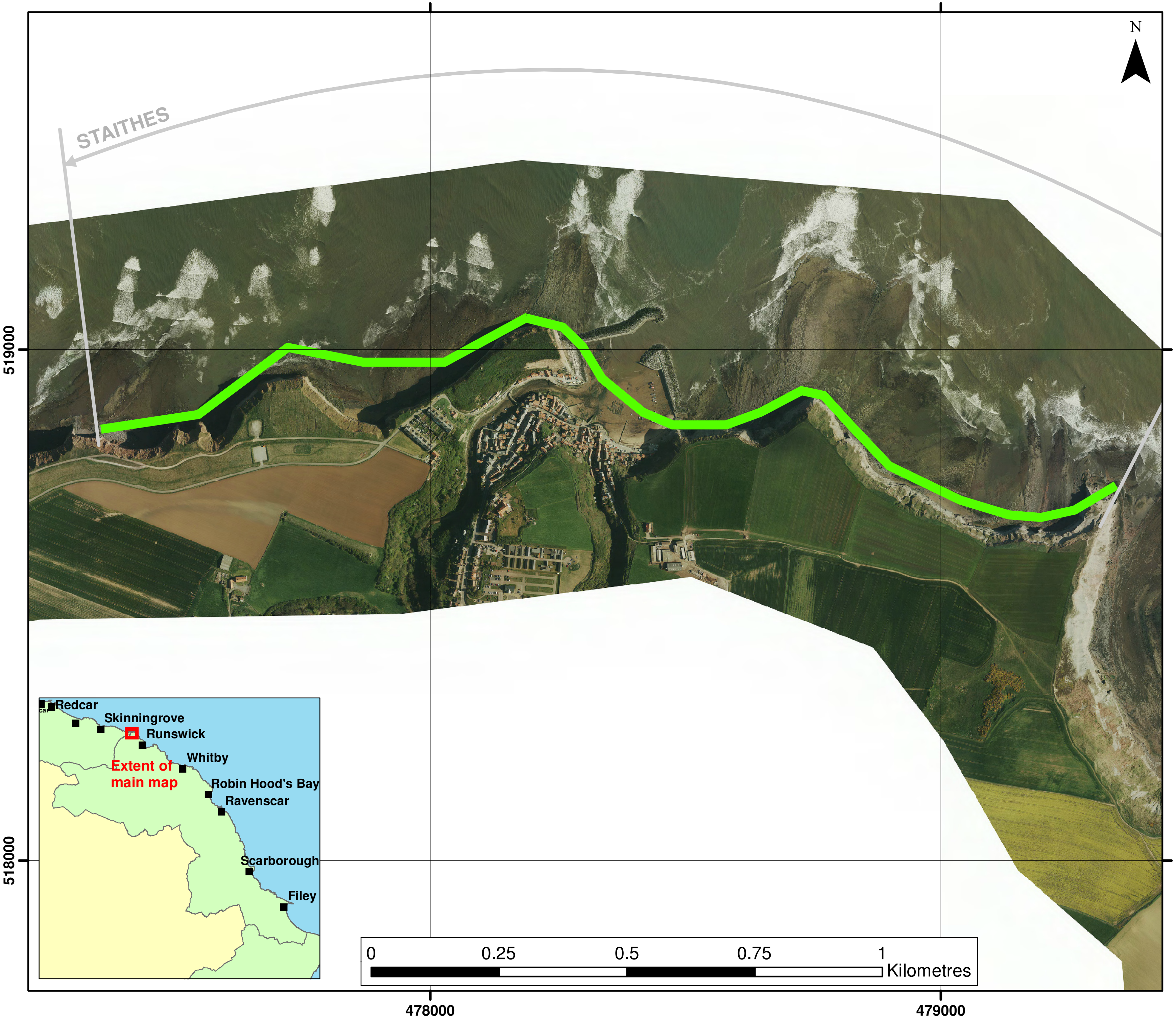
Table 5: Storm analysis for Scarborough WB (data 17/01/2013 to 21/11/2013)

General Storm Information					At Peak			
Start Time	**End Time**	**Duration (Hours)**	**Peak of Storm**	**Mean Dir Vector (°)**	**Hs (m)**	**Tp (s)**	**Dir (°)**	**Energy @ Peak (KJ/m/s)**
21/01/2013 02:00	21/01/2013 20:00	18	21/01/2013 13:00	22	5.1	9.3	65	4,483
06/02/2013 13:30	07/02/2013 02:00	12.5	06/02/2013 17:00	77	4.3	9.3	17	3,177
22/03/2013 20:00	24/03/2013 23:00	51	23/03/2013 15:30	16	5.1	9.9	65	4,988
23/05/2013 21:30	24/05/2013 10:30	13	24/05/2013 00:30	71	5.7	9.9	18	6,302
10/09/2013 13:00	10/09/2013 22:30	9.5	10/09/2013 19:30	77	5.0	8.4	13	3,415
10/10/2013 02:00	11/10/2013 06:30	28.5	10/10/2013 23:00	72	5.8	10.5	21	7,397

Note: the Scarborough wave buoy was not operational during the storm surge on $5^{th}/6^{th}$ December 2013

Table 6: Storm analysis for Whitby WB (data 17/01/2013 to 07/12/2013)

General Storm Information					At Peak			
Start Time	**End Time**	**Duration (Hours)**	**Peak of Storm**	**Mean Dir Vector (°)**	**Hs (m)**	**Tp (s)**	**Dir (°)**	**Energy @ Peak (KJ/m/s)**
21/01/2013 05:30	22/01/2013 03:00	21.5	21/01/2013 14:30	27	5.0	9.3	61	4,259
06/02/2013 11:00	07/02/2013 04:00	17.0	06/02/2013 18:30	73	4.8	9.9	16	4,528
08/03/2013 03:30	11/03/2013 05:00	73.5	11/03/2013 04:00	39	4.3	8.4	45	2,603
18/03/2013 18:30	24/03/2013 17:30	143.0	23/03/2013 13:00	20	5.2	9.3	72	4,678
23/05/2013 21:00	24/05/2013 10:30	13.5	24/05/2013 00:00	70	5.8	10.5	24	7,372
10/09/2013 14:00	10/09/2013 21:00	7	10/09/2013 16:00	71	4.4	9.3	24	3,251
10/10/2013 01:30	11/10/2013 06:30	29	11/10/2013 00:00	69	5.7	11.2	31	7,838
30/11/2013 00:00	30/11/2013 06:00	6	30/11/2013 03:30	74	4.8	10.5	20	4,976
05/12/2013 20:00	06/12/2013 22:00	26	06/12/2013 19:30	70	4.7	14.0	32	8,625



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 6
Full Measures Survey
Autumn 2013

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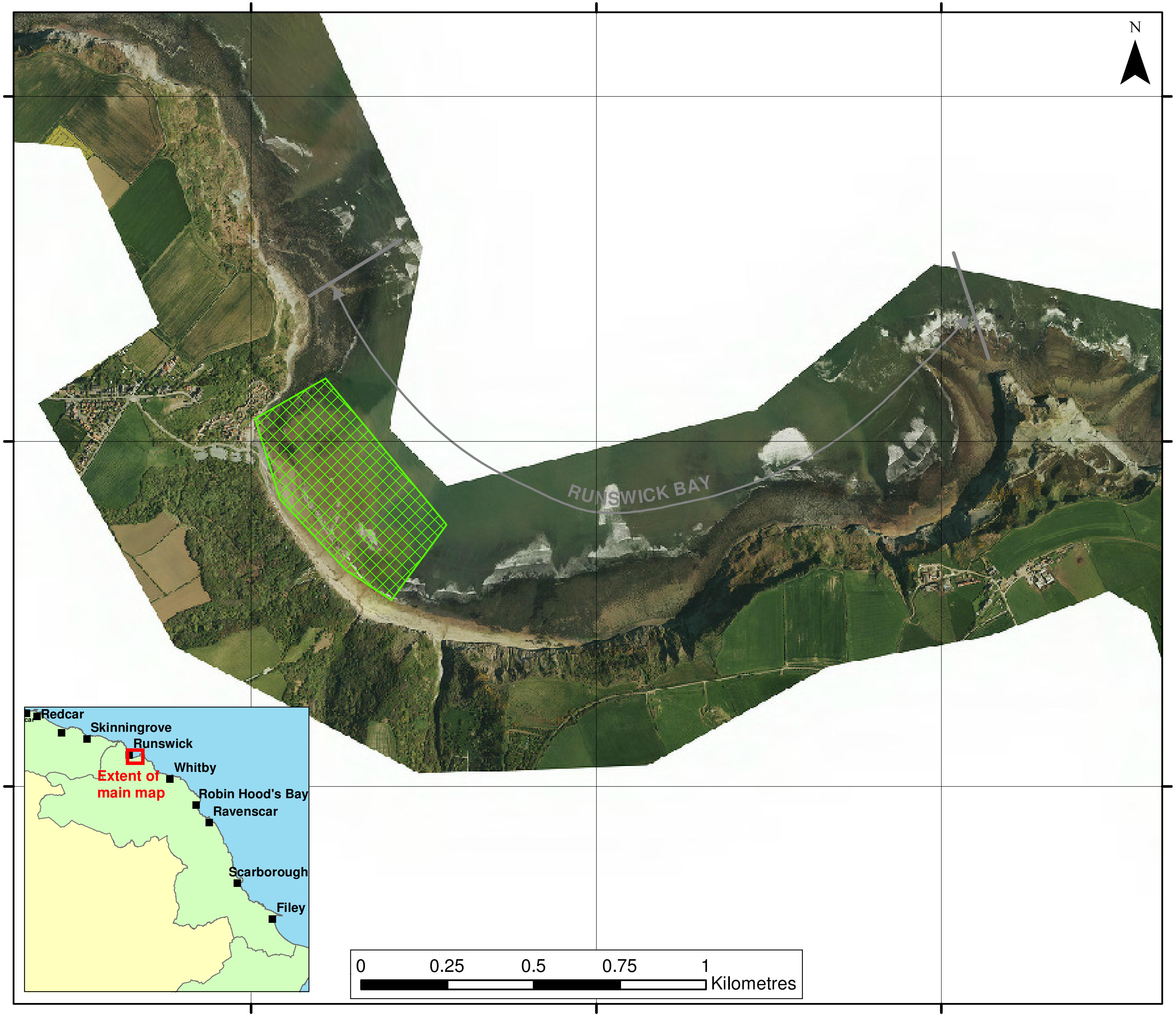

KEY

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 2013

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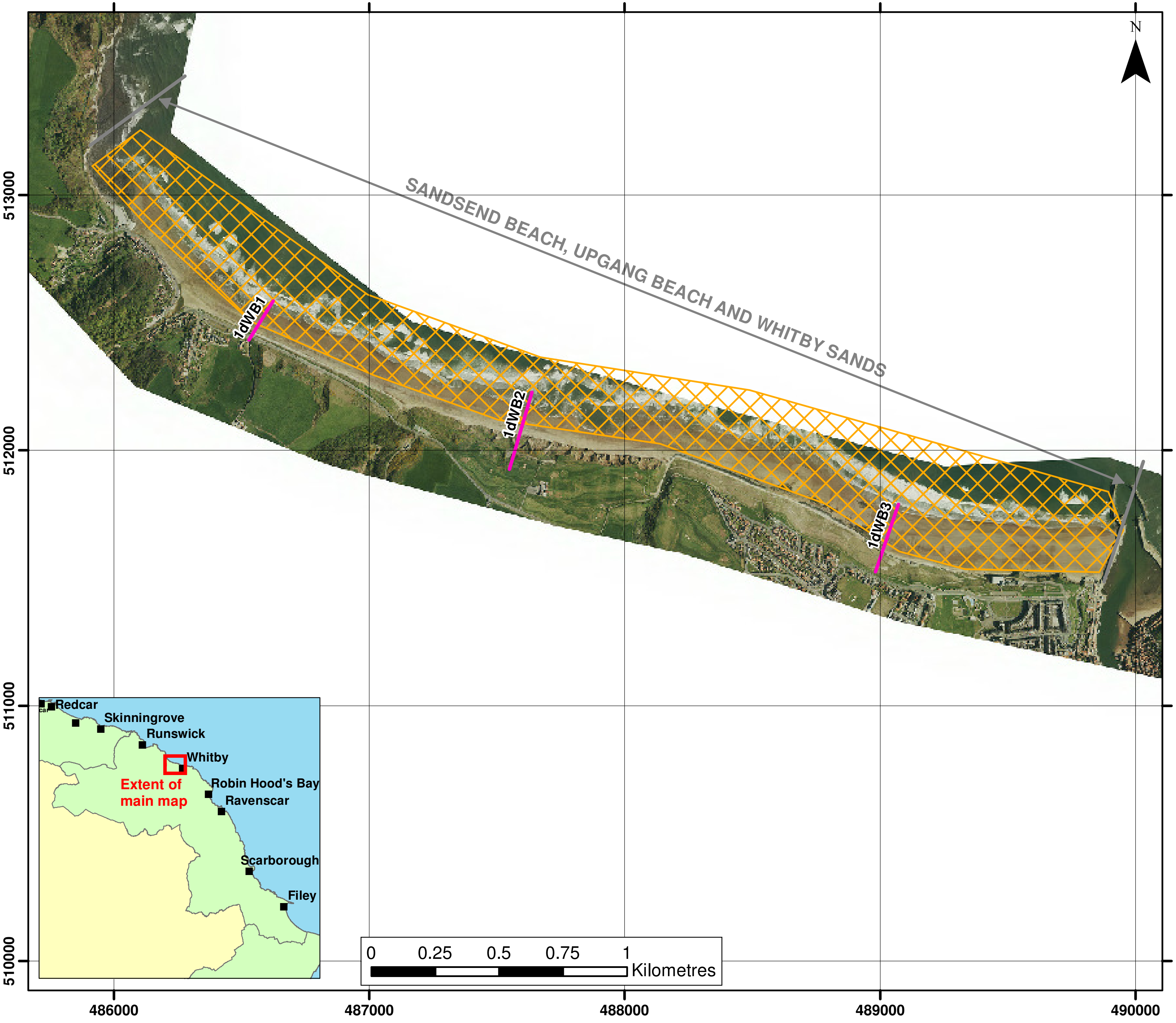

KEY

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 2013

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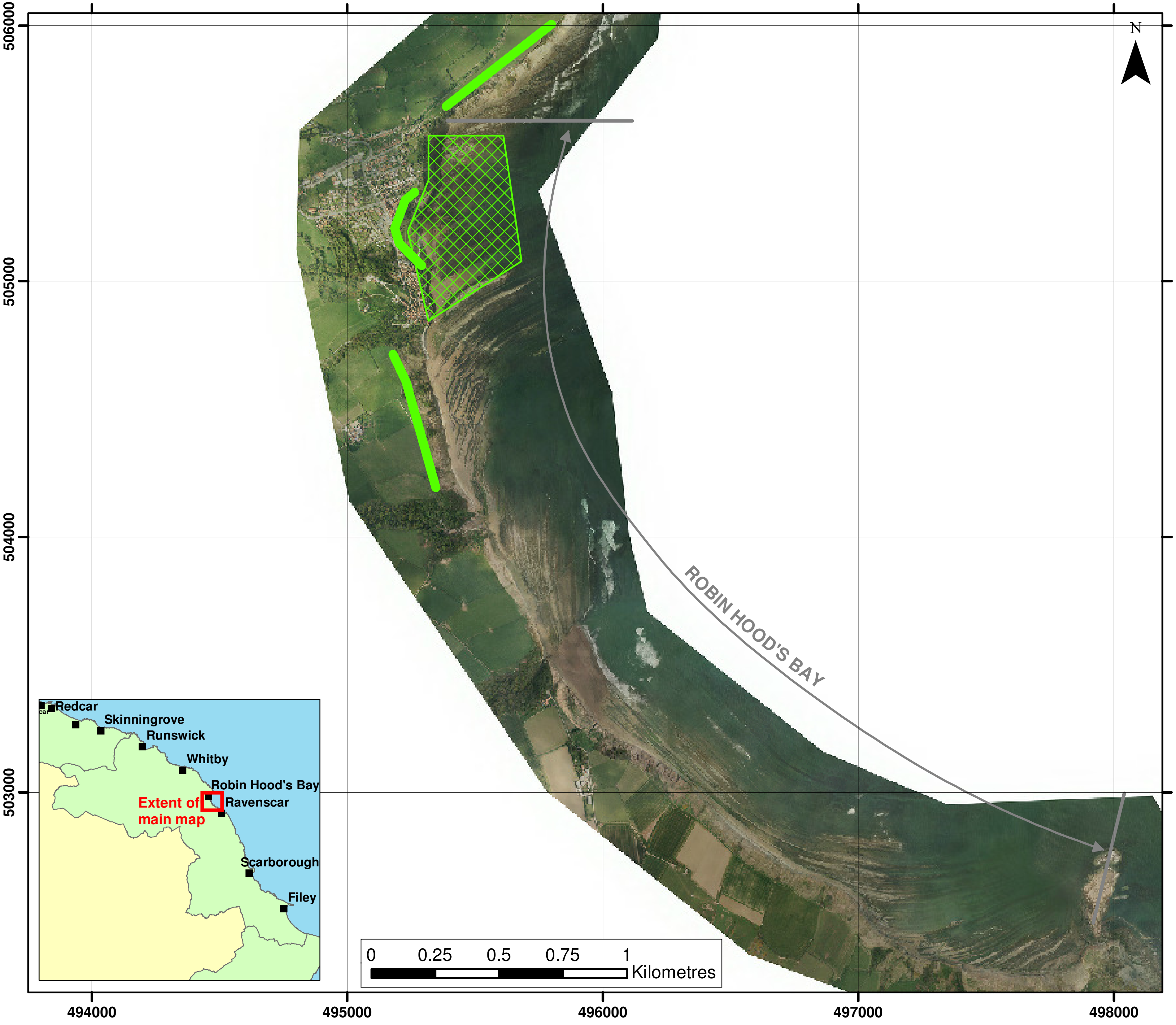

KEY

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 2013

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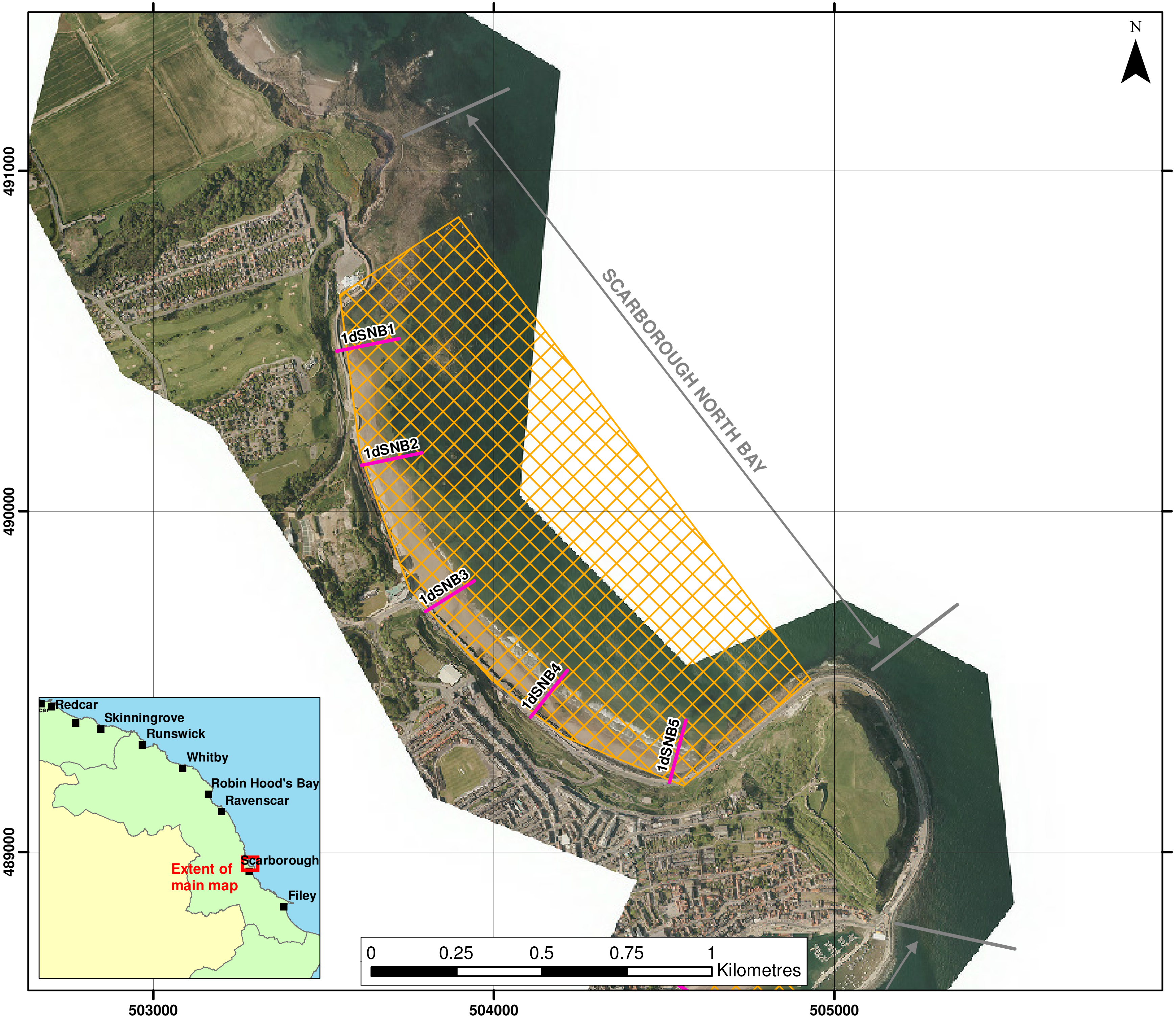

KEY

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 6
Full Measures Survey
Autumn 2013

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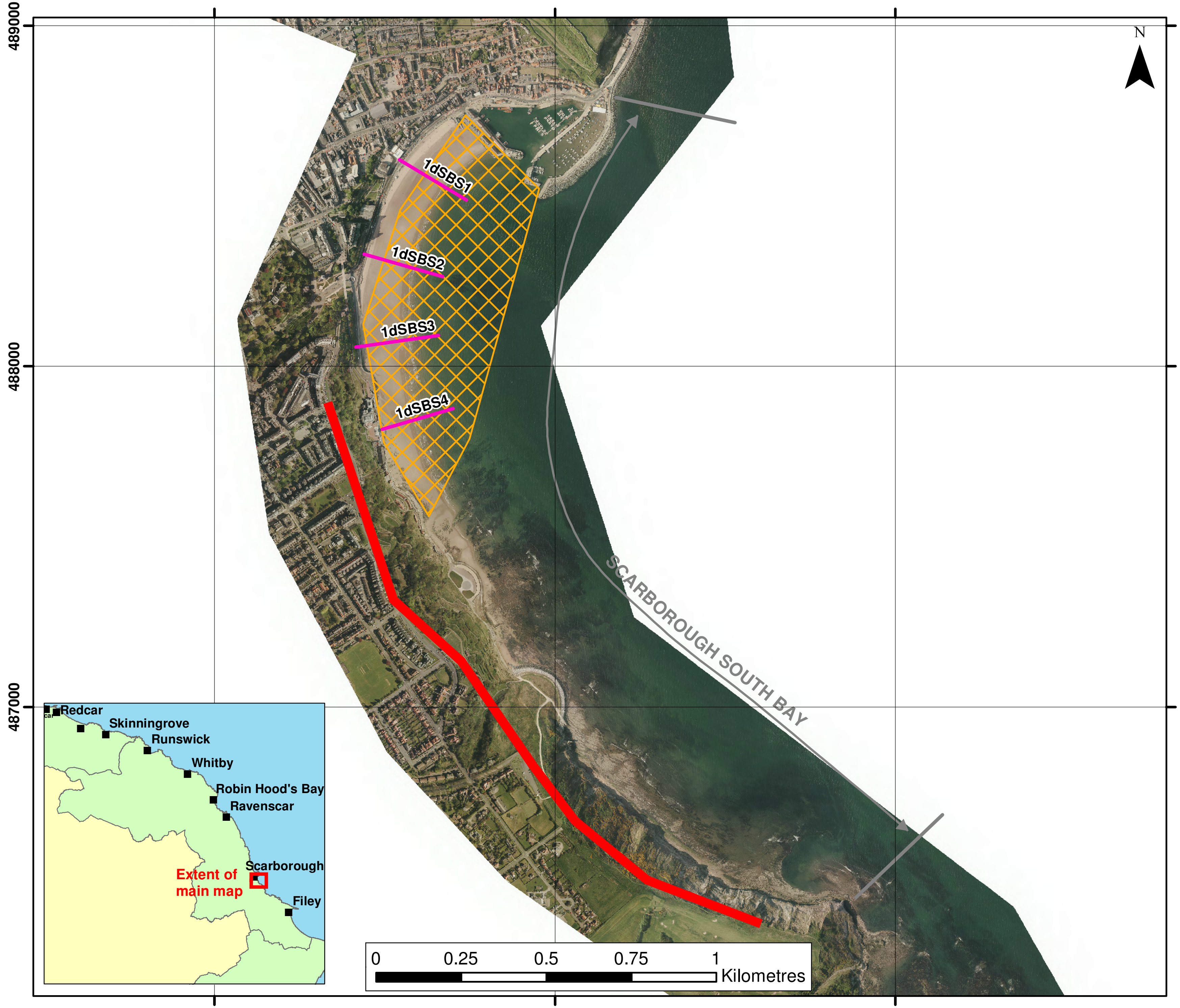

KEY

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 6
Full Measures Survey
Autumn 2013

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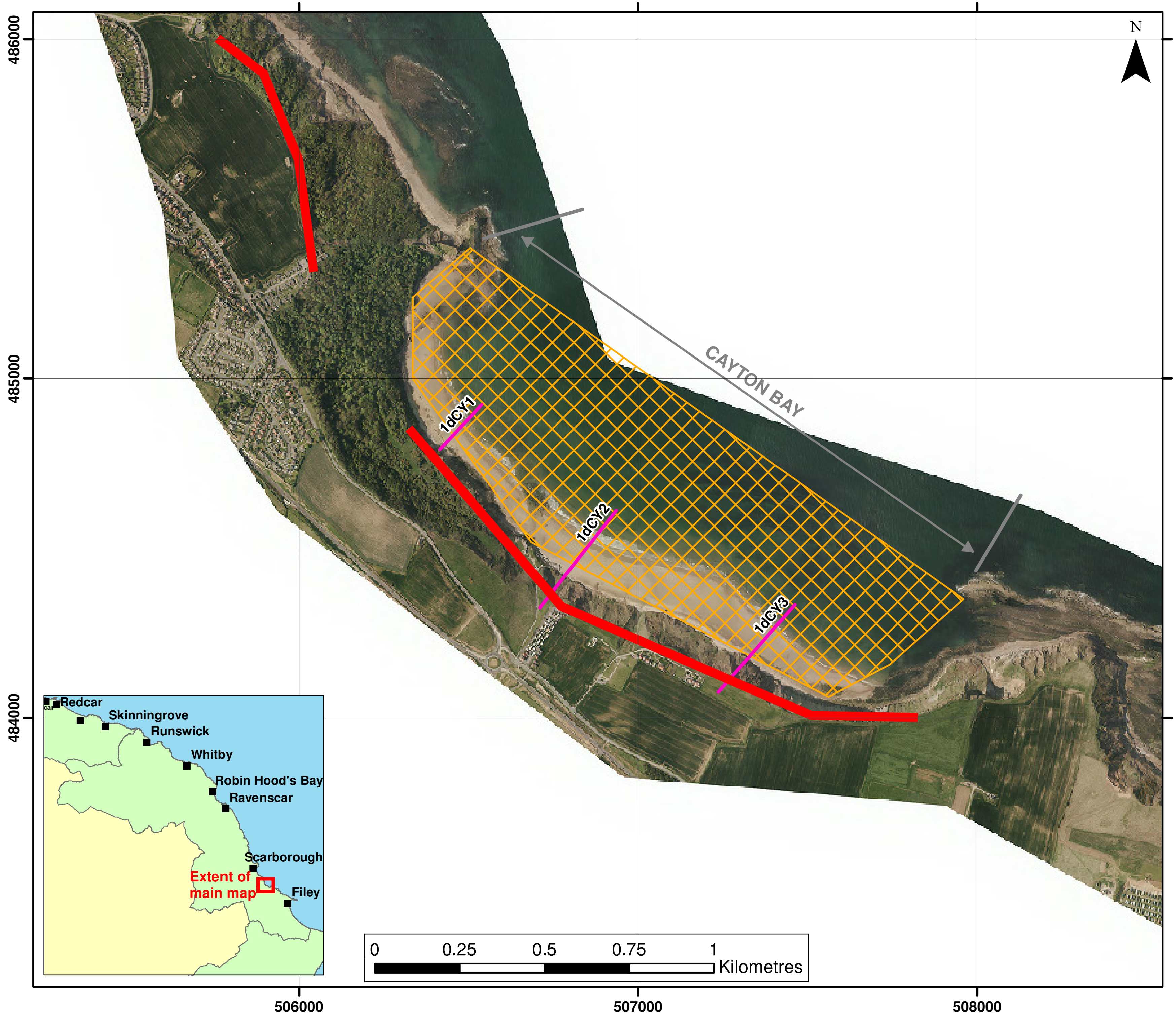

KEY

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 6
Fulll Measures Survey
Autumn 2013

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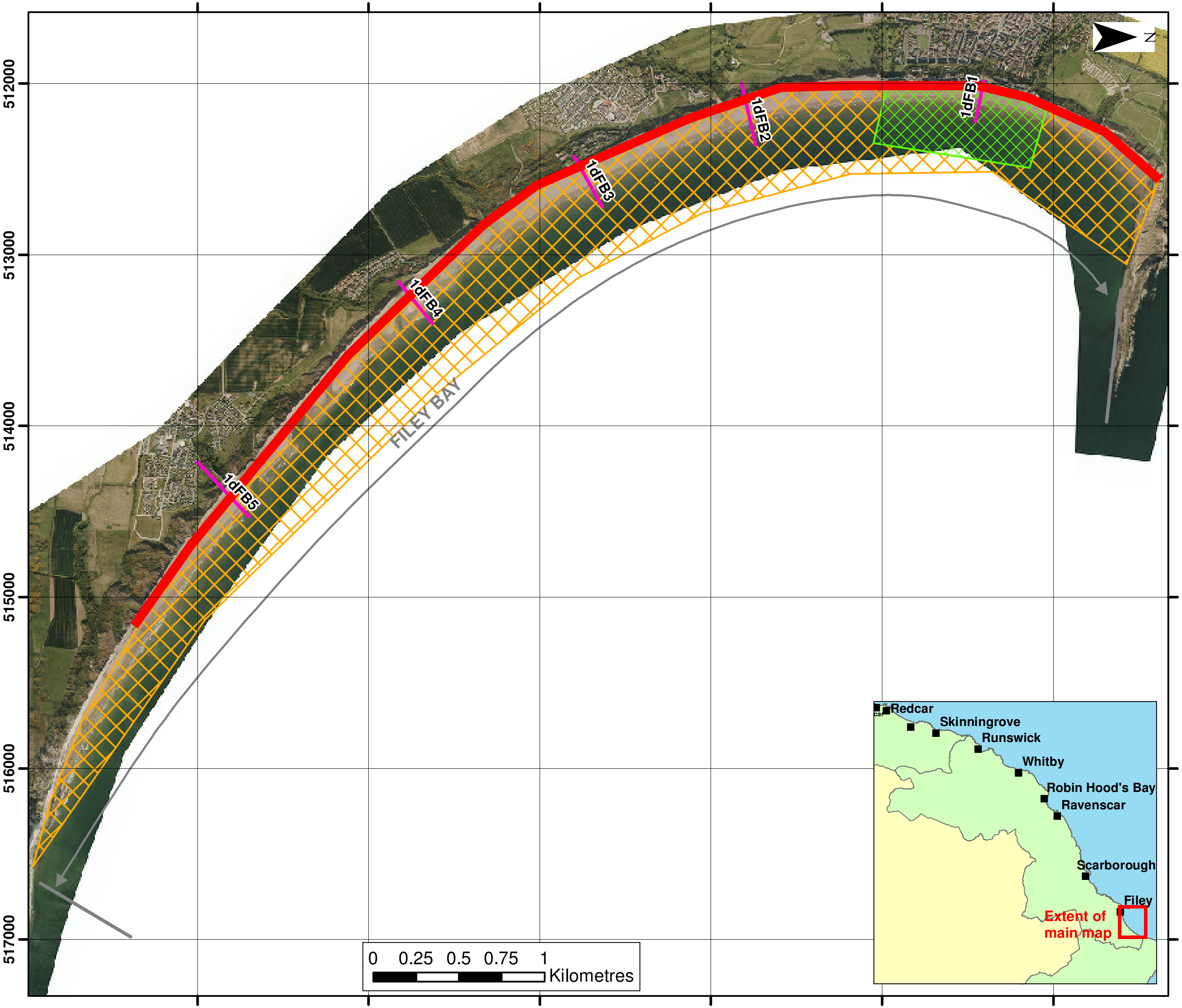

KEY

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 6
Full Measures Survey
Autumn 2013

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3. Analysis of Survey Data

3.1 Staithes

Survey Date	Description of Changes Since Last Survey	Interpretation
October 2013	**Cliff-top Survey:** Twenty ground control points have been established at Staithes for 6-monthly cliff top monitoring. 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. Historically, this method has proved prone to error as the cliff edge cannot be precisely identified due to vegetation cover and its convex shape. Between April 2013 and October 2013 sixteen of the twenty posts showed change within a range of ±0.1m, which is not considered significant. Two posts showed growth of the cliff, which is likely to be error in the measurement. Posts 5 and 12 showed the largest negative change of all of the posts, both had a value of -0.3m of erosion. Calculation of erosion rates based on the recorded change between 2008 and 2013 indicates that sixteen 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. Three of the remaining pots have positive rates, which is due to error. One post shows consistent erosion through the surveys, Post 13 (near the eastern breakwater) has a rate of -0.5m/yr. This pattern was very similar to that observed in the 2012 Full Measures Report. Appendix C provides results from the September 2010 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.	The majority of the Staithes frontage has remained stable over the summer of 2013. There was concern raised over the summer of 2012 due to numerous cliff falls on the eastern part of the bay, close to Point 13. However, that survey location recorded no change between April and October 2013. **Longer term trends**: Table C1 shows that survey location 13 has shown the greatest total erosion with a loss of 2.2m (±0.1m) between the November 2008 baseline and September 2012, resulting in a long term average recession rate of 0.5m/yr. The other survey location which had previously shown recession is Point 4, which has a rate of 0.1m/yr. The rate at Point 4 had reduced because no change was recorded between April and October 2013. The higher recession rates for these points are likely to be due to a small number of large failures that are unlikely to be representative of long term trends. On-going collection of data will provide a more accurate picture of long-term average recession rates and the typical size and timing of episodic cliff failures.

3.2 Runswick Bay

Survey Date	Description of Changes Since Last Survey	Interpretation
6th Sept 2013	**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 2013) and the previous survey (Spring 2013) 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 two main areas of change on the beach at Runswick Bay, both zones run shore-parallel. Close to the shoreline there has been accretion of up to 1m, while further down the beach there is an area of erosion of around 0.5m. The erosion is more concentrated at the shingle bar in the north of the bay. In addition to these general patterns, there were localised areas of the back of the beach where erosion of around 0.5m had been experienced. **Long Term Topographic Trends Winter 2008 to Autumn 2013:** Appendix B - Map 1c shows that the centre of the beach has been dominated by erosion while the upper and lower sections of beach have accreted. In the northern part of the bay, fronting the village, there has been up to 1m of erosion, which could be a precursor to erosion on this part of the shoreline. **Post storm survey of 16th December 2013** When compared to the September 2013 survey, the topographic survey undertaken on 16th December, 10 days after the storm, shows only small changes. The majority of the bay experienced erosion or deposition within a range of ±0.25m, but there are localised areas of more significant change. While the centre of the bay experienced modest accretion, the northern and southern margins and the central part of the back of the beach have eroded by up to 0.5m. The largest recorded change was in the extreme south of the bay where the erosion was around 1m. The surveyor noted that caves exposed in the southern cliff line of the bay had been enlarged and that south of the revetment the soft cliffs had retreated.	During 2013 Runswick Bay showed signs of accretion close to the shore and erosion of the lower beach. This meant that the beach is steepening, which could be a precursor to erosion of the cliff. Erosion of up to 0.5m was noted in patches on the upper beach. The beach level may have been dropping or the change could reflect the erosion of material from the toe cliffs. **Longer term trends**: The erosion of the shore was also noted in the 2011 and 2012 Full Measures Report. It may be that there is a lag between material being deposited on the beach from the eroding cliffs and the fines being washed offshore. In the centre of the bay there is a large bar, which persisted but experienced loss of sediment over the summers of 2011 to 2013. There are also areas of erosion close to the shore along the defended sections of the bay **Autumn 2008 to Autumn 2013 trends:** The long term difference plots show that centre of the beach is eroding while the upper and lower beach have accreted. The erosion observed close to the village over the five year timespan covered in the plots raises some concern about the continued stability of defences in this area. **Post Storm Survey December 2013.** The observed changes were modest, apart from the southern part of the bay where up to 1m of erosion had occurred. It is likely that the north of the bay was

Survey Date	Description of Changes Since Last Survey	Interpretation
		sheltered from the worst of the storm. The most significant erosion of c. 1m was recorded the central part of the bay, which is the southernmost extent of the area surveyed.

3.3 Sandsend Beach, Upgang Beach and Whitby Sands

Survey Date	Description of Changes Since Last Survey	Interpretation
19th and 20th Sept 2013	**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). At profile **1dWB1** the beach level has eroded by around 0.5m between 35 and 55m chainage, close to the HAT and MHWS level. Between 55m and 130m chainage the beach has accreted by up to 0.6m From 130m change to the end of the survey at MLWS (195m chainage) The beach has remained stable. At **1dWB2** the profile above the HAT level has not changed significantly. The surveyor reported the middle of Profile 2 was not accessible due to "soft grass/sand and deep fissures present in the slumping mud dune". The crest of the dune was inaccessible and as a result not measured. The beach gradient has remained similar between the September 2013 and April 2013 surveys. The beach level has accreted by slightly more than 0.5m on the upper beach and slightly less than 0.5m in the lower. The beach is steeper than the 2012 profiles but similar to profiles taken in 2010. At profile **1dWB3** the stabilised face of Whitby West Cliff shows negligible change. From the base of the sea wall at 105m chainage to 115m chainage the beach has eroded by up to 0.5m. Between 115m and 145m chainage there has been modest erosion of around 0.3m. Between 145m and 220m chainage the beach had accreted by 0.5m between April and September 2013. At the end of the survey, below 220m chainage there has been very little change. **Post Storm Survey of 9th December 2013** A subsequent beach survey was undertaken three days after the storm of 6th December and compared to the data collected in September 2013. **1dWB1** and **1dWB2** showed steepening and eroding the upper beach while the lower beach gained a mound of material compared to the previous profiles. The post-storm profile at 1dWB3 was the lowest recorded profile. At **WB1** between September 2013 and December 2013 the upper beach around HAT and MHWS had accreted by 0.2m. The mid and lower beach were comparable in the September and December 2013 profiles. At **1dWB2** the September profile showed a berm in the lower beach, this appeared to have been flattened by the December survey. The beach between MHWS and MLWS appeared to have accreted by around 0.2m throughout.	Both Profiles WB1 and WB 2 have been subject to flattening of the beach. The berms which were present have now gone and the beach is flat. The flattening of the beach may be linked to the storm recorded on the 10th of September, which is shown in the wave data for Whitby. Profile WB2 was flat in April and has accreted almost uniformly by 0.5m over the summer of 2013. When compared to the 2008 baseline the beach level in 2013 was one of the highest recorded for WB1, whereas it was in the middle of the range at WB2 and 3. The topographic difference plots show a complex spatial pattern of erosion and accretion. Net change in the centre of the bay are much more pronounced than at the distal ends, suggesting an area of sand bar development and migration. This pattern has been noted in 2010, 2011 and 2012. 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 redistributed across the beach as migrating sand bars through the subsequent spring and summer. This gives rise to the distinctive pattern of erosion and deposition seen in the survey data.

Survey Date	Description of Changes Since Last Survey	Interpretation
	The profile below the seawall at **1dWB3** had eroded by 0.5m between September and December 2013. The beach level had dropped overall, but the gradient was comparable to previous surveys.	**Longer term trends**: the beach profiles show seasonal variation but no linear trend of accretion or erosion. The topographic difference plots show very similar patterns of accretion and erosion in the 2011, 2012 and 2013 difference plots. The patchy distribution of accretion and erosion show that sediment from the cliffs or alongshore appears to be redistributed within the bay with minimal offshore movement. **Autumn 2008 to Autumn 2013 trends:** The long term difference plot for the Whitby to Sandsend frontage shows that the changes in the centre of the bay are more pronounced than at the margins where accretion of up to 1m is seen. In the centre of the bay the behaviour is spatially variable with no clear net change. The patches of accretion and erosion are likely to relate to the relatively high sediment supply from undefended cliffs and reworking of material across the beach as sand bars. **Post-storm changes December 2013** WB3 showed consistent lowering of the beach level following the storm. This profile is backed by a defence, which may have reflected wave energy back to the beach. In contract, profiles WB1 and 2, which are backed by soft cliffs, showed steepening and lowering of the
	Topographic Survey: The Sandsend to Whitby frontage is covered by an annual topographic survey, providing continuous survey of 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 2013) and the earlier topographic survey DGM (Autumn 2012), 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 that the magnitude of change in the centre of the bay is much larger than the changes recorded at each end. The changes in 2011 to 2013 can be divided into three main areas: In the northern part of the frontage, between Sandsend at the western edge of the topographic survey to East Row Beck, there is accretion at the back the beach of up to 1m and erosion of around 0.75m was towards MLW. The central part of the frontage (Appendix B – Maps 2b and 3b) at Upgang between East Row Beck to White Point Road the changes in beach level were more significant. This part of the frontage is more dominated by shore-parallel strips of change. There was accretion on the upper beach of 1.5m, while at the seaward extent erosion of 2m and more was recorded. This area had also been subject to a pattern of significant erosion and accretion during the summer of 2012. The southern part of the survey fronts Whitby West Cliff, between the golf course and harbour walls. This area was dominated by erosion of around 0.5m. Localised accretion of around 0.5m was observed close to the shore over the summer of 2013. Beach profiles and the topographic survey data were collected at the same time. However, interpretations of beach change are subtly different, reflecting different baseline data (March 2010for beach profiles and October 2009 for topographic survey) and differences expected when comparing 2D and 3D techniques.	

Survey Date	Description of Changes Since Last Survey	Interpretation
	Long Term Topographic Trends Autumn 2008 to Autumn 2013: The long term difference plots look similar to the short-term plot covering the period Autumn 2012 to Autumn 2013. The northern quarter shows accretion of up to 1m; the central section has shore parallel bands of accretion and erosion, with accretion of up to 1m at the upper beach and erosion of up to 2m at the lower beach; the southern section, in front of Whitby, has accreted by up to 0.5m across much of the beach, with localised erosion of up to 1m of erosion at the toe of the defences. **Post storm Topographic Survey** During the topographic survey of 9th December the surveyor noted "...big slumps in the mud cliffs, damage to sea defences and a number of fences have been destroyed." The topographic survey covers a small area of the beach close to the toe of the cliff fronting Sandsend Road east of Sandsend village, where the defence had been damaged. Photos of the area just after the storm show typical damage to the defences.  Photographs showing the extensive damage to revetment and the scoured beach with no sand in front of the revetment (left), 8th December and the slightly recovered beach on the 17th December (right). The topographic difference plot for the area covered shows that the beach at the toe of the cliff has eroded by around 1m between September and December 2013. The difference plot shows that the toe of the cliff was also eroded, which is likely to cause increased cliff recession through the winter of 2013/14.	upper beaches with a small amount of accretion over the majority of the beach. This pattern may reflect material from below MLWS being driven onshore by the storm, or erosion of the cliffs to release beach-building material. The topographic plot covers a small area of beach backed by soft cliffs. It highlights erosion of the back of the beach by around 1m, suggesting cliff recession occurred.

3.4 Robin Hood's Bay

Survey Date	Description of Changes Since Last Survey	Interpretation
7th November 2013	**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 2013) and the earlier topographic survey DGM (Spring 2013), 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. Overall the bay has eroded by up to 0.25m over the summer of 2013, with erosion concentrated on the rocky shore platform in the north of the bay. There are localised patches of accretion of up to 0.5m. **Long Term Topographic Trends Autumn 2008 to Autumn 2013:** The plot of difference between 2008 and 2013 (Appendix B - Map 4c) shows a similar patchy distribution of accretion and erosion with no clear net change. There is a subtle pattern of beach steepening, with erosion on the lower beach and accretion on the upper beach. Much of the central and seaward extent of the bay has experienced erosion of 0.5m since 2008, while accretion of around 1m has occurred at the back of the beach	The topographic change plots show that the whole Bay has experienced slight erosion. This may reflect winter storms that occurred between 10th September and 10th October (see Section 2 on Scarborough wave data), but a similar spatial pattern has been seen in past surveys at this time collected in 2010, 2011 and 2012. Overall the cliffs at Robin Hoods Bay have been stable, with only three locations showing consistent erosion. Marker 1 has the greatest long-term recession rate of 1m/yr. **Longer term trends:** The limited change recorded in Robin Hoods Bay is due to the resistant rock platforms and thin, patchy cover of sand. In contrast, the erosional hotspots are likely to correspond to local

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. Data collection involves a distance offset measurement from the ground control point to the cliff edge along a fixed bearing. Historically, this method has proved prone to error as the cliff edge cannot be precisely identified due to vegetation cover and its convex shape and the survey accuracy is assumed to be +/-0.1m. Data have only been collected for a short time and are therefore unlikely to be representative of long-term trends. Table C2 shows that six of the 13 markers had no change in cliff top position between April and November 2013. Of the other remaining markers three show advance of the cliff, which suggests survey error. Four markers had recession of more than 0.1m between April and November 2013. Using data recorded between March 2010 and November 2013, calculated erosion rates show little change in nine markers and error associated with an advancing cliff at a further location. The remaining three posts (locations 1, 5, and 10) showed erosion of up to -1m/yr.	pockets of more mobile sand adjacent to the shore. **Autumn 2008 to Autumn 2012 trends** Although the long term plot shows patches of accretion and erosion, over the past year very limited change has been observed across much of the bay. This is because of the thin veneer beach and rocky foreshore. Accretion was recorded on the upper beach close at the northern extent of the survey.

3.5 Scarborough North Bay

Survey Date	Description of Changes Since Last Survey	Interpretation
17th Sept 2013	**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 20m chainage a deep gully which was present in the beach in April 2013 has been infilled due to the accretion of 0.5m of material. From 20m chainage to 95m chainage the beach has eroded by 0.4m. Below 95m chainage there was very little change in the profile level. At **1dSBN2** the beach is characterised by a shifting berm in the profile, which can form on the upper or lower beach. In September 2013 the berm is on the upper beach it has accreted by 0.3m since April 2013. From the end of the berm at 85m chainage to the rocks the level of the beach has dropped by 0.4m. When compared to the profiles dating back to November 2008 the upper beach is in the middle of the range of profiles and the middle to lower beach is comparatively high. The beach at profile **1dSBN3** has one of the steeper profiles observed at this location in September 2013. From 5m chainage to 105m chainage the beach has eroded by 0.8m over the summer of 2013. Between 105m and the end of the survey at 150m chainage the beach level has accreted by up to 0.5m. Overall the gradient of the profile reduced between April and September 2013. The profile at **1dSBN4** was low in September 2014. Between 25 and 65m chainage the beach level was so low that the rocks as the base of the sea wall have become exposed. A mound of material at the toe of the defence has been eroded, resulting in the loss of 0.3m of material from the profile. From 65m to 105m chainage the beach has accreted by 0.3m over the summer of 2013. From 105 to 135m change the beach has changed very little, but beyond 135m to the end of the survey the beach has eroded by 0.3m. On profile **1dSBN5** the gradient of the beach is similar to the April 2013 survey, but the beach has eroded by up to 0.4m in the lower third of the profile	The majority of the profiles show that the gradient of the beach has remained similar over the summer of 2013. The exceptions are SBN2 and SBN3, where the beach has become steeper, which is likely to be due to material having been moved up the beach. All of the profiles have been subject to erosion at the bottom of the beach. This may have been due to the storm recorded on 10th September at Scarborough (see section 2). There was some accretion of the upper beach in Profiles SBN2 and 3. Profile SBN1 and 4 had erosion on the upper beach, while SBN5 had a stable upper beach. The changes observed in North Bay are typical of dominant summer beach building processes. The plot of change between topographic surveys shows accretion in the north of the bay, midway down the beach, while the southern part of the bay has widespread erosion. This redistribution of sediment is likely to be a natural process. **Longer term trends:** The observed trends in the topographic plots and beach profiles point to overall stability with superimposed seasonal fluctuations. **Autumn 2008 to Autumn 2013 trends:** accretion of around 0.25m in the north of the frontage has been

Survey Date	Description of Changes Since Last Survey	Interpretation
	Post Storm Survey 11th December 2013. Beach Profiles SBN1, 2 and 3 are all within the range of the previous results, but Profiles SBN 4 and SBN 5 are both close to the lowest recorded elevation. In all cases the December 2013 profile is lower than that recorded in September 2013 indicating widespread erosion. The recorded erosion tended to be in a range of 0.4m-0.6m and in the upper part of the profile. At profile SBN4 the rock platform below the upper beach has been completely exposed.	observed over the last five years. In the south there has been a pattern of more significant erosion of around 1m. The erosion and accretion suggests transport of material towards the north of the bay. Future years' data will help to understand whether this trend is apparent over a longer timescale. **Post-storm Survey December 2013.** All of the profiles have eroded, with most significant losses close to the defences. This is likely to be due to reflection of wave energy by the defences. At SBN4 the rocky shore platform underlying the upper beach had been exposed to a much greater degree than in previous surveys. The length of the profile at SBN4 is limited but where the beach was measured it was at the lowest level recorded.
	Topographic Survey: Scarborough North Bay is covered by an annual topographic survey. Data have been used to create a DGM (Appendix B - Map 5a) with GIS. The GIS has also been used to calculate the differences between the current topographic survey DGM (Autumn 2013) and the earlier topographic survey DGM (Autumn 2012), with 5m resolution raster grids (as shown in Appendix B – Map 5b), to identify areas of erosion and accretion. Appendix B - Map 5b shows that overall, the distribution of erosion and accretion throughout the bay is weakly shore parallel. In detail, the northern third of the bay has accreted overall with changes of around 1m overall. The accretion is centred on the mid beach where up to 1.5m of material has been gained. There is erosion on the landward extent of the survey of up to 0.5m. The southern two-thirds of the bay are dominated by erosion of 0.5 to 0.75m, although there were patches of 0.5m of accretion close to the seawall. **Long Term Topographic Trends Autumn 2008 to Autumn 2013:** The long term topographic plots in Appendix B – Map 5c show that the north of the bay has been dominated by accretion while the south of the bay has been subject to erosion. The accretion in the north of the bay is concentrated close to the defended section where over 1m of material has been deposited. The southern part of the beach has eroded by up to 1m over the five-year period. There was modest accretion of around 0.25m at the southern extent of the survey.	

3.6 Scarborough South Bay

Survey Date	Description of Changes Since Last Survey	Interpretation
18th Sept 2013	**Beach Profiles:** Scarborough South Bay is covered by four beach profile, distributed between the harbour in the north and the Spa Complex in the south (Appendix A). At profile **1dSBS1** two berms have accreted since April 2013 when the profile was gently concave. From the base of the sea wall at 15m chainage to 40m chainage the beach has accreted by 0.8m. From 40m to 120m chainage the beach gradient has remained similar but the beach has eroded by 0.1m. Between 120m and 160m chainage accretion of around 0.2m has formed a mound. From 160m chainage to the end of the survey at 200m chainage the beach level has dropped by 0.4m. In April 2013 the beach at profile at **1dSBS2** was concave. The profile is has a similar elevation and gradient but now has two small berms with a depression between them. The beach level has changed by a maximum of 0.2m. The April 2013 profile **1dSBS3** was flat, but as seen in 1dSBS2, by September 2013 two mounds with a dip had formed. Above MHWS the profiles are similar. From the MHWS level at 10m chainage to 60m chainage the beach has accreted by 0.2m. Between 160m to 110m a depression has formed on the beach as a result of the erosion of 0.3m of material. From 110 to 160m chainage a new mound of material has formed, due to the accretion of 0.2m of material. From 160m chainage to the end of the survey the beach has eroded by up to 0.3m between April and September 2013 The same pattern is seen in profile **1dSBS4** where are two mounds had formed between April and September 2013. From 10m chainage to 50m chainage the beach has accreted by 0.4m. From 50m chainage to 110m chainage the beach level has dropped by 0.6m. Between 110m chainage and 170m the beach has accreted by 0.4m. From 170m to the end of the survey the beach has eroded by up to 1m. **Post Storm Survey 9th December 2013** All of the profiles for December 2013 are near the middle of the range of previous results, apart from SBS3 where the beach level is at the lowest elevation recorded. When comparing the September and	All of the beach profiles have developed two beach berms with a depression in the middle. For all of the September 2013 profiles the upper and mid beach are low compared to previous surveys. The low level of the upper and mid-beach may have been due to the 10th September storm recorded in the wave dataset. Beach reprofiling is undertaken on his part of the coast when necessary, but the work was last done in April-May 2012, and therefore changes seen over the summer of 2013 are due to natural processes. The topographic survey change plots show bands of shore parallel changes in accretion and erosion. The plots in the 2010, 2011 and 2012 Full Measures Report showed a very similar pattern. The pattern of shore parallel bands indicates development and migration of beach berms, as indicated by the profile data. These features are indicative of wave refraction in a stable bay. The topographic survey of the beach itself is showing signs of erosion on the upper beach, which is in general agreement with profile data. 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

Survey Date	Description of Changes Since Last Survey	Interpretation
	December 2013 profiles it is clear the beach has been flattened while maintaining similar levels.	0.5 m/year. **Longer term trends**: The beach profiles show that beach levels recorded in 2013 were among the lowest recorded. The beach was not re-profiled in 2013, but due to the December storms and the low level of the 2013 profiles it is likely that the beach may need to be renourished if it has not recovered naturally by spring 2014. **Autumn 2008 to Autumn 2013 trends:** The bay has been subject to widespread erosion of up to 1m, although there are areas of accretion in the north of the beach adjacent to the harbour arm, and at the back of the beach in front of the Clock Cafe. The most severe erosion was observed in the centre of the bay. **Post Storm Survey December 2013**: The data show that profiles have flattened between September and December 2013 but the overall beach levels have not changed greatly. This suggests that any beach berms and bars were smoothed away by the storm, which persisted over several tides. The majority of the profiles are comparable with the previous surveys, with the exception of SBS3, where the profile is low. At SBS2 and SBS3 all three of the profiles collected in 2013 (April, September and December) are low compared to previous years.
	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 2013) and the earlier topographic survey DGM (Autumn 2012), with 5m resolution raster grids (as shown in Appendix B – Map 6b), to identify areas of erosion and accretion. Appendix B - Map 6b shows that the northern part of the survey is characterised by a sequence of shore parallel changes comprising erosion at the back of the beach with deposition further seaward. The recorded erosion was around 0.75m, while the accretion was up to 1m of change. This is the fourth consecutive year where this pattern has been observed. The shore-parallel trend weakens as towards the south and at the southernmost part of the beach the pattern of change is patchy. Up to 1m of erosion is observed in some areas, with accretion of around 0.25m. **Long Term Topographic Trends Autumn 2008 to Autumn 2013:** The long term plot of change (Appendix B Map 6c) shows that Scarborough South Bay has experienced erosion overall. There is a band of erosion running north to south down the middle of the beach. In the north there are a number of shore parallel bands of up to 1m of accretion. The erosion tends to be up to 1m in the centre of the bay where erosion is most severe. The southern part of the bay on the landward extent has seen modest accretion of up to 0.5m. This pattern reflects migration of sand bars.	
	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 April and September 2013 nine of the thirteen locations showed change of less than ±0.1m.	

Survey Date	Description of Changes Since Last Survey	Interpretation
	One marker recorded growth, showing a probable error in locating the cliff edge. The remaining three markers had been subject to erosion of up to 0.3m during the summer of 2013. The recession rates calculated for the period from April to September 2013 give a picture of the change over the longer term. Eleven of the markers have a recession rate of less than 0.1m/yr. Markers 11 and 12 have shown long-term average erosion rates of 0.6m/yr and 0.5m/yr. Appendix C provides results from the September 2013 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
5th Sept 2013	**Beach Profiles:** Cayton Bay is covered by three beach profile lines, distributed between Tenants' Cliff and the south of Cayton Sands (Appendix A). The cliff face at profile **1dCY1** is largely vegetated and was difficult for the surveyors to access resulting in poor data in the top of the profile. Between 5 and 70m chainage at the upper beach, the April 2013 profile was one of the lowest recorded. Between 70m and 125m chainage the beach has eroded by 0.5m. The remainder of the beach profile shows stability. The centre of cliff profile **1dCY2** could not be accessed for the survey, so there is low confidence in the data. Overall the beach has remained stable since 2008 with the exception of two large mounds in the September 2013 profile. From 120m to 150m chainage a mound of 0.5m of material has accreted between April and September 2013. Between 150m and 180m there was little change. From 180 to 230m another mound of material has formed, due to the accretion of 0.3m. Between 230m and 270m chainage there was erosion of around 0.4m. From 270 to 320m chainage a third mound had formed, due to the accretion of 0.5m of material since April 2013. The centre of cliff profile **1dCY 3** profile could also not be accessed, so there is low confidence in the data. From 125m to 145m chainage the beach had accreted between April and September 2013 by 0.5m. Between 150m and 230m chainage there was little change in beach level. From 230m to 270m chainage the beach had accreted by 0.5m, forming a second mound. **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 current topographic survey DGM (Autumn 2013) and the earlier topographic survey DGM (Autumn 2012), 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, with accretion on the	The beach profiles for Cayton Bay have steepened and formed beach berms between April and September 2013, which is a typical seasonal variation. The 2013 profiles are within the range of previous profiles. The plot of difference between Autumn 2012 to Autumn 2013 surveys shows variability in the erosion and accretion in the bay. The magnitude of change recorded over 2013 was modest and within the range of seasonal beach fluctuations. Difference plots in previous reports show a similar pattern of shore parallel bands of accretion and erosion, indicating migration of sand bars with no net change in beach level. The cliff top survey data shows that there was stability overall during the summer of 2013. The highest recorded erosion rate is 0.1m/yr. **Longer term trends:** The pattern of migrating sand bars/berms has remained consistent from 2010 to the summer of 2013, indicating variation in beach level, but no net change. The undefended cliffs are a source of sediment, but beach accretion has not been detected. This may be because the sediment supplied is too fine grained to be retained on the beach, because the supply rate is low compared to the beach area, or because material is lost from the bay.

Survey Date	Description of Changes Since Last Survey	Interpretation
	upper and lower beach and erosion in the centre. The accretion was limited to 0.5m, while the erosion in the mid beach was up to 0.75m. In 2012 the upper beach was dominated by erosion at the toe of the cliffs. However, this trend has reversed in 2013. The current beach profiles and the topographic survey were collected on the same day. However; interpretations of beach change are in large part different between these data series, this reflects the use of different baseline data, i.e. beach profiles (March 2010, partial measures data), and topographic survey (October 2009, full measures data) in the respective comparisons. **Long Term Topographic Trends Autumn 2008 to Autumn 2013:** The long term difference plots in Appendix B – Map 7c show that there has been no overall trend in Cayton Bay between 2008 and 2013. The difference plot shows a patchy distribution of accretion and erosion with a very subtle shore parallel pattern, with most net change within a range of ±0.75m.	The cliff top survey results show little or no erosion, with only four profiles showing recession between 0.1m/yr and 1m/yr. The overall pattern of change observed is similar to that in past reports. **Autumn 2008 to Autumn 2013 trends:** The patchy distribution of change on the difference plots are likely to reflect sediment distribution within the bay rather than progressive erosion or accretion. The undefended cliffs are a source of sediment which is moved down the beach and along the littoral transport direction. Overall it is considered that the bay form is fairly stable although the cliffs are slowly eroding.
	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 varied, as shown in Table C4. Between April and September 2013 five of the eight profiles show very little change (within the ±0.1m accuracy of the survey). One point has shown growth, which points to error in precise location of the cliff edge. The remaining two profile locations, markers 1 and 2, show erosion of 0.1m over the summer of 2013. Long-term erosion rates calculated using data collected since November 2008 show error at half of the locations due to problems precisely locating the cliff edge. The remaining markers show erosion rates of retreat of between 0.1m/yr and 1m/yr. The largest retreat rate of 1m/yr was recorded at Point 2. Appendix C provides results from the September 2013 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
4th Sept 2013	**Beach Profiles:** Filey Bay is covered by five beach profile lines, distributed between Filey Sands and Speeton Sands (Appendix A). At profile **1dFB1**, which fronts Filey seawall, the overall the beach profile has fluctuated but shows no pattern of accretion or erosion. The profile has remained stable above MHWS from April to September 2013. Between MHWS at 20m chainage and 50m chainage the beach level has accreted by 0.7m. From 50m chainage to 100m chainage the beach has eroded by 0.3m. From 100m chainage to the end of the survey at 240m the beach has remained reasonably stable and only varied by up to ±0.2m. The changes observed at profile **1dFB2** since March 2013 are predominantly due to the movement of berms on the beach. The beach has changed little above the HAT level at 65m chainage. From 65m to 85m chainage the beach has accreted by 0.5m. Between 85m and 105m chainage a dip or channel has formed due to a drop in love of around 0.5m. From 105m to 150m chainage a mound has formed due to the accretion of 0.5m. Between 150m and 210m chainage the beach level has dropped by 0.7m. From 210m to 260m a berm has formed and the beach has accreted by 0.6m. From 260m to the end of the survey at 310m chainage there has been erosion of around 0.3m. At profile **1dFB3**, near Flat Cliffs, the cliff face above HAT remains unchanged. Overall the beach level has remained the same, but the gradient has steepened since April 2013. Between the HAT level at 40m chainage and 160m chainage the beach has accreted by 0.4m. From 160m chainage to the end of the survey at 280m (MLWS) the beach has eroded by 0.5m over the summer of 2013. Profile **1dFB4** at Hunmanby Gap, has changed very little above the HAT level. From 30m chainage to 80m chainage the beach has accreted by 0.8m with formation of a berm. A depression has opened up between 80m and 130m due to loss of 1m of sediment since April 2013. From 130m to 180m the beach has accreted by 1m, where a berm has formed. From 180m to the end of the survey at 240m chainage there has been modest erosion of around 0.2m. The profile for **1dFB5** has remained stable between April and September 2013, with a pattern of local fluctuations about a mean elevation. Above HAT the profile has remained stable. From 225m to 270m	All of the Filey Bay beach profiles have remained stable over the summer of 2013, with change related to migration of beach berms. The beach gradients have not changed. All of the profiles are within the range of previous results on the upper and lower beach. The topographic change assessment shows that the whole of Filey Bay is dominated by shore parallel successive bands of accretion and erosion associated with migrating berms. This is a continuation of the trend observed in the 2010 and 2011 reports. The difference plot of Filey Town shows shore parallel strips of accretion and erosion with the most change being observed in the centre and south of the bay. There has been no overall trend of accretion or erosion, and it is considered that the changes reflect migration of berms with no net loss of sediment. The cliff top survey data provided in Table C5 shows that of the 27 profiles only four showed erosion. The maximum total erosion seen since the baseline survey is at location 5, just south of Filey seawall where there has been 6.2m of erosion, equivalent to an annual rate of 1.3m/yr. The pattern of overall stability and erosion at these locations was also observed in past reports.

Survey Date	Description of Changes Since Last Survey	Interpretation
	chainage the beach has accreted by 0.5m. Between 270m and 320m the beach has eroded by 1m to form a dip between the two berms. From 320m to 380m the beach has accreted by around 1m. From 380m onwards the beach level has changed little between April and September 2013. **Post Storm Survey 17th December 2013.** Between September and December 2013 Profiles FB1 to FB4 have flattened although the beach level has remained similar and are all in the middle of the range of historical results. Profile FB5 is slightly lower than in September 2013, but is not at its lowest recorded elevation. **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 2013) and the earlier topographic survey DGM (Autumn 2012), 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 shows shore parallel strips of change between Filey Brigg and Hunmanby Gap, with alternating bands of erosion and accretion that are most prominent in the centre of the bay. Erosion has tended to occur near MHW and MLW while the accretion is concentrated in the centre of the beach. The northern half of the bay had been subject to erosion and accretion in the order of ±0.5m. Appendix B – Map 9b shows the continuation of the shore parallel trend on the Filey frontage but the distribution of accretion and erosion is less clearly marked. The magnitude of change observed in the centre and southern end of the bay is greater than in the north. In the southern half of the bay the plots show areas of accretion of around 0.5m and erosion of over 1m in the same bands of change, but further south. Overall the beach appears to have eroded by around 0.75m the most consistent area of accretion was at the toe of the cliff. At the southern end of the plot the erosion of the beach has been significant and over 1m of material was lost during 2013. **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.	**Longer term trends**: the topographic difference plots for the past reports also showed that the erosion and accretion was more significant in the south, which is largely undefended. Filey Town was subject to little change, but over the summer of 2013 there was more change recorded. **Autumn 2008 to Autumn 2013 trends:** The overall trend in Filey Bay over the last five years has been a patchy distribution of change. Overall there was erosion in the south of the bay, localised accretion in the centre of the bay and modest accretion in the north of the bay. The trend for the upper beach is accretion. The magnitude of changes observed in the long term difference plots are within a range of ±1m over the past five years. As a result it is considered that Filey Bay beaches have a fairly stable form. **Post Storm Survey December 2013.** Filey Bay did not show large scale erosion following the storm of 6th December 2013. However, the beaches have flattened, which is likely to be due to the redistribution of material that had been built into berms observed in the September 2013 survey. The results of the first 5 years of cliff top monitoring have mostly showed low rates of retreat that are within the error bands of the technique with erosion rates over the 5 years less than +/-0.1m/yr. however, control point 5, immediately south of the Filey town defences,

Survey Date	Description of Changes Since Last Survey	Interpretation
	The GIS has been used to calculate the differences between the current (full measures) topographic survey DGM (Autumn 2013) and the earlier (partial measures) topographic survey DGM (Spring 2013), with 5m resolution raster grids (as shown in Appendix B – Map 10a), to identify areas of erosion and accretion during the previous 6 months. Appendix B - Map 10a shows that there have been areas of accretion and erosion, with a pattern of shore parallel areas of accretion and erosion. The largest change has been observed close to the seawall where up to 1m of material has accreted. The remaining bands of accretion and erosion show a maximum magnitude of change of ±0.5m. The smallest changes were observed at the base of the beach where around 0.25m of material had accreted. **Long Term Topographic Trends Autumn 2008 to Autumn 2013:** The long term trends of change in Filey Bay are shown in Appendix B – Maps 8c and 9c. The plots show that there has been a patchy distribution of net change since 2008. The magnitude of change is larger in the central and southern parts of the bay, with net change of up to up to 1m. The pattern of change shows there tended to be erosion in the northern and southern parts of the bay with accretion in the centre. **Filey Town Long Term Trends:** The long term difference plot for the Filey town frontage is in Appendix B Map 10b. The plot shows that over the previous five years there has been a clear trend of erosion by around 0.5m in the middle of the beach and accretion of up to 1m towards MLW and MHW.	has a recession rate of 1.3m/yr, marker 7 at Muston Sands has a rate of 0.4m/yr and markers 14 to the north side of Hunmanby Gap has a rate of 0.2m/yr. Due to the episodic nature of cliff recession a longer time series is required to establish representative data. The recession rates will therefore become clearer as the more data is collected on the erosion rates in future years of this monitoring programme.
	Cliff-top Survey: Twenty-seven ground control points have been established within Filey Bay for the purposes of cliff top monitoring. This includes the installation of three new locations in September 2010, these being 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). The maximum separation between any two points is nominally 300 m. The cliff top surveys at Filey Bay are undertaken every 6 months. Data collection involves a distance offset measurement from the ground control point to the cliff edge along a fixed bearing. Between April 2013 and September 2013 twenty-three of the twenty-seven ground control points showed erosion less than ±0.1m. The remaining four points had shown erosion of -0.2 to -0.4m Long term rates of change since the baseline show few areas have changed. Only four of the markers	

Survey Date	Description of Changes Since Last Survey	Interpretation
	show erosion, with rates between 0.1m/yr and 1.3m/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 2013 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 Sept/Oct 2012 and a second repeat survey is planned for 2014. 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.

Parts of Whitby, Cayton and Filey were inaccessible due to dense vegetation or soft ground and mudflows. At Scarborough North vegetation and construction works on the shore impeded access to the beach and cliff. Finally, at Robin Hoods Bay it was difficult to measure the edge of the cliff due to the fly tipping of garden waste.

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 five 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

The following recommendations are suggested:

- Consideration to be given to the analysis and reporting of longer-term beach behaviours demonstrated by the topographic survey data. This may include the calculation of volumetric sediment budgets (as best possible) for each successive time period.

6. Conclusions and Areas of Concern

The following points have been observed:

- The Staithes cliff face shows stability overall. Between April 2013 and October 2013 posts 5 and 12 showed the largest negative change of all of the posts, both had a value of -0.3m of erosion. The erosion rates also show that the cliff where monitored has been generally stable, with only one post having been subject to consistent erosion through the surveys, Post 13 (near the eastern breakwater) has a rate of -0.5m/yr.
- Runswick Bay showed signs of accretion close to the shore and erosion of the lower beach. This meant that the beach is steepening, which could be a precursor to erosion of the cliff. Erosion of up to 0.5m was noted in patches on the upper beach. The beach level may have been dropping or the change could reflect the erosion of material from the toe of the cliffs.
- At Sandsend Beach, Upgang Beach and Whitby Sands the topographic difference plots do not show a straightforward pattern to the distribution of erosion and accretion. However, the losses and gains in the centre of the Bay are much more pronounced than at the distal ends of the Bay where the changes tend to be smaller. This distinction between the large changes in the middle of the bay with modest change at each end of the bay was also noted in 2010, 11 and 12.

- At Robin Hoods Bay the topographic change plots show that the Bay as a whole appears to have been subject to slight erosion. Although the changes on the difference plot are generally small and very patchy, the pattern was observed in the 2010, 11 and 12 Full Measures Reports. Overall the cliffs at Robin Hoods Bay have been stable with minimal change since cliff-top monitoring began in 2010. Marker 1 at the northern extremity has had consistent recession and currently has a high rate. The annual rates show that three of the 13 points had been subject to erosion through the duration of the data collection.
- For Scarborough North Bay the plot of change between topographic surveys shows accretion in the north around part of the mid beach. While in the southern part of the bay there was widespread erosion. This trend is consistent on both the recent 2012 to 2013 and longer term2008 to 2013 differernce plots.
- At Scarborough South Bay all of the beach profiles gained two beach berms with a depression in the middle prior to the autumn survey. For all of the September 2013 profiles the upper and mid beach are low compared to previous surveys. Beach recycling and reprofiling is undertaken in some years in South Bay. Beach management was last undertaken in South Bay in April / May 2012, when about 8,000m^3 of sand was moved from the northern part of the bay to the southern part, see 2012 Analytical Report. Although there was no beach management between the autumn 2012 and autumn 2013 surveys the impact of the previous recycling may still be influencing beach levels so it is unclear how much of the change is due to human action or natural processes. The topographic survey change plots show bands of shore parallel changes in accretion and erosion. The plots in the 2010, and 2011 and 2012 Full Measures Report showed a very similar pattern. The cliff was stable overall but some of the points are showing recession of 0.5 to 0.6m/yr.
- The Cayton Bay beach profiles show seasonal variation, rather than a progressive change. There was little overall change in beach volumes was observed through the profiles. The change plot shows variability in the erosion and accretion in the bay. The magnitude of change recorded over 2013 was modest and within the range of normal fluctuations in beach level. The cliff has remained stable overall with just 0.1m of recession being recorded over the summer of 2013.
- The beach profiles at Filey Bay have remained reasonably stable over the summer of 2013. The beach gradients have remained the same, the changes described relate to the position of the berms. The topographic change assessment shows that the whole of Filey Bay is dominated by shore parallel successive bands of accretion and erosion. The beach sediment appears to be being redistributed within the bay. Cliff erosion is greatest at location 5, which is immediately south of the Filey Town sea wall. This suggests that outflanking of the defences remains a problem.

Conclusions from the December 2013 Post-Storm Survey.

The beach profiles and difference plots for the post storm survey show the impact of the surge event of 6th December and the associated storm waves which also spanned the subsequent two tides. There were a number of profiles in Whitby and the topographic change plots in Sandsend that showed erosion. However, in most locations the beach level had flattened.

The data from the wave buoy shows that the storm surge that damaged many defences and received significant media attention on 5th and 6th December 2013 does not appear to have had exceptional wave conditions. At the Tyne/Tees buoy, the record shows a peak significant wave height of 4.7m and storm duration of 38 hours. However, the wave period was over 14 seconds, is unusual, and the longest storm wave period recorded. At Whitby the waves were again unremarkable in terms of wave height. However the wave period was 14 seconds and the longest recorded by a significant amount (3 seconds). The wave energy at peak was 8,625KJ/m/s, which is twice the amount of typical previous events in the Whitby storm record.
Further examination of the recorded wave data indicates that at the time of the maximum water level the wave heights were still building and larger waves were experienced on the two subsequent high waters. This means that the storm beach profiles created during the highest water levels of the surge event on the 5th will have been redistributed during the subsequent

two days. It is notable that considerable quantities of beach sediment and storm debris was pushed onto the highway and adjacent properties in the northern part of Scarborough's South Bay.

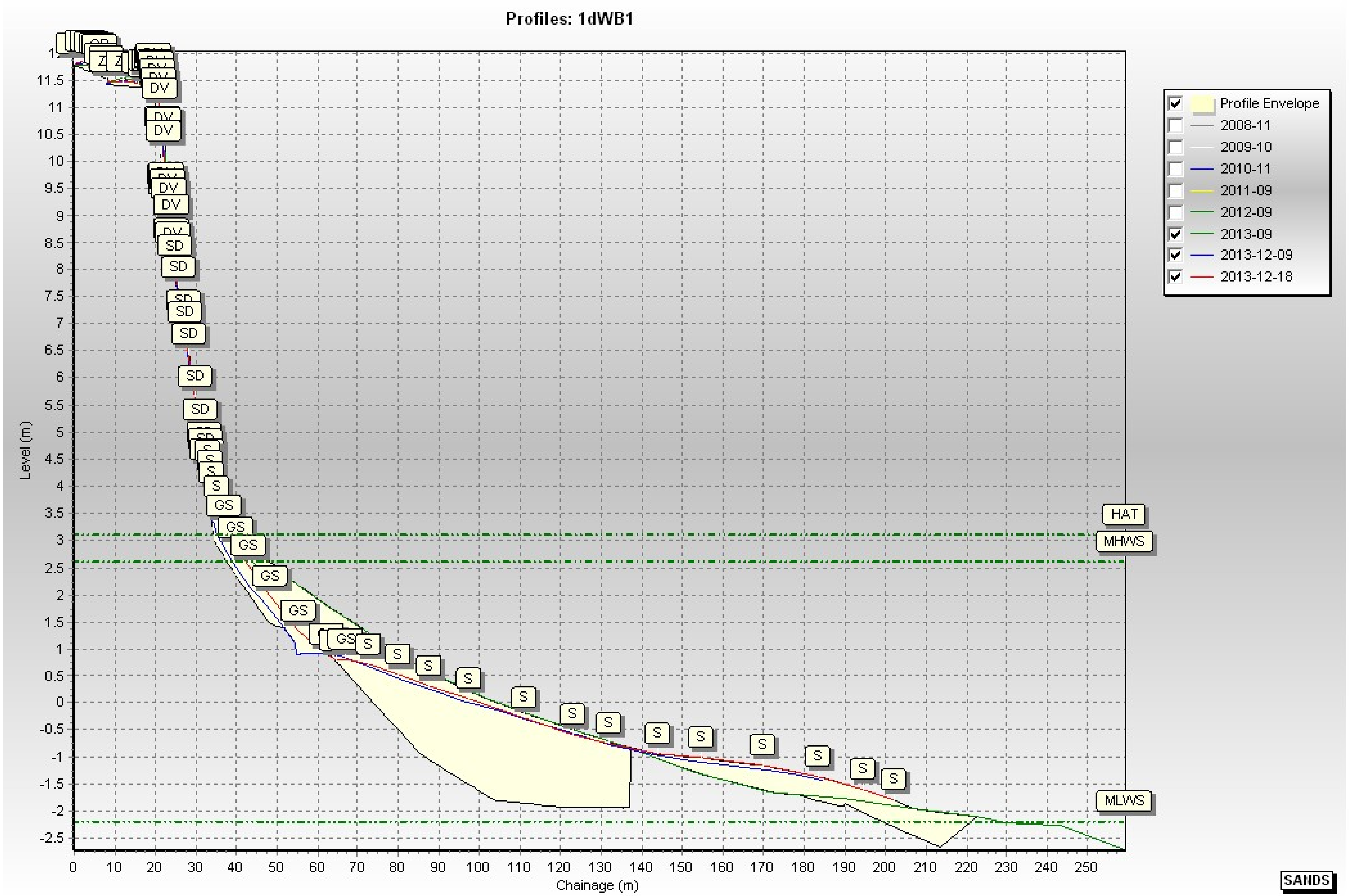
Appendices

Appendix A

Beach Profiles

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



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Chainage (m)
Profile Envelope
2008-11
2009-10
2010-11
2011-09
2012-09
2013-09
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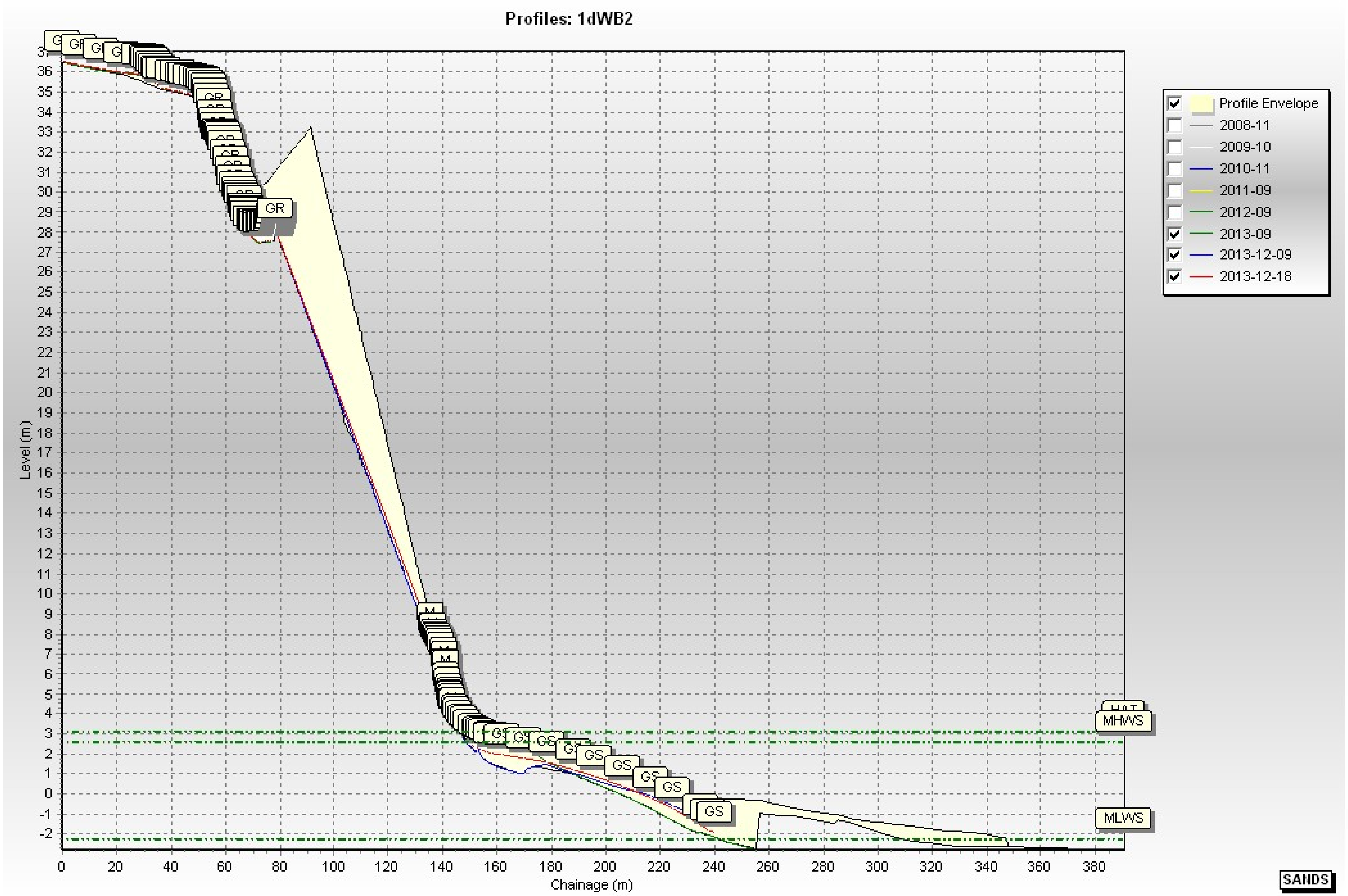
MLWS
DV
SD
S
GS
SANDS



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2010-11
2011-09
2012-09
2013-09
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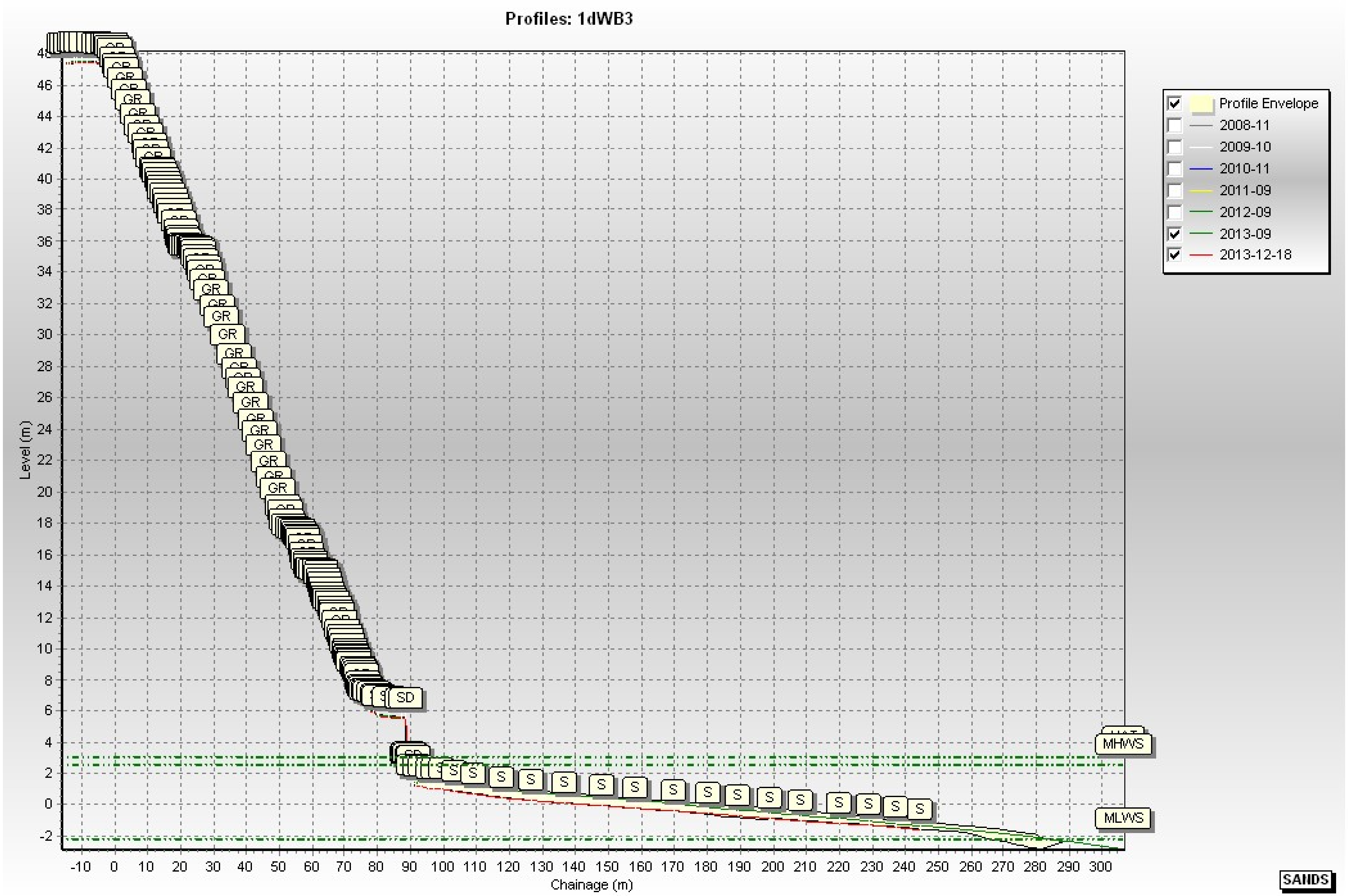
MLWS
SANDS



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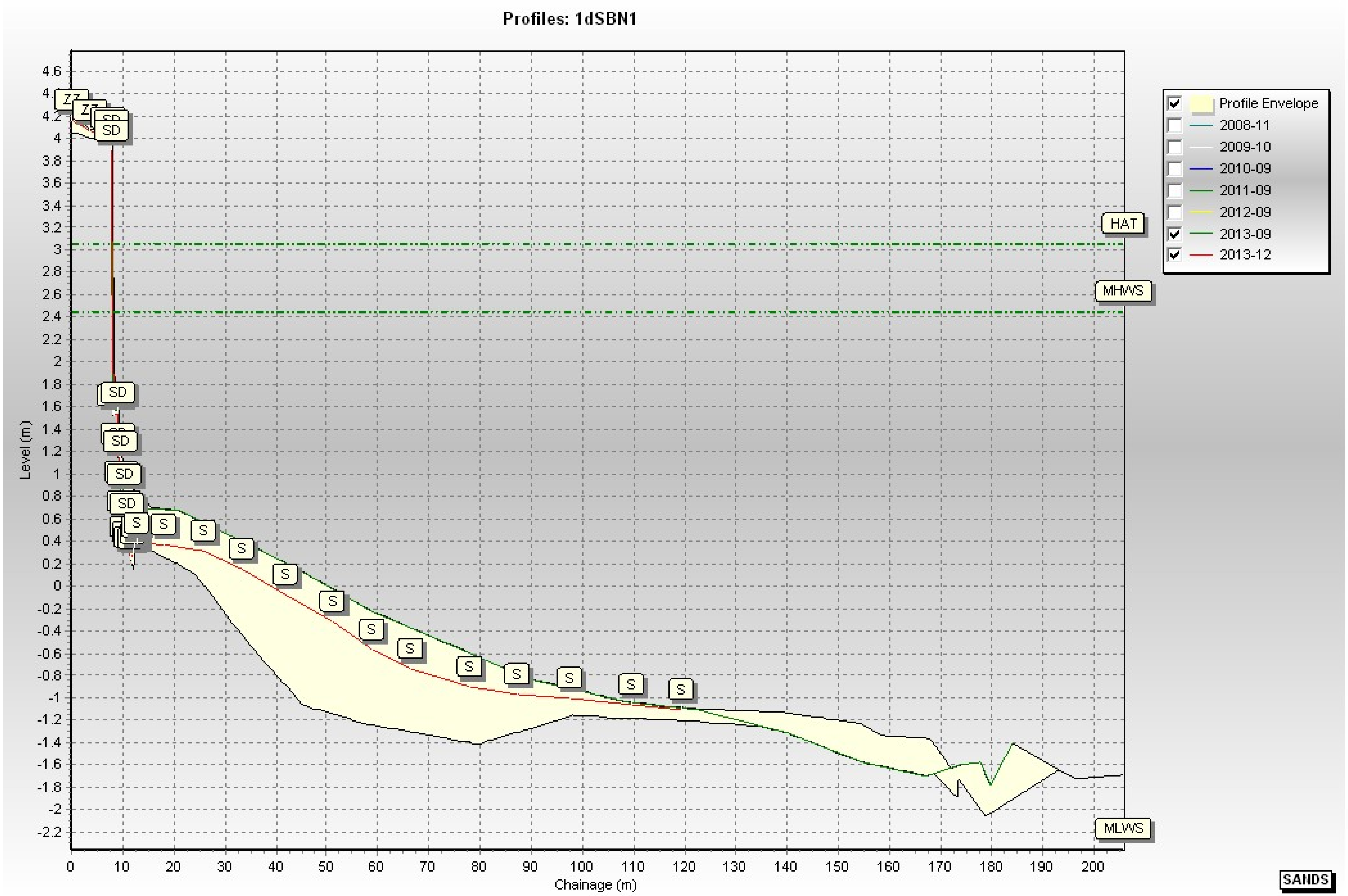
GR
SD
S
SANDS



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2011-09
2012-09
2013-09
2013-12
HAT
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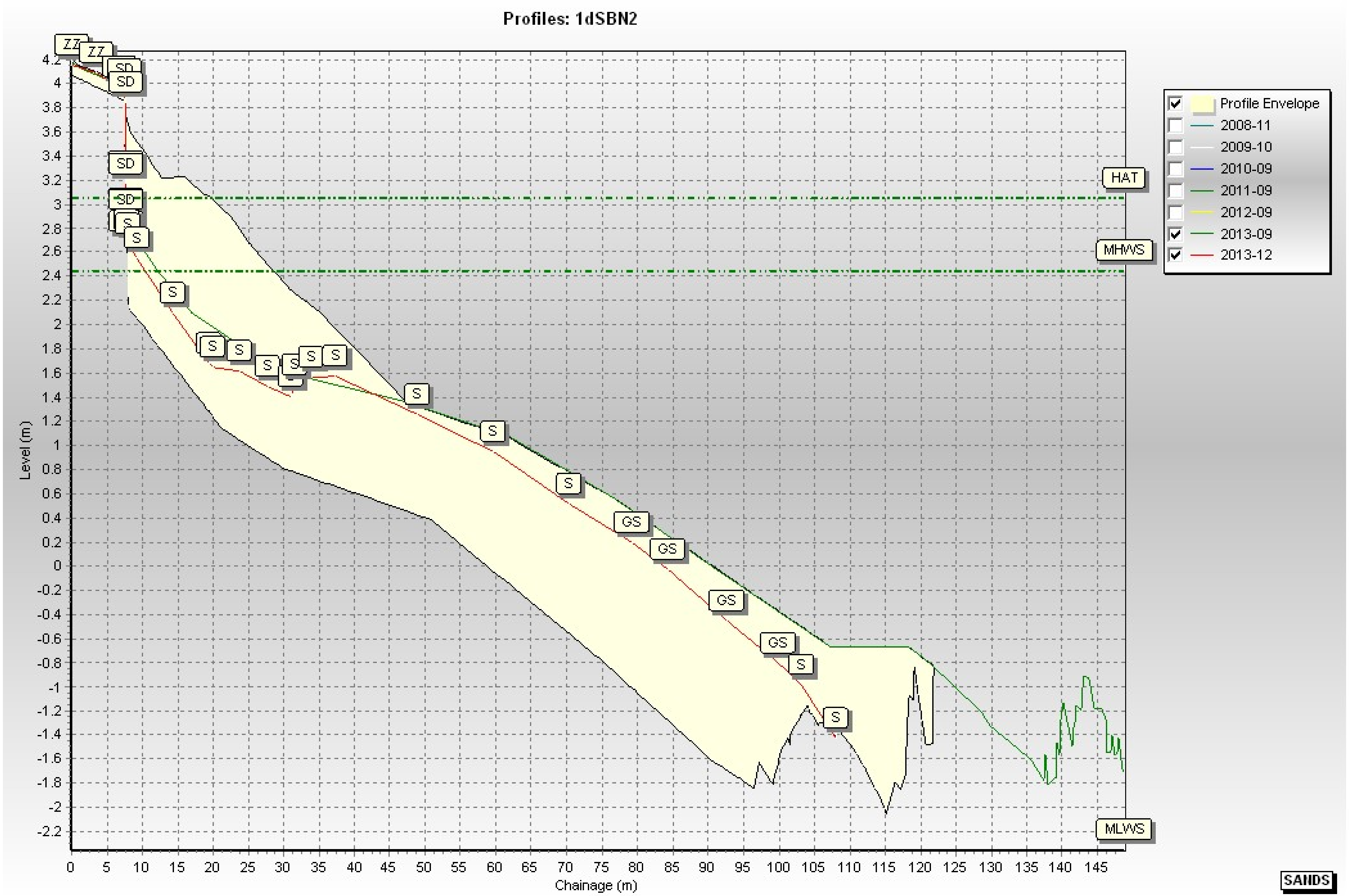
MLWS
Level (m)
Chainage (m)
SANDS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2011-09
2012-09
2013-09
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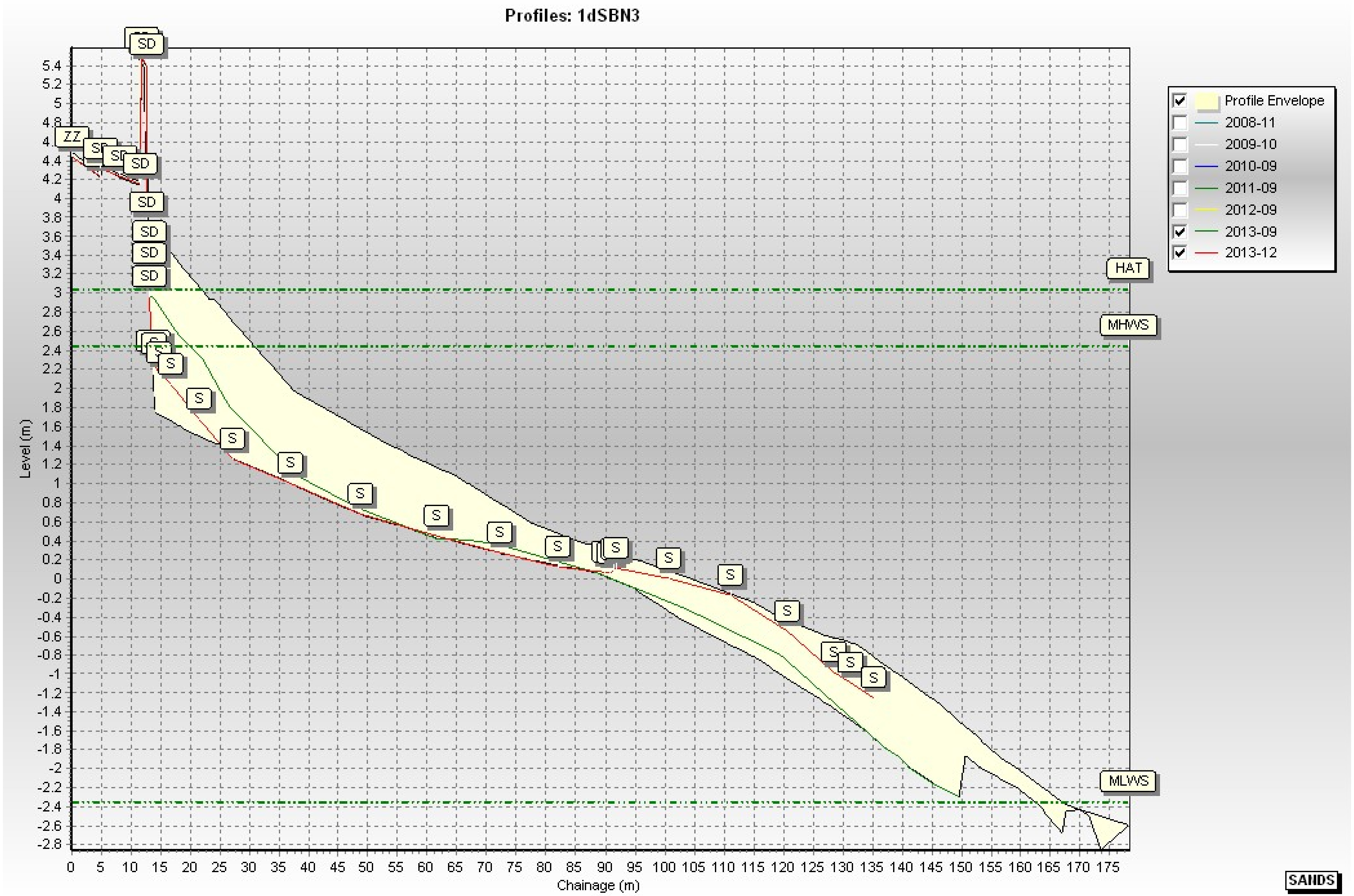
ZZ
SD
S
GS
SANDS



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Chainage (m)
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2011-09
2012-09
2013-09
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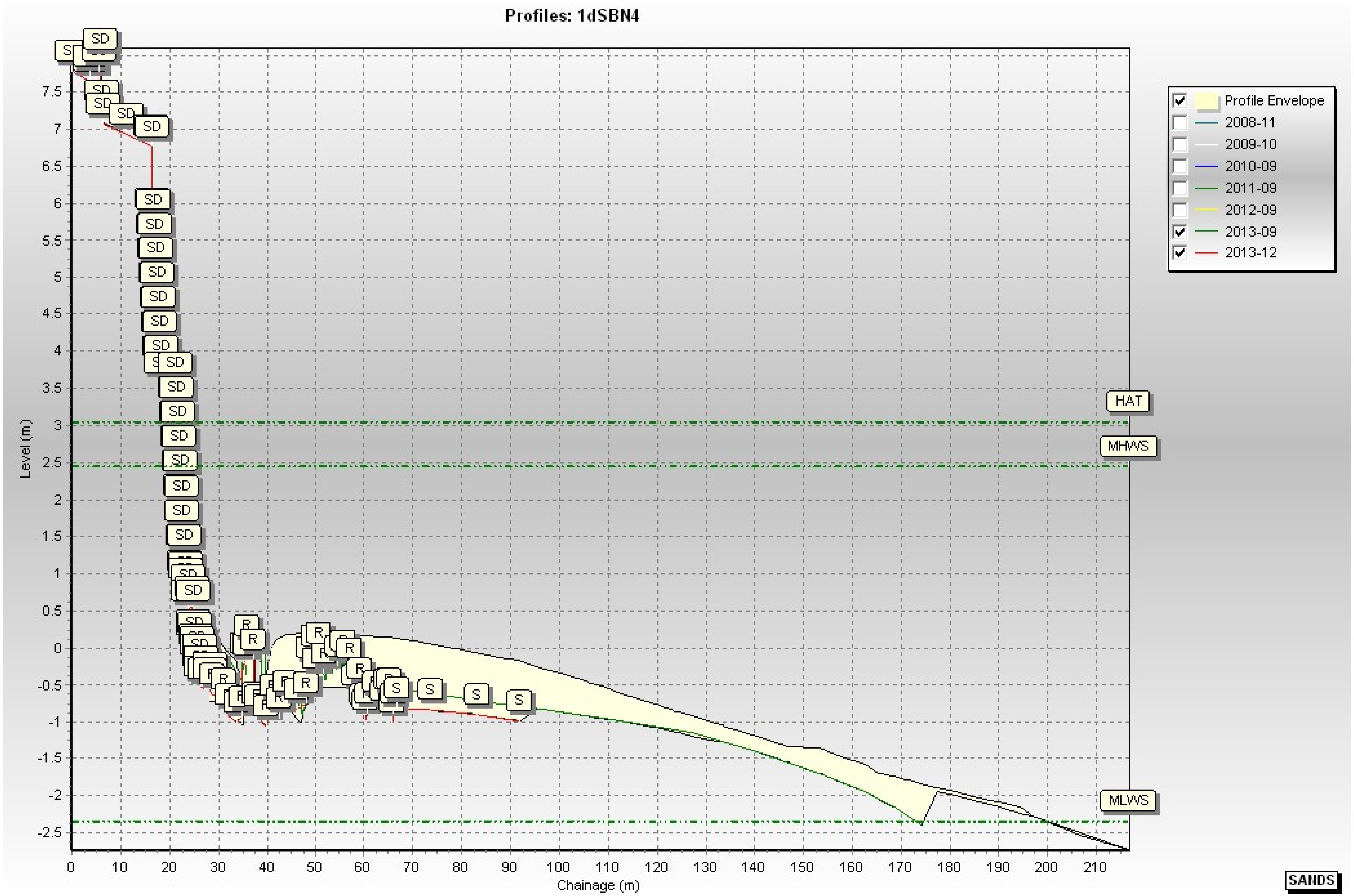
SD
S
ZZ
SANDS



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Chainage (m)
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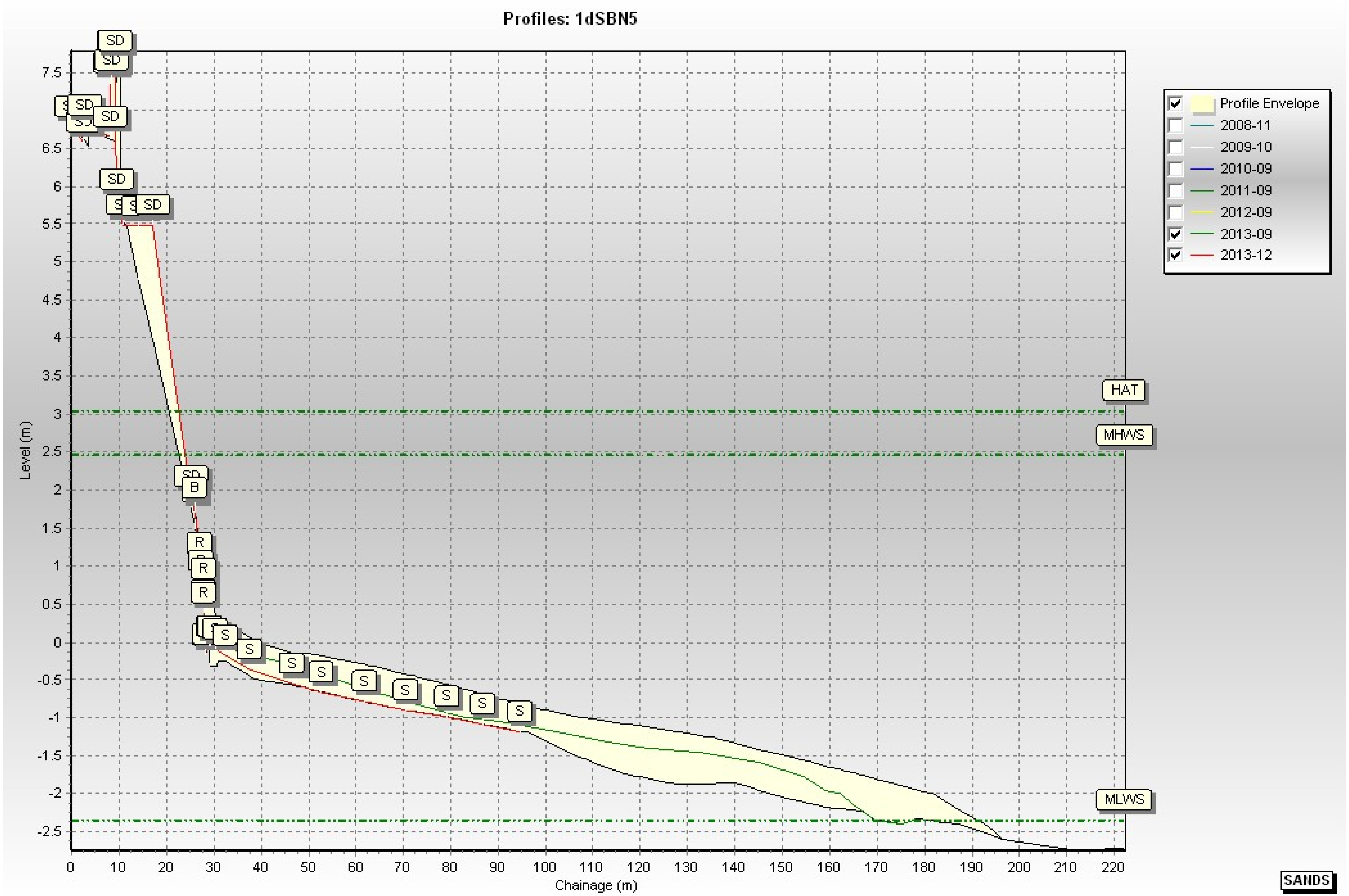
2011-09
2012-09
2013-09
2013-12
HAT
MHWS
MLWS
SANDS



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Level (m)
Chainage (m)
Profile Envelope
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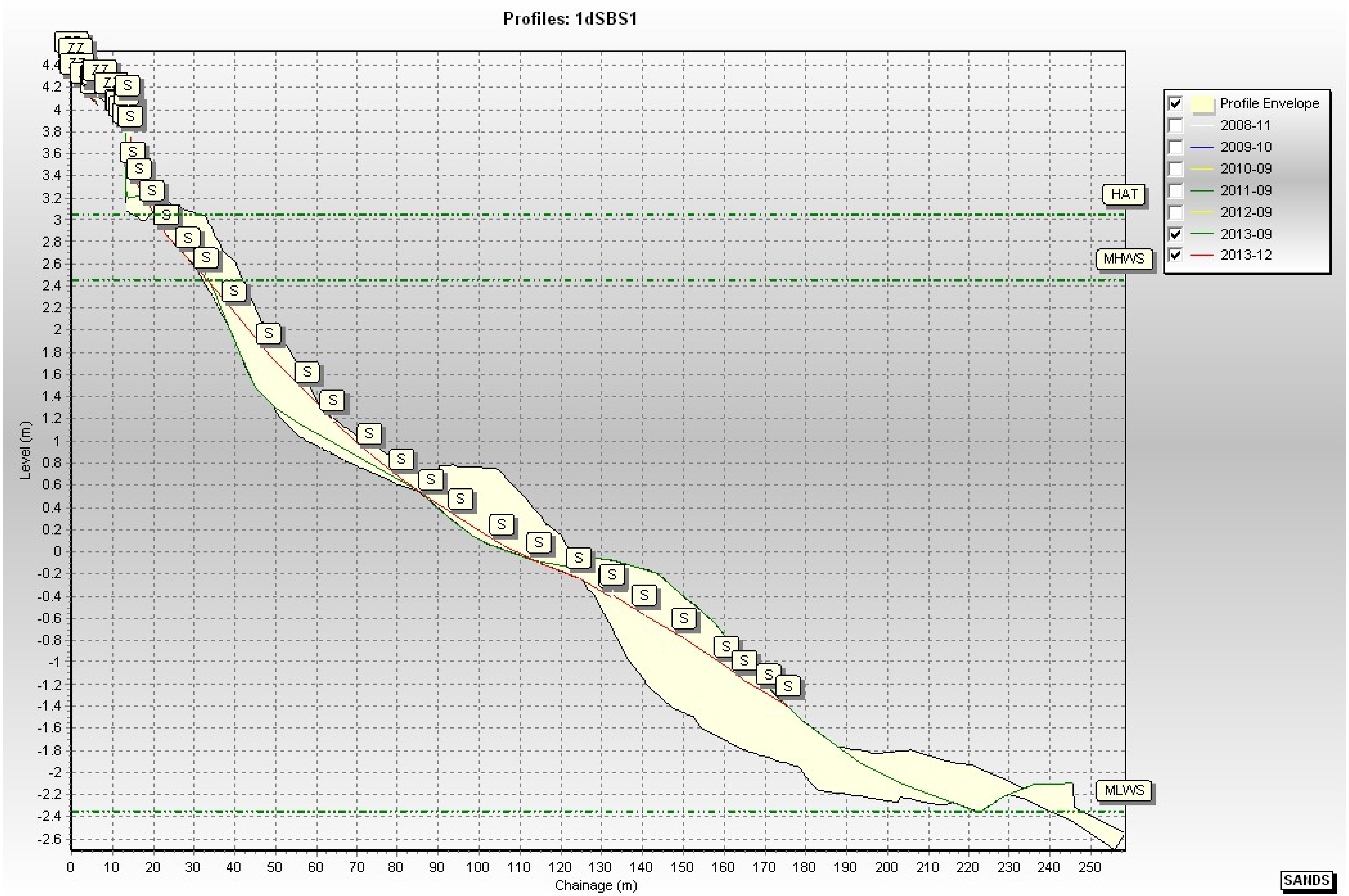
2011-09
2012-09
2013-09
2013-12
HAT
MHWS
MLWS
SD
B
R
S
SANDS



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2011-09
2012-09
2013-09
2013-12
HAT
MHWS
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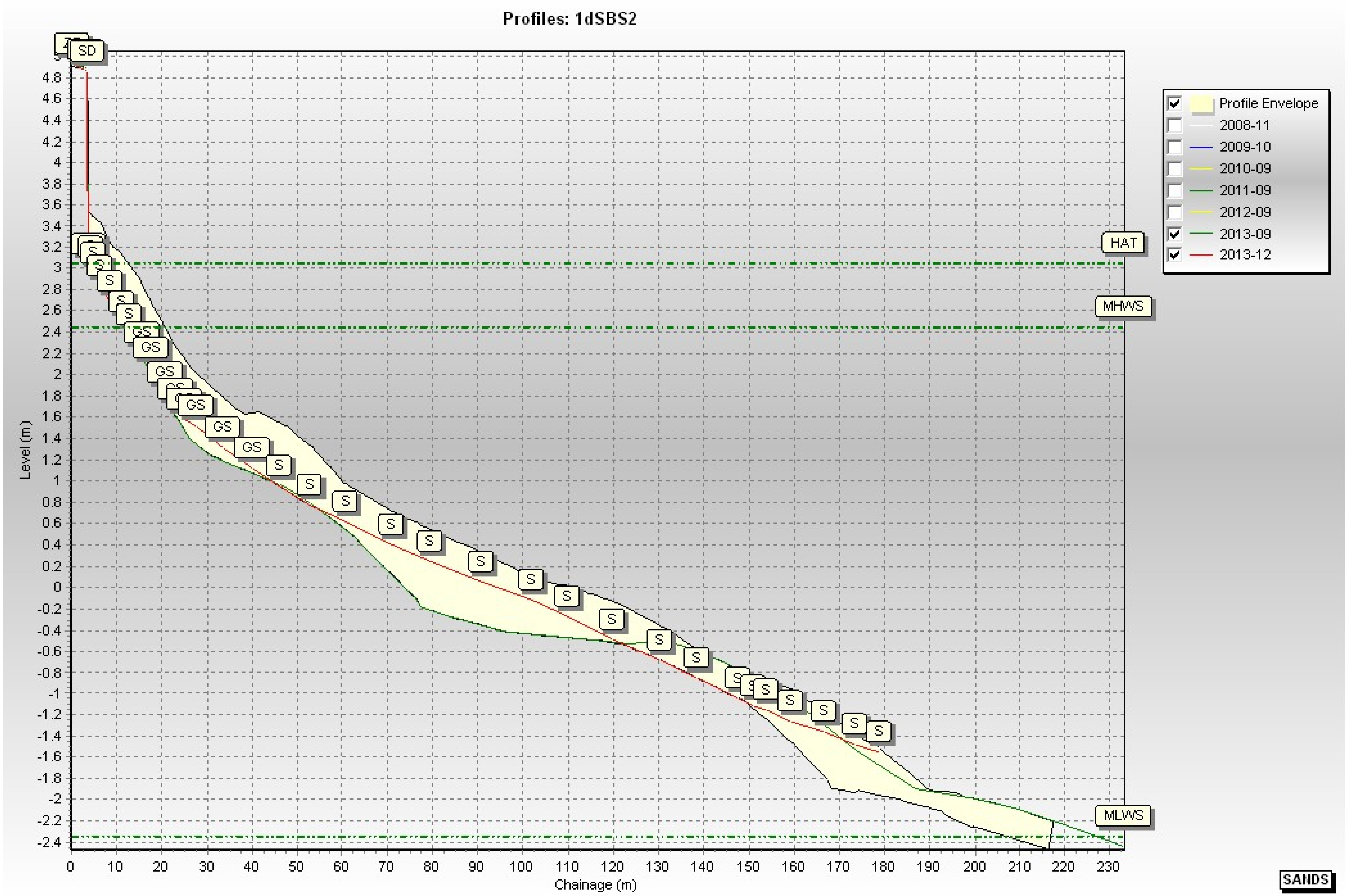
Chainage (m)
SANDS



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Chainage (m)
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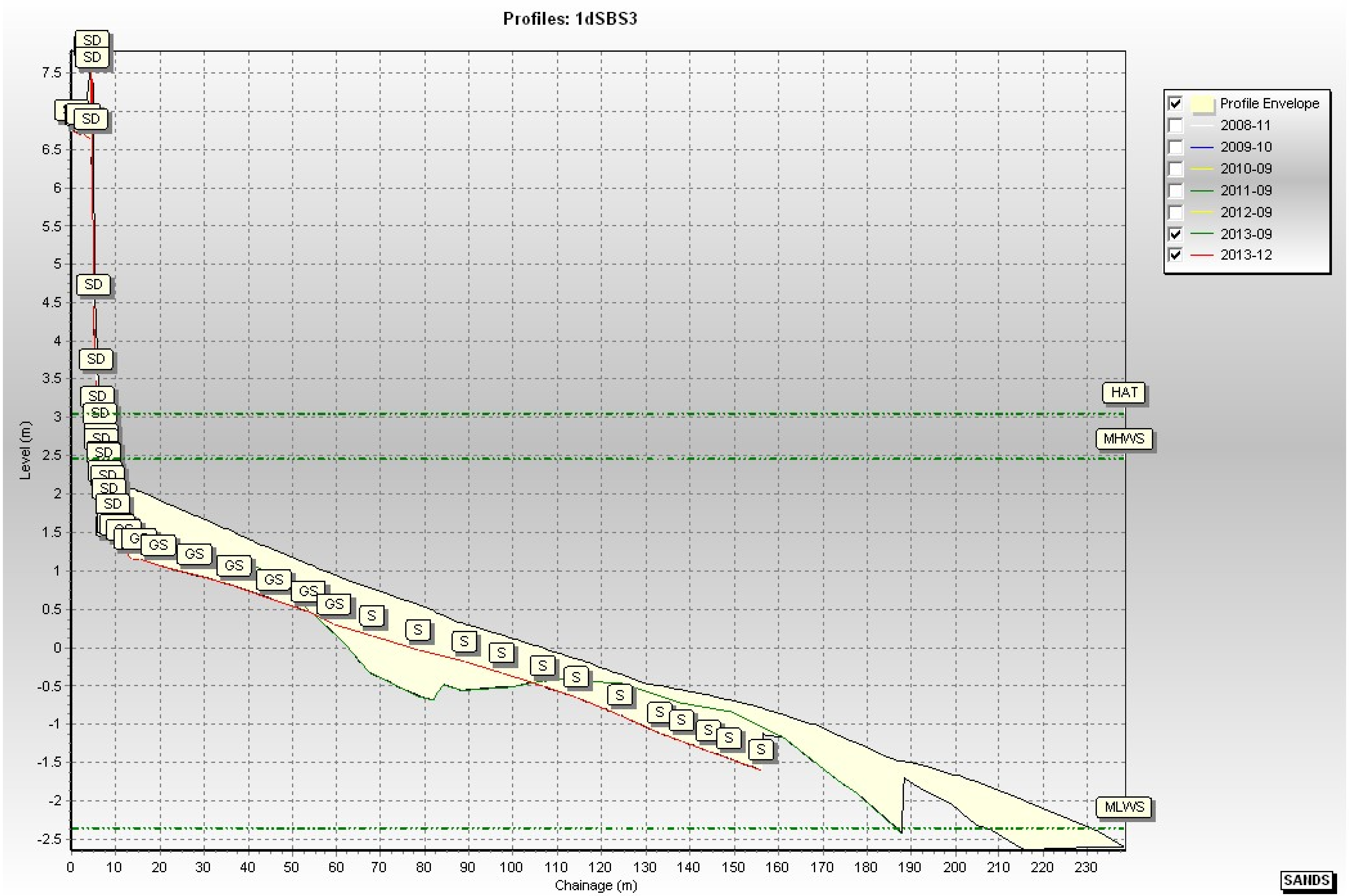
2011-09
2012-09
2013-09
2013-12
HAT
MHWS
MLWS
SD
S
GS
SANDS



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2011-09
2012-09
2013-09
2013-12
HAT
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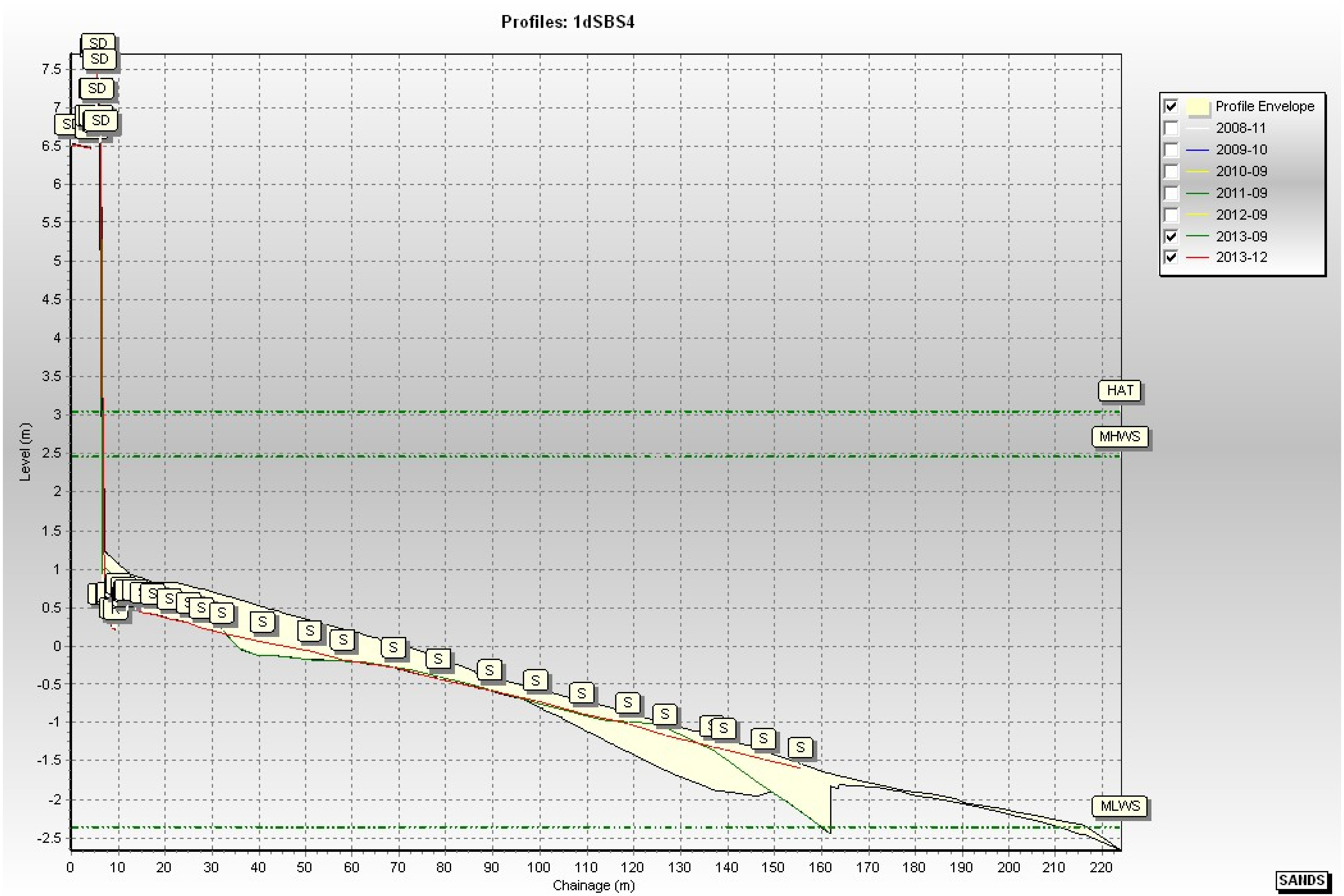
Level (m)
Chainage (m)
SANDS



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Chainage (m)
Profile Envelope
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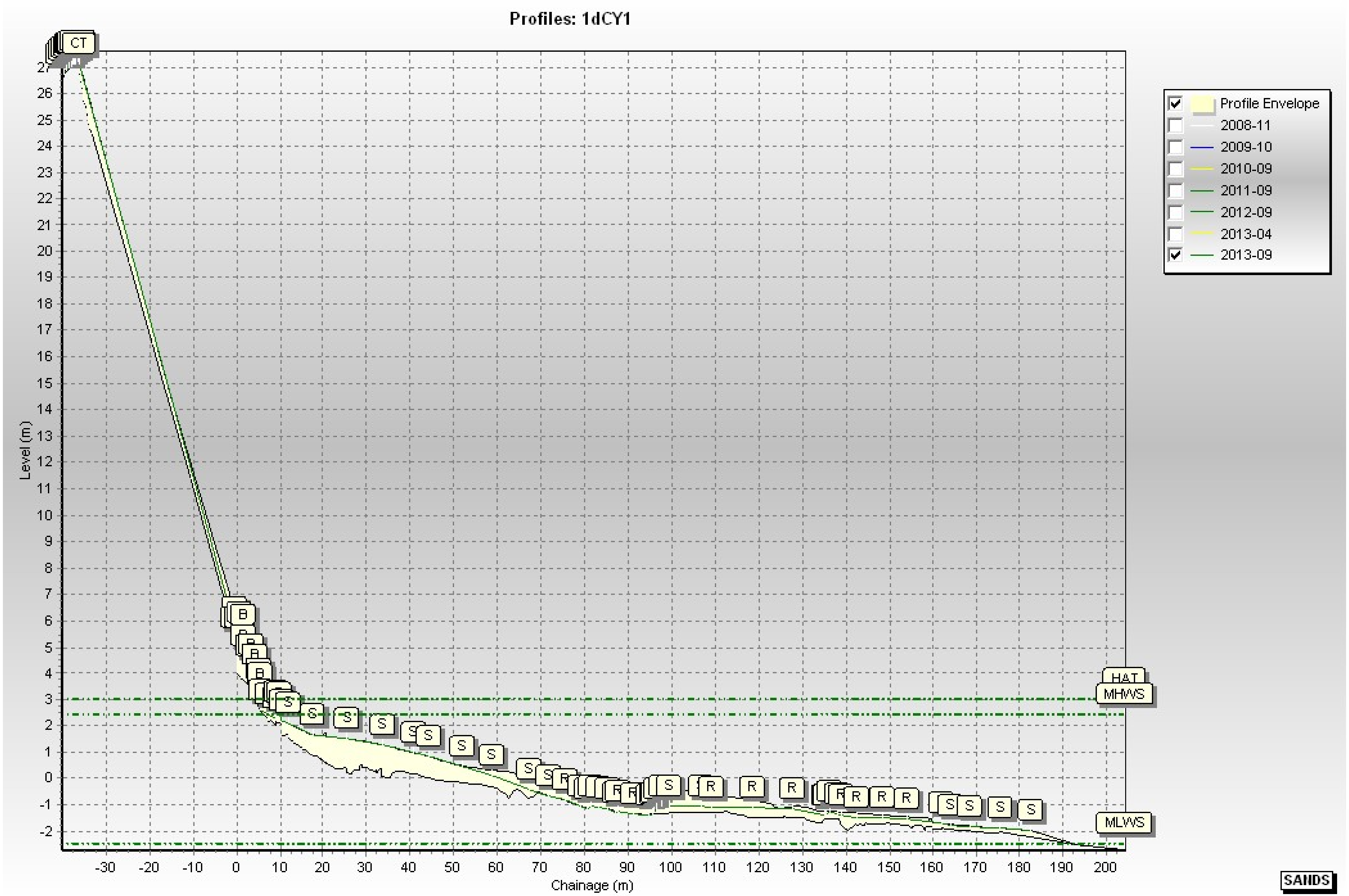
2010-09
2011-09
2012-09
2013-09
2013-12
HAT
MHWS
MLWS
SD
S
SANDS



Profiles: 1dCY1
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Chainage (m)
CT
B
S
R
HAT
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MLWS
Profile Envelope
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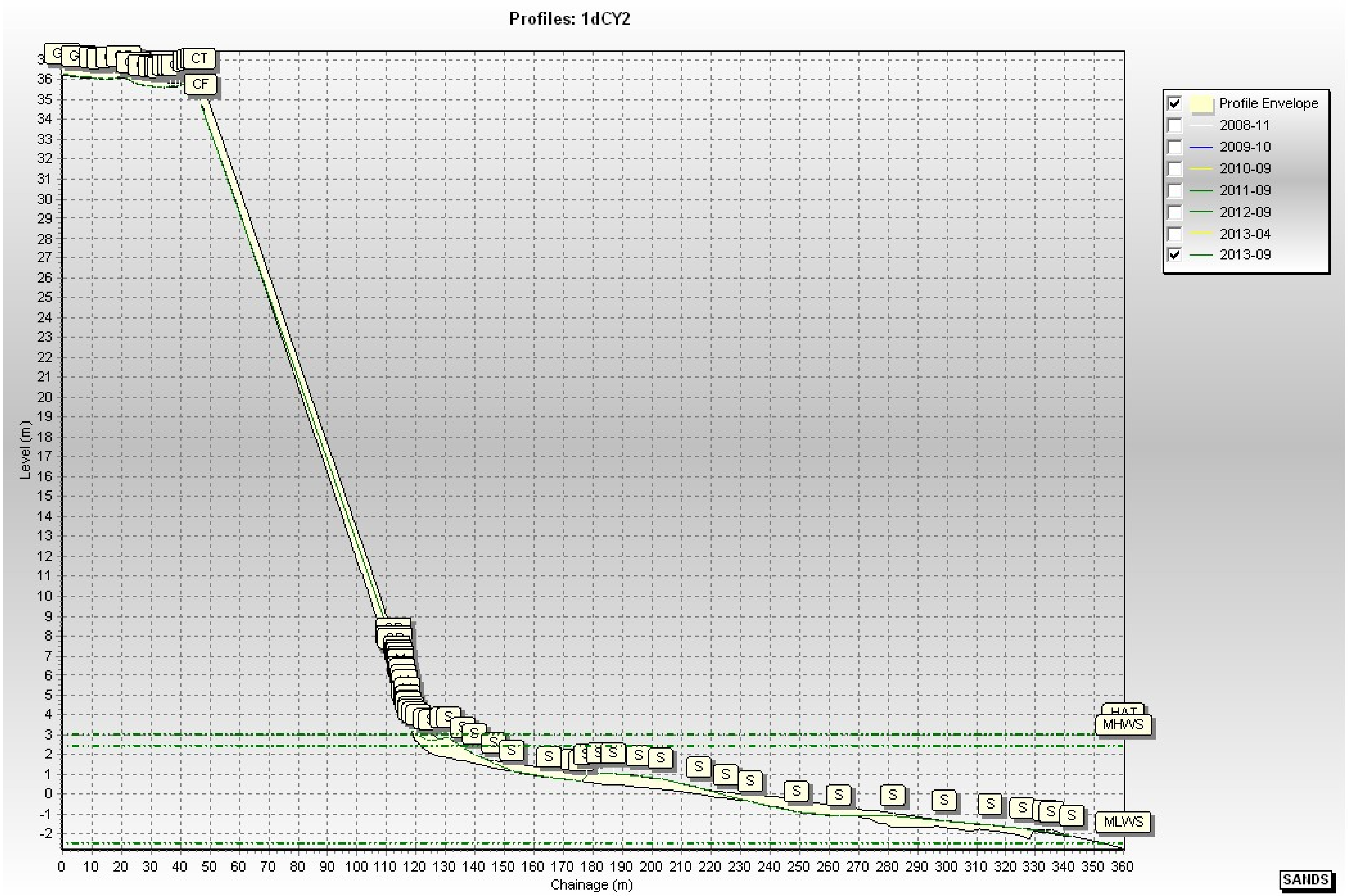
2009-10
2010-09
2011-09
2012-09
2013-04
2013-09
SANDS



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Chainage (m)
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2009-10
2010-09
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2012-09
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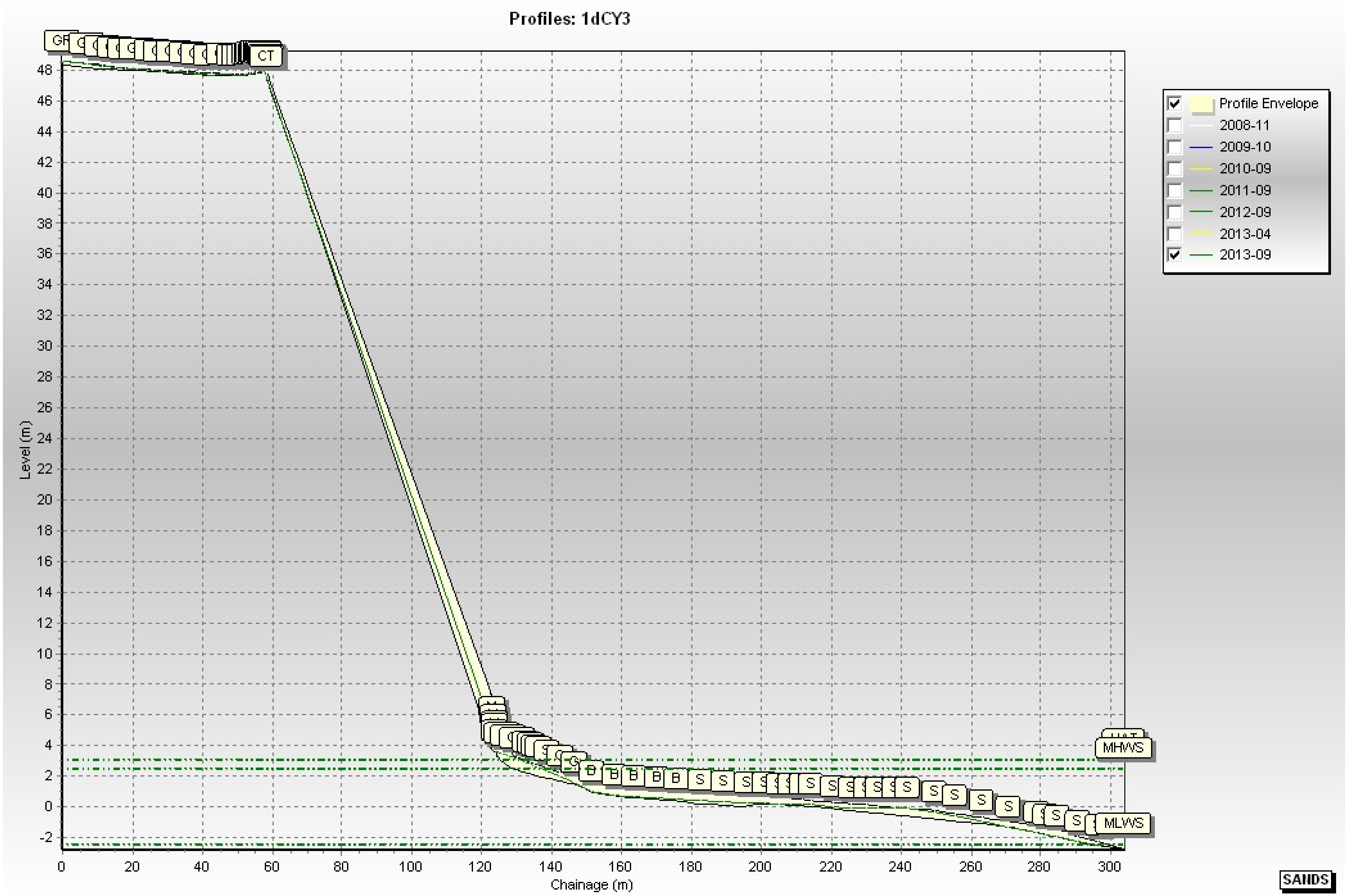
2013-09
CT
CF
MHWS
MLWS
SANDS



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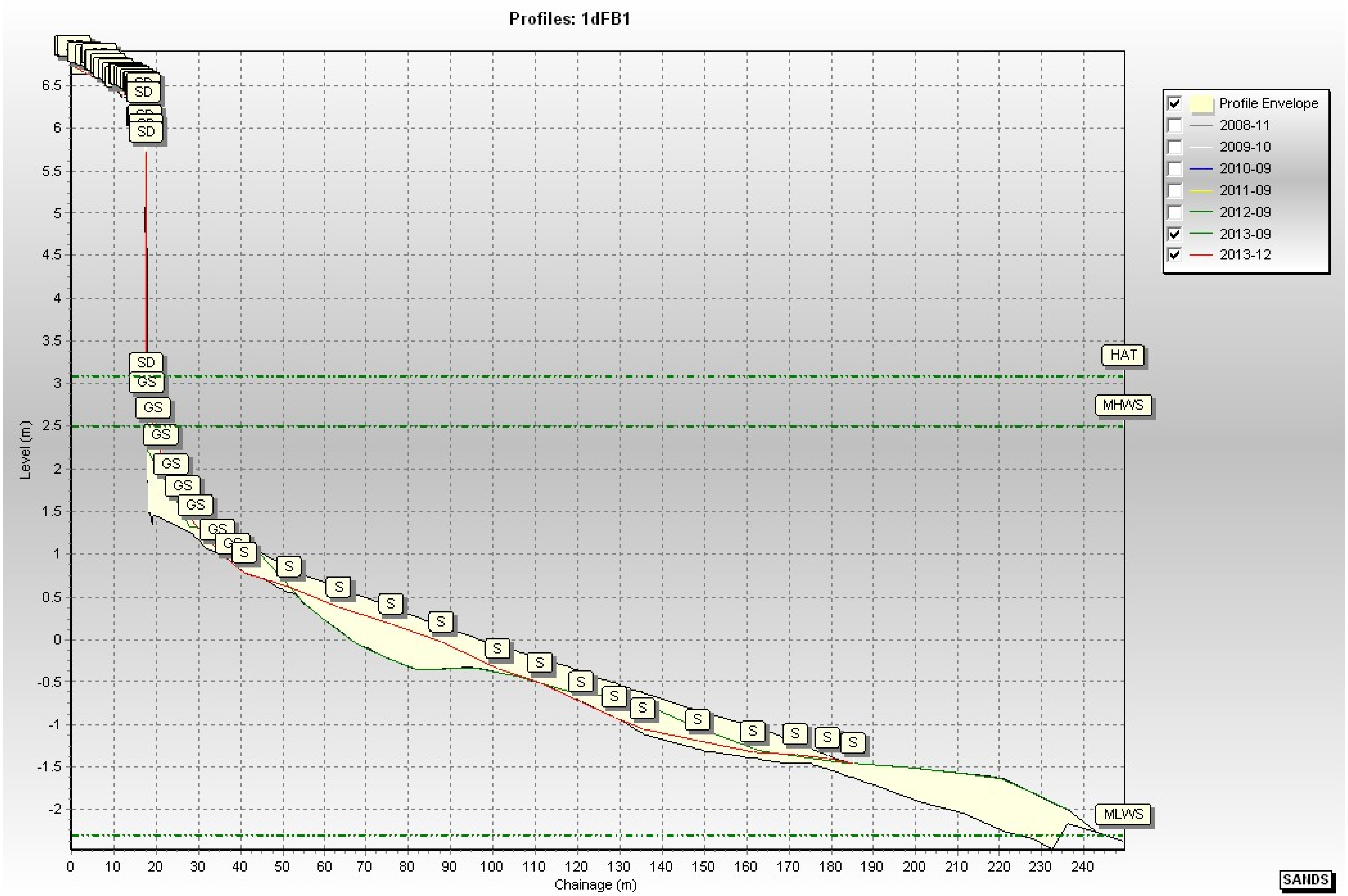
MLWS
SANDS



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2010-09
2011-09
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2013-09
2013-12
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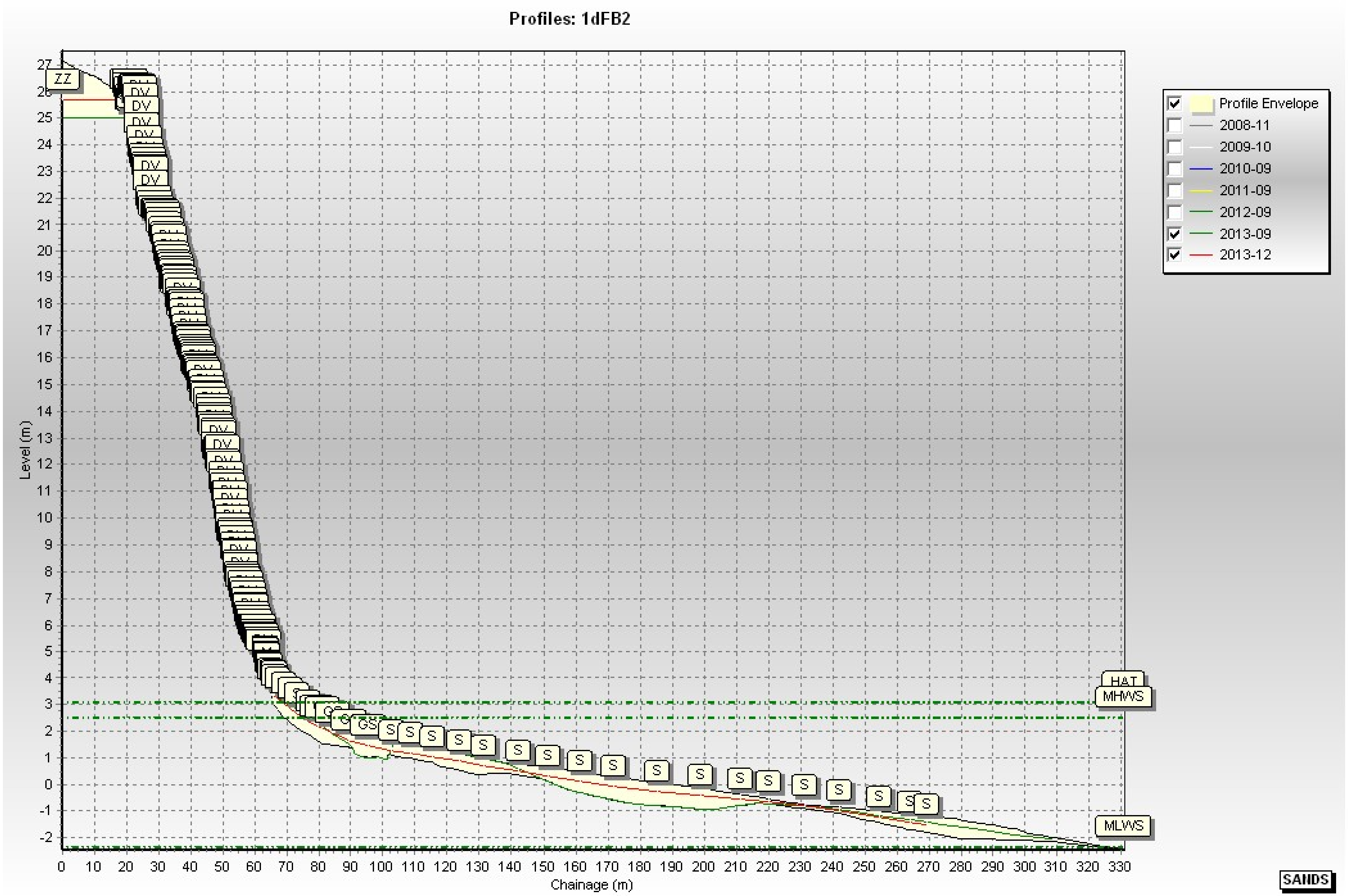
MLWS
SD
GS
S
Level (m)
Chainage (m)
SANDS



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Level (m)
Chainage (m)
Profile Envelope
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2012-09
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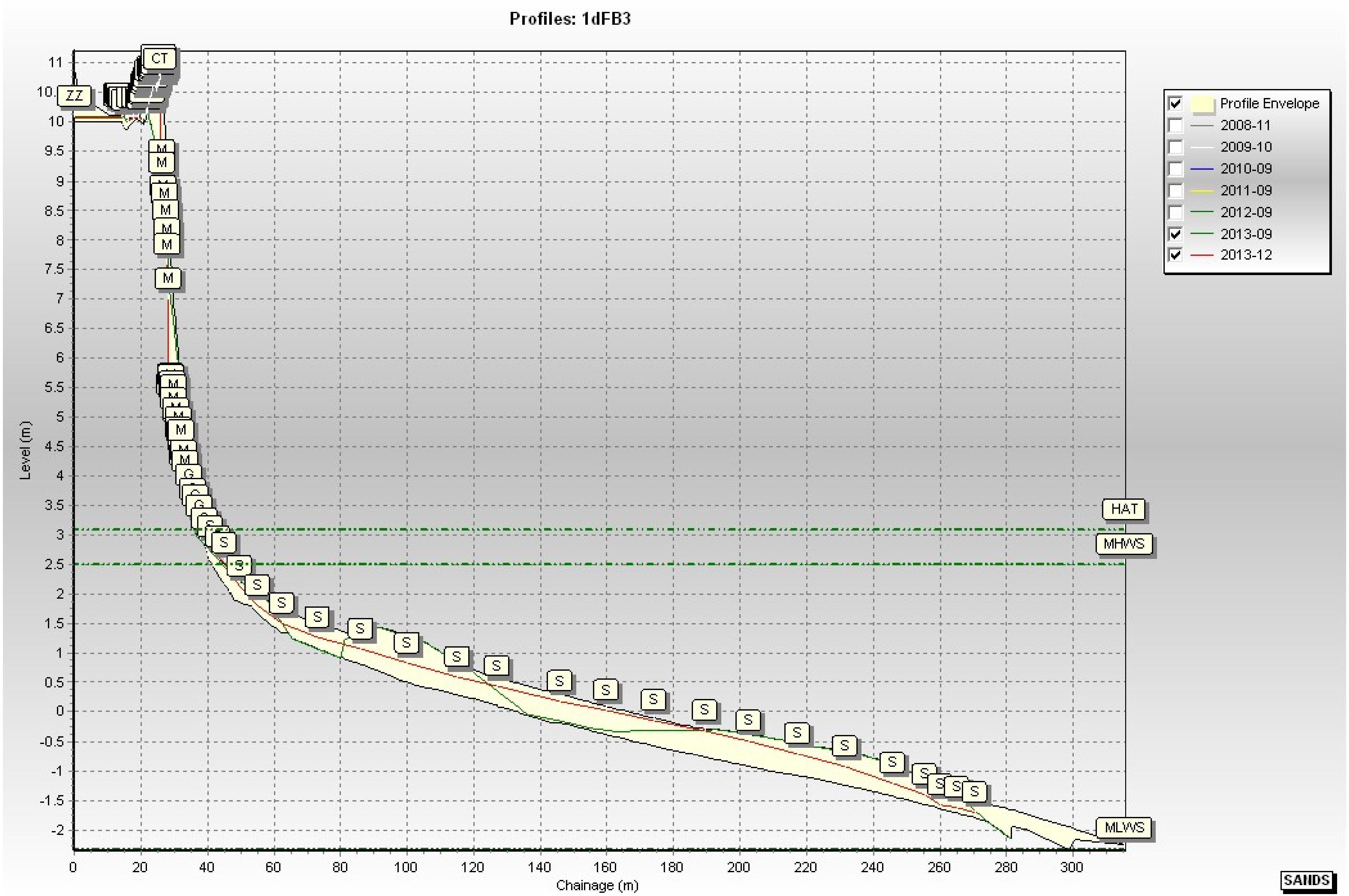
2013-12
ZZ
DV
GS
S
HAT
MHWS
MLWS
SANDS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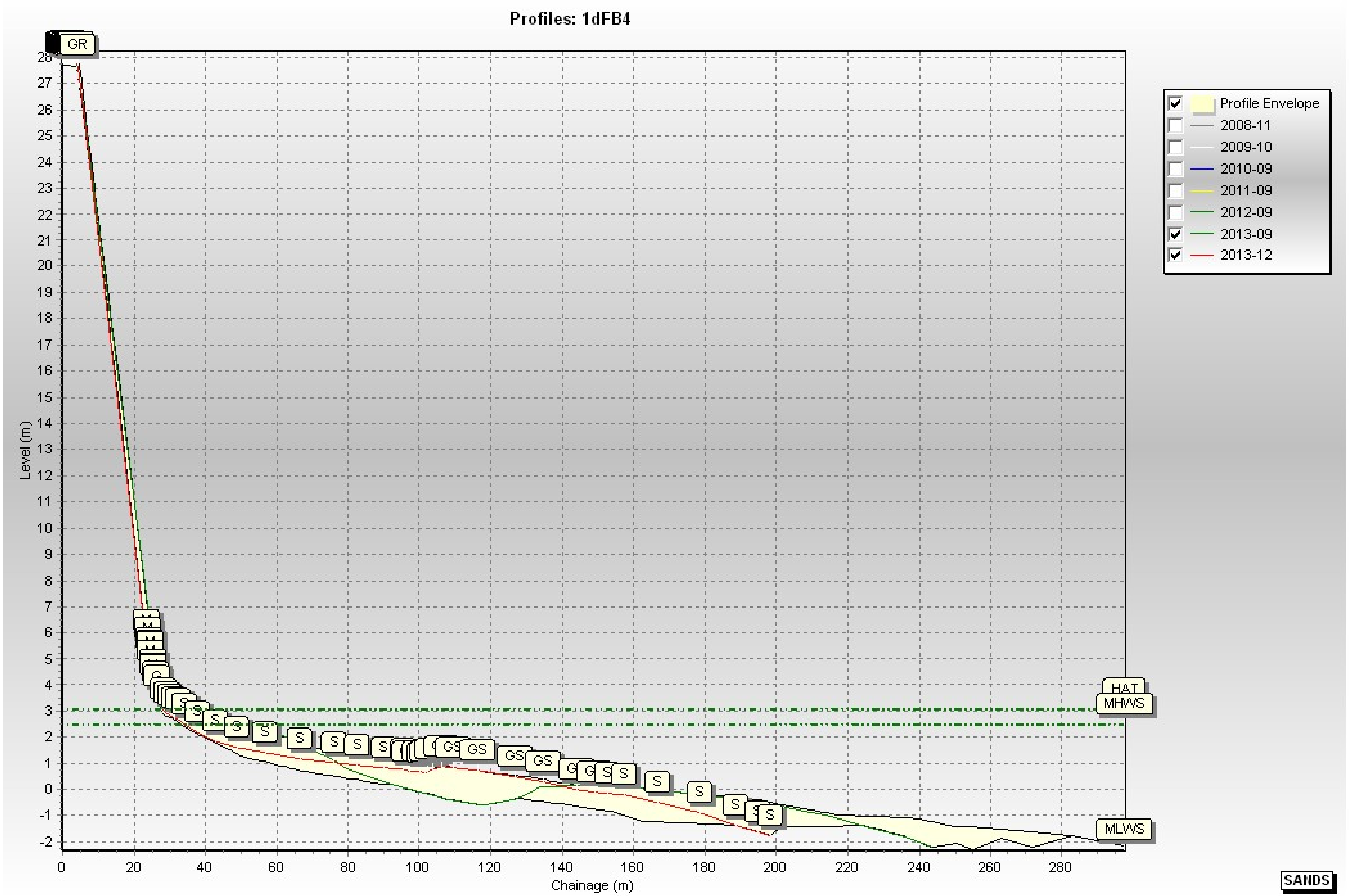
MLWS
CT
ZZ
M
G
S
SANDS



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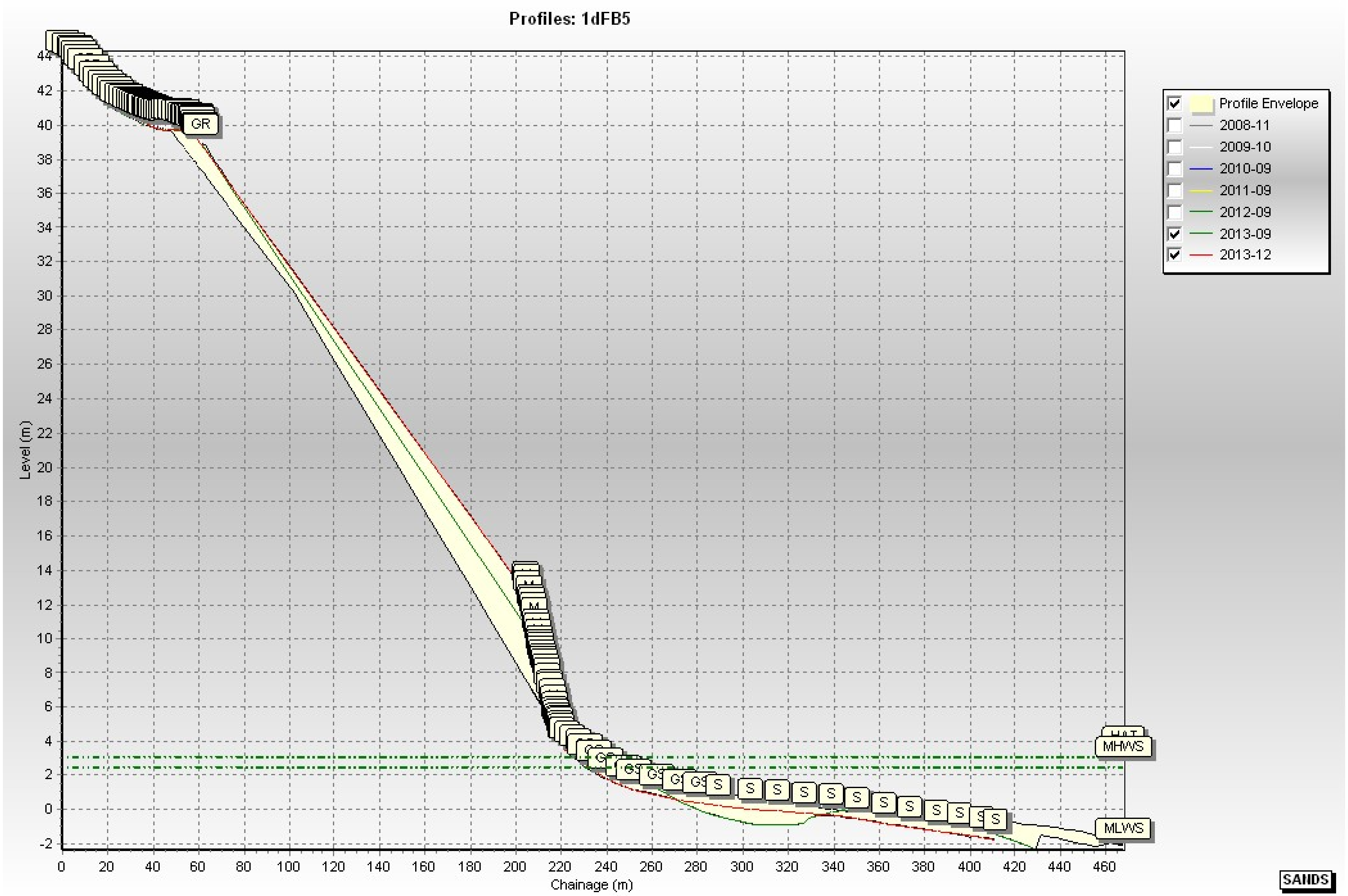
MLWS
SANDS



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Level (m)
Chainage (m)
Profile Envelope
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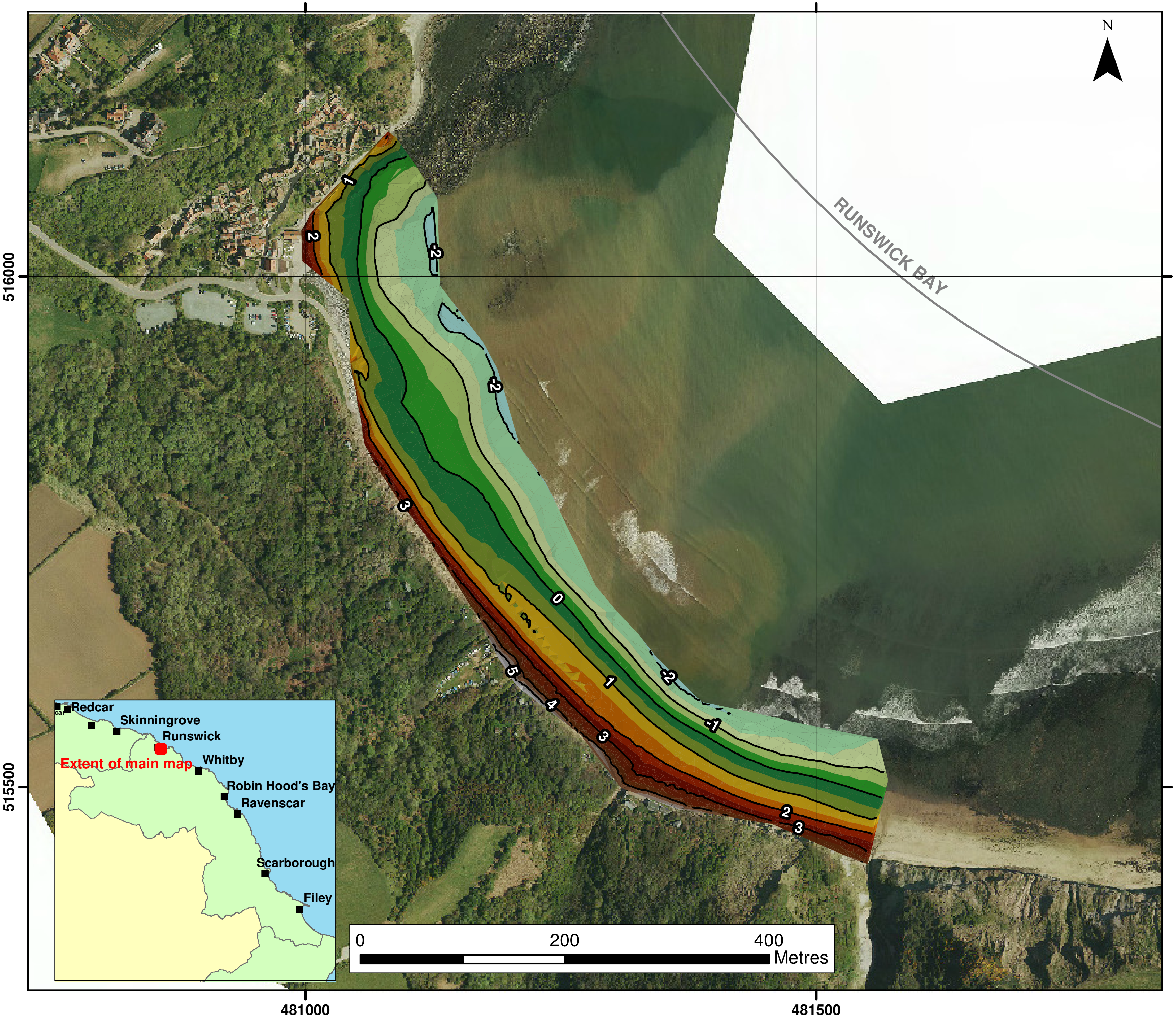
2009-10
2010-09
2011-09
2012-09
2013-09
2013-12
GR
M
S
MHWS
MLWS
SANDS

Appendix B

Topographic Survey



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
- 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 6
Full Measures Survey
Autumn 2013

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www.halcrow.com

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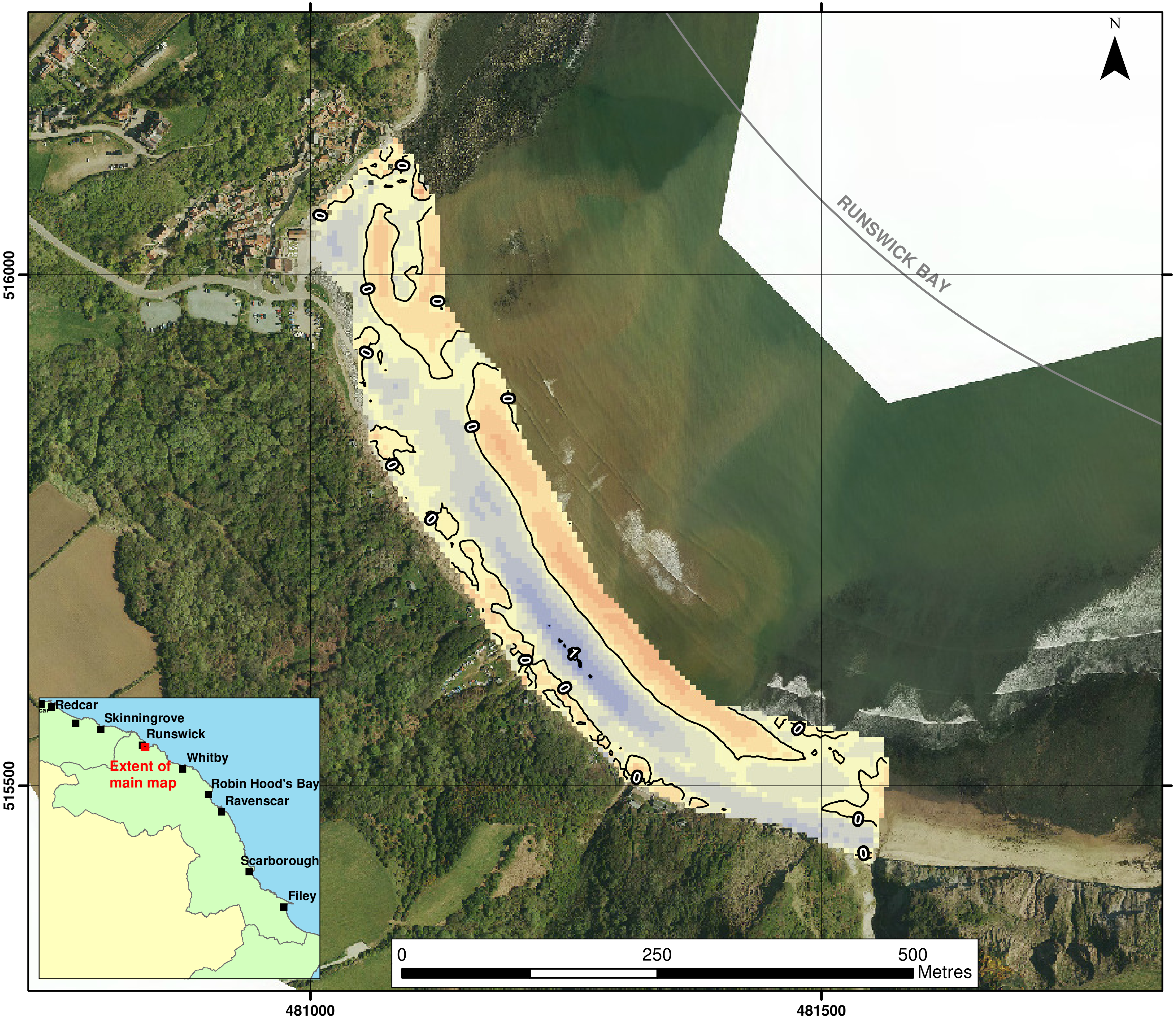
www.northeastcoastalobservatory.org.uk



KEY Spring 2013 and Autumn 2013
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 1b
Short-term Elevation Change
Runswick
Scarborough Borough Council

Analytical Report 6
Full Measures Survey
Autumn 2013

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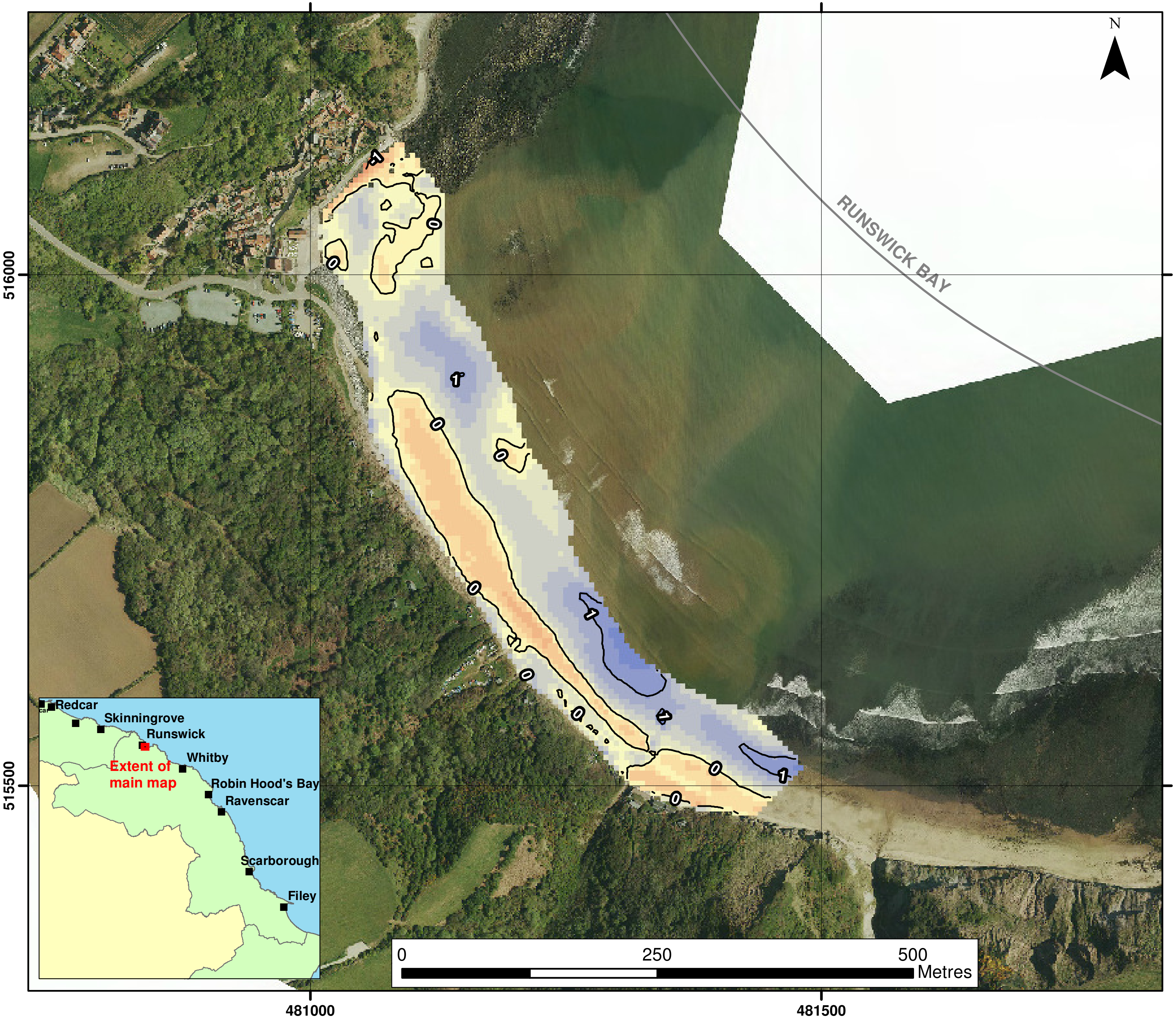

KEY Autumn 2008 Autumn 2013
Change in elevation (m)

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 1c
Long-term Elevation Change Runswick
Scarborough Borough Council

Analytical Report 6
Full Measures Survey
Autumn 2013

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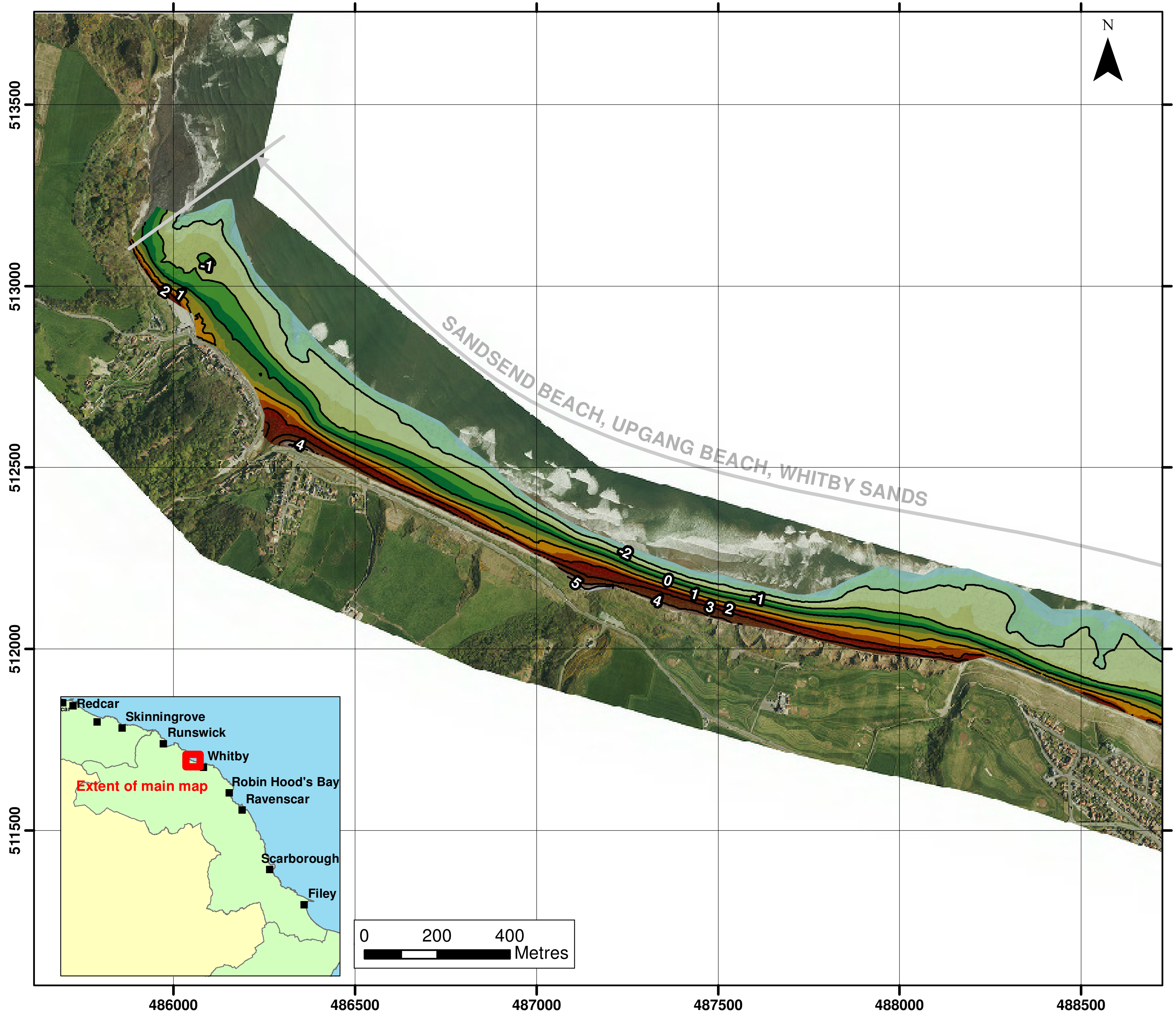

KEY

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 2a
Topographic Survey
Whitby
Scarborough Borough Council

Analytical Report 6
Full Measures Survey
Autumn 2013

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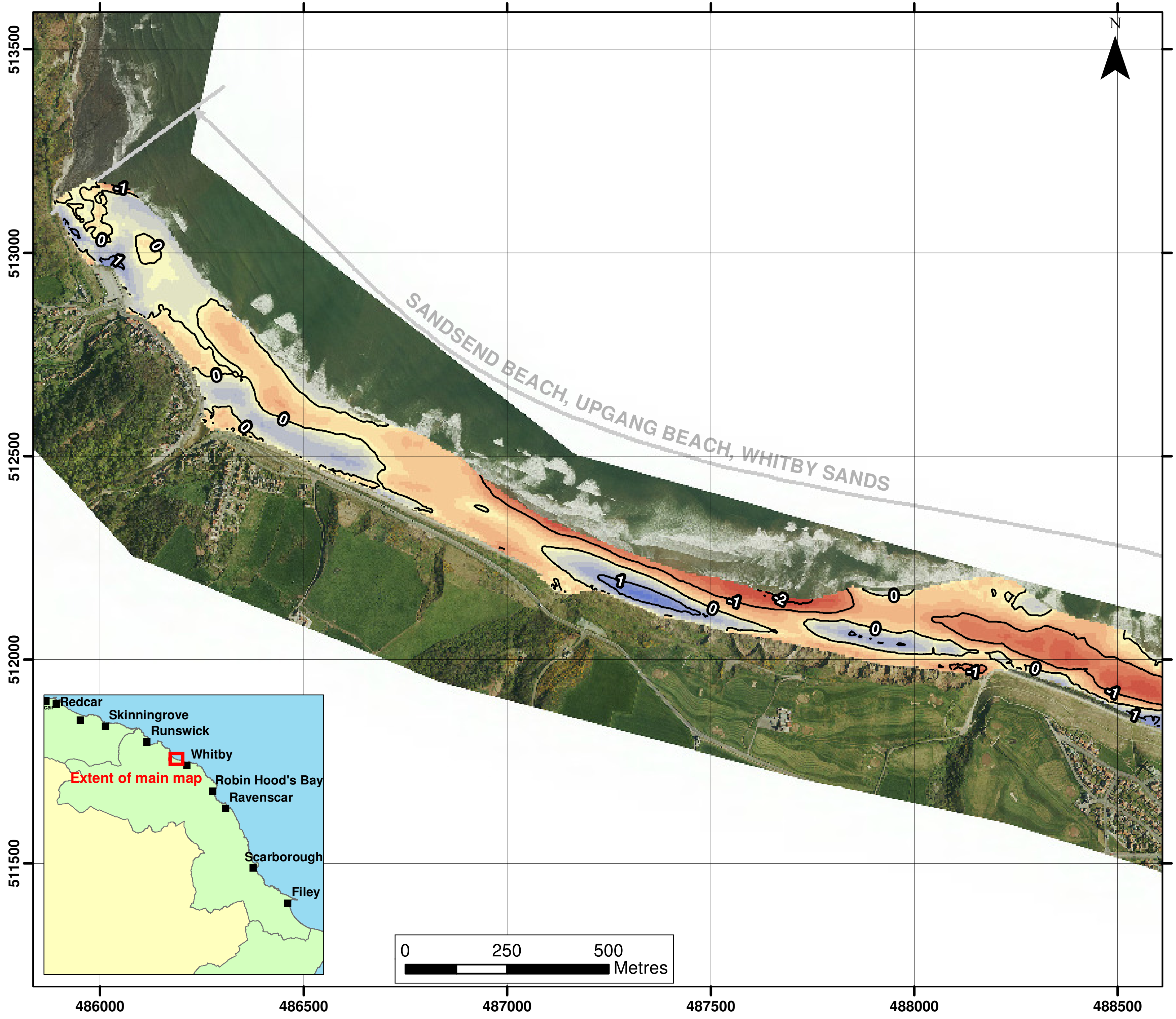

KEY

Autumn 2012 and Autumn 2013
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 2b
Short-term Elevation Change
Whitby
Scarborough Borough Council

Analytical Report 6
Full Measures Survey
Autumn 2013

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

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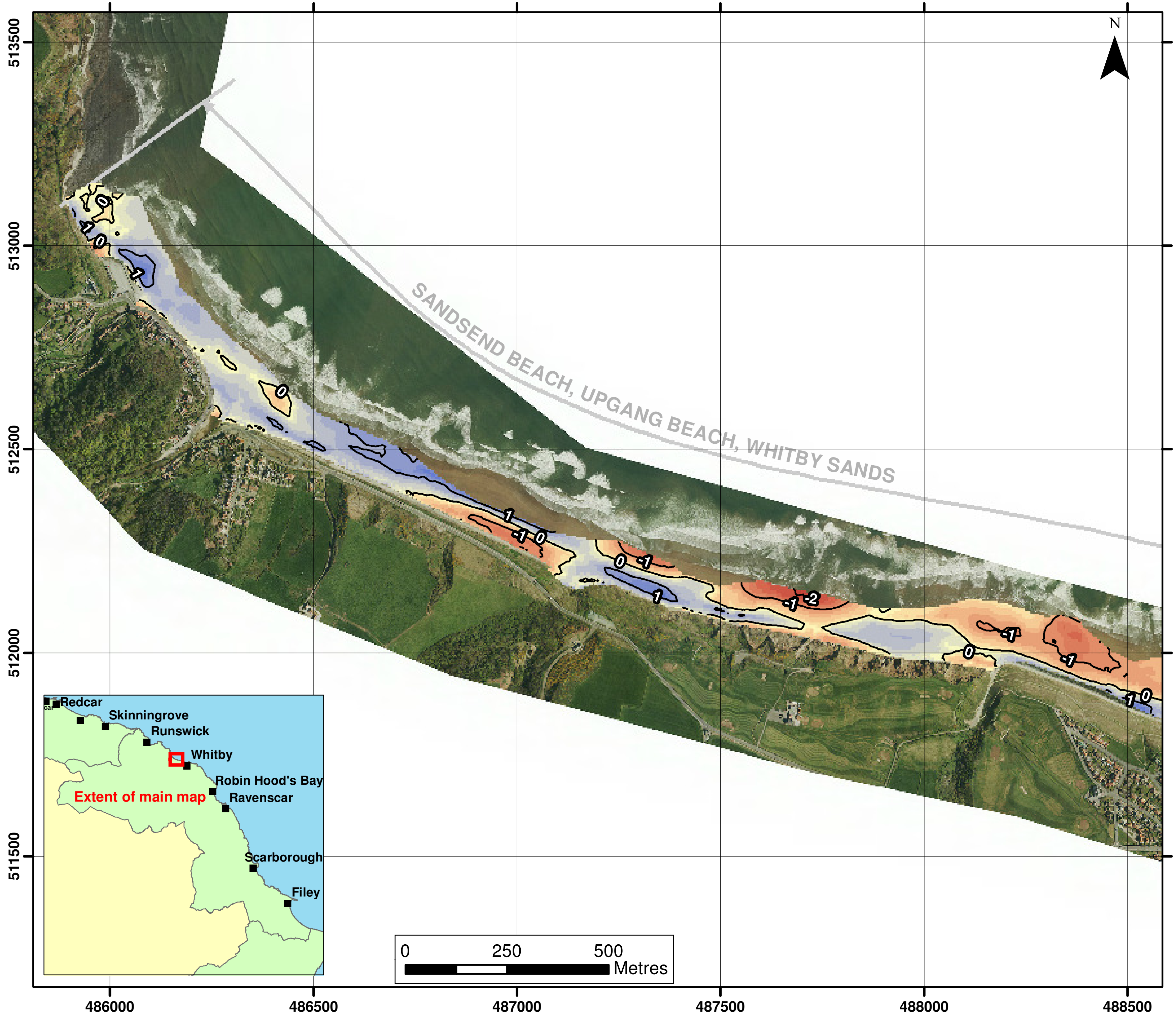

KEY Autumn 2008 and Autumn 2013
Change in elevation (m)

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

Contours of change

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

Appendix B - Map 2c
Long-term Elevation Change
Whitby
Scarborough Borough Council

Analytical Report 6
Full Measures Survey
Autumn 2013

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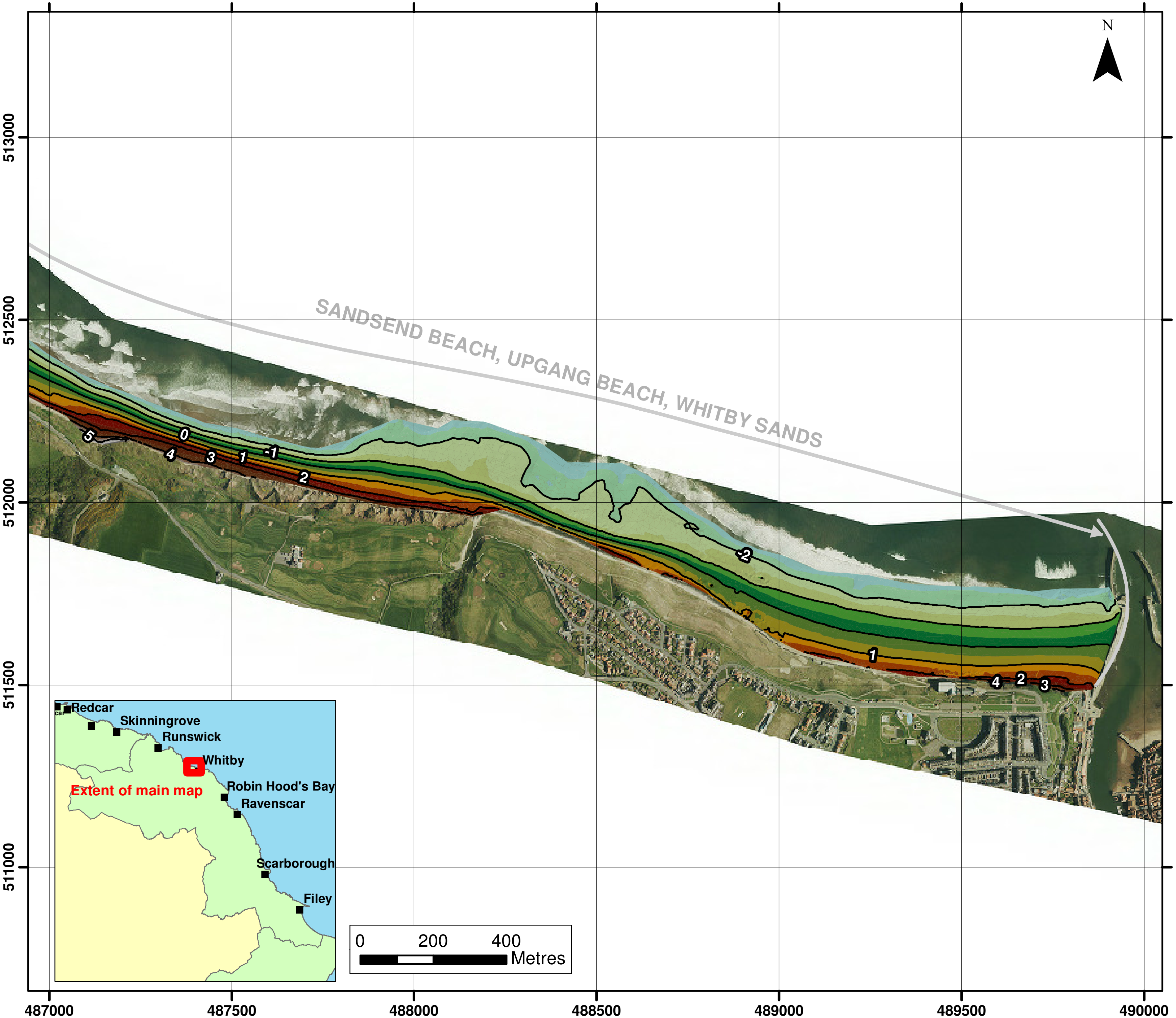

KEY
Elevation (m OD)
6 - 6.5
5.5 - 6
5 - 5.5
4.5 - 5
4 - 4.5
3.5 - 4
3 - 3.5
2.5 - 3
2 - 2.5
1.5 - 2
1 - 1.5
0.5 - 1
0 - 0.5
-0.5 - 0
-1 - -0.5
-1.5 - -1
-2 - -1.5
-2.5 - -2
-3 - -2.5
Contour 1m

Client: North East Coastal Group

Project: Cell 1 Regional Coastal Monitoring Programme 2011 to 2016

Appendix B- Map 3a
Topographic Survey
Whitby
Scarborough Borough Council

Analytical Report 6
Full Measures Survey
Autumn 2013

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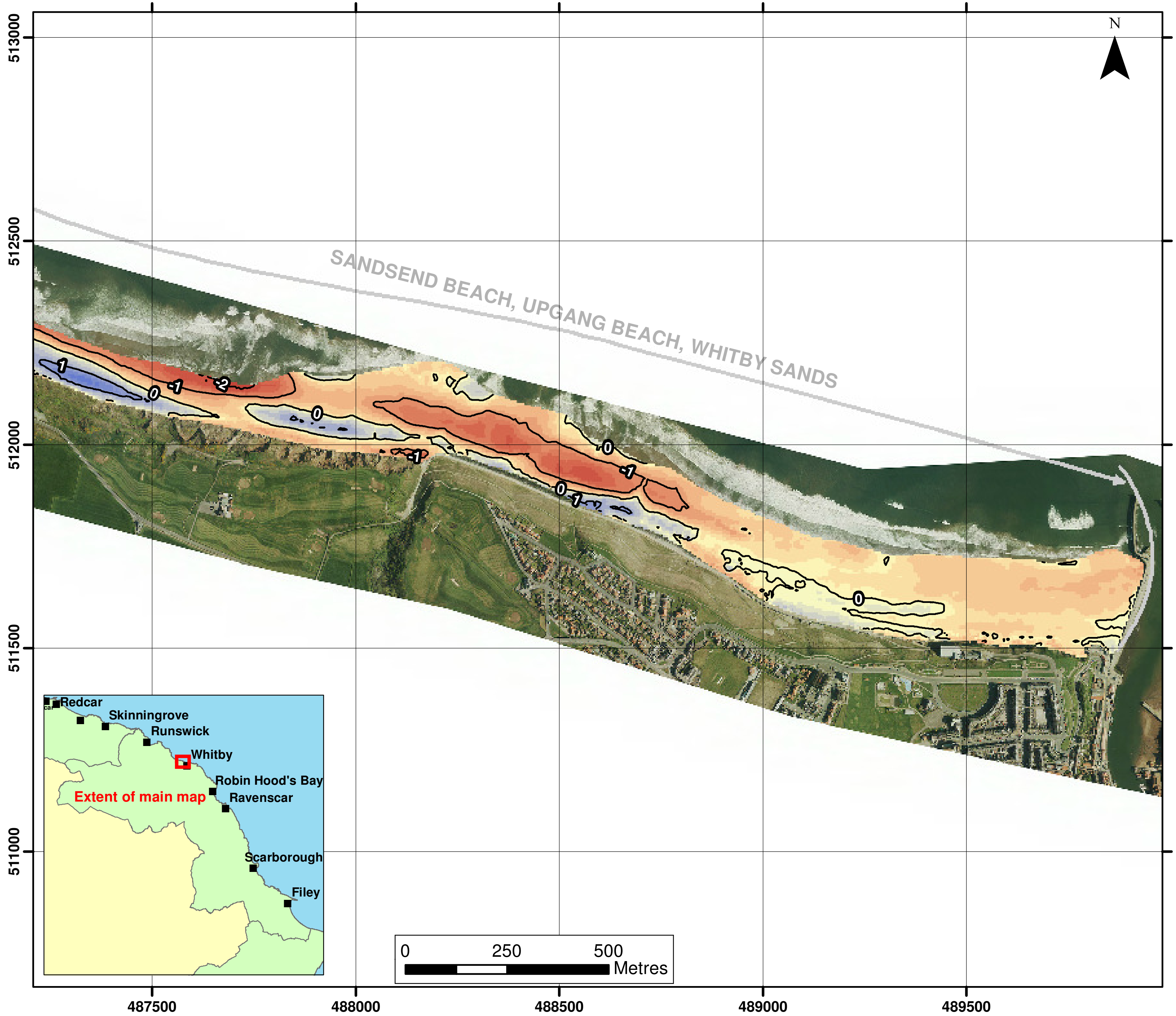

KEY Autumn 2012 and Autumn 2013
Change in elevation (m)

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

Contours of change

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

Appendix B - Map 3b
Short-term Elevation Change Whitby
Scarborough Borough Council

Analytical Report 6
Full Measures Survey
Autumn 2013

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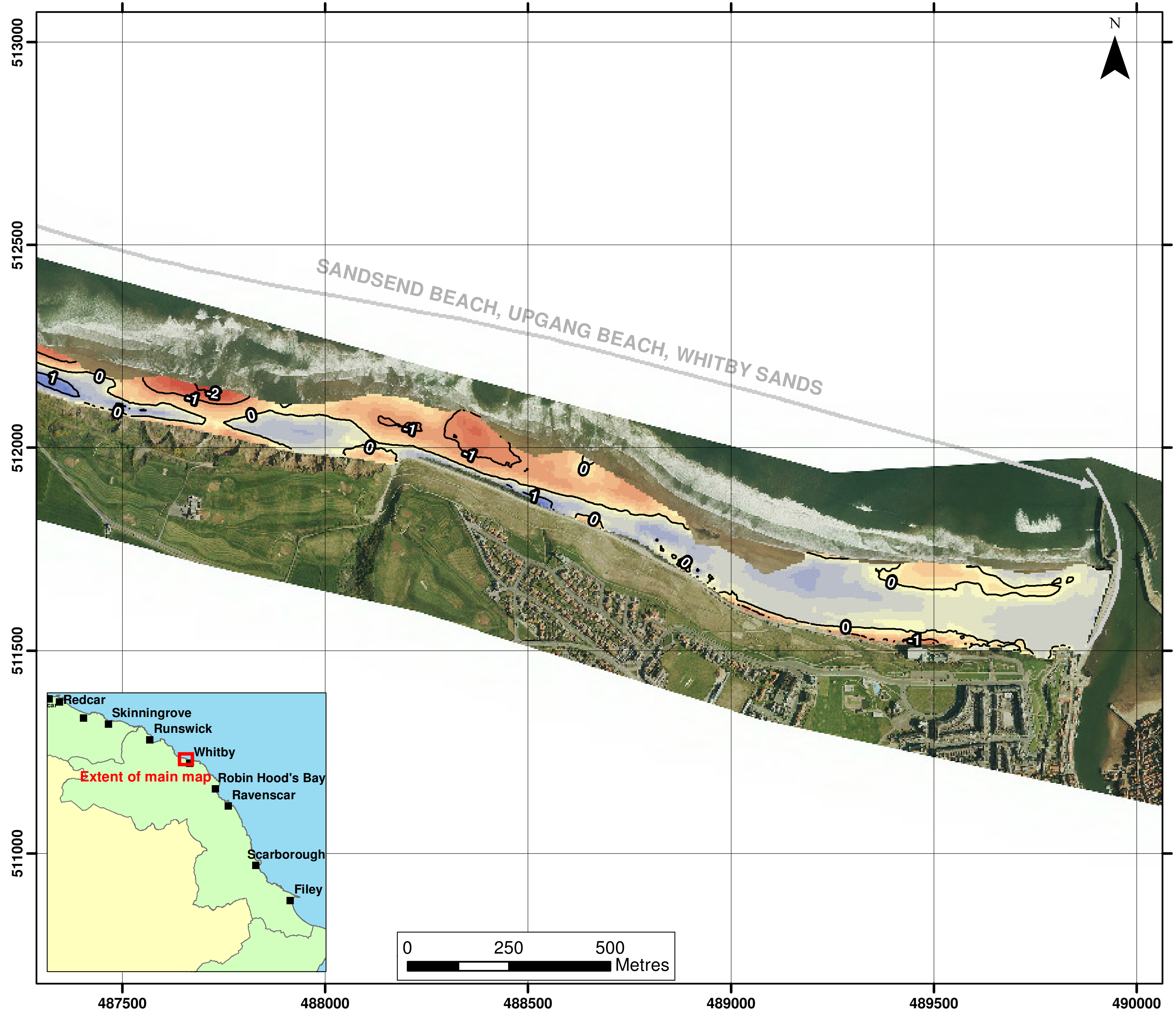

KEY Autumn 2008 and Autumn 2013
Change in elevation (m)

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

Loss

Change < 0.1 m

Gain

Contours of change

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

Appendix B - Map 3c
Long-term Elevation Change Whitby Scarborough Borough Council

Analytical Report 6
Full Measures Survey
Autumn 2013

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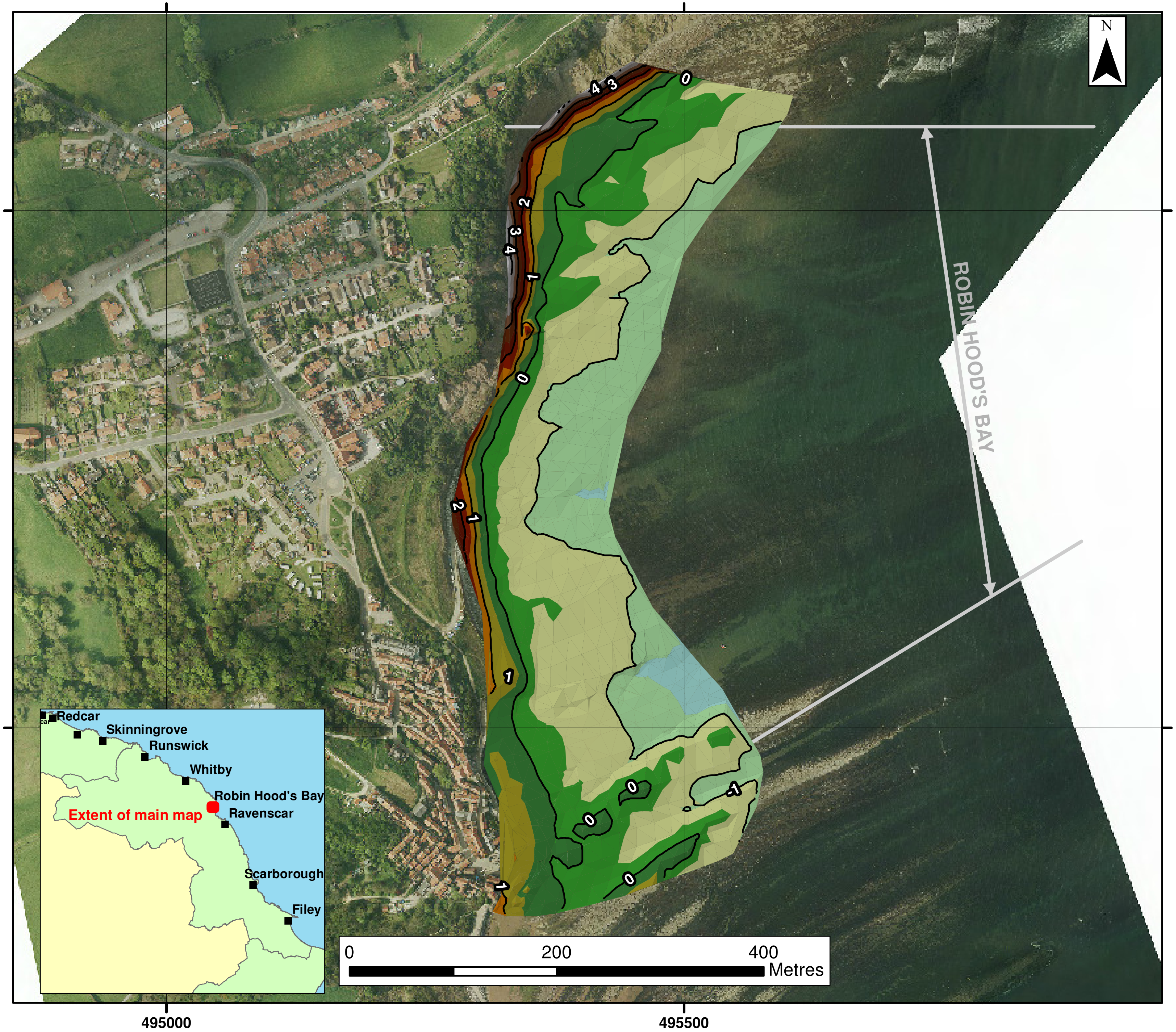

KEY

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
- 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 6
Full Measures Survey
Autumn 2013

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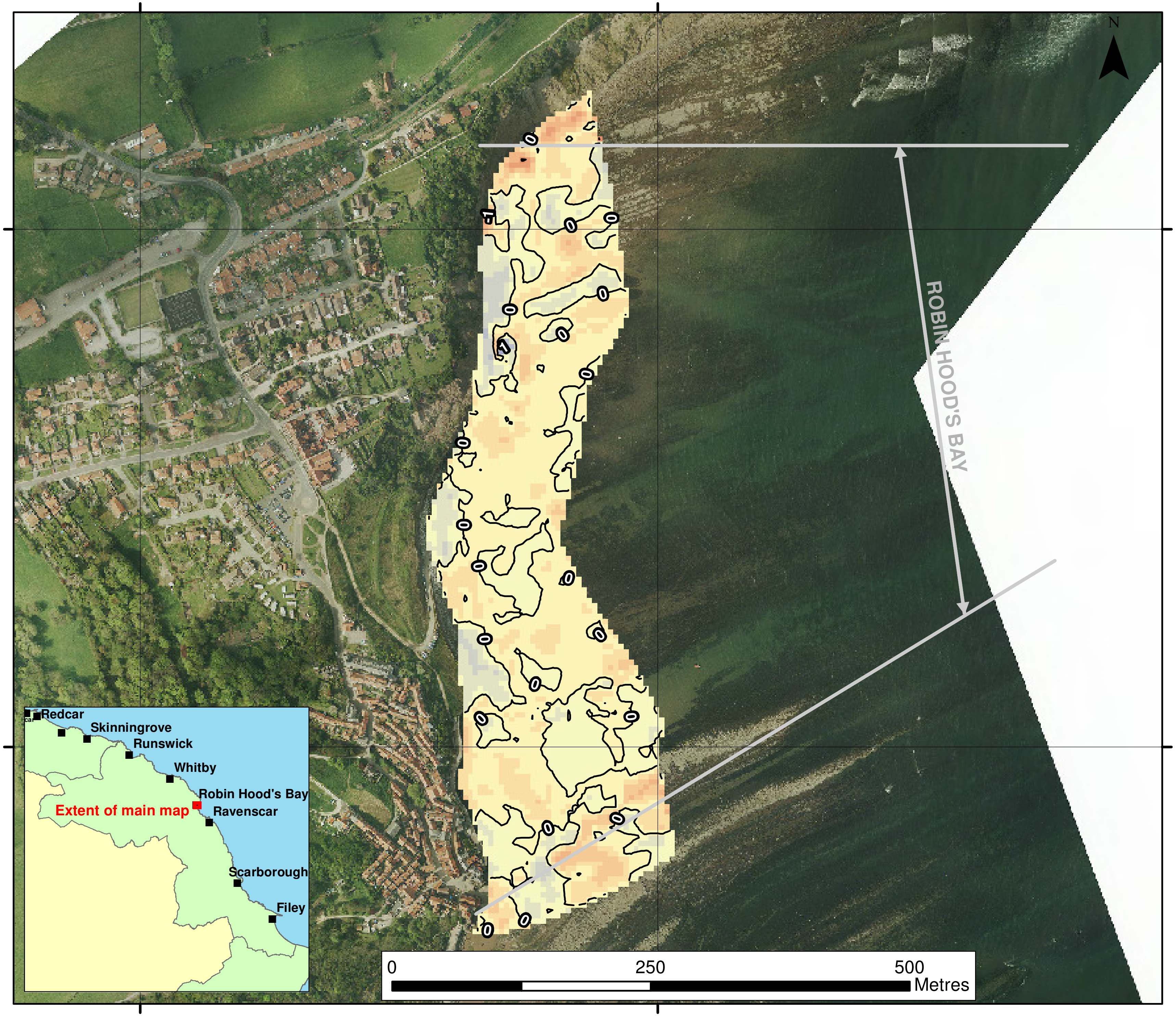

KEY Spring 2013 and Autumn 2013
Change in elevation (m)

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

Contours of change

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

Appendix B- Map 4b
Short-term Elevation Change Robin Hood's Bay Scarborough Borough Council

Analytical Report 6
Full Measures Survey
Autumn 2013

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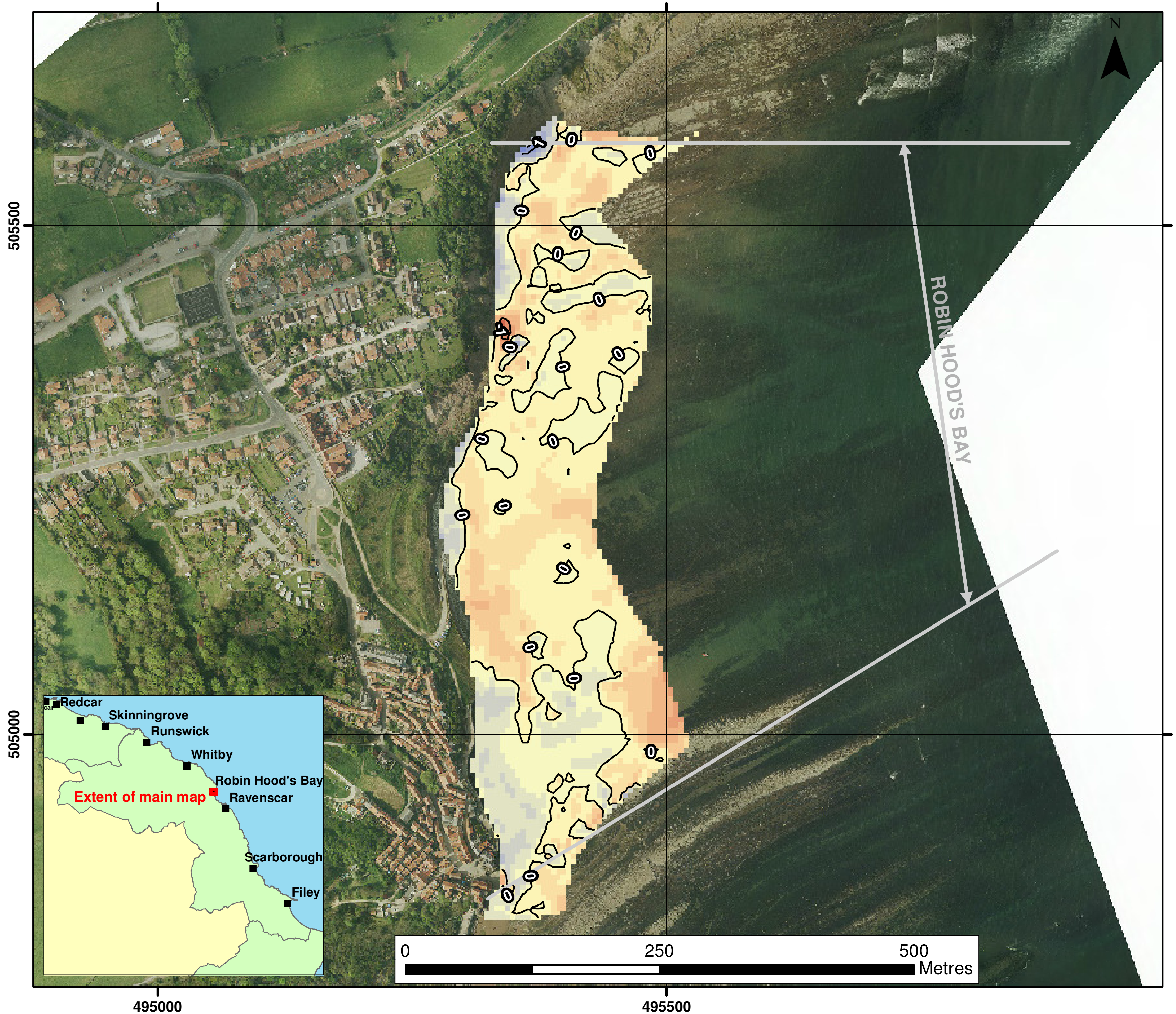

KEY Autumn 2008 and Autumn 2013
Change in elevation (m)

- <-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 6
Full Measures Survey
Autumn 2013

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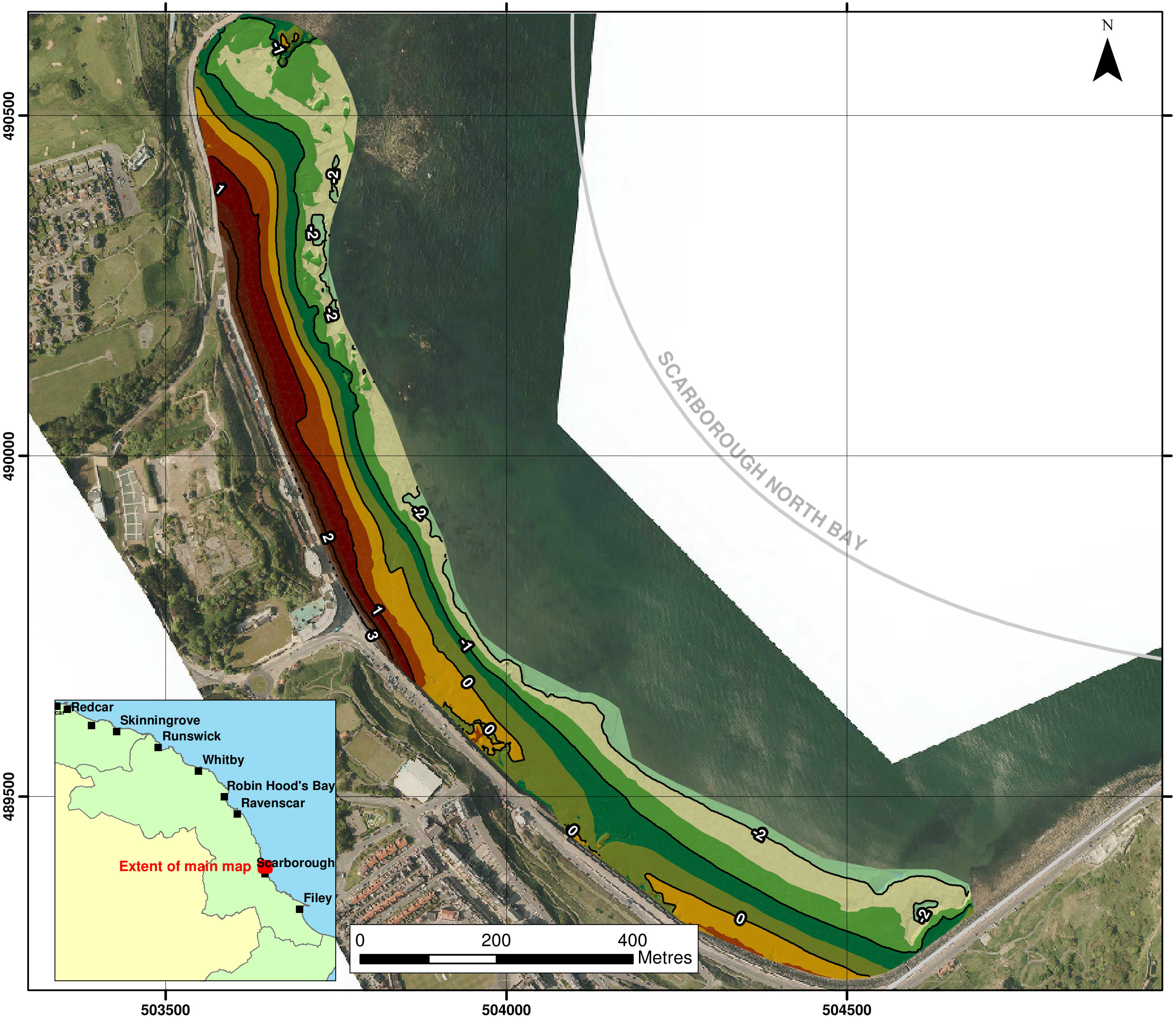

KEY

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
- -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 6
Full Measures Survey
Autumn 2013

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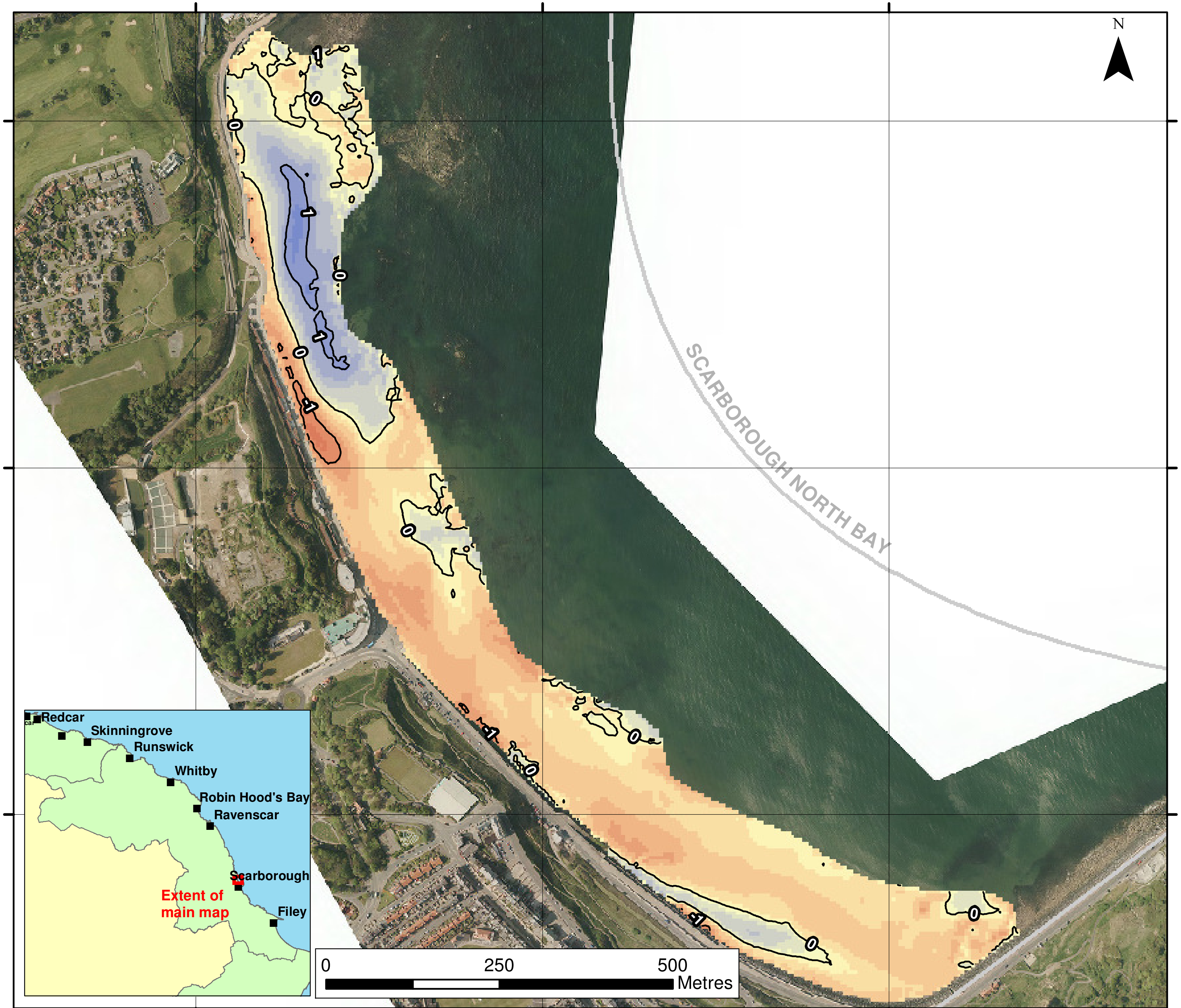

KEY Autumn 2012 and Autumn 2013 Change in elevation (m)

- <-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 6
Full Measures Survey
Autumn 2013

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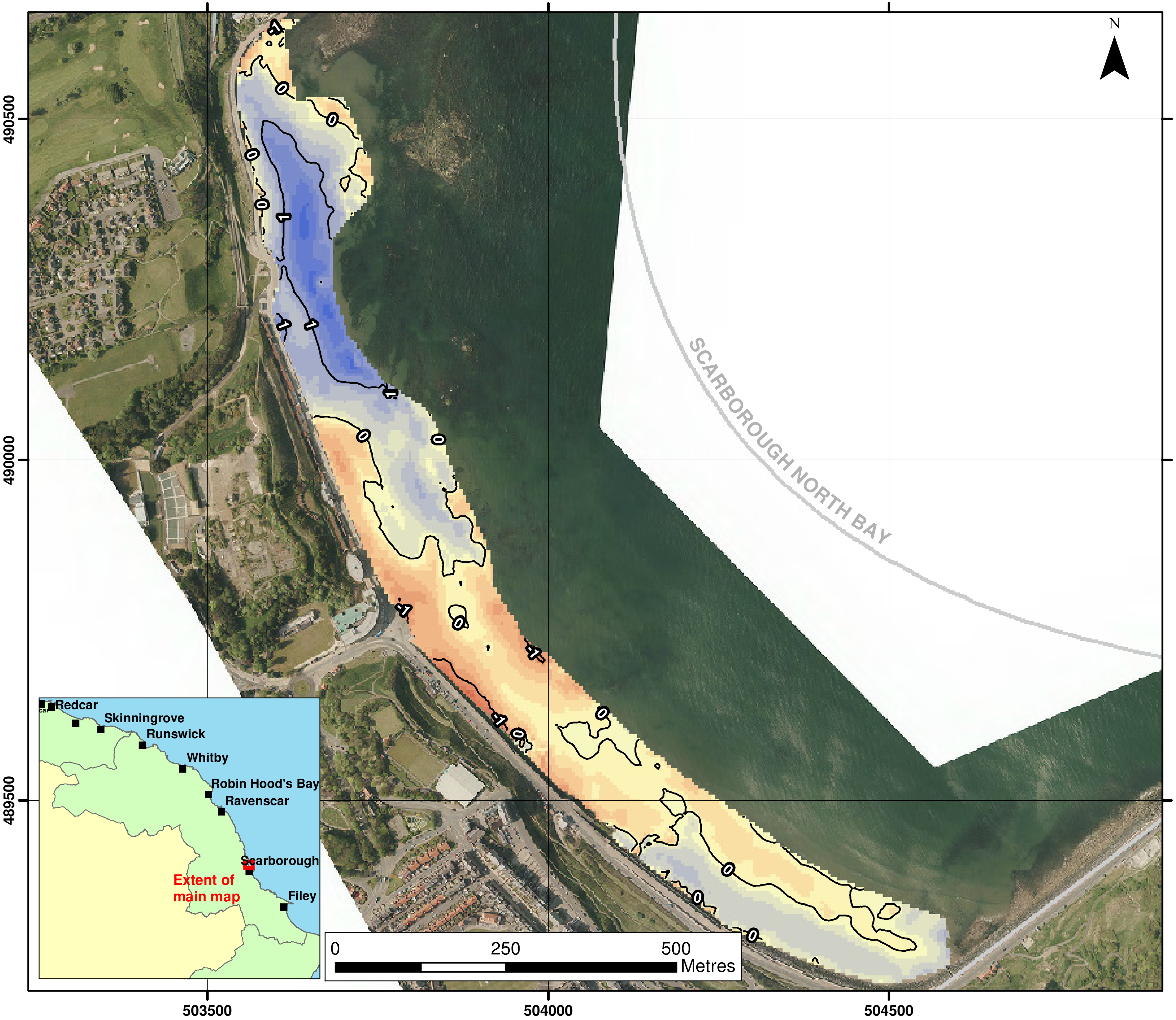

KEY Autumn 2008 and Autumn 2013
Change in elevation (m)

- <-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 6
Full Measures Survey
Autumn 2013

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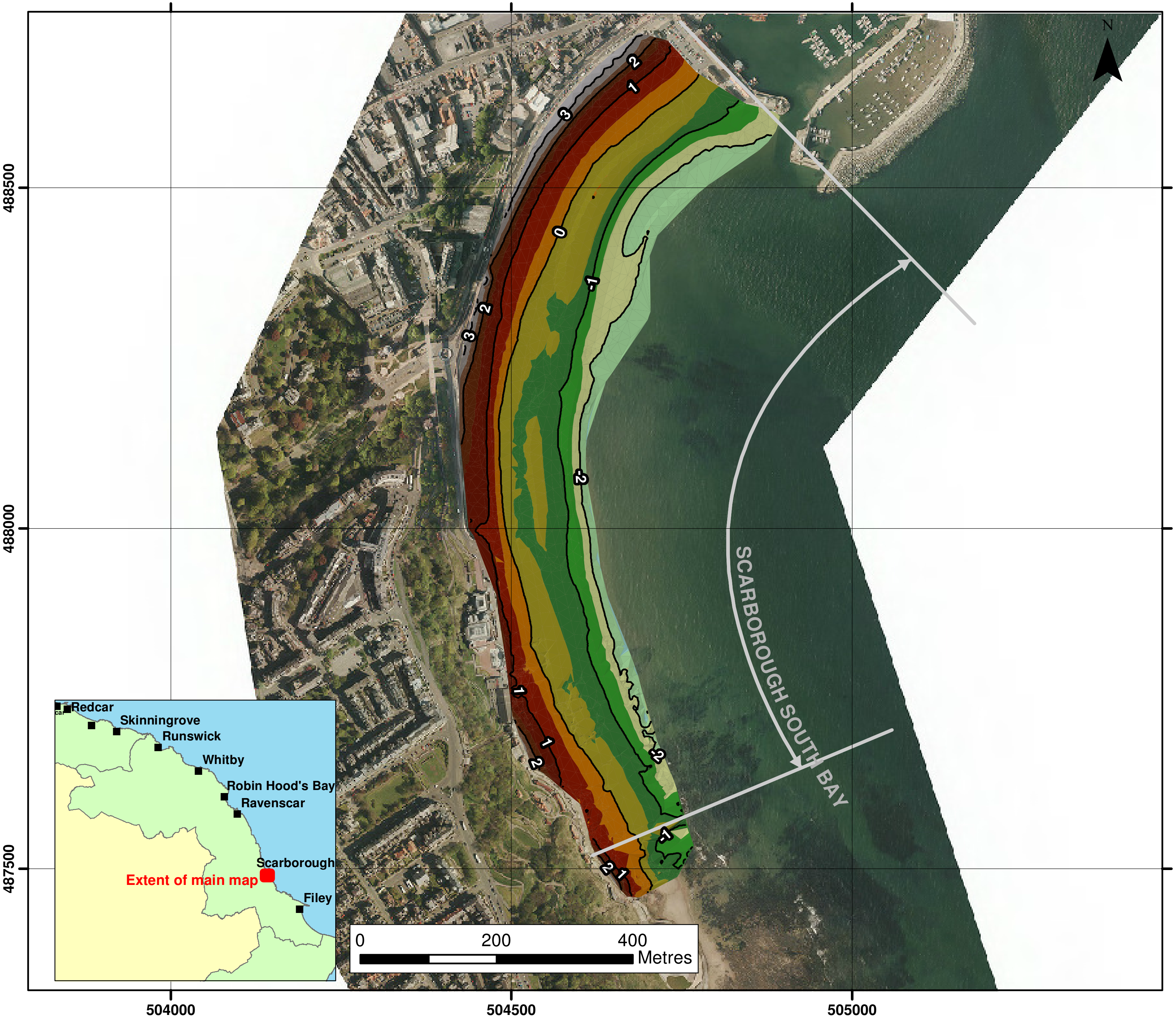

KEY

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 6
Full Measures Survey
Autumn 2013

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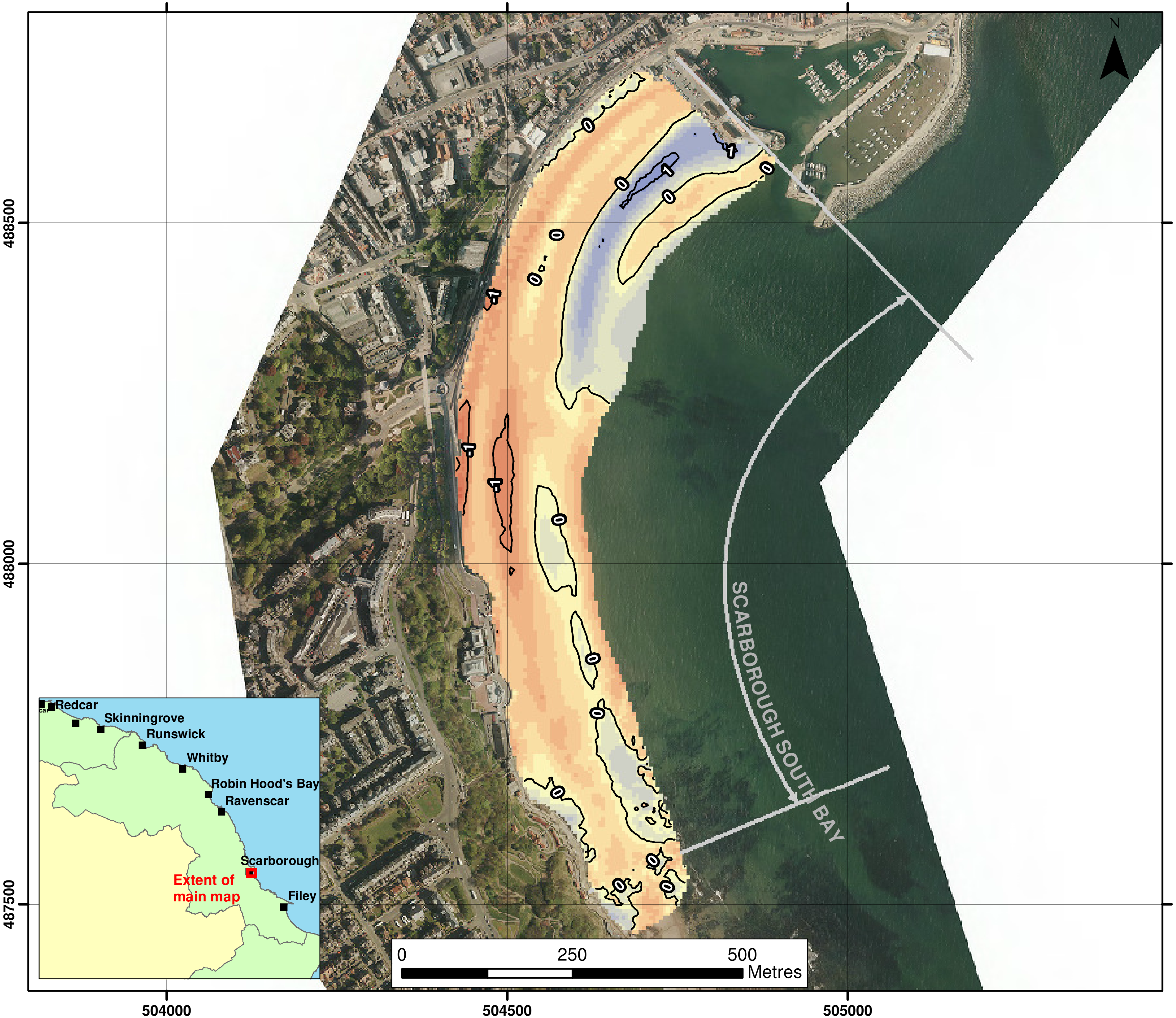

KEY Autumn 2012 and Autumn 2013
Change in elevation (m)

Class (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 6b
Short-term Elevation Change Scarborough South Scarborough Borough Council

Analytical Report 6
Full Measures Survey
Autumn 2013

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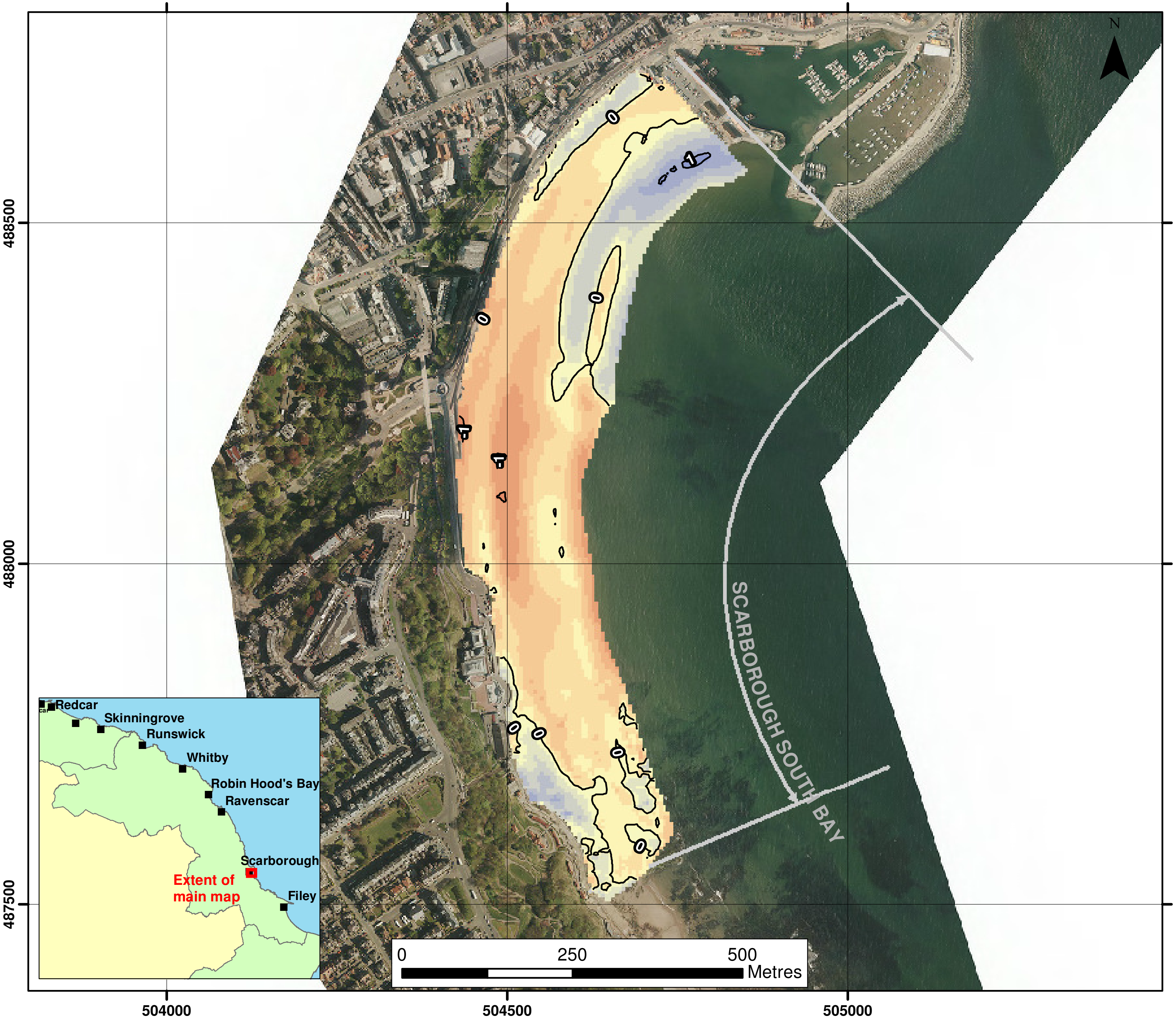

KEY Autumn 2008 and Autumn 2013
Change in elevation (m)

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

Analytical Report 6
Full Measures Survey
Autumn 2013

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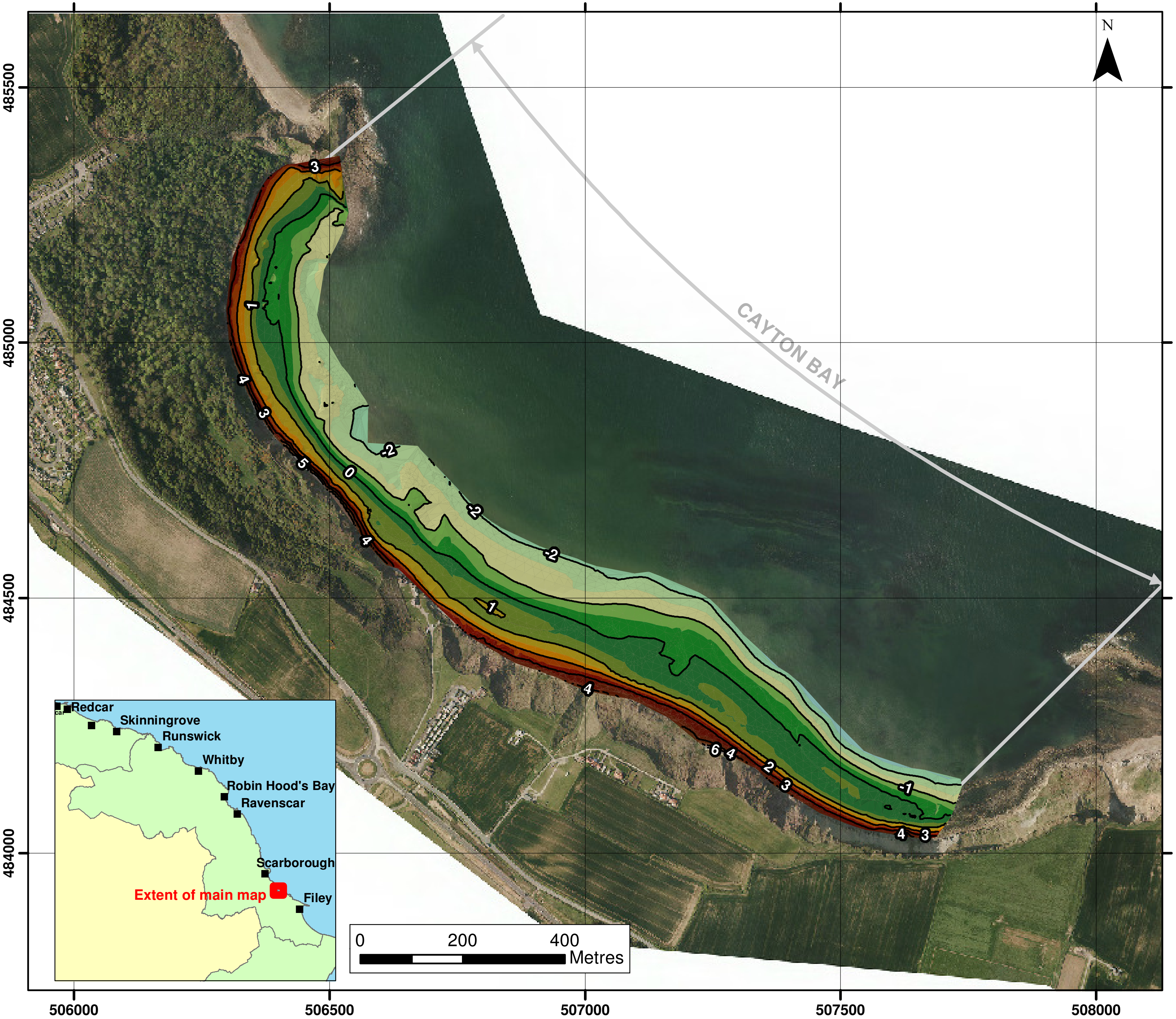

KEY
Elevation (m OD)

- 7 - 7.5
- 6.5 - 7
- 6 - 6.5
- 5.5 - 6
- 5 - 5.5
- 4.5 - 5
- 4 - 4.5
- 3.5 - 4
- 3 - 3.5
- 2.5 - 3
- 2 - 2.5
- 1.5 - 2
- 1 - 1.5
- 0.5 - 1
- 0 - 0.5
- -0.5 - 0
- -1 - -0.5
- -1.5 - -1
- -2 - -1.5
- -2.5 - -2
- -3.0- -2.5
- 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 6
Full Measures Survey
Autumn 2013

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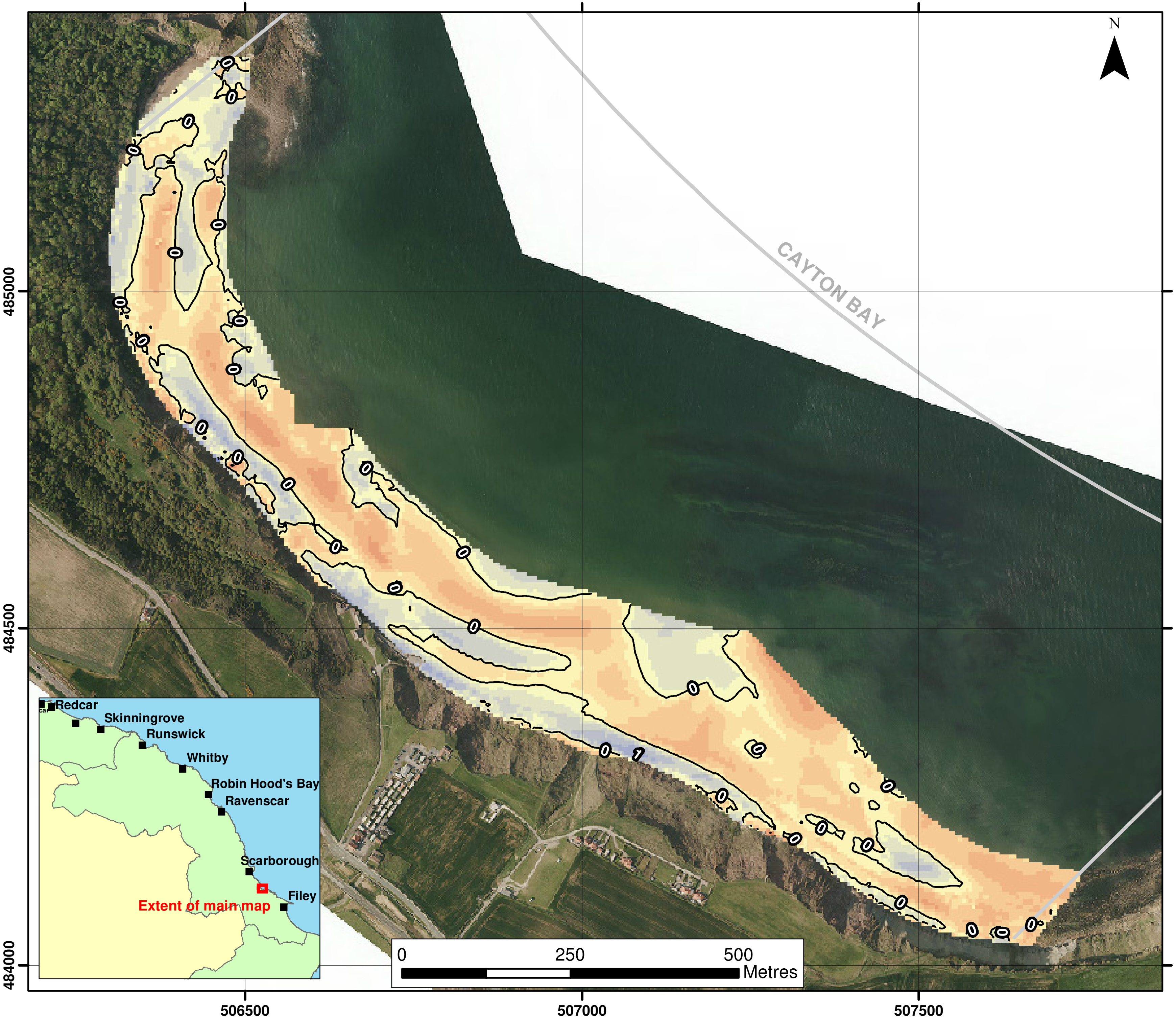

KEY Autumn 2012 and Autumn 2013
Change in elevation (m)

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

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

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

Contours of change

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

Appendix B- Map 7b
Short-term Elevation Change Cayton Scarborough Borough Council

Analytical Report 6
Full Measures Surveys
Autumn 2013

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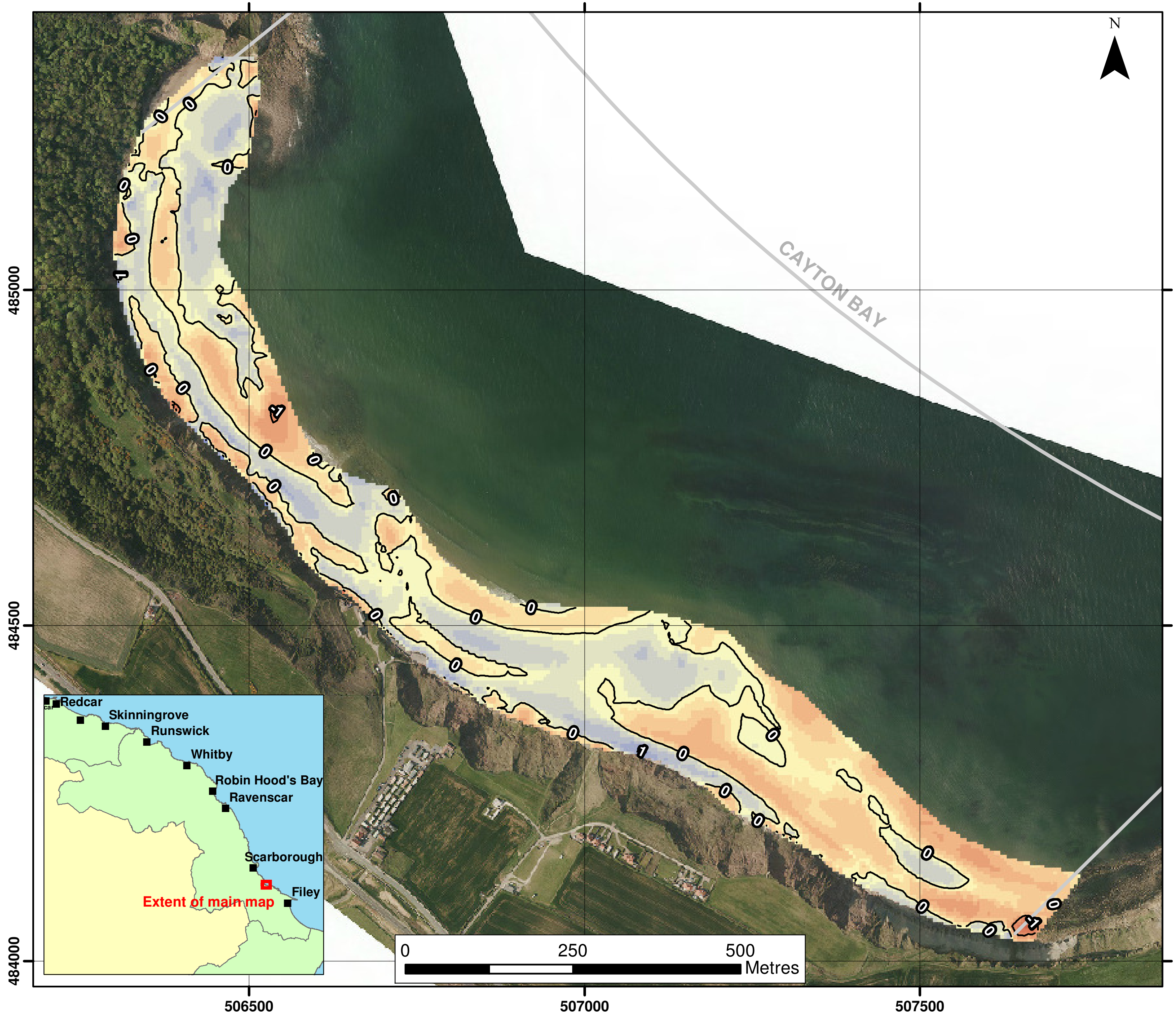

KEY Autumn 2008 and Autumn 2013
Change in elevation (m)

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

Analytical Report 6
Full Measures Survey
Autumn 2013

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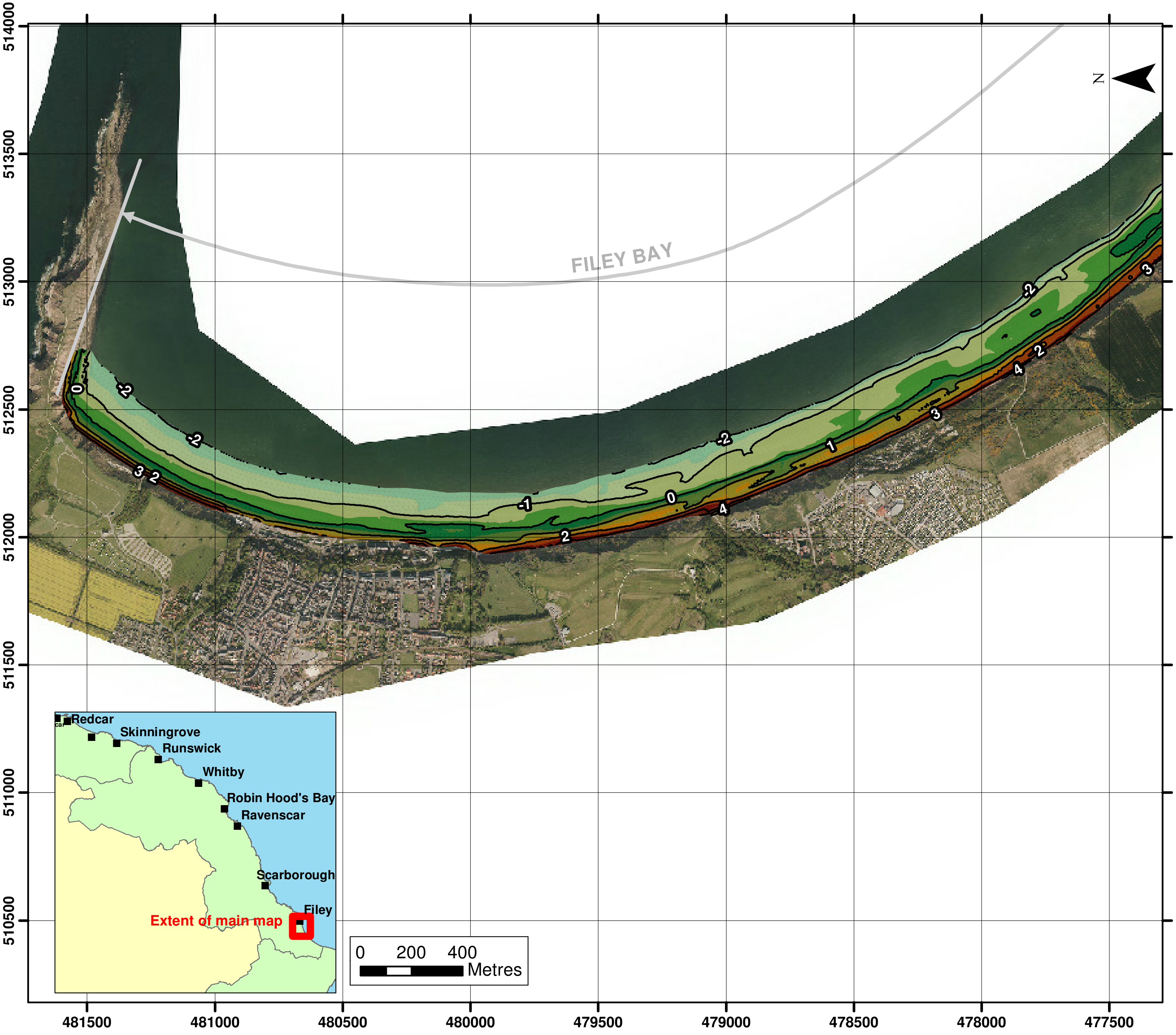

KEY

Elevation (m OD)

- 6.5 - 7
- 6 - 6.5
- 5.5 - 6
- 5 - 5.5
- 4.5 - 5
- 4 - 4.5
- 3.5 - 4
- 3 - 3.5
- 2.5 - 3
- 2 - 2.5
- 1.5 - 2
- 1 - 1.5
- 0.5 - 1
- 0 - 0.5
- -0.5 - 0
- -1 - -0.5
- -1.5 - -1
- -2 - -1.5
- -2.419 - -2
- 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 6
Full Measures Survey
Autumn 2013

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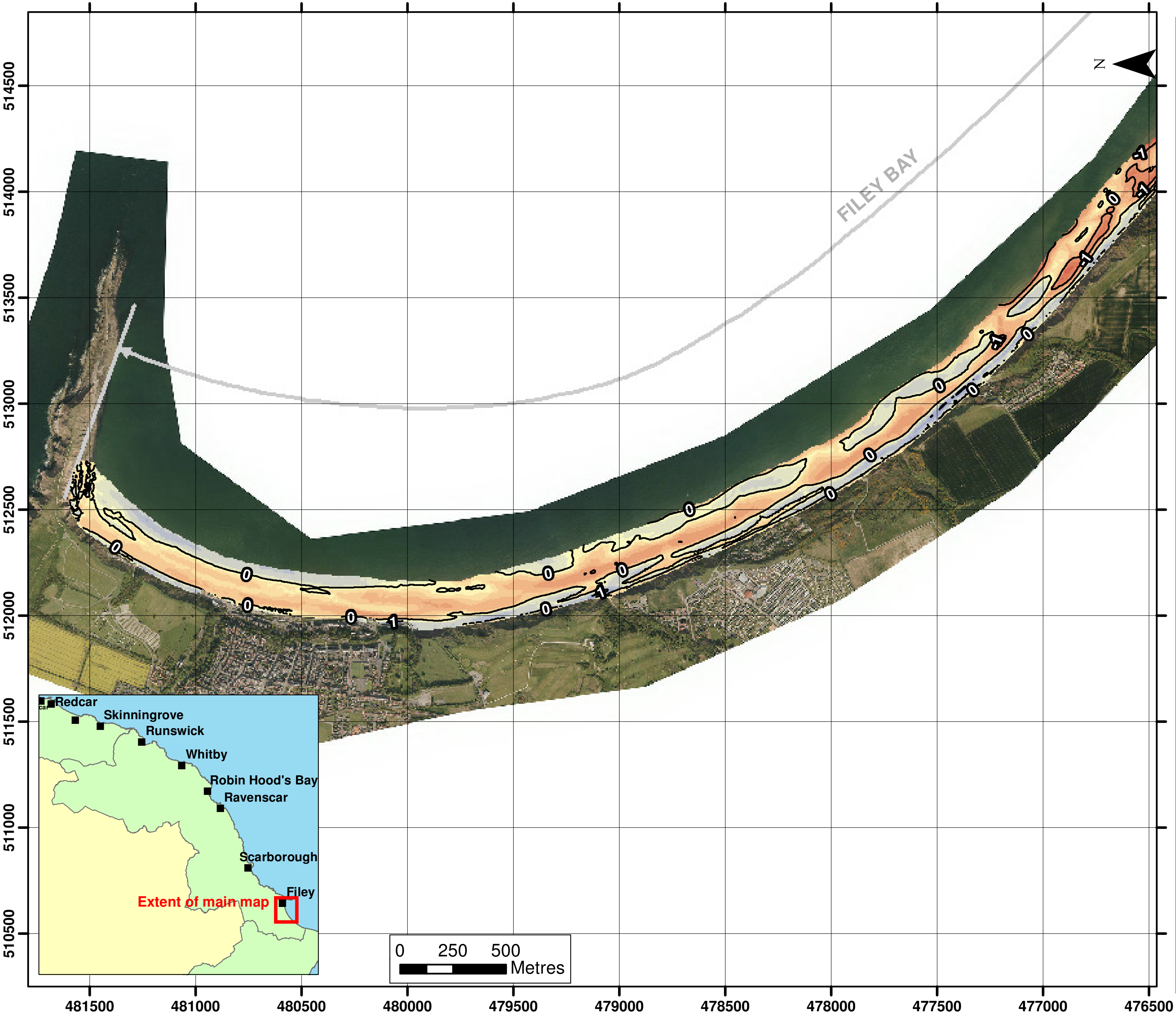

KEY Autumn 2012 and Autumn 2013
Change in elevation (m)

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

Analytical Report 6
Full Measures Survey
Autumn 2013

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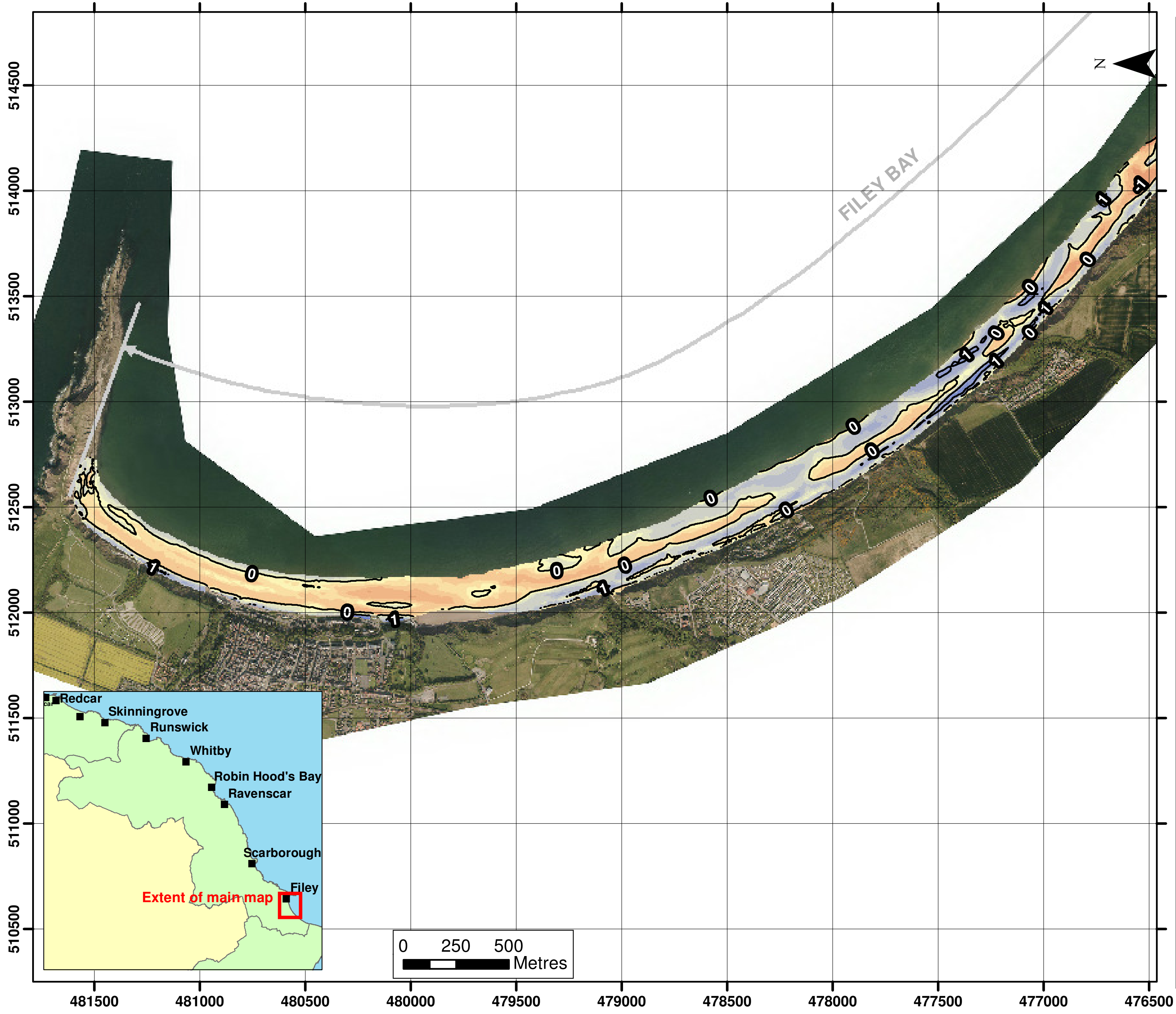

KEY Autumn 2008 and Autumn 2013
Change in elevation (m)

- <-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 6
Full Measures Survey
Autumn 2013

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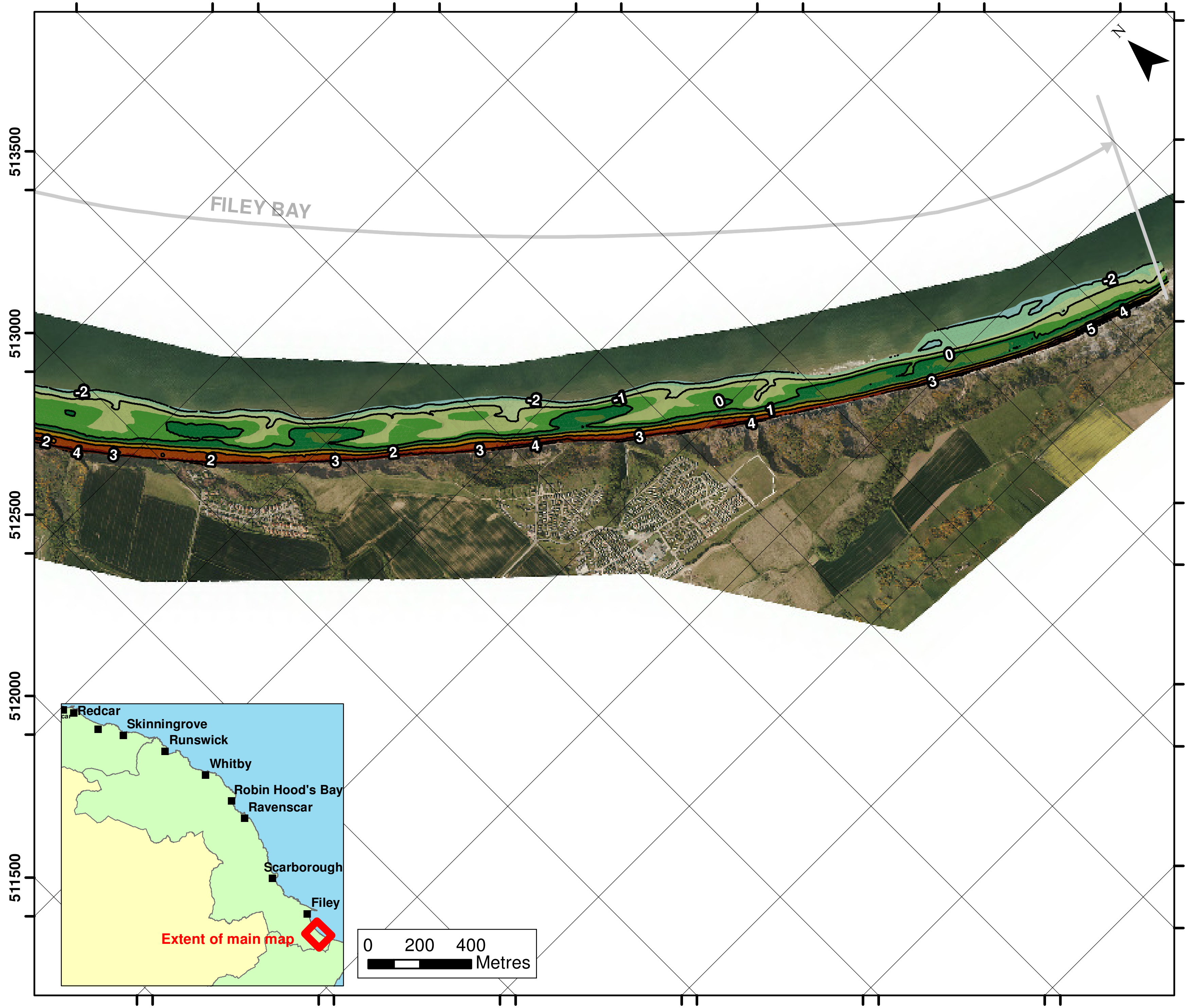

KEY

Elevation (m OD)

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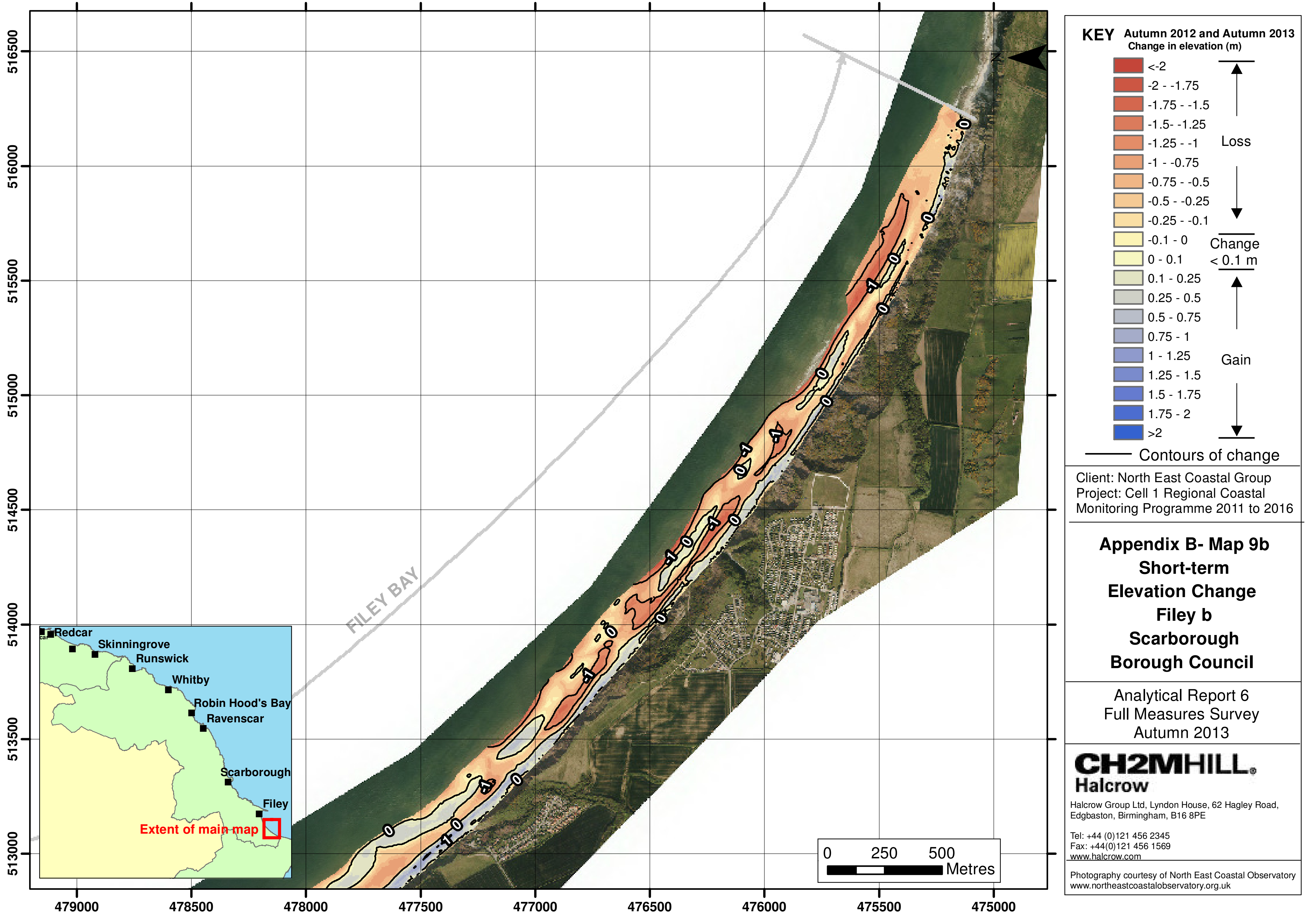

516500
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478500
478000
477500
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476500
476000
475500
475000
FILEY BAY
0
-1
Redcar
Skinningrove
Runswick
Whitby
Robin Hood's Bay
Ravenscar
Scarborough
Filey
Extent of main map
0 250 500
Metres
KEY Autumn 2012 and Autumn 2013
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 9b
Short-term Elevation Change
Filey b
Scarborough Borough Council
Analytical Report 6
Full Measures Survey
Autumn 2013
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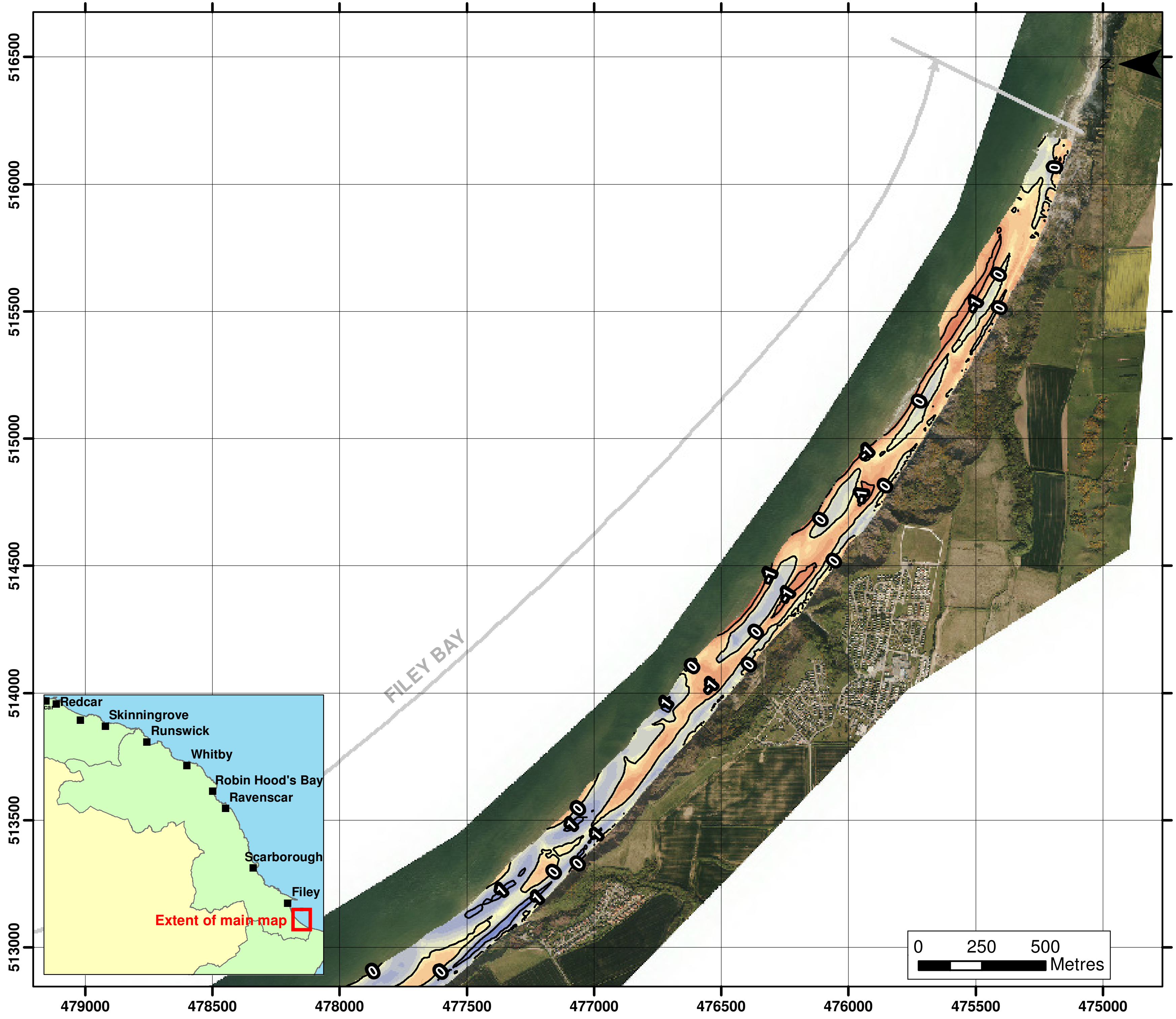

KEY Autumn 2008 and Autumn 2013
Change in elevation (m)

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

Contours of change

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

Appendix B- Map 9c
Long-term Elevation Change Filey b Scarborough Borough Council

Analytical Report 6
Full Measures Survey
Autumn 2013

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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.

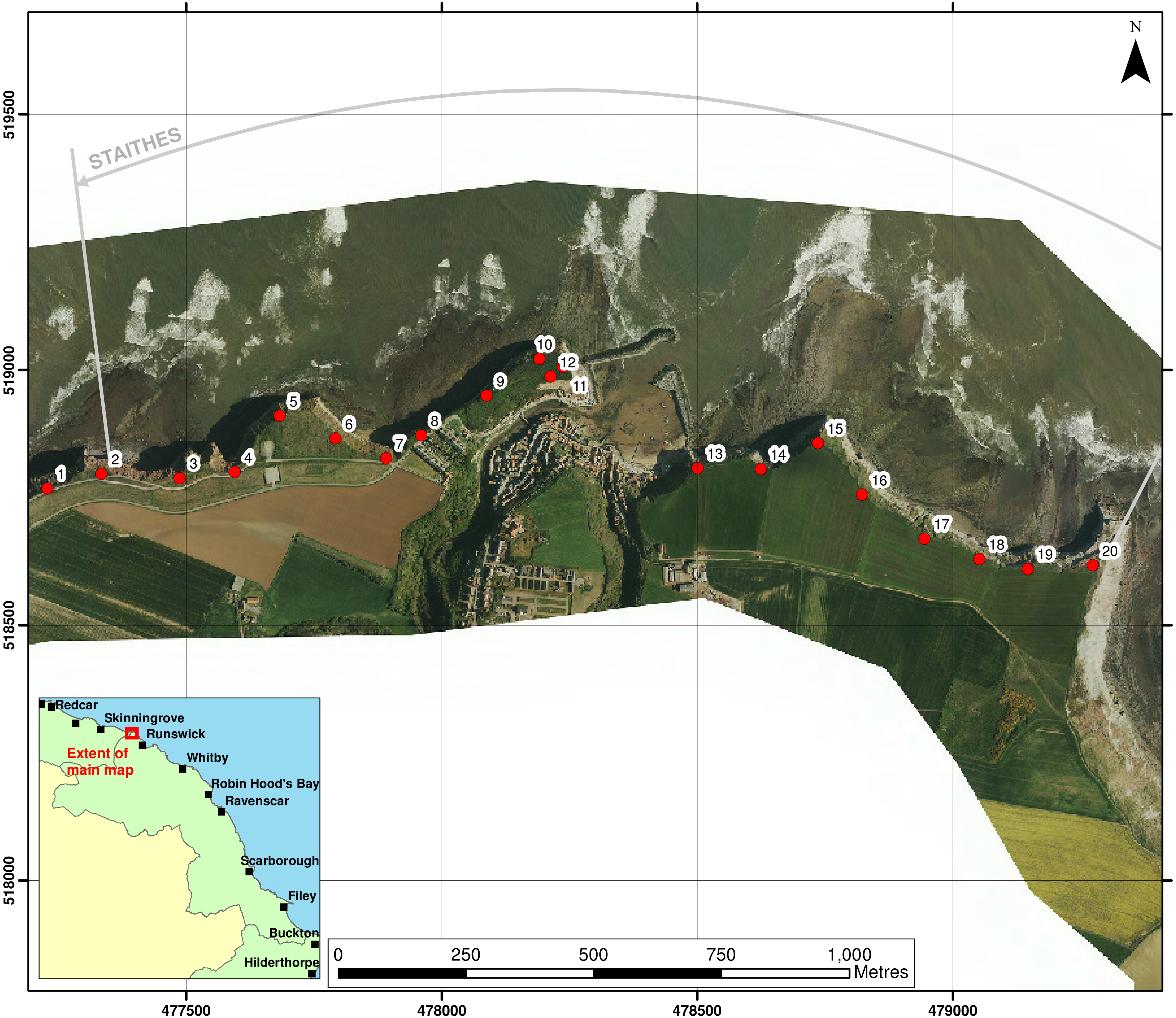
Table C1 provides baseline information about these ground control points and results from the 2008 (baseline) survey showing the position from the ground control point to the edge of the cliff top along the defined bearing. Future reports will show results from subsequent surveys and provide a means 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 (April 2013)	Present Survey (Oct 2013)	Baseline (Nov 2008) to Present (Oct 2013)	Previous (April 2013) to Present (Oct 2013)	Baseline (Nov 2008) to Present (Oct 2013)
1	477228	518769	320	1.9	1.7	1.7	-0.2	0.0	-0.04
2	477334	518798	0	10.9	10.8	10.8	-0.1	0.0	-0.03
3	477487	518789	350	7.1	8.3	8.5	1.4	0.2	0.28
4	477594	518801	340	5.9	5.1	5.2	-0.7	0.0	-0.15
5	477683	518911	350	8.4	9.2	8.9	0.5	-0.3	0.11
6	477792	518867	30	8.6	8.5	8.5	-0.1	0.0	-0.02
7	477891	518828	60	7.7	7.5	7.5	-0.2	0.0	-0.04
8	477959	518873	350	8.7	9.8	9.9	1.2	0.0	0.23
9	478088	518950	350	7.6	8.3	8.3	0.7	0.1	0.14
10	478191	519023	340	8.4	8.8	8.8	0.4	0.0	0.08
11	478237	519007	60	6.9	6.7	6.7	-0.2	0.0	-0.03
12	478213	518988	150	6.1	6.5	6.2	0.1	-0.3	0.02
13	478501	518809	15	11.4	9.2	9.2	-2.2	0.0	-0.46

14	478624	518807	20	7.5	7.5	7.5	0.0	0.1	0.00
15	478737	518858	60	6.1	6.4	6.4	0.3	0.0	0.07
16	478823	518757	60	8	9.0	9.3	1.3	0.3	0.25
17	478944	518671	30	9.3	9.4	9.4	0.1	0.0	0.02
18	479052	518630	20	9.2	9.4	9.4	0.2	0.0	0.03
19	479147	518610	0	14.2	14.4	14.4	0.2	0.0	0.04
20	479274	518618	20	11.4	11.4	11.4	0.0	-0.1	-0.01

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.



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 6
Full Measures Survey
Autumn 2013

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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.

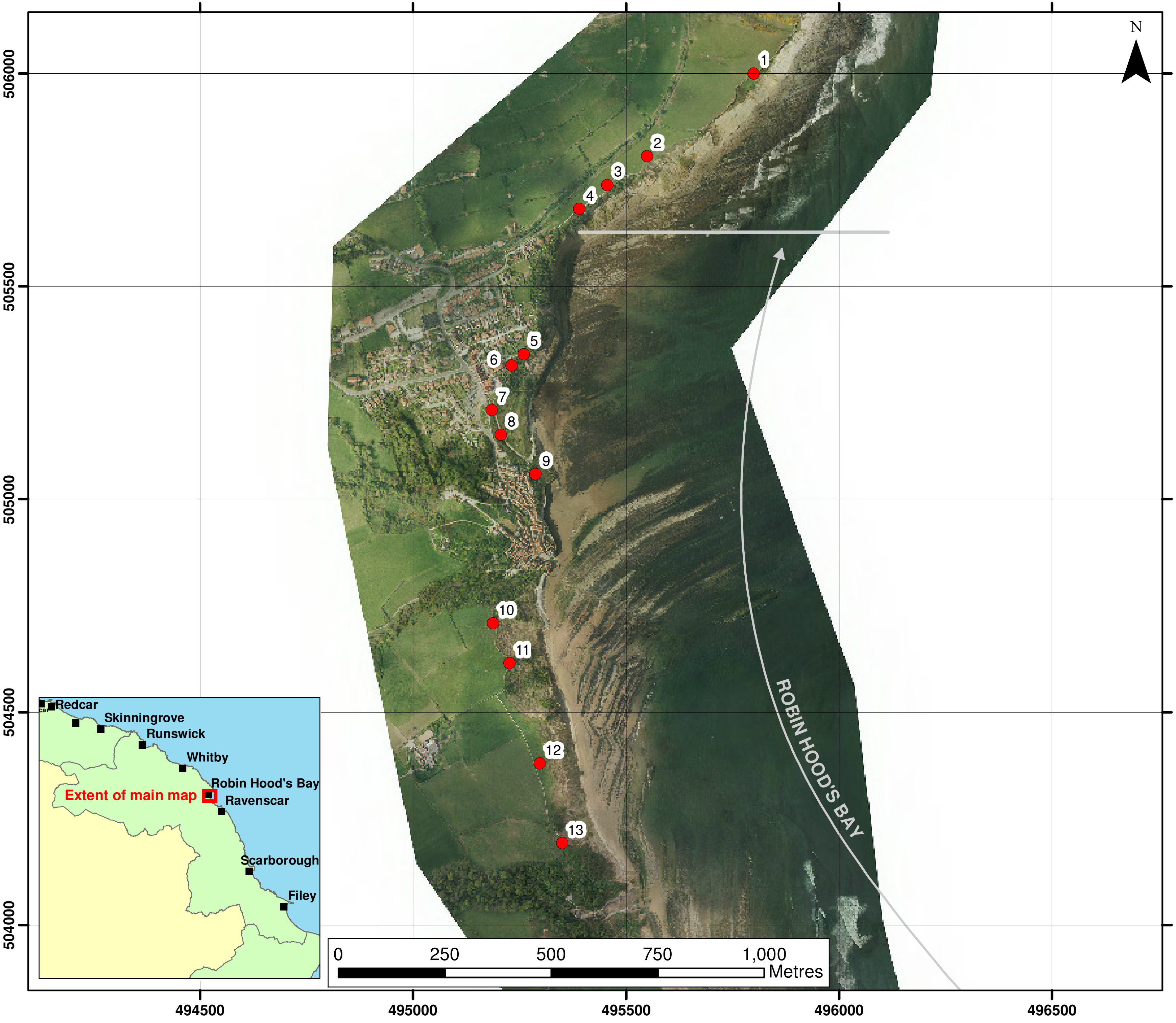
The cliff top surveys at Robin Hoods Bay are undertaken annually. Measurements are taken from a fixed ground control point along a fixed bearing to the edge of the cliff top.

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 (April 2013)	Present Survey (Nov 2013)	Baseline (March 2010) to Present (Nov 2013)	Previous (April 2013) to Present (Nov 2013)	Baseline (March 2010) to Present (Nov 2013)
1	495799.5	506002.2	130	11.6	8.0	7.9	-3.7	-0.1	-1.0
2	495549.2	505807.3	135	9.3	9.3	9.2	-0.1	-0.1	0.0
3	495456.3	505740	130	5	4.9	5.2	0.2	0.3	0.0
4	495389.9	505683.7	140	6.3	6.5	6.3	0.0	-0.2	0.0
5	495259.4	505342.5	130	11.3	10.9	10.0	-1.3	-0.9	-0.4
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	6.0	6.4	0.0	0.4	0.0
8	495206.5	505153	75	5	5.5	5.1	0.1	-0.4	0.0
9	495287.8	505060.5	80	4.3	4.2	4.7	0.4	0.5	0.1
10	495187.8	504708.8	70	3.1	2.6	2.6	-0.5	0.0	-0.1
11	495226.2	504615.7	120	3.8	4.1	3.9	0.1	-0.2	0.0
12	495297.5	504380.2	80	11	11.0	11.1	0.1	0.1	0.0
13	495350.4	504193	55	3.7	3.7	3.8	0.0	0.0	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.



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 6
Full Measures Survey
Autumn 2013

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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.

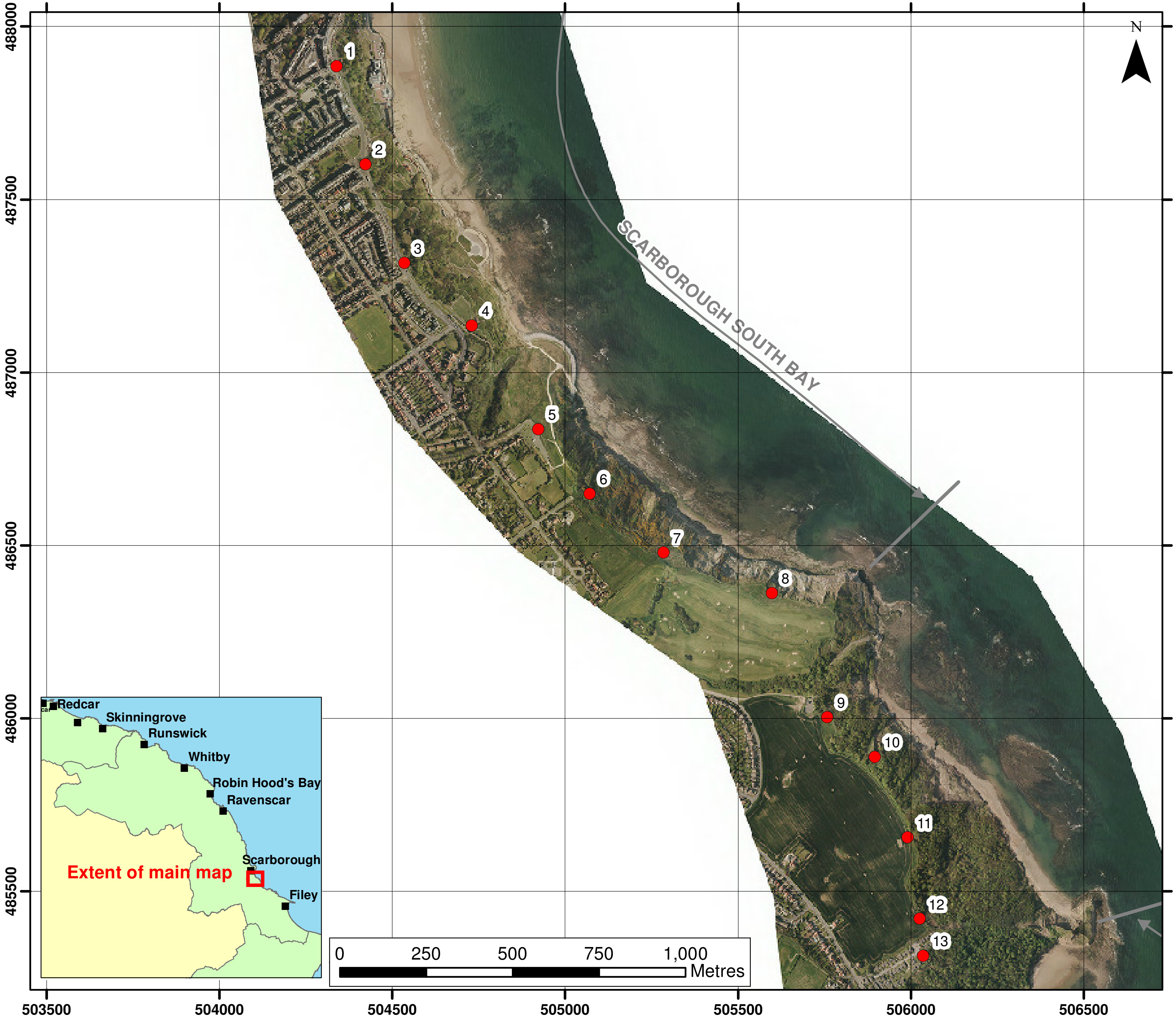
Table C3 provides baseline information about these ground control points and results from the 2010 (baseline) survey showing the position from the ground control point to the edge of the cliff top along the defined bearing. Future reports will show results from subsequent surveys and provide a means 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 (April 2013)	Present Survey (Sept 2013)	Baseline (March 2010) to Present (Sept 2013)	Previous (April 2013) to Present (Sept 2013)	Baseline (March 2010) to Present (Sept 2013)
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	14.9	15.1	0.0	0.2	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	8.8	8.6	-0.2	-0.3	-0.1
6	505071.1	486652.1	75	3.8	3.8	3.9	0.1	0.1	0.0
7	505284.3	486480	35	7.0	7.1	6.9	-0.1	-0.1	0.0
8	505597.9	486363.4	30	8.6	8.6	8.6	0.0	0.0	0.0
9	505758.6	486005.1	45	9.1	9.0	8.9	-0.2	-0.1	-0.1
10	505896	485889.6	15	14.8	14.9	14.9	0.1	0.0	0.0
11	505990	485657.1	80	4.7	2.5	2.5	-2.2	0.0	-0.6
12	506024.9	485421.8	55	6.1	4.2	4.2	-1.9	0.0	-0.5

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 (April 2013)	Present Survey (Sept 2013)	Baseline (March 2010) to Present (Sept 2013)	Previous (April 2013) to Present (Sept 2013)	Baseline (March 2010) to Present (Sept 2013)
13	506036	485315.3	90	7.0	7.0	7.1	0.1	0.0	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.



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 6
Full Measures Survey
Autumn 2013

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Cayton Bay

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

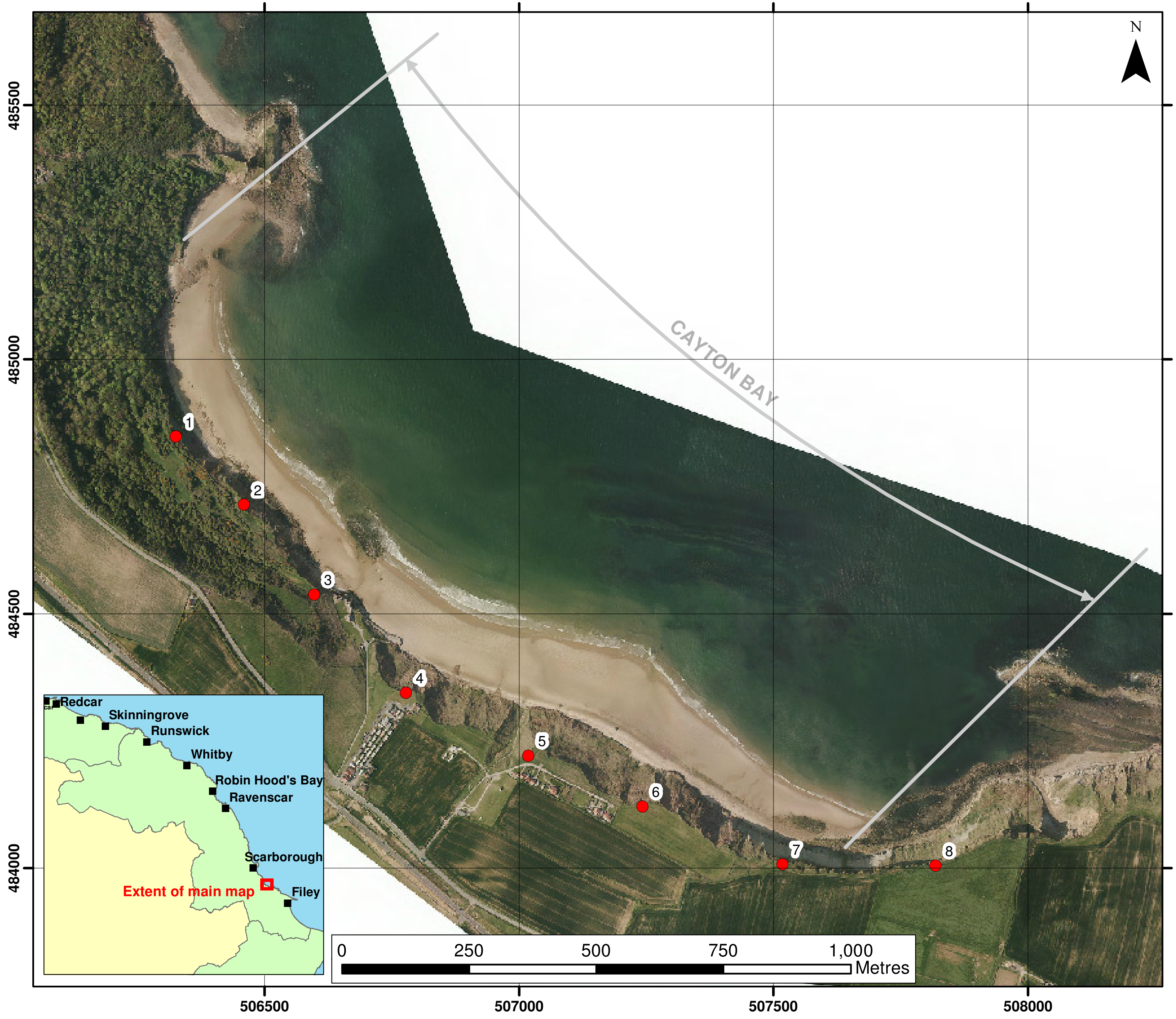
The cliff top surveys at Cayton Bay are undertaken annually. Measurements are taken from a fixed ground control point along a fixed bearing to the edge of the cliff top.

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 (April 2013)	Present Survey (Sept 2013)	Baseline (Nov 2008) to Present (Sept 2013)	Previous (April 2013) to Present (Sept 2013)	Baseline (Nov 2008) to Present (Sept 2013)
1	506325.5	484849.7	50	4	3.6	3.5	-0.5	-0.1	-0.1
2	506459.4	484715.9	65	5	0.2	0.1	-5.0	-0.1	-1.0
3	506597.4	484538.6	65	5	6.3	6.3	1.3	0.0	0.3
4	506778.1	484345.5	21	9	6.1	6.0	-3.0	0.0	-0.6
5	507018.6	484221.6	342	7.7	8.0	8.2	0.5	0.2	0.1
6	507242.3	484121.7	2	7.4	6.6	6.6	-0.8	0.0	-0.2
7	507518.2	484008.2	25	7.5	7.9	7.9	0.4	0.0	0.1
8	507818.7	484006	1	5.5	5.6	5.6	0.1	0.0	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.



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

Analytical Report 6
Full Measures Survey
Autumn 2013

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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 (April 2013)	Present Survey (Sept 2013)	Baseline (Nov 2008) to Present (Sept 2013)	Previous (April 2013) to Present (Sept 2013)	Baseline (Nov 2008) to Present (Sept 2013)
1	512444.9	481630.9	130	8.7	8.8	8.9	0.2	0.0	0.03
2	512306.7	481490.3	144	7.6	7.8	7.9	0.3	0.1	0.05
3	512153.6	481234.6	122	8.3	8.5	8.5	0.2	0.0	0.05
4	512029.2	480959.9	115	7.4	7.6	7.7	0.3	0.1	0.07
5	511895.4	479888	89	7.1	1.0	0.9	-6.2	-0.2	-1.29
6	511908.5	479597.1	48	6.7	7.1	7.2	0.5	0.1	0.10
7	511991.4	479310.4	69	6.7	5.1	4.7	-2.0	-0.4	-0.42
8	512083.4	478981.5	66	10.2	10.4	10.3	0.1	-0.1	0.02
9	512121.3	478786.3	76	8.3	8.4	8.4	0.1	0.0	0.02
10	512226.2	478547.9	74	7.5	7.3	7.3	-0.2	0.0	-0.05
11	512471.4	478153.5	53	6.6	6.5	6.6	0.0	0.1	0.00
12	512558.9	477901.9	66	7.7	7.8	7.8	0.1	0.1	0.03
12A*	512655.8	477822.4	67	13.9	13.9	13.9	0.0	0.0	0.02

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 (April 2013)	Present Survey (Sept 2013)	Baseline (Nov 2008) to Present (Sept 2013)	Previous (April 2013) to Present (Sept 2013)	Baseline (Nov 2008) to Present (Sept 2013)
13**	512697.6	477719	34	4.2	No Data	No Data	No Data	No Data	No Data
14	512939.4	477400.9	66	8	7.0	7.0	-1.0	0.0	-0.20
15	513157	477192.7	51	5.2	4.8	4.7	-0.5	-0.1	-0.11
16	513299.5	477024.6	30	7.7	7.8	7.5	-0.2	-0.3	-0.04
17	513507.7	476821.1	34	10.7	10.9	10.7	0.0	-0.2	-0.01
18	513721	476602.3	31	7.2	7.1	7.0	-0.2	-0.1	-0.04
19	513916.6	476354.1	51	6.6	6.4	6.4	-0.2	0.0	-0.04
20	514174.8	476179.4	32	7	7.4	7.2	0.2	-0.1	0.05
21	514471.5	475965.7	66	7.6	7.7	7.5	-0.1	-0.2	-0.01
22	514656.2	475728.8	101	8.1	8.2	8.1	0.0	-0.1	0.00
23	514889.5	475537.6	60	9.1	9.1	9.1	0.0	0.0	0.00
24*	512603.7	481665.9	14	19.9	19.8	19.9	0.0	0.0	-0.02
25*	512607.1	481648.9	184	17.2	17.2	17.1	-0.1	0.0	-0.02
26*	512301.9	481825.5	18	11	10.9	10.9	-0.1	0.0	-0.03
27*	512475.8	481712.1	20	11.6	11.58	11.58	0.0	0.0	-0.01

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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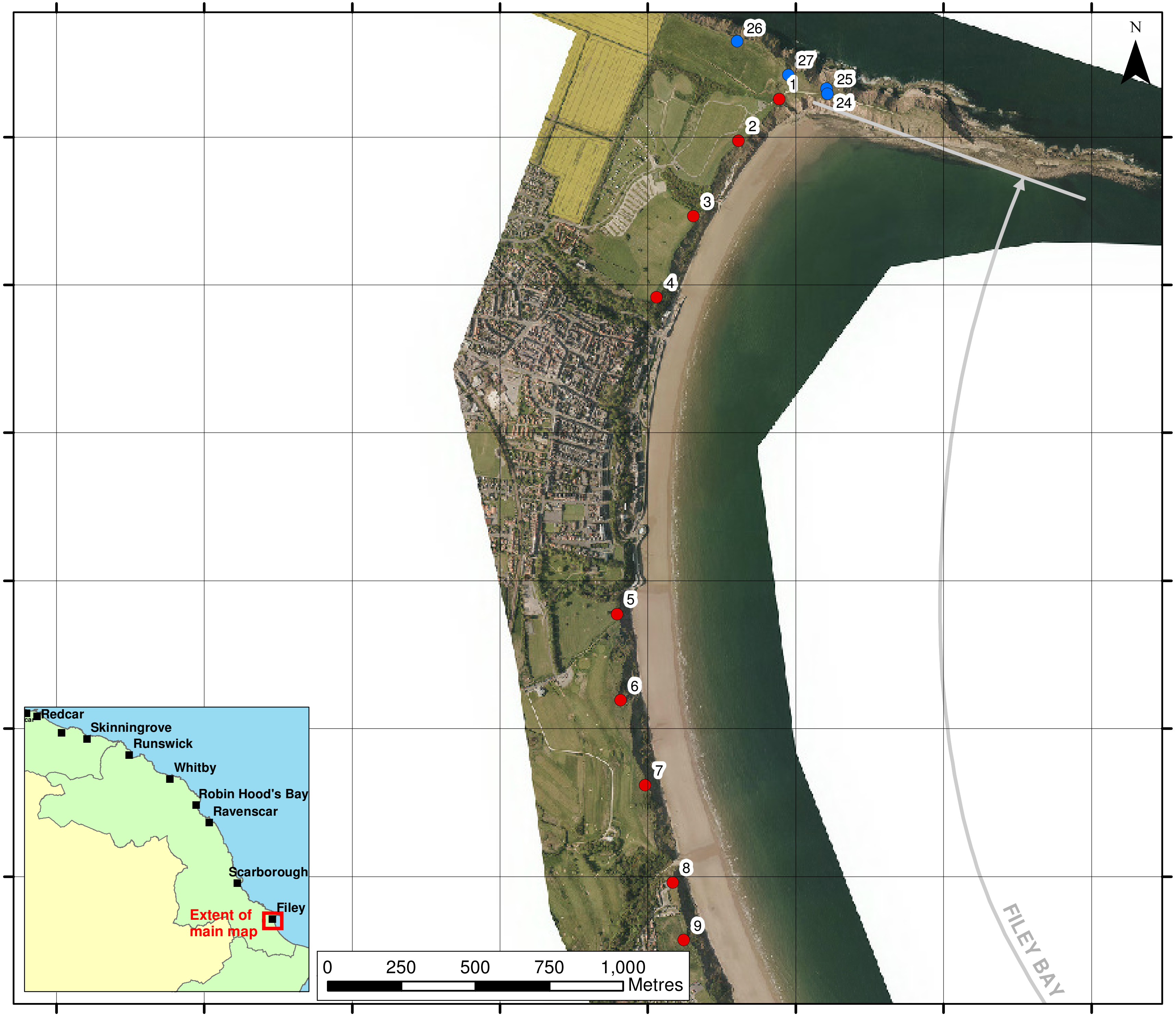

KEY

Ground Control Points

- Established March 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 6
Full Measures Survey
Autumn 2013

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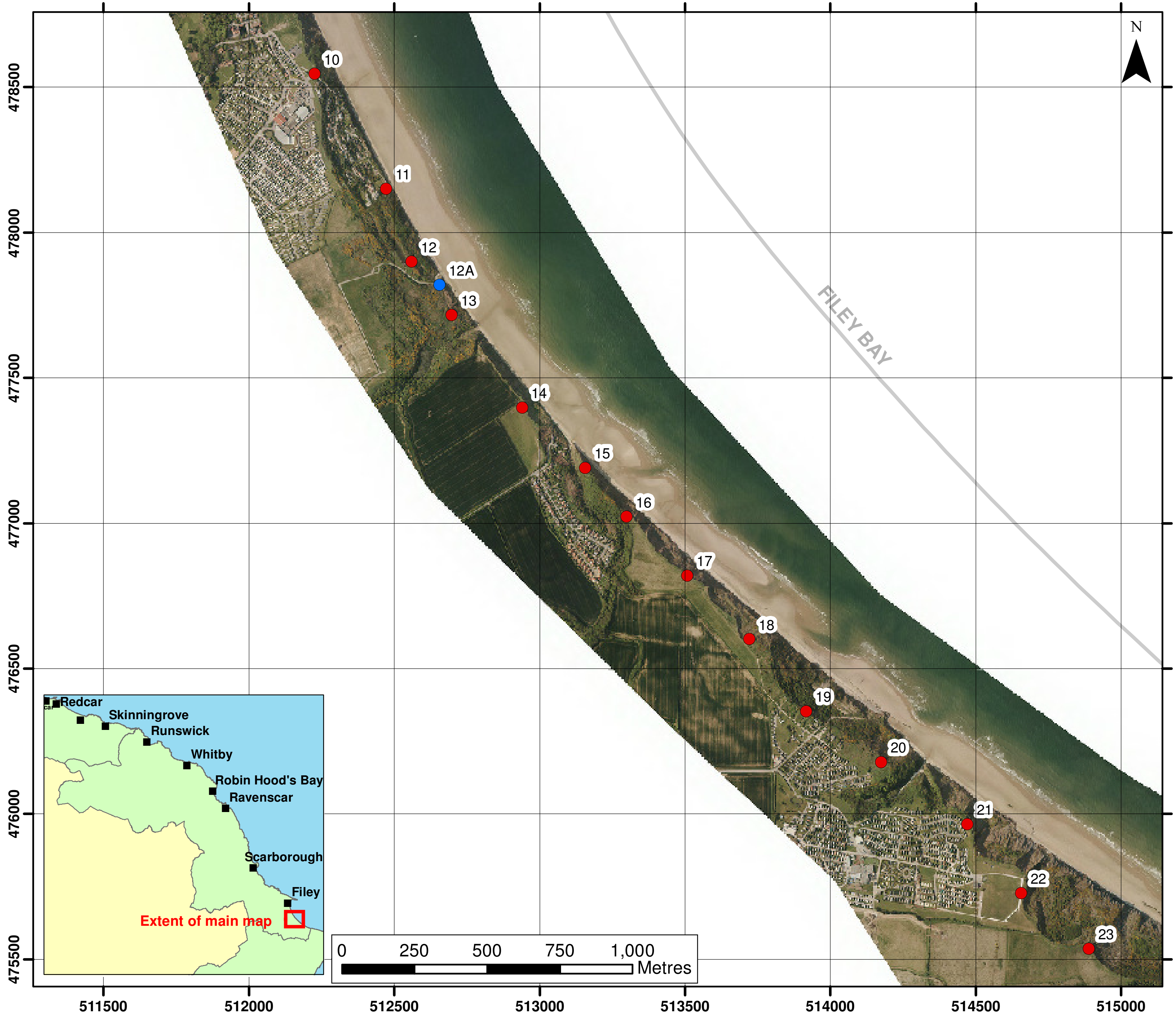
Photography courtesy of North East Coastal Observatory
www.northeastcoastalobservatory.org.uk



KEY

Ground Control Points

- Established March 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 6
Full Measures Survey
Autumn 2013

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