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

Sunderland City Council
Final Report

February 2016

Contents

Appendices

List of Figures

List of Tables

Authors	
Alex Bellis	CH2M
Dr Paul Fish – Review of Draft	CH2M
Dr Andy Parsons – Approval of Final	CH2M

Disclaimer

CH2M (formerly Halcrow) has prepared this report in accordance with the instructions of our client Scarborough Borough Council (SBC) for the client's sole and specific use. Any other persons who use any information contained herein do so at their own risk. This report is a review of coastal survey information made available by SBC. The objective of this report is to provide an assessment and review of the relevant background documentation and to analyse and interpret the coastal monitoring data. Halcrow has used reasonable skill, care and diligence in the interpretation of data provided to them and accepts no responsibility for the content, quality or accuracy of any Third party reports, monitoring data or further information provided either to them by SBC or, via SBC from a Third party source, for analysis under this term contract.

Raw data analysed in this report is available to download via the project's webpage: www.northeastcoastalobservatory.org.uk. The North East Coastal Observatory does not "license" the use of images or data or sign license agreements. The North East Coastal Observatory generally has no objection to the reproduction and use of these materials (aerial photography, wave data, beach surveys, bathymetric surveys), subject to the following conditions:

1. North East Coastal Observatory material may not be used to state or imply the endorsement by North East Coastal Observatory or by any North East Coastal Observatory employee of a commercial product, service, or activity, or used in any manner that might mislead.

2. North East Coastal Observatory should be acknowledged as the source of the material in any use of images and data accessed through this website, please state "Image/Data courtesy of North East Coastal Observatory". We recommend that the caption for any image and data published includes our website, so that others can locate or obtain copies when needed. We always appreciate notification of beneficial uses of images and data within your applications. This will help us continue to maintain these freely available services. Send e-mail to Robin.Siddle@scarborough.gov.uk

3. It is unlawful to falsely claim copyright or other rights in North East Coastal Observatory material.

4. North East Coastal Observatory shall in no way be liable for any costs, expenses, claims, or demands arising out of the use of North East Coastal Observatory material by a recipient or a recipient's distributees.

5. North East Coastal Observatory does not indemnify nor hold harmless users of North East Coastal Observatory material, nor release such users from copyright infringement, nor grant exclusive use rights with respect to North East Coastal Observatory material.

6. North East Coastal Observatory material is not protected by copyright unless noted (in associated metadata). If copyrighted, permission should be obtained from the copyright owner prior to use. If not copyrighted, North East Coastal Observatory material may be reproduced and distributed without further permission from North East Coastal Observatory.

Abbreviations and Acronyms

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

Water Levels Used in Interpretation of Changes

	Water Level (m AOD)
Water Level Parameter	**Souter Point to Chourdon Point**
HAT	3.18
MHWS	2.48
MLWS	-1.92

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

Glossary of Terms

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

Preamble

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

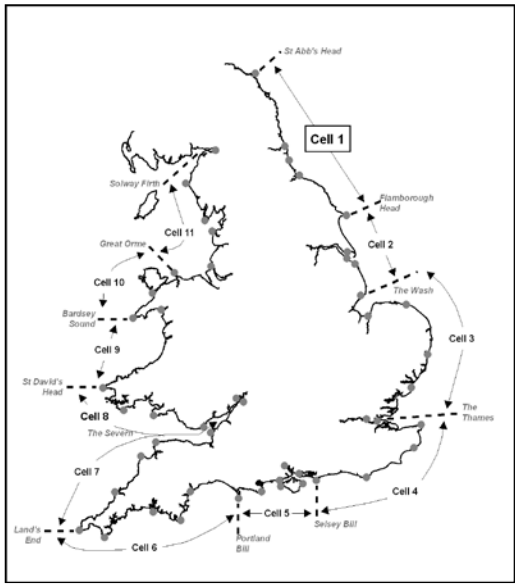


Figure 1 Sediment Cells in England and Wales

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

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

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

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

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

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

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

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

Table 1 Analytical, Update and Overview Reports Produced to Date

Year		Full Measures		Partial Measures		Cell 1 Overview Report
		Survey	Analytical Report	Survey	Update Report	
1	2008/09	Sept-Dec 08	May 09	Mar-May 09		-
2	2009/10	Sept-Dec 09	Mar 10	Feb-Mar 10	July 10	-
3	2010/11	Aug-Nov 10	Feb 11	Feb-Apr 11	Aug 11	Sept 11
4	2011/12	Oct-Nov 11	Oct 12	Mar-May 12	Oct 12	-
5	2012/13	Sept-Oct 12	Mar 13	Mar 13	June 13	-
6	2013/14	Sept-Oct 13	Feb 14	Mar 14	July 14	-
7	2014/15	Sept & Nov 14	Feb 15	Mar – Apr 15	July 15	
8	2015/16	Sept & Nov 15	Feb 16 (*)			

(*) The present report is **Analytical Report 8** and provides an analysis of the 2008 'baseline' Full Measures survey for Sunderland City Council's frontage.

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

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

Table 2 Sub-divisions of the Cell 1 Coastline

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

Sunderland City Council's frontage extends from The Bents to Ryhope. For the purposes of this report and for consistency with previous reporting, it has been sub-divided into three areas, namely:

- Whitburn Bay
- Sunderland Harbour and Docks
- Hendon to Ryhope (including Halliwell Banks)

1.2 Methodology

Along Sunderland City Council's frontage, the following surveying is undertaken:

- Full Measures survey annually each autumn comprising:
    - Beach profile surveys along 58 transect lines (commenced 2009)
    - Topographic survey at Whitburn Bay (commenced 2009)
    - Topographic survey at Hendon to Ryhope (including Halliwell Banks) (commenced 2009)
- Partial Measures survey annually each spring comprising:
    - Beach profile surveys along 16 transect lines (commenced 2009)
- Cliff top survey bi-annually at:
    - Hendon to Ryhope (including Halliwell Banks) (commenced 2009)

The location of these surveys is shown in Figure 2. The Full Measures survey was undertaken along this frontage on the 23rd and 24th November 2015 (Whitburn Bay), 15th November 2015 (Sunderland Harbour and Docks) and from the 10th to the 18th September 2015 (Hendon to Ryhope (incl. Halliwell Banks)). During this time weather conditions varied considerably. Refer to the survey reports for details of the weather conditions over this survey period.

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

Upon receipt of the data from the survey team, they are quality assured and then uploaded onto the programme's website for storage and availability to others and also input to SANDS and GIS for subsequent analysis.

The Analytical Report is then produced following a standard structure for each authority. This involves:

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

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

1.3 Uncertainties in data and analysis

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

For beach profiles and topographic surveys, all incoming data are checked allowing systematic errors to be identified, and removed from plots and subsequent analysis. The accuracy of these surveys is not known, but it is likely that all measurements are correct to ±0.1m. Therefore, changes 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 can 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 bands 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 to 10 years of data.

2. Wave Data and Interpretation

2.1 Introduction

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

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

In order to help put the beach and cliff changes discussed in this report into context, analysed storm data for the wave buoys is presented in this section which includes storm analysis for data collected up to the end of November 2015, extending the wave analysis to cover the period prior to the Full Measure surveys.

An overview plot of wave height data from the three Cell 1 wave buoys is shown in Figure 3. Note that there were significant gaps in the data at both Scarborough and Whitby, but the record is nearly continuous from Newbiggin. There were a large number of small storms over the wither 2014-15 with the largest wave heights occurring in mid-October 2014 and beginning of February 2015. A storm with significant wave heights over 4m occurred in early September, just before the 2015 Full Measures survey data were collected.

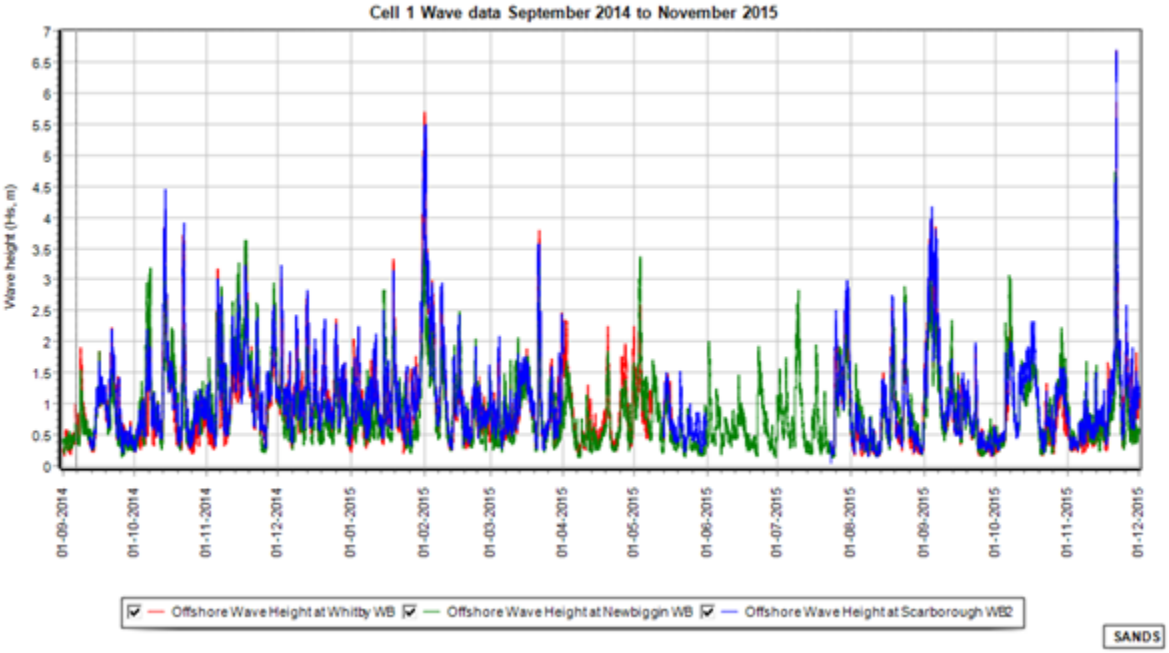


Figure 3 Wave monitoring data from the three Cell 1 wave buoys

2.2 Tyne/Tees WaveNet Buoy storms analysis

The longest consistent relevant wave data record in the Cell 1 region is from the WaveNet Tyne Tees buoy deployed under the national coastal monitoring programme by Cefas. Data has been

downloaded from WaveNet and loaded into SANDS for analysis alongside the beach and cliff monitoring data and results of a SANDS Storms analysis is presented in Table 4 below.

To aid interpretation of the results in Table 4 alternate years have been shaded and the storm with the largest peak wave height each year has been highlighted in bold. The annual storm with the highest wave energy at peak has also been highlighted in bold red text as this depends on wave period as well as wave height and so is not always the same as the largest wave height, e.g. in 2007 and 2008.

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

General Storm Information							At Peak					
Start Time	**End Time**	**Dur (hr)**	**Peak of Storm**	**Mean Dir (°)**	**No Events**	**Mean Dir Vector (°)**	**Hs (m)**	**Tp (s)**	**Tz (s)**	**Dir (°)**	**Energy @ Peak (KJ/m/s)**	**Total Energy (KJ/m)**
19/03/2007 10:30	21/03/2007 05:30	43	20/03/2007 14:30	23	64	78.2	6.2	14.8	8.5	23	1.7E+04	1.4E+07
25/06/2007 20:30	26/06/2007 13:30	17	26/06/2007 10:00	54	18	77.3	4.4	10.3	7.2	23	4.0E+03	1.7E+06
26/09/2007 03:00	27/09/2007 05:00	26	26/09/2007 19:00	11	33	79.7	4.6	13.8	7.6	6	**7.8E+03**	3.6E+06
08/11/2007 20:00	**12/11/2007 15:00**	**91**	**09/11/2007 08:30**	**16**	**58**	**77.7**	**6.2**	15.9	**9.0**	**6**	**1.9E+04**	**1.6E+07**
19/11/2007 03:30	25/11/2007 21:30	162	23/11/2007 05:00	88	52	76.8	4.9	12.7	7.6	17	7.6E+03	6.8E+06
08/12/2007 03:00	10/12/2007 14:30	59.5	08/12/2007 03:30	106	8	82.9	4.1	12.8	7.6	17	5.4E+03	7.5E+05
03/01/2008 10:30	04/01/2008 01:30	15	03/01/2008 23:30	77	24	14.6	4.2	10.9	7.6	62	4.2E+03	2.5E+06
01/02/2008 15:00	02/02/2008 09:30	18.5	02/02/2008	41	30	80.1	6.0	16.4	9.0	17	1.9E+04	8.7E+06
10/03/2008 08:30	10/03/2008 12:30	4	10/03/2008 11:00	146	9	307.5	4.6	9.6	6.5	141	3.8E+03	7.3E+05
17/03/2008 15:00	**25/03/2008 03:00**	**180**	**22/03/2008 05:00**	**81**	**58**	**82.1**	**7.9**	14.8	**9.0**	**6**	**2.7E+04**	**1.7E+07**
05/04/2008 22:00	07/04/2008 05:00	31	06/04/2008 19:00	49	20	83.1	4.6	13.9	7.6	6	7.9E+03	3.0E+06
20/07/2008 16:00	21/07/2008 09:30	17.5	20/07/2008 23:30	15	8	76.0	4.2	11.8	7.6	11	4.9E+03	9.1E+05
03/10/2008 03:00	03/10/2008 20:30	17.5	03/10/2008 16:30	55	17	76.7	4.7	13.6	7.6	23	**8.1E+03**	2.8E+06
21/11/2008 04:00	25/11/2008 12:30	104.5	22/11/2008 11:30	15	112	75.8	6.0	15.6	8.5	11	1.7E+04	2.2E+07
10/12/2008 12:00	13/12/2008 18:00	78	13/12/2008 08:00	109	37	332.1	4.9	10.0	7.2	129	4.7E+03	4.0E+06
31/01/2009 16:30	03/02/2009 09:00	64.5	02/02/2009 22:00	84	57	7.2	5.8	11.4	8.5	84	8.7E+03	8.1E+06
23/03/2009 22:30	28/03/2009 20:30	118	28/03/2009 16:30	217	14	89.4	5.3	10.0	7.6	6	5.4E+03	1.3E+06
10/07/2009 01:30	10/07/2009 02:30	1	10/07/2009 01:30	13	2	78.7	4.2	11.9	7.2	11	5.0E+03	2.3E+05
29/11/2009 20:30	**30/11/2009 15:00**	**18.5**	**30/11/2009 00:30**	**18**	**36**	**72.7**	**6.0**	11.2	**8.0**	**11**	**9.0E+03**	**5.9E+06**
17/12/2009 10:30	18/12/2009 05:00	18.5	17/12/2009 19:30	64	36	26.3	5.4	12.7	8.0	68	**9.4E+03**	5.7E+06
30/12/2009 09:00	30/12/2009 23:00	14	30/12/2009 12:30	84	24	7.7	5.1	9.0	7.2	90	4.1E+03	2.3E+06
06/01/2010 05:30	06/01/2010 11:00	5.5	06/01/2010 06:30	30	10	63.6	4.2	12.7	7.2	11	5.7E+03	1.1E+06
29/01/2010 10:30	30/01/2010 00:30	14	29/01/2010 22:30	9	21	81.9	5.4	10.2	8.0	6	6.0E+03	2.1E+06
26/02/2010 22:30	27/02/2010 02:30	4	27/02/2010 01:00	18	7	72.4	4.6	10.1	7.6	17	4.2E+03	7.0E+05
19/06/2010 07:00	20/06/2010 08:30	25.5	19/06/2010 20:00	21	49	69.2	5.4	12.7	7.6	23	**9.4E+03**	8.5E+06
29/08/2010 14:00	30/08/2010 06:30	16.5	30/08/2010 01:00	243	17	92.8	4.7	10.3	7.6	6	4.7E+03	1.6E+06

General Storm Information							At Peak					
Start Time	End Time	Dur (hr)	Peak of Storm	Mean Dir (°)	No Events	Mean Dir Vector (°)	Hs (m)	Tp (s)	Tz (s)	Dir (°)	Energy @ Peak (KJ/m/s)	Total Energy (KJ/m)
06/09/2010 22:30	07/09/2010 16:00	17.5	07/09/2010 15:30	101	22	353.2	4.6	10.5	8.0	90	4.5E+03	2.3E+06
17/09/2010 07:00	17/09/2010 18:30	11.5	17/09/2010 08:30	10	17	80.7	4.7	13.1	8.0	11	7.5E+03	2.9E+06
24/09/2010 03:00	26/09/2010	45	24/09/2010 10:00	21	80	71.6	5.3	12.1	8.0	11	8.0E+03	1.2E+07
20/10/2010 02:00	24/10/2010 16:30	110.5	20/10/2010 10:00	13	16	78.2	4.2	13.4	7.2	17	6.4E+03	1.8E+06
08/11/2010 14:00	**09/11/2010 20:30**	**30.5**	**09/11/2010 10:00**	**88**	**58**	**3.0**	**5.6**	10.5	**8.0**	**73**	**6.9E+03**	**7.8E+06**
17/11/2010 11:00	17/11/2010 18:30	7.5	17/11/2010 12:00	136	9	322.4	4.7	9.2	6.9	129	3.7E+03	8.1E+05
29/11/2010 19:30	02/12/2010 08:30	61	29/11/2010 21:00	80	45	11.8	5.1	11.2	7.6	56	6.3E+03	5.4E+06
16/12/2010 15:00	17/12/2010 06:30	15.5	17/12/2010 03:30	12	22	79.1	4.6	12.5	7.6	17	6.4E+03	2.8E+06
23/07/2011 14:00	**24/07/2011 11:00**	**21**	**24/07/2011 03:00**	**23**	**39**	**67.1**	**4.7**	12.8	**7.6**	**17**	**7.2E+03**	**5.8E+06**
24/10/2011 18:30	25/10/2011 09:30	15	25/10/2011 09:30	103	26	348.5	4.1	11.3	6.9	79	4.2E+03	2.6E+06
09/12/2011 08:30	09/12/2011 10:00	1.5	09/12/2011 08:30	7	3	84.0	4.1	14.2	8.0	6	6.7E+03	4.8E+05
05/01/2012 16:00	06/01/2012 05:00	13	06/01/2012 03:00	12	19	79.0	4.6	12.5	7.6	17	6.4E+03	2.6E+06
03/04/2012 13:30	04/04/2012 10:30	21	03/04/2012 17:30	66	38	25.1	5.6	9.7	7.6	56	5.9E+03	5.5E+06
24/09/2012 08:30	25/09/2012 10:30	26	25/09/2012 01:30	74	50	16.7	4.7	12.3	8.0	62	6.6E+03	7.4E+06
26/10/2012 16:30	27/10/2012 14:30	22	26/10/2012 23:00	12	34	79.4	4.9	15.3	7.6	11	1.1E+04	4.9E+06
05/12/2012 16:00	15/12/2012 01:30	225.5	14/12/2012 19:30	78	31	18.4	5.4	10.5	7.6	96	6.4E+03	4.5E+06
20/12/2012 06:00	**21/12/2012 14:30**	**32.5**	**20/12/2012 23:00**	**101**	**56**	**348.4**	**5.6**	11.3	**8.0**	**96**	**8.0E+03**	**8.8E+06**
18/01/2013 18:30	22/01/2013 06:00	83.5	21/01/2013 10:00	81	54	9.2	6.7	11.2	8.5	84	1.1E+04	1.1E+07
06/02/2013 08:00	07/02/2013 06:00	22	06/02/2013 12:30	47	38	81.6	5.4	11.9	7.6	11	8.2E+03	6.1E+06
07/03/2013 21:00	10/03/2013 21:30	72.5	08/03/2013 04:00	67	37	24.6	4.9	10.7	7.6	73	5.4E+03	4.3E+06
18/03/2013 09:00	25/03/2013 00:30	159.5	23/03/2013 14:30	85	153	5.1	6.0	12.1	8.0	90	1.0E+04	2.8E+07
23/05/2013 18:00	**24/05/2013 12:00**	**18**	**23/05/2013 22:30**	**13**	**32**	**77.5**	**6.7**	12.5	**8.5**	**17**	**1.4E+04**	**7.1E+06**
10/09/2013 13:00	10/09/2013 19:30	6.5	10/09/2013 14:00	11	14	79.3	4.4	11.0	7.2	11	4.6E+03	1.5E+06
09/10/2013 22:30	11/10/2013 09:00	34.5	10/10/2013 17:00	68	62	79.8	5.4	12.7	7.6	22	9.4E+03	1.2E+07
29/11/2013 22:30	30/11/2013 06:30	8	30/11/2013 00:30	42	17	84.5	5.6	12.7	8.0	11	1.0E+04	3.3E+06
05/12/2013 14:00	07/12/2013 04:30	38.5	06/12/2013 20:00	24	59	80.8	4.7	17.0	9.0	6	1.3E+04	1.2E+07
27/12/2013 09:30	27/12/2013 12:30	3	27/12/2013 10:00	218	3	249.3	4.1	7.3	6.5	202	1.8E+03	1.3E+05
05/02/2014 04:00	05/02/2014 18:00	14	05/02/2014 05:30	139	9	318.4	4.4	9.3	6.9	129	3.3E+03	7.2E+05
12/02/2014 20:00	**14/02/2014 19:00**	**47**	**12/02/2014 21:00**	**183**	**8**	**275.6**	**4.6**	8.9	**6.5**	**141**	**3.2E+03**	**7.8E+05**
21/10/2014 22:00	22/10/2014 01:30	3.5	21/10/2014 23:00	6	5	84.4	4.4	11.5	7.6	6	**5.0E+03**	6.0E+05
31/01/2015 08:30	01/02/2015 19:30	35.0	31/01/15 23:30	78	71	88.7	6.2	13.1	8.0	6	1.3 E+4	1.4 E+7
03/09/2015 05:30:00	04/09/2015 06:00:00	24.5	03/09/2015 18:30:00	13	15	78.1	4.4	10.5	6.8	11	4.2 E+3	1.6 E+6
21/11/2015 01:30:00	**21/11/2015 14:30:00**	**13.0**	**21/11/2015 05:30:00**	**72**	**27**	**85.9**	**7.1**	**11.8**	**8.5**	**356**	**1.4 E+4**	**5.7 E+6**

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

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

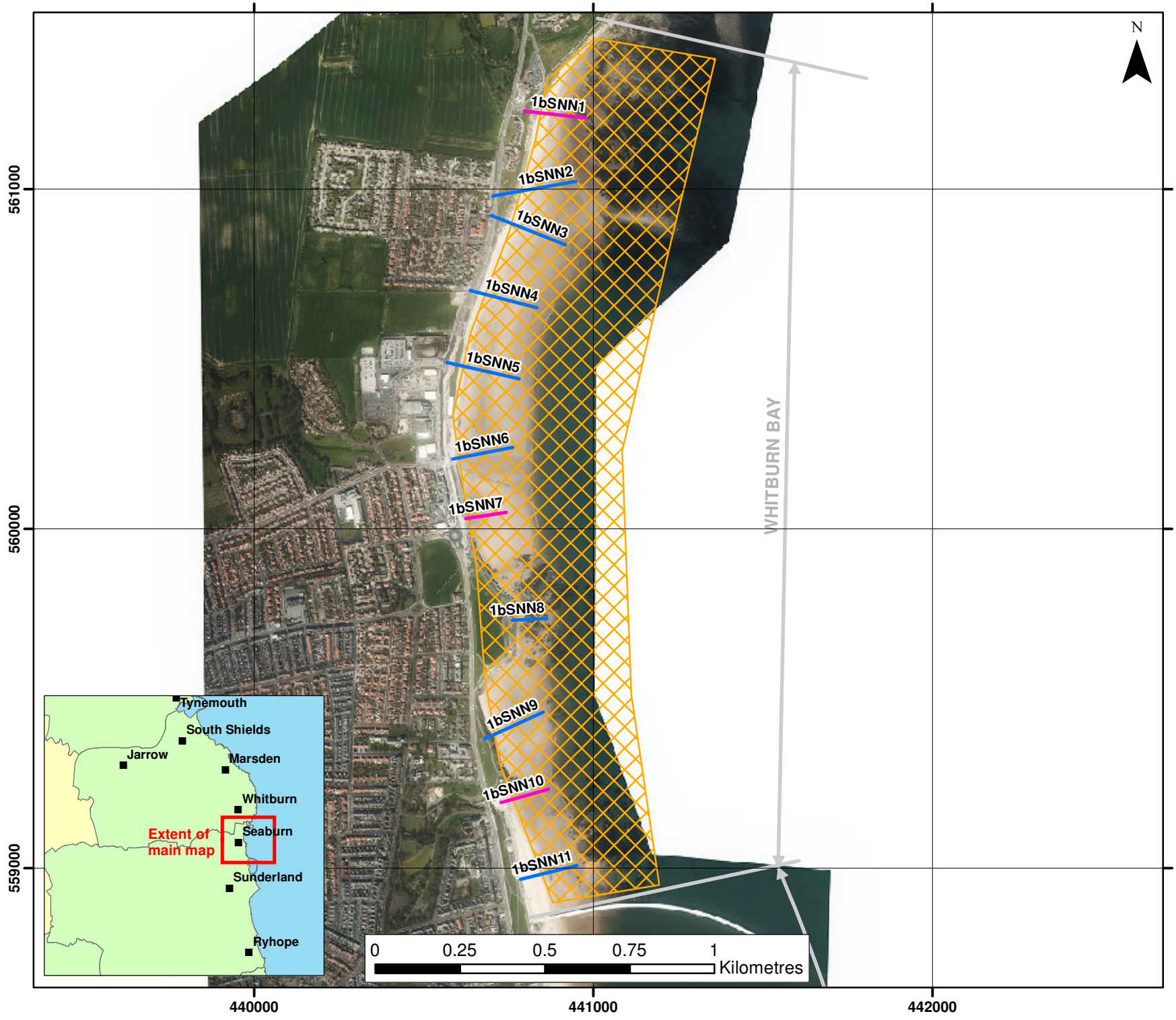
The years with the fewest storms was 2011, 2014 and 2015. In 2011 and 2014 this was reflected by a combination of accretion and overall stability recorded within the annual Full Measures reports.

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

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

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

During 2015 there were only three storms with peak wave heights above the threshold, but all had large wave heights and much greater wave energy than the 2014 storms. This 3rd/4th September 2015 storm occurred less than two weeks before the surveys were undertaken at Hendon to Ryhope (including Halliwell Banks) and therefore some of the ‘drawdown’ from the higher energy waves may have been caused by this storm. Additionally, erosion is more prevalent in the north of this survey area, which would fit with a peak wave direction of 11° during the storm which may have contributed to a southwards redistribution of sediment. The Whitburn Bay survey was undertaken shortly after the 21st November 2015 storm, but does not show any clear signature of this storm, most likely as it would have been predominantly sheltered as the peak wave direction was 356° during this later event.



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

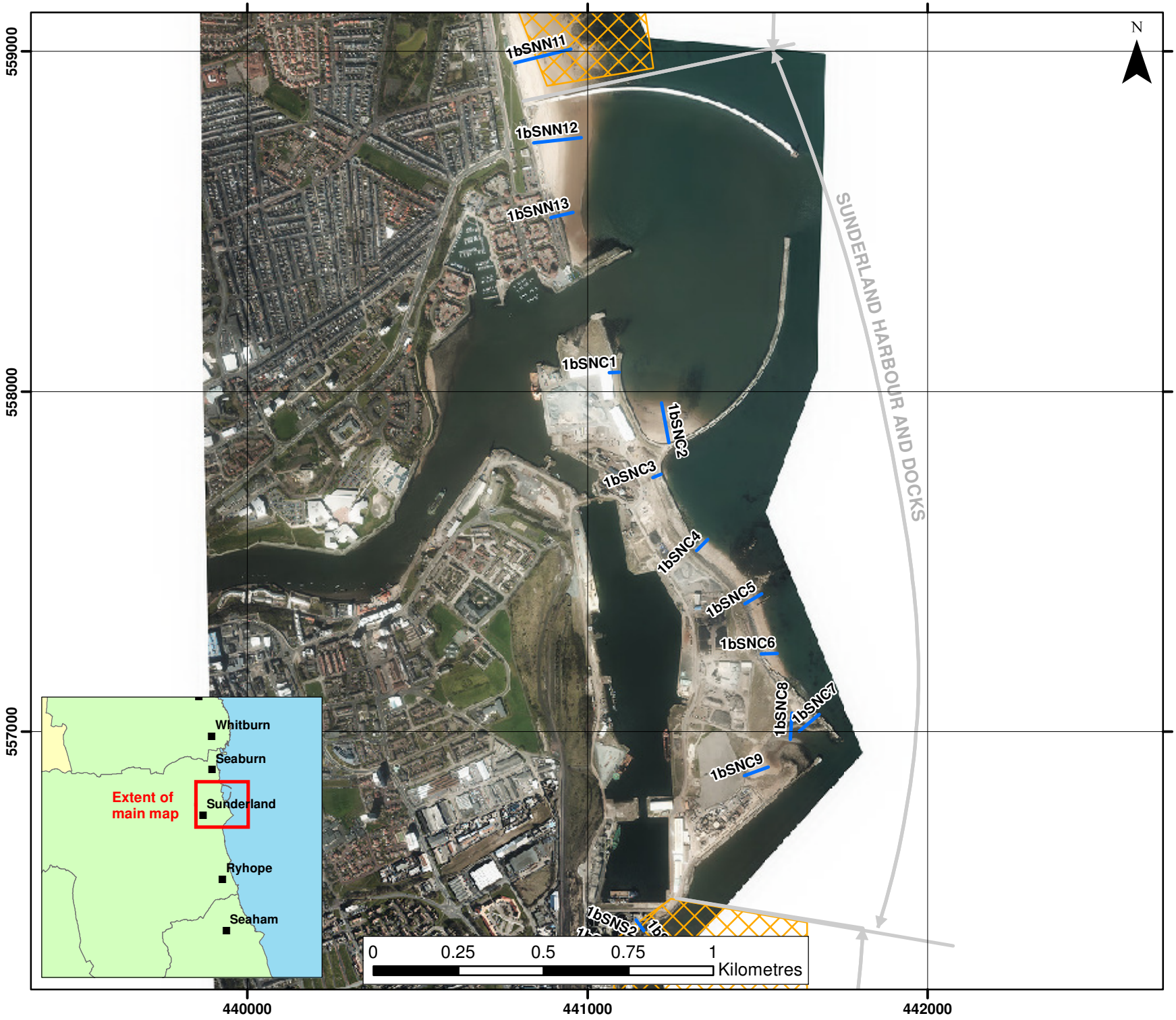
Figure 2- Map 1
Survey Locations
Whitburn Bay
Sunderland City Council

Analytical Report 8
Full Measures Survey
Autumn 2015

ch2m

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

Tel: +44 (0)121 456 2345
Fax: +44(0)121 456 1569
www.ch2m.com



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

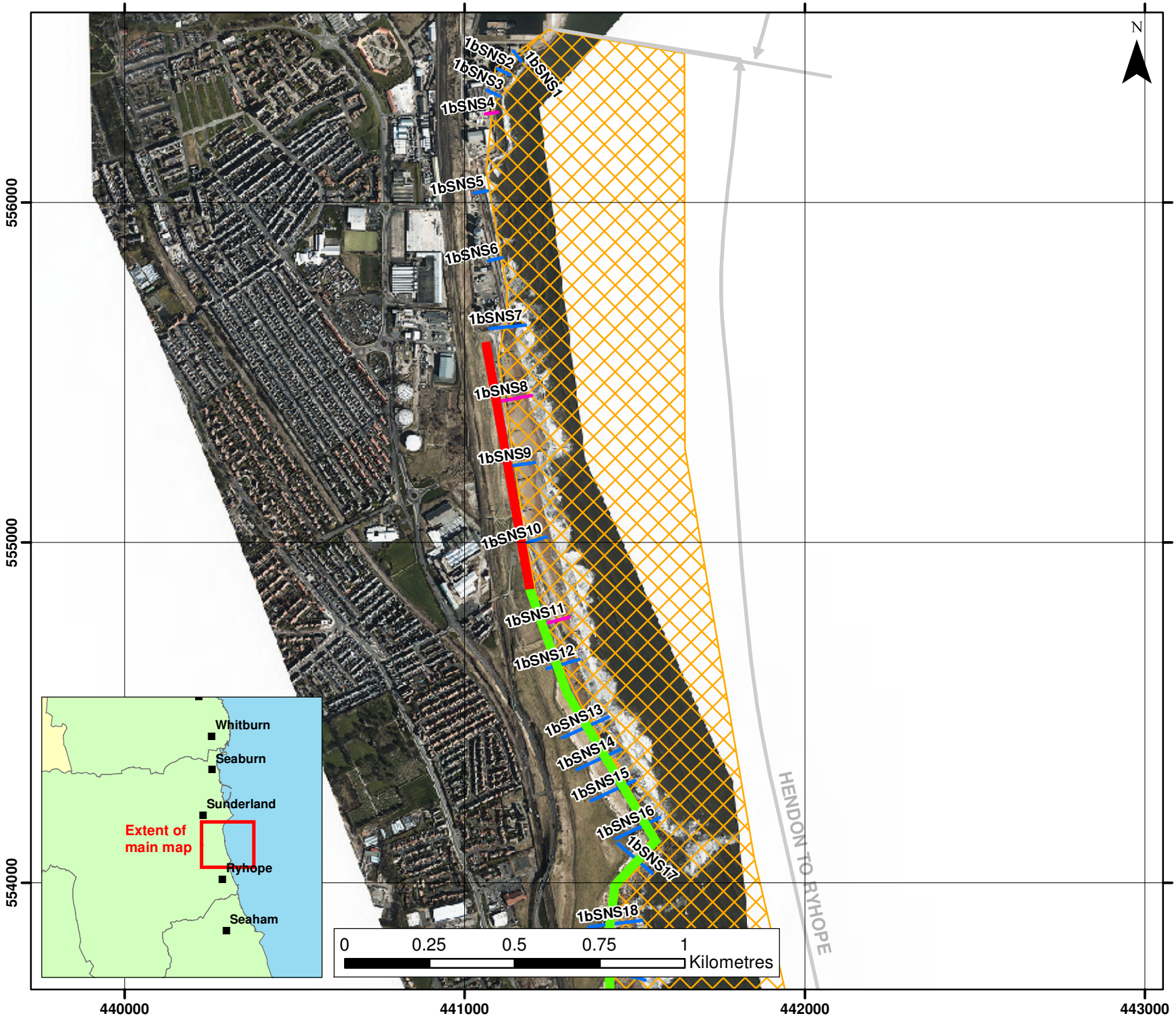
Figure 2- Map 2
Survey Locations
Sunderland Harbour and Docks
Sunderland City Council

Analytical Report 8
Fulll Measures Survey
Autumn 2015

ch2m

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

Tel: +44 (0)121 456 2345
Fax: +44(0)121 456 1569
www.ch2m.com



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

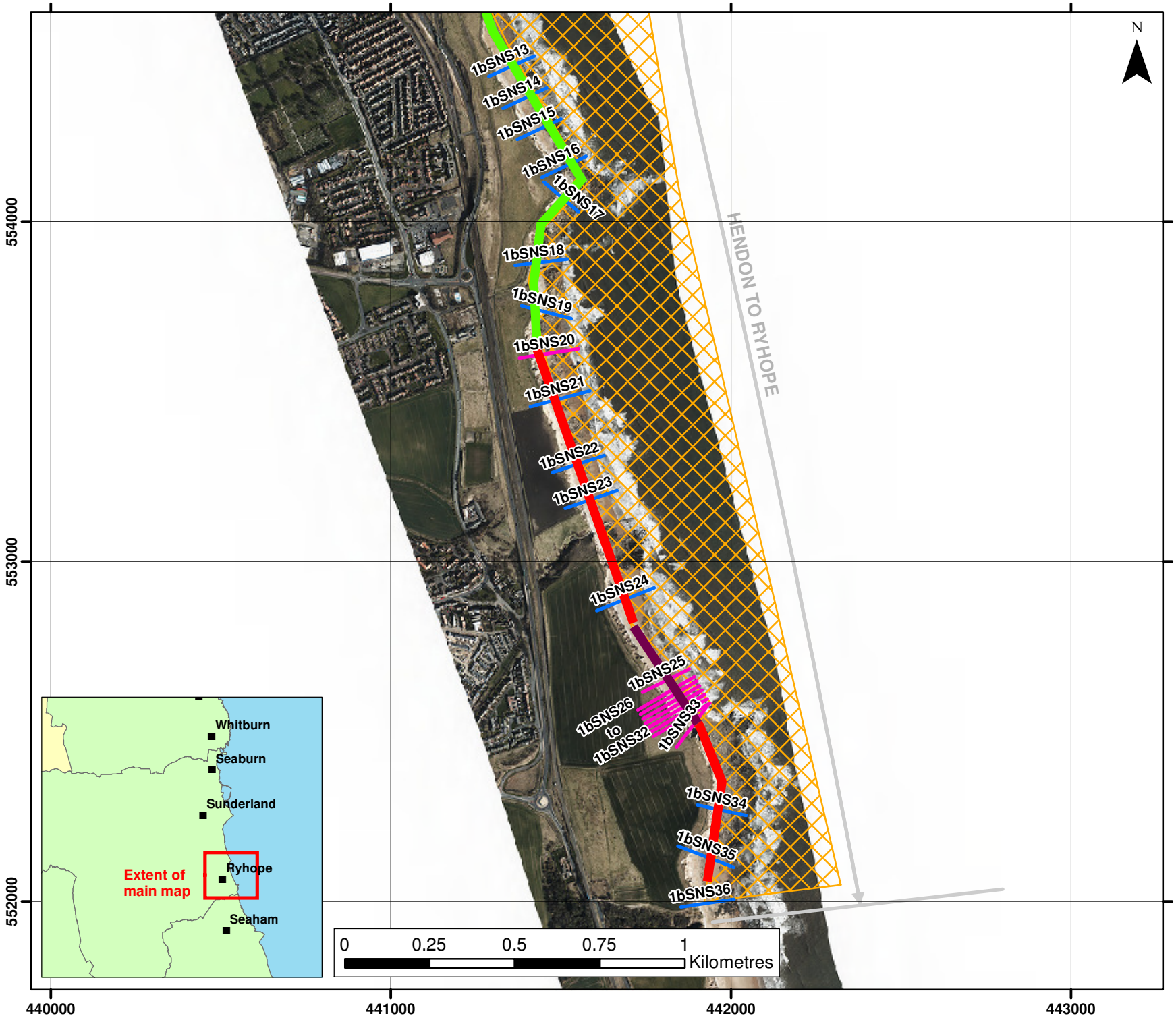
Figure 2- Map 3
Survey Locations
Hendon to Ryhope North
Sunderland City Council

Analytical Report 8
Full Measures Survey
Autumn 2015

ch2m

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

Tel: +44 (0)121 456 2345
Fax: +44(0)121 456 1569
www.ch2m.com



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
Hendon to Ryhope South
Sunderland City Council

Analytical Report 8
Full Measures Survey
Autumn 2015

ch2m

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

Tel: +44 (0)121 456 2345
Fax: +44(0)121 456 1569
www.ch2m.com

3. Analysis of Survey Data

3.1 Whitburn Bay

Survey Date	Description of Changes Since Last Survey	Interpretation
Nov 2015	**Beach Profiles:** Whitburn Bay is covered by eleven beach profile lines for the Full Measures survey (Appendix A). The previous survey was the Partial Measures survey undertaken in March 2015 and the previous Full Measures survey was undertaken in October 2014. Profiles 1bSNN3 to 1bSNN4, 1bSNN7 and 1bSNN10 were last surveyed during the Partial Measures spring survey, 2015. Profiles 1bSNN2, 1bSNN5 to 1bSNN6, 1bSNN8 to 1bSNN9 and 1bSNN11 were last surveyed during the Full Measures autumn survey, 2014. **1bSNN1** is immediately south of Sunderland City Council's northern boundary. The profile is unchanged above HAT (40m chainage). Between 40m chainage and 90m chainage the level of the beach has fallen by up to 0.5m, eroding a berm that was present just below MHWS in the last survey. Between 90m chainage and the end of the profile at c.260m chainage the profile has accreted. Together these changes result in a smoother, gently concave profile. In the vicinity of this profile an outflow has incised a channel into the beach (see Plate 1). Overall the beach level is at medium-high levels compared to earlier surveys. Profiles **1bSNN2** and **1bSNN3** are located towards the north of Whitburn Bay and extend across scrubland before reaching the upper gravel foreshore and then dropping across the lower sandy foreshore towards the rocky outcrop of Whitburn Steel. At profile **1bSSN2**, the dune has remained stable since the last survey. Beach levels throughout the profile seaward of 80m chainage have increased by 0.3-0.5m, bringing the beach to its highest level on record, except for a very limited extent at the toe of the dunes. At **1bSNN3**, the dunes remain unchanged since the previous survey. The beach level between 50m chainage (above HAT, at the dune toe) and 220m chainage has increased by between 0.3 and 0.9m. In the lower part of the foreshore a berm which was present in the previous survey has been eroded	Most profiles in Whitburn bay have accreted since the previous survey. Exceptions are profile 1bSNN1 in the north of the bay, where erosion has occurred throughout a significant length of the profile, and 1bSNN8 and 1bSNN9 in the vicinity of Parsons Rocks where no change has occurred **Longer term trends:** All the profiles in Whitburn Bay are at medium to high levels compared earlier surveys in the record. The survey report notes some beach maintenance activities which may be the reason for this. Alternatively, it is possible that sediment has been naturally redistributed across the shoreface.

Survey Date	Description of Changes Since Last Survey	Interpretation
	by up to 0.4m. These changes have created a straighter beach profile. Overall the beach is near its highest level on record, except in the lower foreshore where it is at a medium level. Profiles **1bSNN4** to **1bSNN6** are between the shoreline opposite the southern edge of South Bents housing estate and Parsons Rock. At profile **1bSNN4**, beach levels have changed little (<0.2m) except where flow from an outfall has eroded the upper beach between HAT and MHWS (between 25m chainage and 50m chainage). Overall the beach is near its highest level on record except in the very lowest part of the foreshore. At profile **1bSNN5**, the beach profile has accreted throughout its length, with the maximum change being 0.3m in the upper beach. Overall the beach is at a high level compared to earlier surveys. At profile **1bSNN6**, beach levels have increased by a maximum of 0.5m at the toe of the seawall, which accretion gradually decreasing seaward of this until 140m chainage, beyond which change is minimal (<0.1m). An exception is between 14.5m and 19.5m chainage where the outflow of Cut Throat Dean has incised a 0.4m deep channel across the profile (see plate 2). Overall the beach is at a high level compared to earlier surveys. **1bSNN7** is at Seaburn, just to the north of Parson's Rocks. Beach levels between the seawall and 70m chainage have increased by up to 0.3m. Between 70m chainage and 140m chainage the beach level has fallen by <0.2m and changed little seaward of this. Overall the beach retains a smoothly convex form and is high compared to earlier surveys. Profile **1bSNN8** extends across Parsons Rocks. There are no discernible changes in this profile since the previous Full Measures survey. Profile **1bSNN9** drops from the cliff top to the foreshore at Roker. No discernible change has occurred at this profile since the previous Full Measures survey. **1bSNN10** is located approximately mid-way between Parson's Rocks and Roker Pier. A small berm present at MHWS in the previous survey between 20m and 30m chainage has been eroded. Seaward of this, however, the beach level has accreted, increasingly so towards the beach toe. Overall the beach here is now at a medium level compared to earlier surveys. **1bSNN11** is located to the south of Whitburn. The beach level between the seawall and 110m chainage has accreted by up to 0.3m, except for a short section of the profile between 30m chainage	

Survey Date	Description of Changes Since Last Survey	Interpretation
	and 40m chainage (HAT). Seaward of 130m chainage, the lower foreshore has accreted by up to 1.2m, extending the beach toe 20m seaward across the rocky lower foreshore. Except in the lowest extents of the foreshore, the beach is at high level throughout the profile.	
Nov 2015	**Topographic Survey:** Whitburn Bay, between the Bents and Roker Pier, is covered by an annual topographic survey which commenced in September 2009. Data from the most recent topographic survey (Full Measures, autumn 2015) have been used to create a digital ground model (DGM) (Appendix B – Map 1a) using GIS. A difference plot has also been produced using the DGM (Appendix B – Map 1b) produced from the last produced topographic survey (Full Measures, autumn 2014) and the present survey. The majority of the beach appears to have accreted by up to 1m. Exceptions include the far north of the bay towards Whitburn Village, the lower foreshore to the south of Whitburn Steel rocks, the upper beach and foreshore immediately south of Parson's Rocks and the beach landward of Roker Rocks, The accretion is most intense (>1m) in the lower foreshore just to the north of Roker Rocks and in the upper foreshore in front of South Bents. **Longer Term Topographic Trends Autumn 2009 to Autumn 2015:** The long term difference plot (Appendix B – Map 1c) shows the net change in beach levels between autumn 2010 and autumn 2015. North of Parson's Rocks the picture is almost exclusively one of accretion except for some very limited patches of erosion associated with scour around the outfall at Queen's Parade and berm erosion in the upper beach. South of Parson's Rocks, erosion is much more dominant with the most intense erosion between Parson's Rocks and Roker Rocks, with accretion more dominant immediately north of Roker Pier.	The topographic survey shows that since the last survey, there has been a mixture of change on the beach. There is a general trend for movement of sediment to the south from the headlands (White Steel, Whitburn Steel and Parson's Rocks) to the centre of the bays. Notable areas of change also include scour around the outfall at Queen's Parade. **Longer term topographic trends Autumn 2009 to Autumn 2015:** The plot shows a general pattern of accretion north of Parson's Rocks and erosion to the south. This pattern of northwards sediment movement may, in part, be due to on-going beach maintenance.

Plate 1 - Survey photograph 1bSNN1_20151114_Up 1

Plate 2 – Survey photograph 1bSNN6_2015112_N4

3.2 Sunderland Harbour and Docks

Survey Date	Description of Changes Since Last Survey	Interpretation
Nov 2015	**Beach Profiles:** Sunderland Harbour and Docks is covered by eleven beach profile lines (Appendix A), all surveyed annually. The previous survey was the Full Measures survey undertaken in autumn 2014. **1bSNN12** and **1bSNN13** are both located within the shelter of Roker Pier. At profile **1bSNN12**, there has been a variable amount of accretion throughout the profile. A gravel berm has formed around HAT (between 50m and 60m chainage) through the accretion of 0.4m of gravel and sand. Seaward of here, accretion of up to 0.5m has occurred to create a smoother concave profile in the foreshore. Above HAT the beach is at a high level, the upper foreshore is relatively low and the lower foreshore is relatively high compared to earlier surveys. At **1bSNN13**, beach levels have increased by up to 0.25m between the toe of the rock revetment and 70m chainage, and fallen by a similar amount seaward of this. The beach is high compared to earlier surveys. **1bSNC1** and **1bSNC2** are located within the shelter of New South Pier. Profile **1bSNC1** starts at the seaward edge of the dock building and extends across an earth mound before reaching the stepped landward face of the dock wall. The profile then drops from the wall crest directly into deep water. As there is no beach present profile 1bSNC1 has not been analysed. Profile **1bSNC2** starts at the crest of New South Pier and drops several metres to foreshore level. The beach level has fallen between the toe of the seawall and 30m chainage by up to 0.3m, eroding a berm that was present here in the earlier survey. Seaward of this, the beach level has increased by up to 0.4m as far as 105m chainage, seaward of which the beach toe appears to have retreated landward. Overall the beach level is relatively high compared to earlier surveys. **1bSNC3** to **1bSNC6** are on the seaward face of the dock. Profile **1bSNC3** extends from the dock yard across a back flood wall, which has a crest level of around 7.2mOD, and promenade to the main seaward dock wall, which has a crest level of 7.55mOD.	Within the breakwaters north of the River Wear, beach trends vary with cross-shore movement of material at profile 1bSNN12 and beach accretion at profile 1bSNN13. Between the breakwaters, the level of the upper foreshore has fallen and the lower foreshore level has increased, indicating a cross-shore movement of sediment. Outside of the breakwaters the north and central parts of the beach remain high and the south remains low and there has been redistribution of sediment towards the south. Within the breakwaters either side of the former South Outlet of the docks there has been very limited change, the most noticeable change being the addition of new spoil to the top of the harbour arm in profile 1bSNC8. **Longer term trends:** Within the breakwaters to the north and south of the River Wear, the beach levels are high compared to earlier surveys. Outside of the harbour breakwaters despite the redistribution of the some sand from the north of the embayment to south of the embayment, the northerly and central profiles (1bSNC4 and 1bSNC5) remain high compared to earlier surveys and the more southerly profile, 1bSNC6, remains low.

Survey Date	Description of Changes Since Last Survey	Interpretation
	The profile then extends down the seaward face of the wall into deep water. As there is no beach, profile 1bSNC3 has not been analysed. Profiles **1bSNC4** and **1bSNC5** extend from the rock armoured revetment across the short width of foreshore down to low water. At profile **1bSNC4**, beach levels have fallen by up to 0.9m, The profile has straightened slightly but retains a similar overall gradient to that seen in the last survey. The beach is at a medium-high level compared to earlier surveys. At profile **1bSNC5**, beach levels seaward of the revetment have increased by up to 1m throughout the beach profile, with no change in beach form other than to bury the seaward part of the rock revetment. The beach is at its highest level on record. **1bSNC6** extends across the revetment and seawall. The apparent change between 2m and 5m chainage is likely an artefact of the detailed placement of survey points around the broken boulder size fragments of seawall on the upper beach. Seaward of this the beach level has increased by 0.4m, increasing to 0.5m in the lower foreshore, but still remains relatively low compared to earlier surveys. **1bSNC7** to **1bSNC9** are within the shelter of North East Pier and South West Breakwater in the former South Outlet, parts of which have been in-filled with tipped rubble. **1bSNC7** is a section across North East Pier. There has been no discernible change in the overall profile. Small apparent changes will be artefacts of the placement of survey points along the profile. Profile **1bSNC8** crosses the boulders and rubble, the maximum height of which has increased from c.6.2m to c.8m through the addition of new material (see Plate 3). Otherwise there is no discernible change to the profile. Profile **1bSNC9** extends from the dock facilities and crosses a short length of concrete wall and sheetpiling before extending across the sand and gravel backshore, and foreshore to reach and cross a boulder mound that is towards the seaward end of the south west breakwater. The profile generally remains unchanged except for a small amount (<0.3m) of erosion on the landward side of the berm above HAT and the migration of a small berm crest up the beach from just above MHWS to just above HAT. There has also been minor (<0.1m) deposition in the foreshore 'trough' between the beach face and the rubble mound. The profile remains high relative to earlier surveys.	Within the breakwaters either side of the former South Outlet of the docks, long term change is small at 1bSNC7 and 1bSNC8, except for the addition of new rubble at profile 1bSNC8 well above HAT. At profile 1bSNC9, beach levels throughout the profile are at or near their highest recorded levels since surveys began in October 2009.

Plate 3 – Survey photograph 1bSNC8_20151115_E1

3.3 Hendon to Ryhope (incl. Halliwell Banks)

Survey Date	Description of Changes Since Last Survey	Interpretation
Sept 2015	**Beach Profiles:** Hendon to Ryhope is covered by thirty six beach profile lines (Appendix A). Most profiles are measured annually, but profiles 1bSNS4, 1bSNS8, 1bSNS11, 1bSNS20 and 1bSNS26 to 1bSNS32 are surveyed every 6 months. The previous Full Measures survey was undertaken in autumn 2014 and the previous Partial Measures survey was undertaken in spring 2015. **1bSNS1** to **1bSNS6** are located along the sea wall protecting the Hendon Sewage Treatment Works. The profiles typically include a section along the concrete deck, wall crest (which varies in elevation between around 7.0mOD in the north and 7.6mOD in the south after the dog-leg in the wall position), near-vertical seaward face of the wall, and sloping rock armour revetment. The form of the profiles at **1bSNS1**, **1bSNS2**, and **1bSNS3** are defined by a seawall, a small section of fine rubble and rock revetment foreshore. The survey data is varied each year due to the precise part of the boulders that are surveyed, but as no beach has yet developed on the foreshore the profiles have not been analysed. Profiles **1bSNS4, 1bSNS5** and **1bSNS6** drop directly from the structure into deep water and have not been analysed. **1bSNS7** to **1bSNS10** are located along the defended coastal slopes along south Hendon, which rise in elevation to higher defended cliffs at **1bSNS11**. Profile **1bSNS7** extends across a seawall and concrete revetment, which is fronted by a foreshore comprised of large pebbles and coarse shingle. Since the previous survey the gravel that had accumulated at the toe of the sea wall has reduced in elevation by 0.6m and some of it has been deposited slightly further seaward between 27m and 35m chainage. This change has exposed a line of sheetpiling c.2m from the toe of the seawall (see Plate 4). The beach level is very low compared to earlier surveys. Profile **1bSNS8** extends across the seawall, rock revetment and beach. Gravel has accreted at the toe of the revetment raising the beach elevation by 0.2m as far as 40m chainage, burying the most seaward blocks (see Plate 5). Between 40m chainage and 70m chainage the beach level has fallen by	Along the length of south Hendon, profiles 1bSNS7 to 1bSNS10 have shown falls but remain relatively high compared to earlier surveys. At 1bSNS11, the beach has accreted, indicating a possible southward movement of sediment in the bay. At Grangetown (south Hendon to Salterfen Rocks), many of the profiles show erosion of talus at the cliff toe. Beach level changes are limited but show a tendency for drawdown of material from the upper beach to the foreshore. Between Salterfen Rocks and the landfill at Halliwell banks (profiles 1bSNS20 to 1bSNS25), the cliff has remained stable since the last survey. Beaches show a tendency for sediment to move towards the north and offshore, with accretion in the north of the coast and at the lower beach and erosion further south and on the upper beach. Very little change has occurred at the landfill site (1bSNS26 to 1bSNS32) except for variation in the size of the shingle berm at the cliff toe which has accreted at some profiles and eroded at others, indicating dynamic sediment movement in response to storms. To the south of Halliwell Banks, around Pincushion, the cliffs have generally retained the same form and position since the last survey. At profile 1bSNS36, the cliff data suggests retreat of by c. 1.5m, but this is not shown in survey photographs and is therefore

Survey Date	Description of Changes Since Last Survey	Interpretation
	up to 0.3m, but is unchanged seaward of this. Overall the beach is at a high level compared to earlier surveys. At profile **1bSNS9**, beach levels remain unchanged except for a small fall (up to 0.2m) at the toe of the revetment. Overall the beach level remains high compared to earlier surveys. At profile **1bSNS10**, beach levels have fallen throughout the profile by up to 0.5m. This has exposed the toe of the rock revetment c.3m further seaward than in the previous survey. The landward part of the beach profile is low compared to earlier surveys, but is at medium levels further seaward. At profile **1bSNS11**, the cliffs have remained stable since the last survey. Beach levels have increased across the profile, by up to 0.7m between the toe of the sea defences and 75m chainage. Overall the beach is at a medium level compared to earlier surveys. **1bSNS12** to **1bSNS36** are located along the undefended cliffs between Grangetown and Ryhope Dene. Profiles **SNS12** to **SNS19** are between the end of the Hendon sea wall and Salterfen Rocks. Cliff top levels are typically between 20m and 22mOD. They are highest along the profiles further north, dropping in the centre and then increasing again to the south. Profile **1bSNS12** extends from the cliff across the boulder foreshore. There is apparent retreat of the toe of the cliff in the survey profile, but this is likely to be a data artefact due to interpolation between limited data points. Otherwise the profile is unchanged. At profile **1bSNS13**, the majority of the cliff face has not changed in form since the previous survey. However, a talus deposit at the toe of the cliff present in the previous (Full Measures, autumn 2014) survey, has been eroded to re-expose the bedrock cliff toe. Beach levels have fallen by up to 0.3m between the cliff toe and 50m chainage, removing the gravel cover and exposing coarser material. Seaward of 65m chainage, the level of the lower foreshore has increased by up to 0.8m covering the rocks and shore platform which were exposed at the time of the previous survey. The beach profile is at a high level compared to earlier surveys and the cliff top has receded 4m since 2009. At profile **1bSNS14**, the cliff top position has not changed since the previous survey. The toe of the cliff has retreated 5m landward due to the erosion of a talus deposit present in the previous survey. Beach levels have remained stable across the profile with no discernible pattern. The cliff top has retreated 3m since 2009.	considered to be survey error. Beach levels in the lower foreshore have increased since the previous survey. **Longer term trends:** Along the length of south Hendon, beach levels in the north are generally near their highest, and are lower further south. At Grangetown (south Hendon to Salterfen Rocks), the cliff top position has not changed substantially compared to the last survey, but since 2009 the cliff tops have receded several metres at some locations. Despite the most recent survey periods showing limited change at the cliff top, there has been erosion of the talus deposits at the cliff toe, indicating that the in-situ bedrock will once again be exposed to wave action and therefore more liable to undercutting and subsequent cliff retreat. Between Salterfen Rocks and the landfill at Halliwell banks (profiles 1bSNS20 to 1bSNS25), the cliff has generally remained stable and beach levels are relatively low in the upper beach and high in the foreshore. At the landfill site (profiles 1bSSN26 to 1bSSN32), the cliff position and beach levels are within the bounds of previous surveys. To the south of Halliwell Banks, at profiles 1bSNS33 and 1bSNS35, cliff and beach are within the bounds of previous surveys.

Survey Date	Description of Changes Since Last Survey	Interpretation
	At profile **1bSNS15**, the cliff top has remained stable, however, as at profile 1bSNS14 the cliff toe has eroded by c.5m. Beach levels have increased by approximately 0.4m along profile the as far as the rocky outcrop which extends seaward from c.82m chainage. Seaward of 82m chainage there has been little change, other than the possible accumulation of a thin veneer of sand seaward of 130m chainage. The beach is at a medium level compared to earlier surveys. The cliff top has receded c.3m since 2009. At profile **1bSNS16**, the cliff face and rocky foreshore of the Salterfen Rocks headland have remained stable and there have been no discernible changes to beach levels since the last survey (autumn 2014). The cliff top has receded 5m since 2009 but the cliff toe has only receded c.2m over the same period. Survey photos indicate this may be to do with the variable erosivity of the sandy upper cliff and more clay rich (glacial till) lower cliff. Profiles **1bSNS17** to **1bSNS36** extend between Salterfen Rocks and Ryhope Dean/Pincushion Rocks along Shirley Banks and Halliwell Banks. Profiles between 1bSNS17 and 1bSNS25 typically exhibit a characteristic cliff height of between 23m and 29mOD, with beaches at the toe typically at levels between 3.1m and 4.6mOD. At **1bSNS17**, the profile shows the cliff toe to have receded by approximately 0.5m. Across the foreshore there are no discernible changes. At **1bSNS18**, the profile shows the cliff toe to have retreated c.2m since the last survey. Beach levels from the cliff toe to 66m chainage have decreased by approximately 0.2m, and increased by up to 0.5m seaward of there, increasing the thickness of sand covering the underlying rocky foreshore. It is possible that beach material has been drawn-down across the beach. The upper beach is low compared to previous surveys and the foreshore is high. There has been no change in the cliff top position since surveys began. At **1bSNS19**, the cliff toe has retreated c.1m, which may relate to erosion of a talus or access problems. The rocky foreshore remains unchanged, although a veneer of sand has been deposited on the shore platform seaward of 120m chainage between the more prominent rocks, bringing the foreshore to its highest level on record. The cliff top has receded 0.5m since 2009. At profile **1bSNS20**, the cliff toe has receded by approximately 1m, likely due to erosion of talus at the cliff toe. Beach levels have fallen throughout the profile, lowering the upper gravel beach by c.0.3m	

Survey Date	Description of Changes Since Last Survey	Interpretation
	and removing the veneer of sand, present in the previous survey, from the rocky shore platform in the foreshore between 70m chainage and 135m chainage. Seward of this there is sand present in the lowest part of the foreshore. The cliff top has receded c.1m since 2009. At **1bSNS21**, the cliff has generally remained stable since the last survey. Beach levels have fallen by up to 0.6m in the upper foreshore, exposing cobbles and the rocky shore platform which had previously been covered by a veneer of sand. There has been little change in the lower part of foreshore seaward of 90m chainage. At profile **1bSNS22**, the cliff has generally remained stable since the last survey. Low points between more prominent parts of the shore platform have infilled with up to 0.3m of sand, otherwise the shore platform remains unchanged. At profile **1bSNS23**, the cliff has generally remained stable since the last survey. Beach levels remain unchanged from the previous survey in landward of 80m chainage. Seaward of this the level of the foreshore has fallen by up to 0.4m since the last survey. The upper beach is low compared to earlier surveys and the foreshore is high. At **1bSNS24**, the cliff top has remained stable, but the toe has retreated a further 3m. This represents ongoing erosion of debris deposited by an earlier landslide. The level of the upper beach has fallen by up to 1.2m, eroding a gravel berm that was present in the previous survey. Seaward of 95m chainage, the foreshore has accreted by up to 0.5m. The upper beach is low compared to earlier surveys and the foreshore is relatively high. At profile **1bSNS25**, there has been no change to the cliff face. The gravel berm at the cliff toe has accreted by up to 0.8m, pushing the berm crest slightly seaward. Limited change (<0.1m) has occurred between 60m chainage and 75m chainage. Between 75m chainage and 90m chainage the beach level has fallen by up to 0.5m to expose a more landward portion of the shore platform. However, a similar amount of accretion has occurred in the lowest part of the foreshore seaward of 105m chainage to form a low berm. The upper beach is at a medium level and the foreshore is relatively high. Profiles **1bSNS26** to **1bSNS32** are located at Halliwell Banks specifically to assess risks from erosion at a former land fill. Cliff height is between 26m and 27mOD, with beaches at the toe typically at levels between 3.3m and 3.9mODN. Profiles**1bSNS26** to **1bSNS32**, have changed little since the last survey	

Survey Date	Description of Changes Since Last Survey	Interpretation
	other than accretion or erosion of the gravel berm at the toe of the cliff indicating movement of gravel between the profiles. All profiles are at medium to low levels in the upper beach and high levels in the lower foreshore indicating a drawdown of sediment from the upper beach. Profiles **1bSNS33** to **1bSNS36** are located around the Pincushion Headland. The cliffs have generally retained the same form and position since the last survey. Exceptions include the accumulation of shingle berms against the cliff toe at 1bSNS33 and 1bSNS36, and apparent retreat of the whole cliff face by 1.5m at 1bSNS36. However, this seems unlikely from the photographs and may be an artefact of the survey data points.	
Sept 2015	**Topographic Survey:** Hendon to Ryhope is covered by an annual topographic survey between the Hendon Sea Wall and Ryhope Dene, which commenced in autumn 2009. Data from the most recent topographic survey (Full Measures, autumn 2015) have been used to create a DGM (Appendix B – Map 2a and Map 3a) using a GIS. A difference plot has also been produced using the DGM (Appendix B – Map 2b and Map 3b) produced from the last produced topographic survey (Full Measures, autumn 2014) and the present survey. From the northern end of the survey area at Hendon, down to the southern end of the sea defences erosion is dominant, particularly in the upper beach with there being some accretion in the lower foreshore. This erosion is >1m at the back of the beach in the centre of this defended section. South of the defended section these is a more even balance between erosion and accretion, with the vast majority of beach level change being less than 1m except for small discontinuous patches of erosion >1m around the Salterfen Rocks headland. As in the more northerly defended section, erosion is concentrated towards the back of the beach and the accretion on the lower foreshore. **Longer Term Topographic Trends Autumn 2009 to Autumn 2015:** The trend indicated in the long term difference plot is very similar to that shown in the short term difference plot, with a near continuous band of erosion <1m at the back of the beach and commensurate accretion in the lower part of the foreshore.	The short term change plot indicates that there has been a pattern of sediment movement from the upper beach towards the lower foreshore but that change has been limited (<1m). **Longer term topographic trends Autumn 2009 to Autumn 2014:** The plot shows a similar pattern to the short term change plot indicating a seaward movement of sediment of moderate magnitude (<1m) from the back of the beach to the lower foreshore.

Survey Date	Description of Changes Since Last Survey	Interpretation
Sept 2015	**Cliff Top Survey:** Cliff top survey data collected between the baseline survey (spring 2009) and the present Full Measures survey (autumn 2015) is documented here. 32 ground control points (numbered 1-32) were established along the cliff top between Hendon and Ryhope in March 2009, with a further three (28A, 28B and 28C) added in September 2009. Note: the numbering of ground control points is not intended to correlate with that of the beach profile lines and reference should be made to Appendix B - Map 1 and Appendix B – Map 2 for the location of ground control points. Measurements are taken from each ground control point along a fixed bearing to the edge of the cliff top. These cliff top surveys are undertaken bi-annually and are intended to inform on erosion rates of the sea cliffs extending from the defended industrial areas at Hendon southwards along the undefended cliffs to Ryhope Dene. Appendix B – Table B1 provides results from the cliff top survey, showing the position from the ground control point to the edge of the cliff top along a defined bearing. Results show that since the Partial Measures (spring 2015) survey apparent erosion greater than the error has only occurred at five locations, where losses of between 0.2 and 3.1m has occurred. . Survey photographs indicate that the erosion of 0.2-0.3m recorded at GCPs 14, 24, 27 28C and 31 is real erosion, but at GCP 5 is most likely due to difficulty locating the true cliff edge due to its rounded nature in this defended section. Since surveys began in March 2009 (or September 2009 for 28A and 28B) erosion greater than the survey error has occurred at around 60% of the ground control points, where total losses are 11m (at location 27) at their greatest, and more typically less than 4m. The long-term erosion rates are up to 1.7m/yr (location 27), with up to 0.7m/yr being more typical.	Episodic and localised recession, which contributes to overall coastline retreat in the undefended parts of this coastline has continued over the most recent survey period, but is limited to only four profiles and ≤0.3m. **Longer term trends:** The data indicate that the fastest erosion since 2009 is concentrated in three broad sections; a) the northern part of the developing embayment between the southern extent of the sea defences and Salterfen Rocks, b) throughout the majority of Halliwell Banks and c) to the south of Pincushion rocks. Recession is least, as might be expected, along the defended sections and at the promontories of Salterfen Rocks and Pincushion Rocks.

Plate 4 – Survey photograph 1bSNS7_20150923_N5

Plate 5 – Survey photograph 1bSNS8_20150913_N7

4. Problems Encountered and Uncertainty in Analysis

Individual Profiles

The survey report notes that '*the bottom of sections* [1bSNS] *1, 2, 3, 4, 5 and 6 were unable to be surveyed, due to lack of access or dangerous conditions*'.

Topographic Survey

The survey report notes '*dense seaweed present in areas*' and '*JCB present on beach combing and moving sand and seaweed*' at Whitburn Bay.

Cliff Top Surveys

n/a

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

No changes are recommended at the present time.

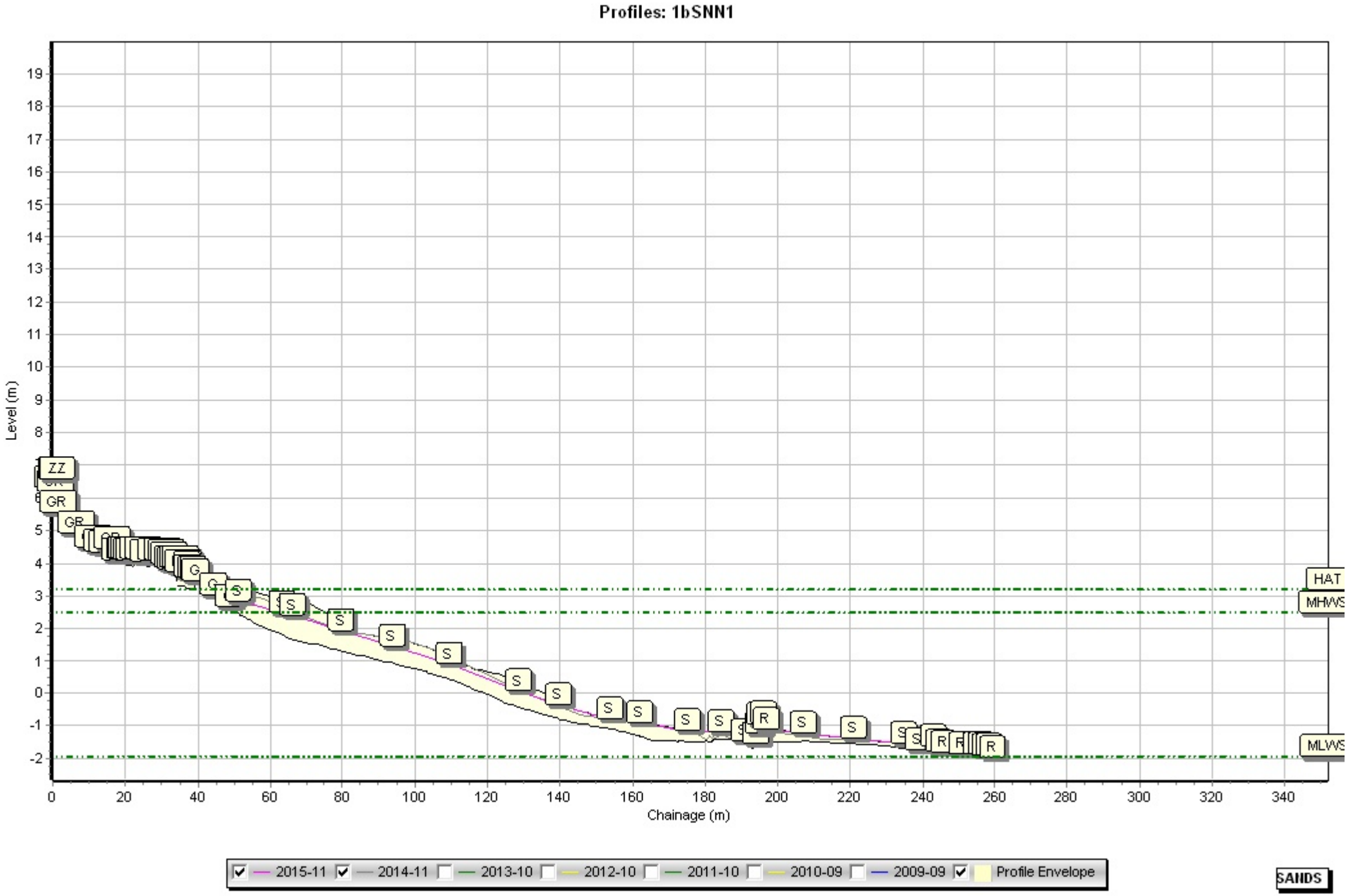
6. Conclusions and Areas of Concern

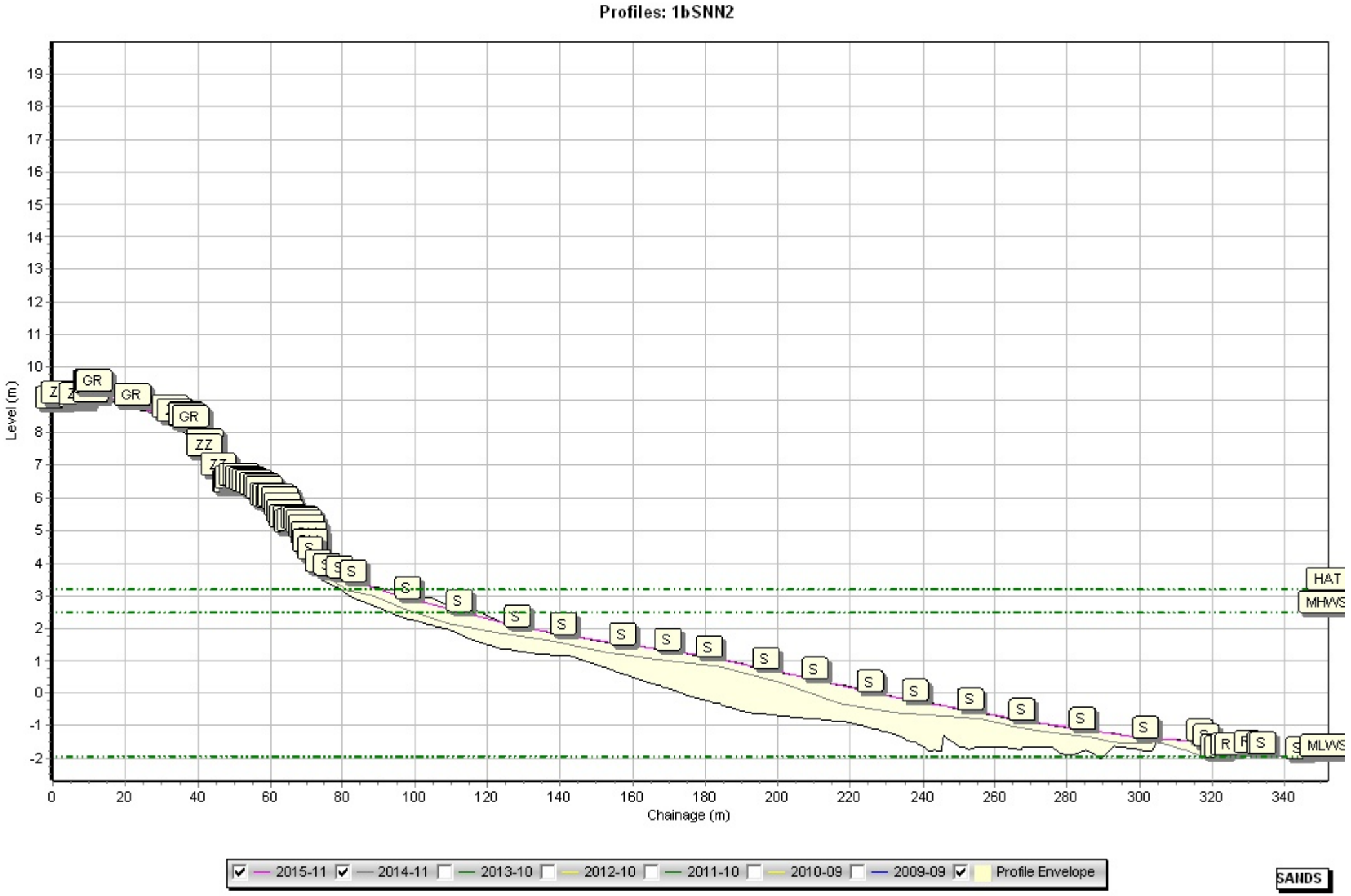
- At Whitburn Bay, the recorded profiles and topographic survey present no causes for concern.
- At Sunderland Harbour and Docks, the recorded profiles present no causes for concern.
- At Hendon to Ryhope (incl. Halliwell Banks), the recorded profiles, topographic survey and clifftop survey present no causes for concern. Ongoing cliff erosion is of a similar magnitude to previous surveys.

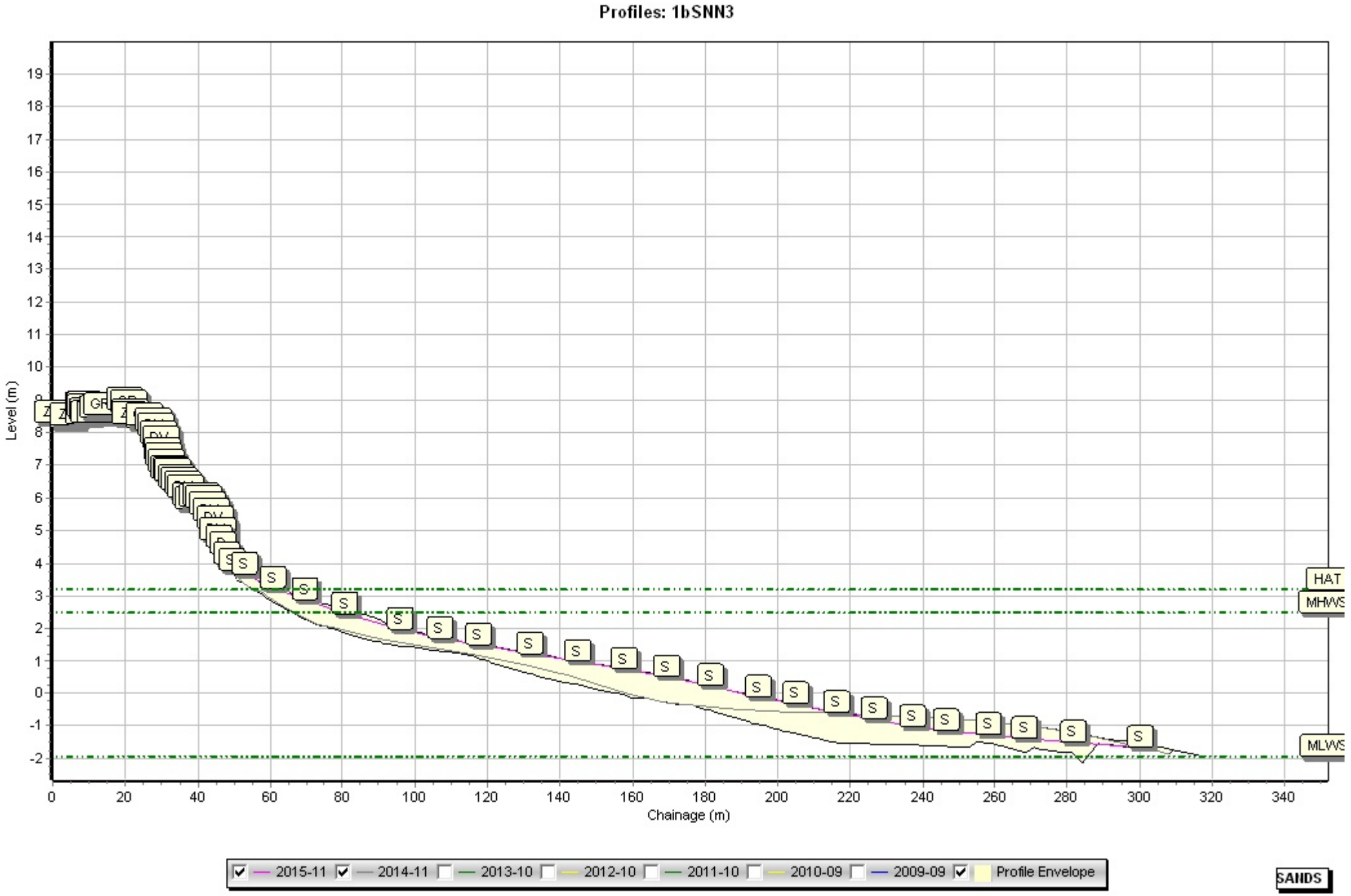
Appendices

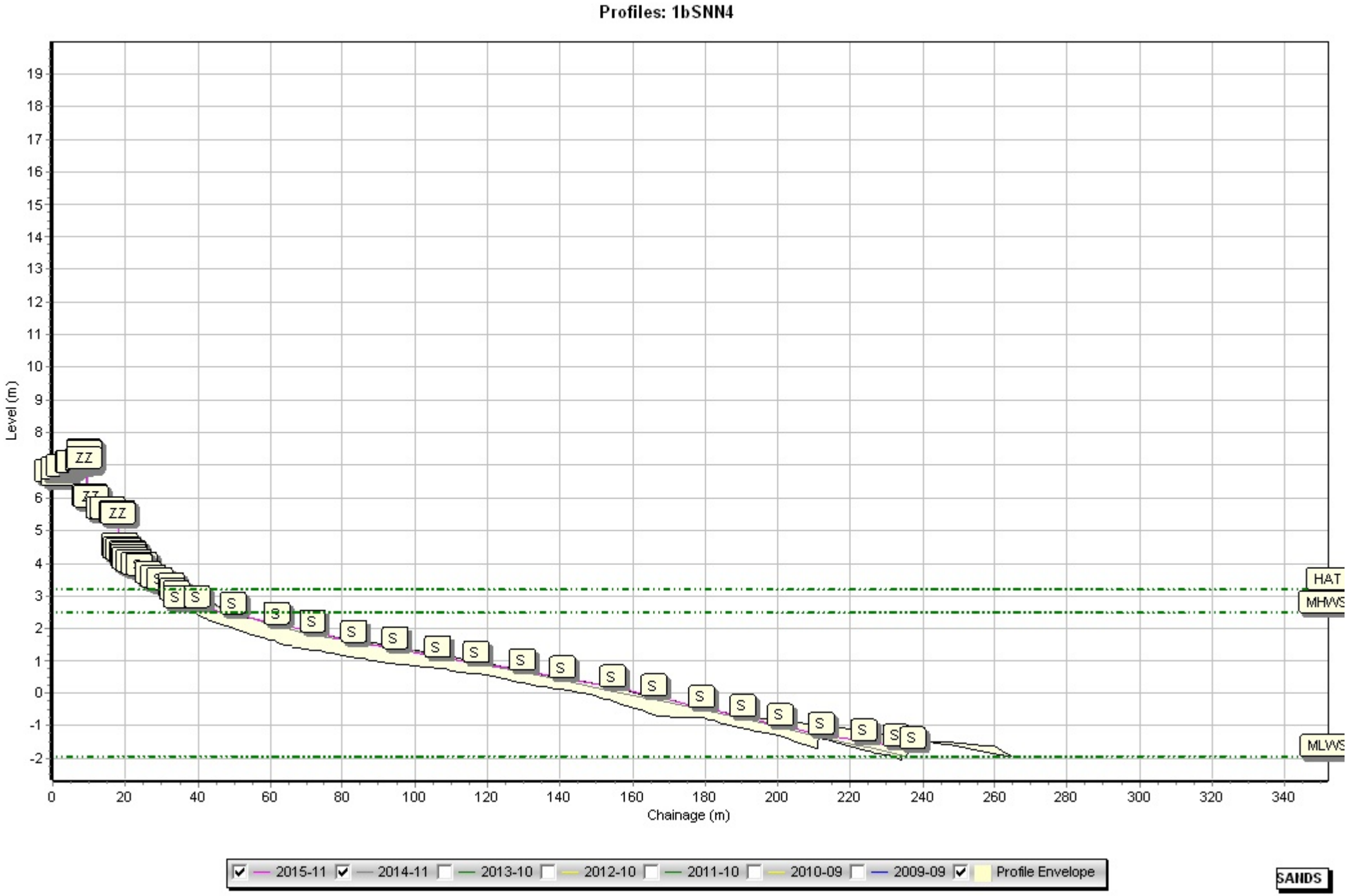
Appendix A

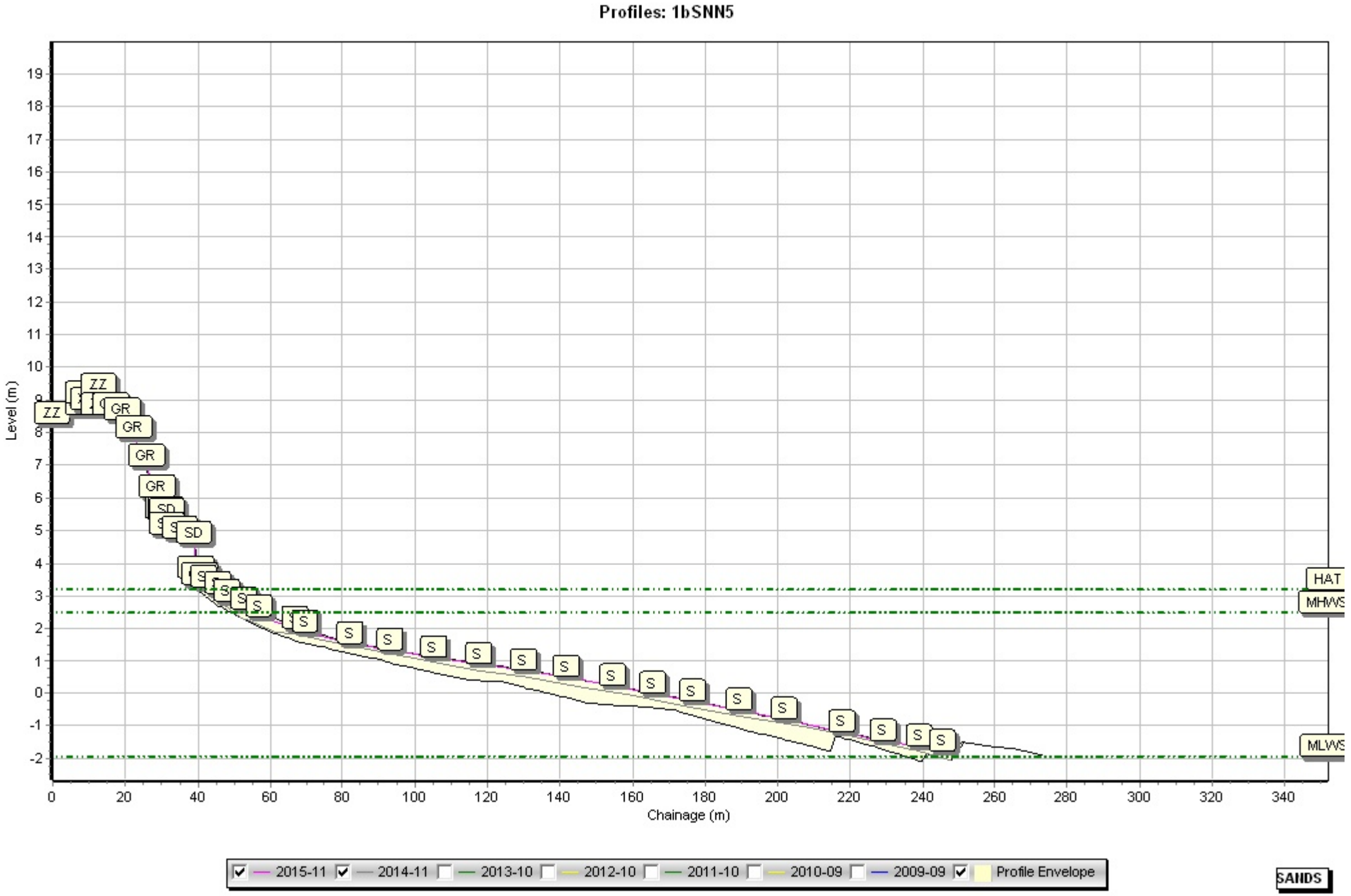
Beach Profiles

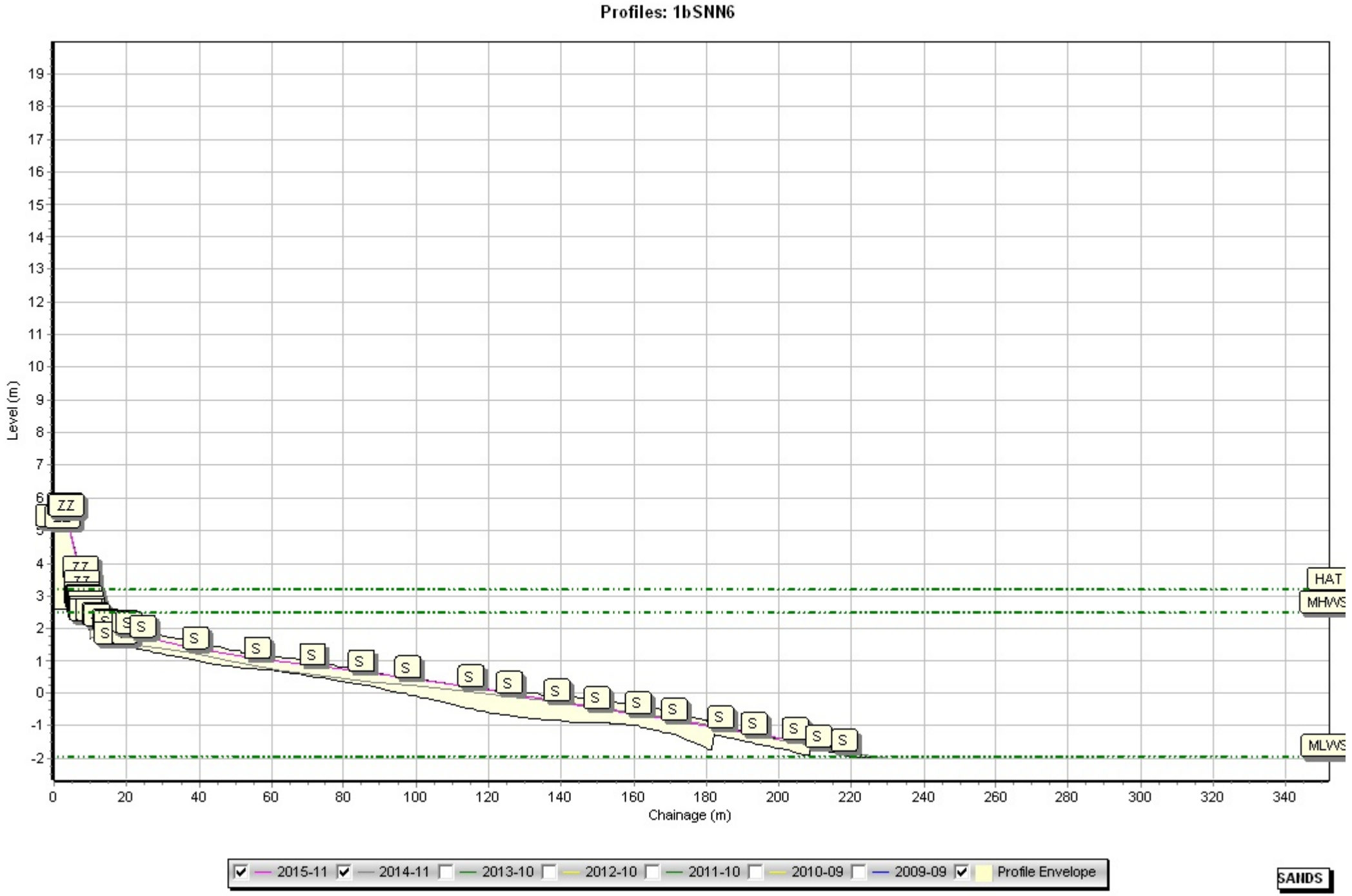

Profiles: 1bSNN1
Level (m)
Chainage (m)
HAT
MHWS
MLWS
2015-11
2014-11
2013-10
2012-10
2011-10
2010-09
2009-09
Profile Envelope
SANDS

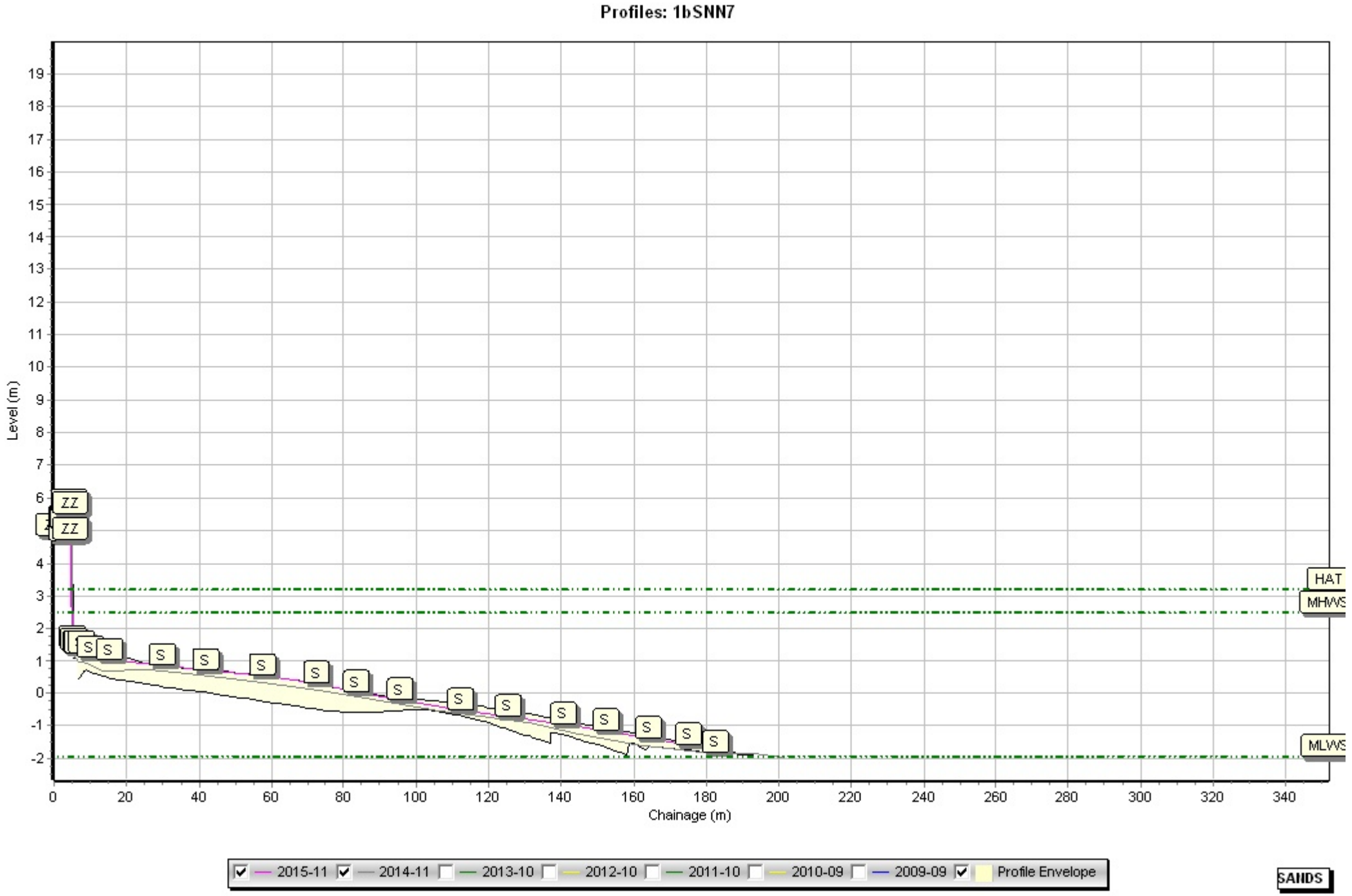

Profiles: 1bSNN2
Level (m)
Chainage (m)
GR
ZZ
S
R
HAT
MHWS
MLWS
2015-11
2014-11
2013-10
2012-10
2011-10
2010-09
2009-09
Profile Envelope
SANDS

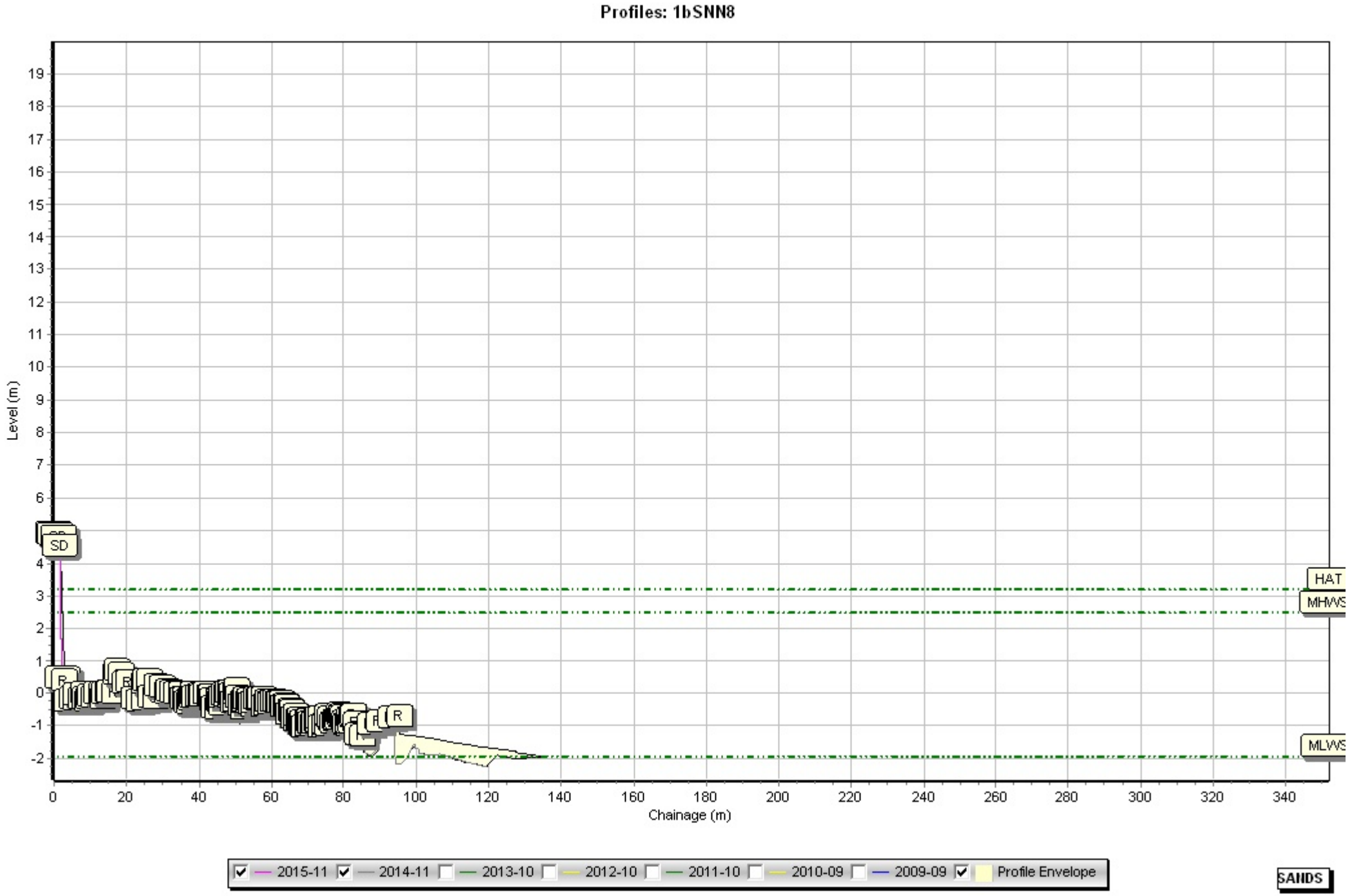

Profiles: 1bSNN3
Level (m)
Chainage (m)
HAT
MHWS
MLWS
2015-11
2014-11
2013-10
2012-10
2011-10
2010-09
2009-09
Profile Envelope
SANDS

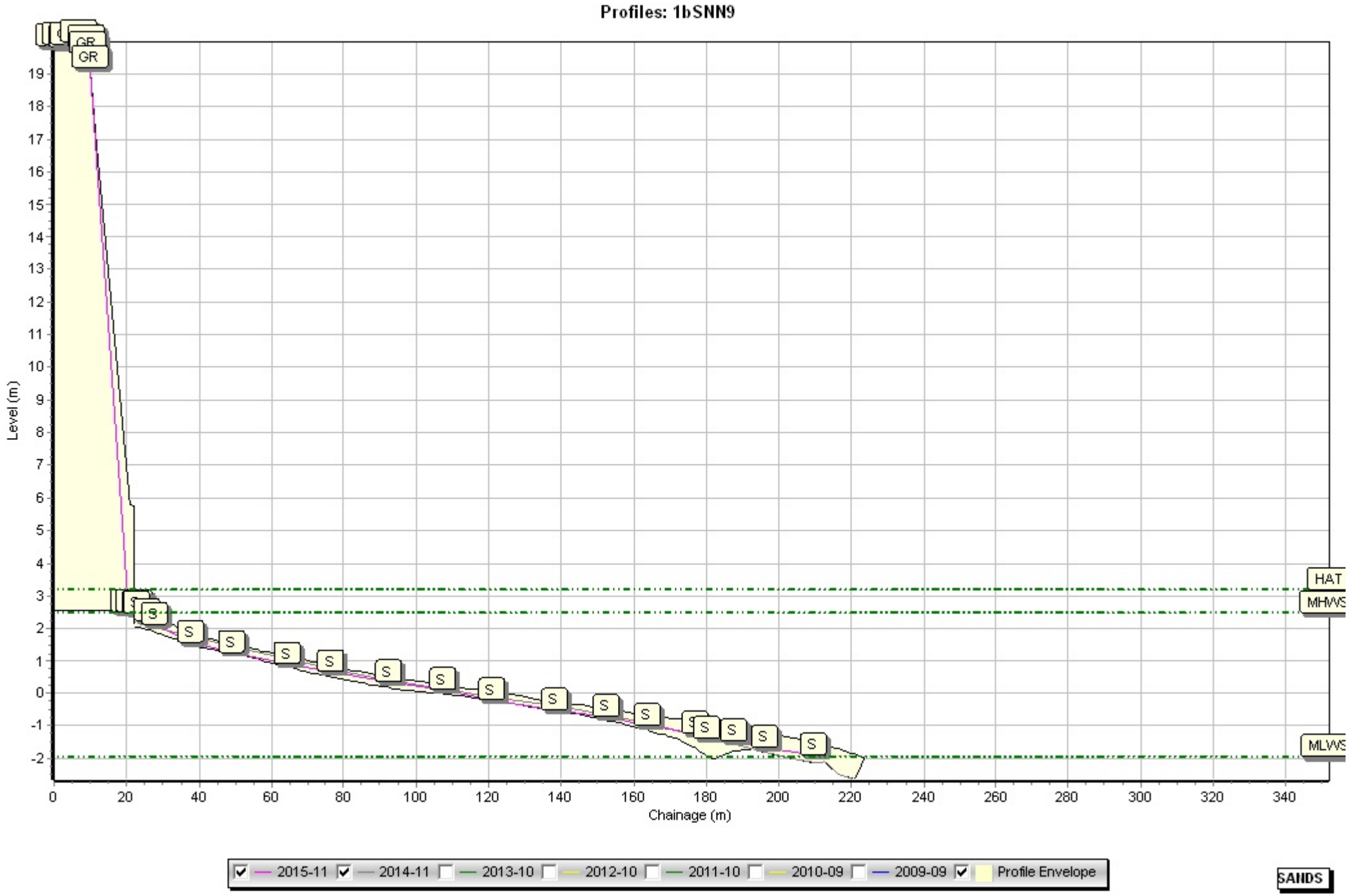

Profiles: 1bSNN4
Level (m)
Chainage (m)
HAT
MHWS
MLWS
2015-11
2014-11
2013-10
2012-10
2011-10
2010-09
2009-09
Profile Envelope
SANDS

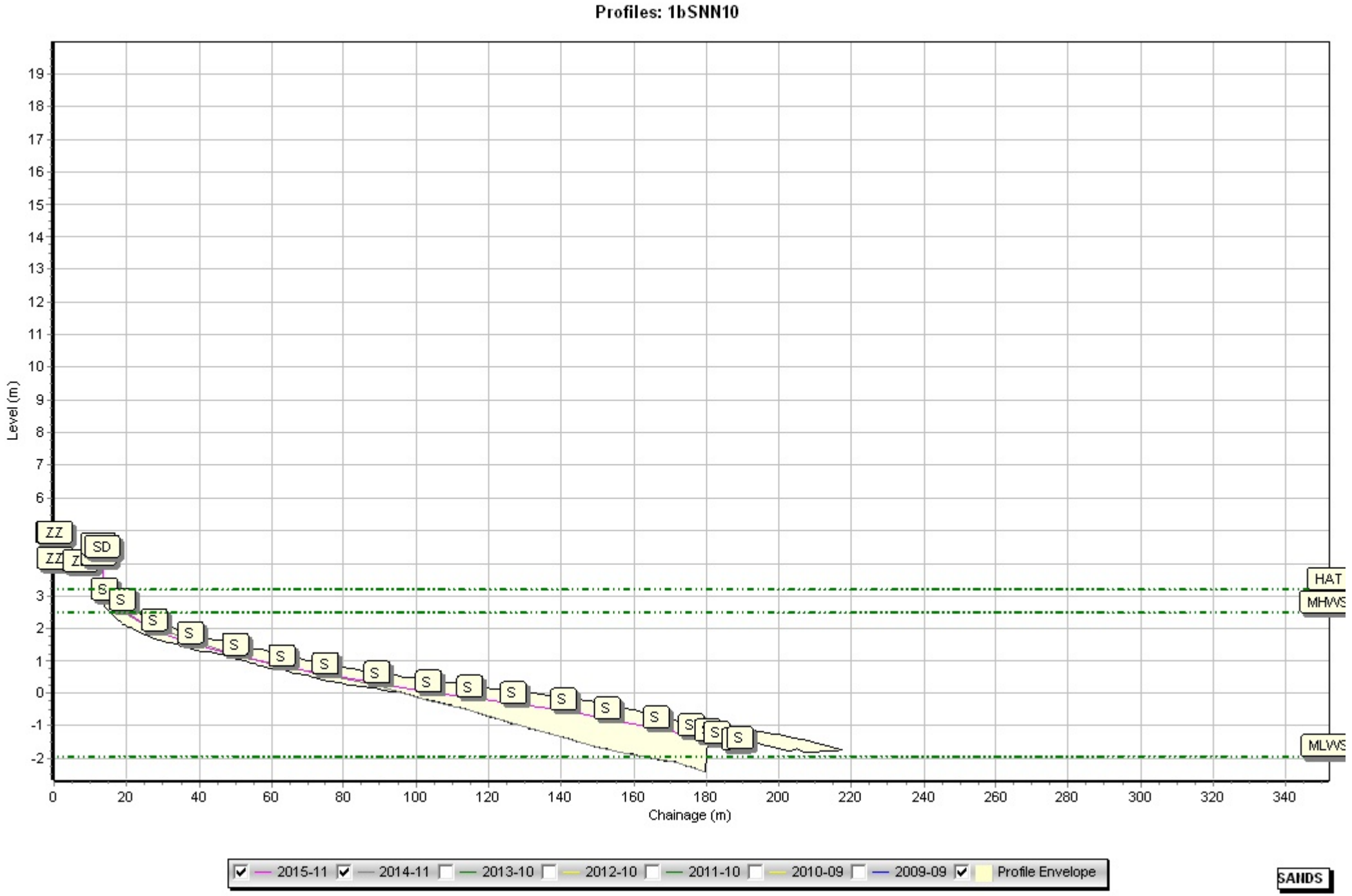

Profiles: 1bSNN5
Level (m)
Chainage (m)
HAT
MHWS
MLWS
2015-11
2014-11
2013-10
2012-10
2011-10
2010-09
2009-09
Profile Envelope
SANDS

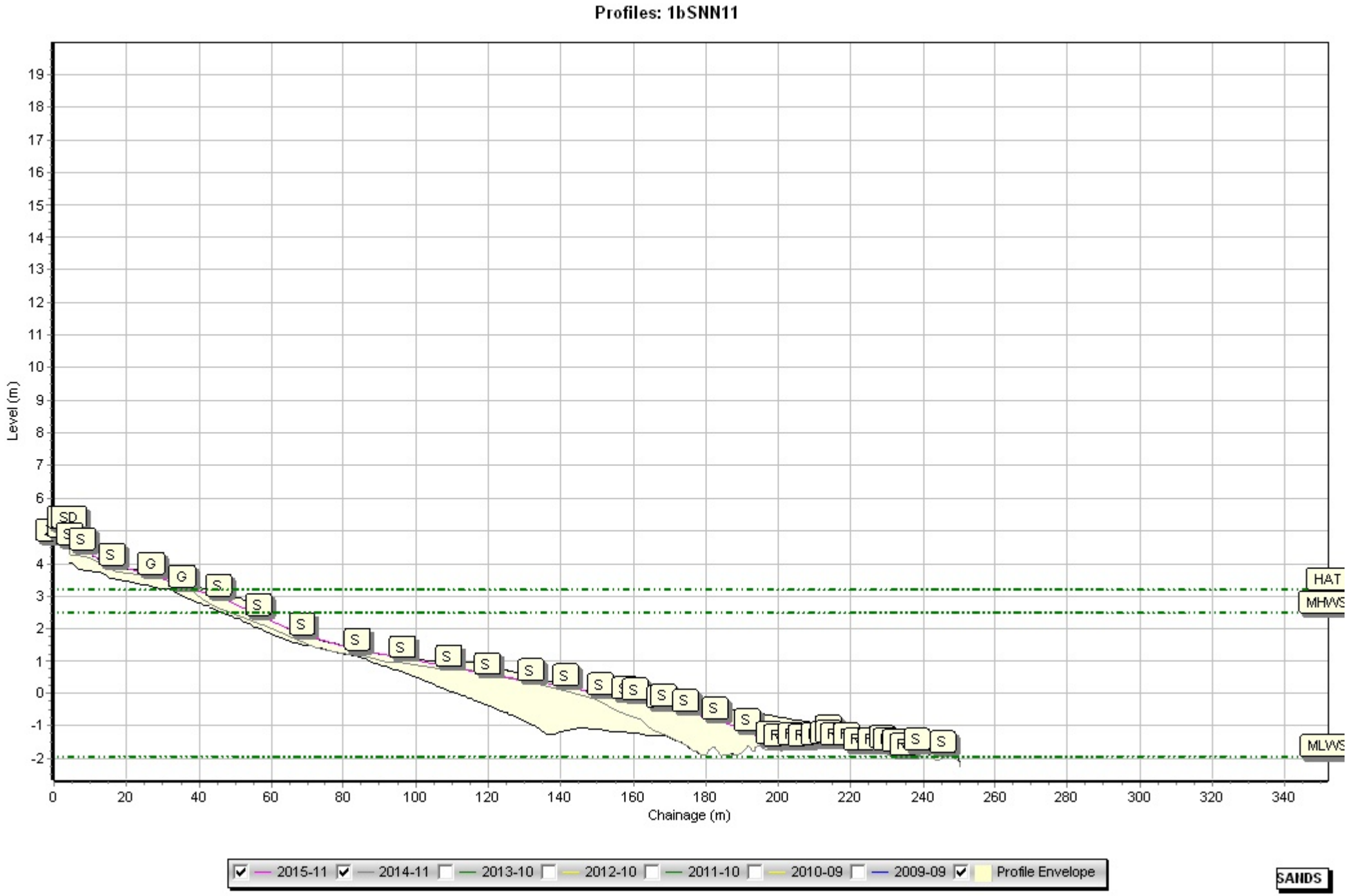

Profiles: 1bSNN6
Level (m)
Chainage (m)
HAT
MHWS
MLWS
2015-11
2014-11
2013-10
2012-10
2011-10
2010-09
2009-09
Profile Envelope
SANDS

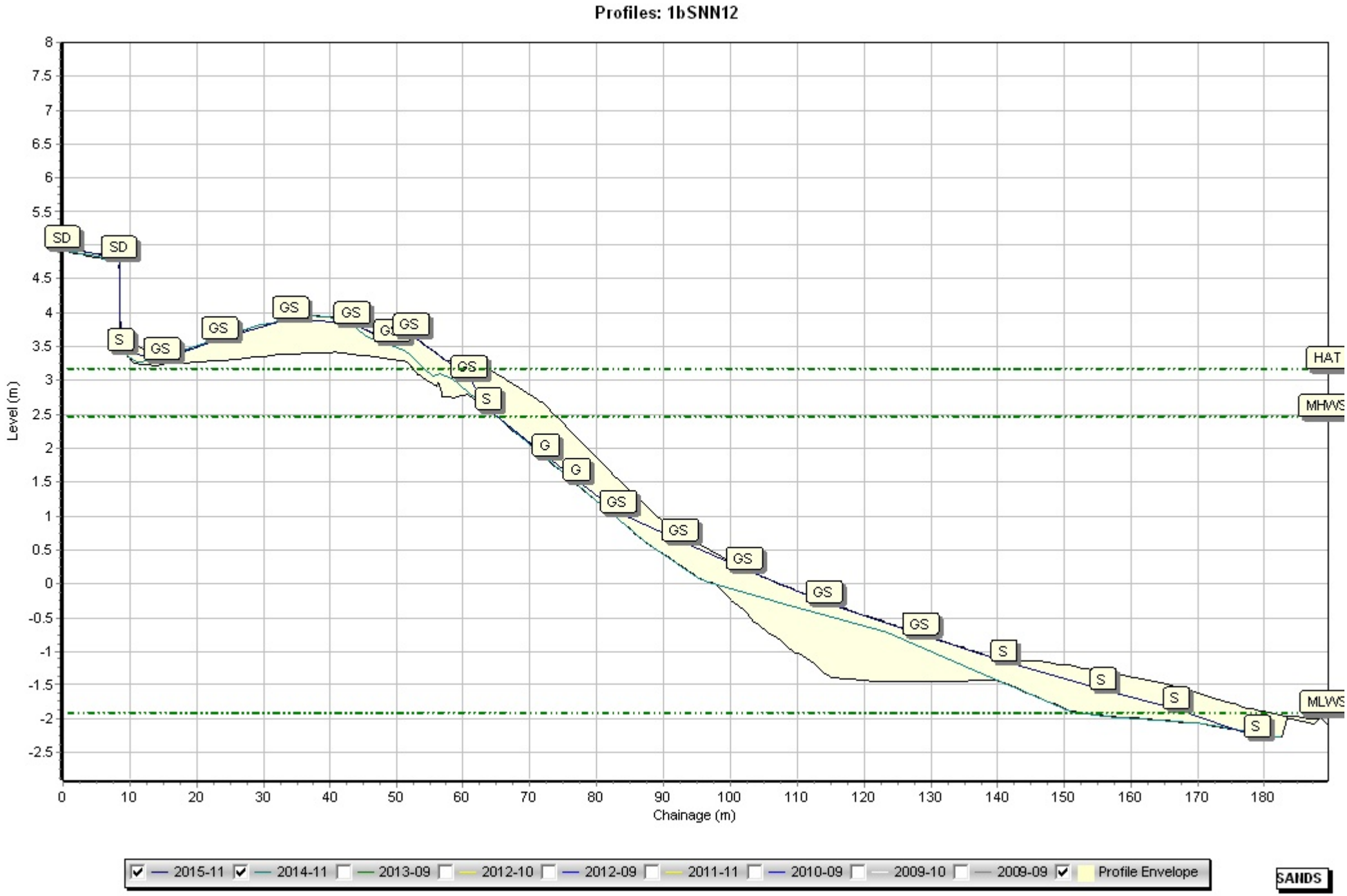

Profiles: 1bSNN7
Level (m)
Chainage (m)
ZZ
ZZ
S
HAT
MHWS
MLWS
2015-11
2014-11
2013-10
2012-10
2011-10
2010-09
2009-09
Profile Envelope
SANDS

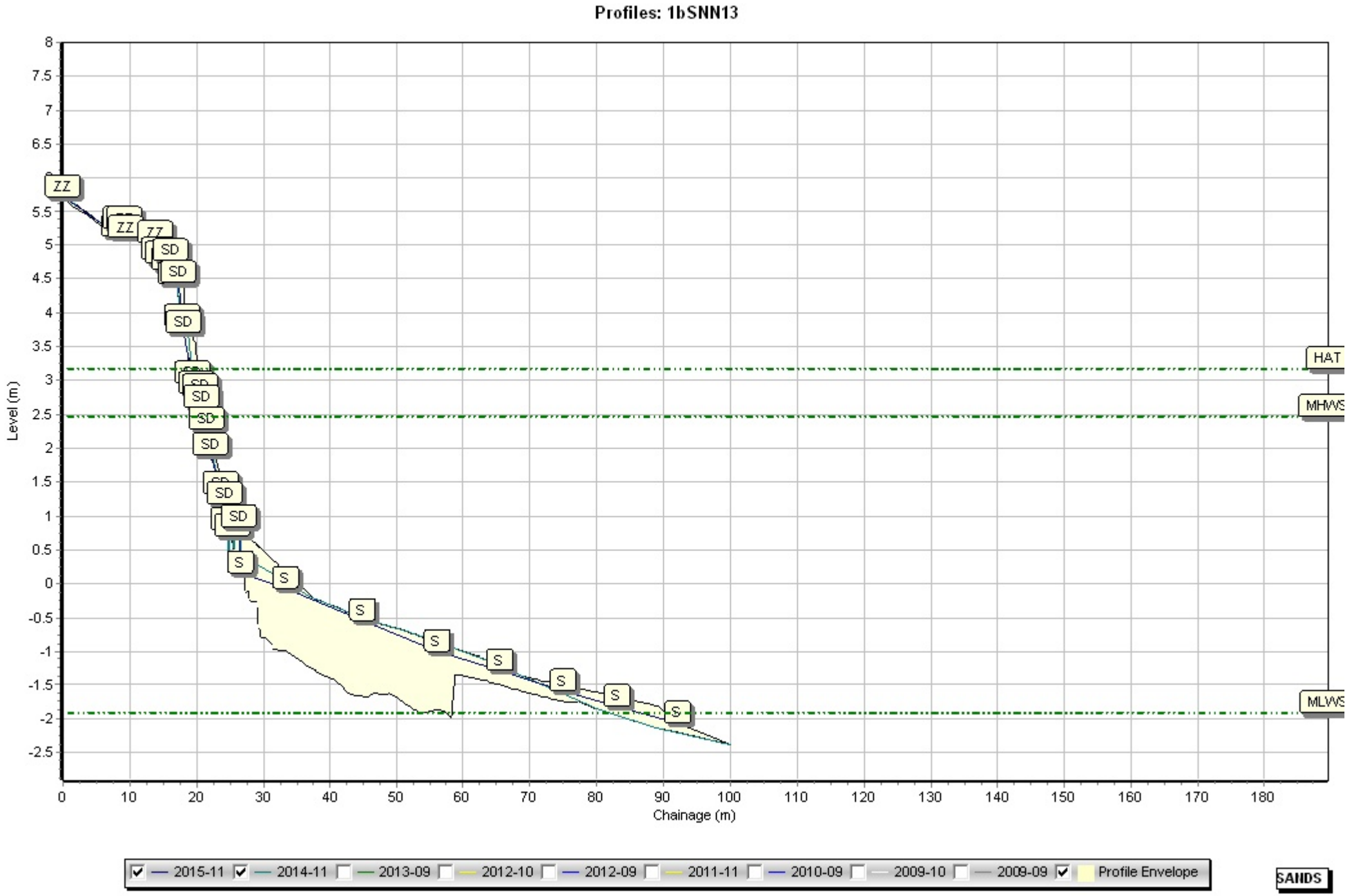

Profiles: 1bSNN8
Level (m)
Chainage (m)
SD
HAT
MHWS
MLWS
2015-11
2014-11
2013-10
2012-10
2011-10
2010-09
2009-09
Profile Envelope
SANDS

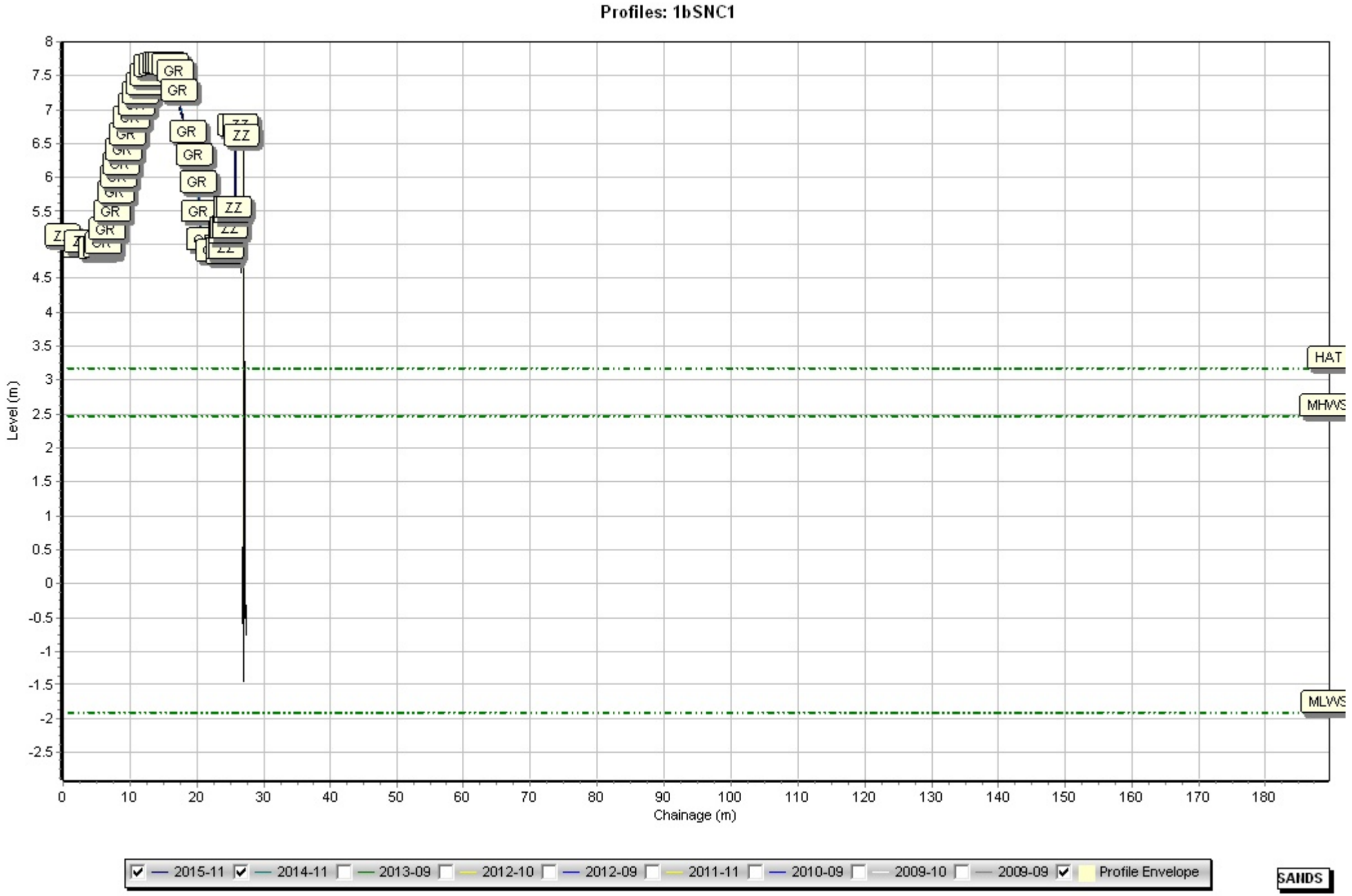

Profiles: 1bSNN9
GR
GR
HAT
MHWS
MLWS
S
Level (m)
Chainage (m)
0
20
40
60
80
100
120
140
160
180
200
220
240
260
280
300
320
340
19
18
17
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
0
-1
-2
2015-11
2014-11
2013-10
2012-10
2011-10
2010-09
2009-09
Profile Envelope
SANDS

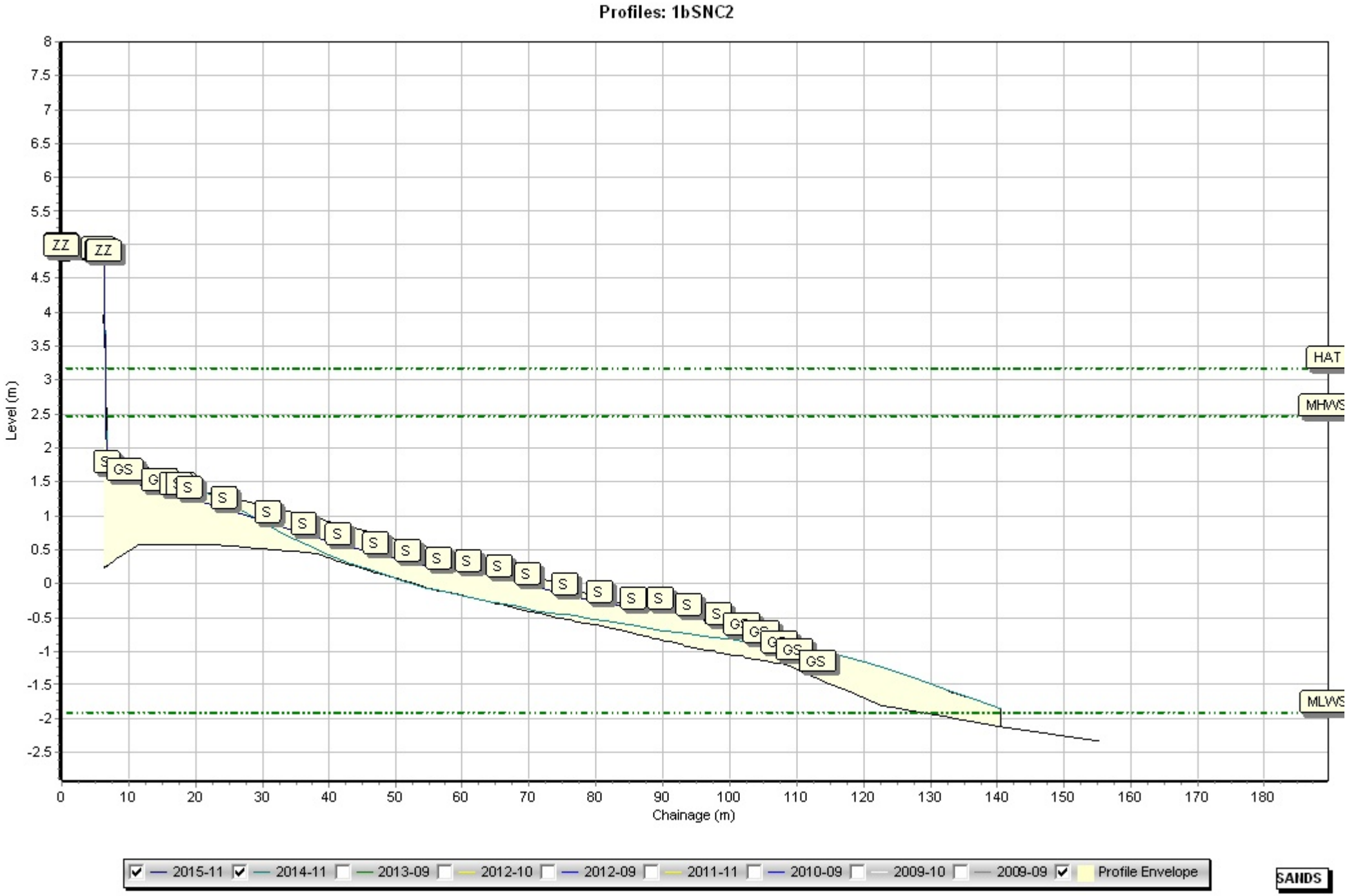

Profiles: 1bSNN10
Level (m)
Chainage (m)
ZZ
SD
S
HAT
MHWS
MLWS
2015-11
2014-11
2013-10
2012-10
2011-10
2010-09
2009-09
Profile Envelope
SANDS

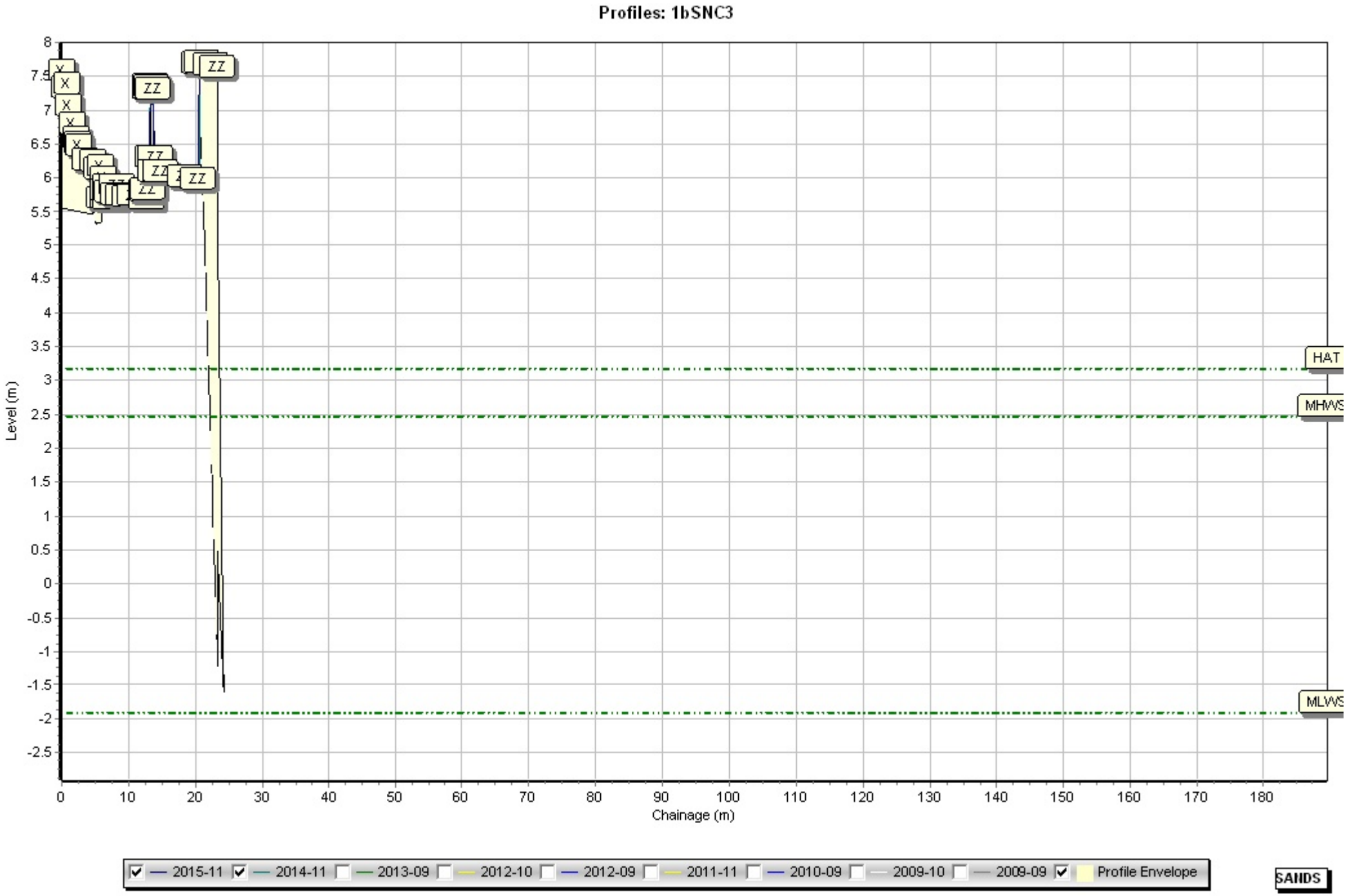

Profiles: 1bSNN11
Level (m)
Chainage (m)
HAT
MHWS
MLWS
2015-11
2014-11
2013-10
2012-10
2011-10
2010-09
2009-09
Profile Envelope
SANDS

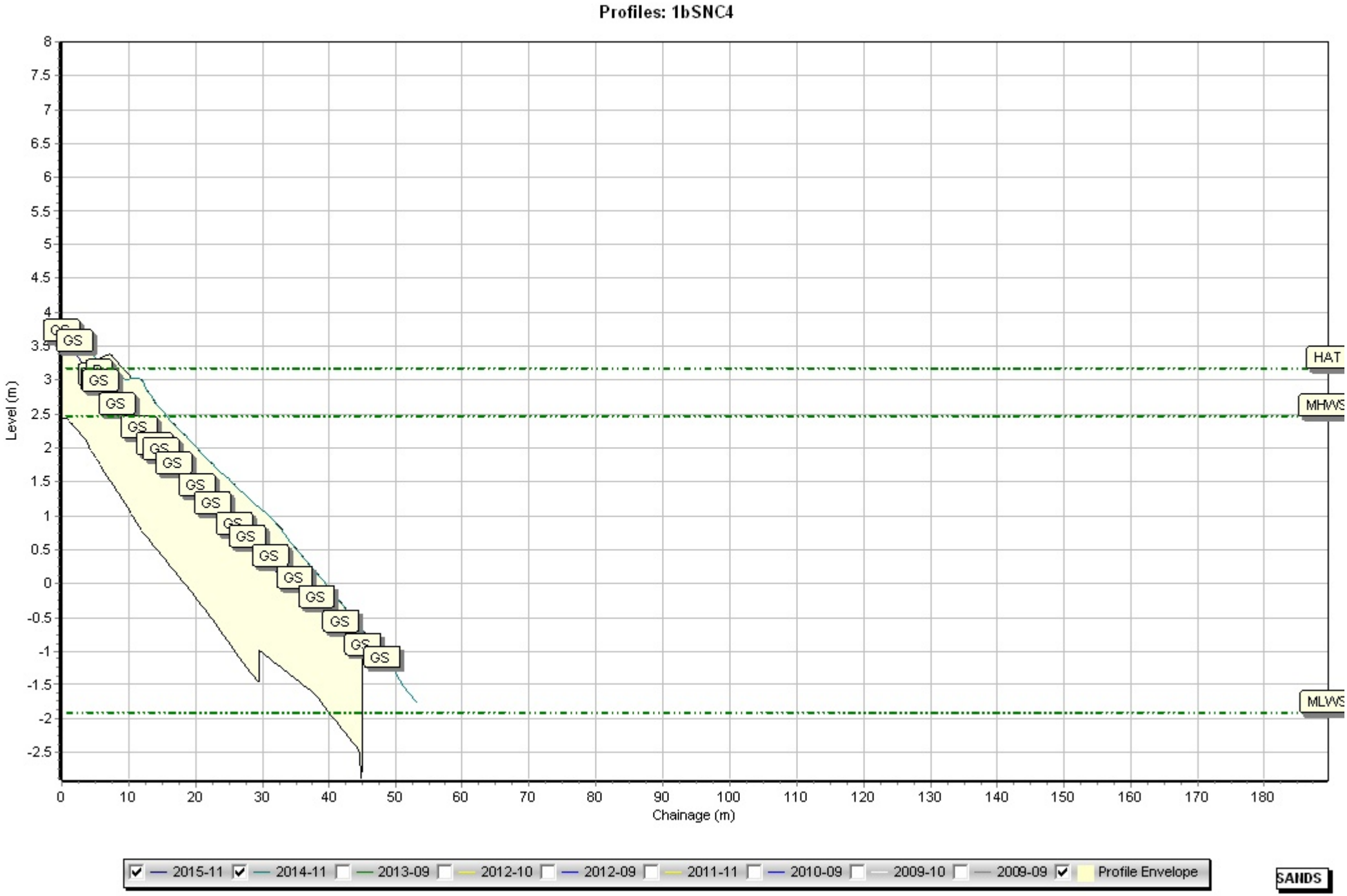

Profiles: 1bSNN12
Level (m)
Chainage (m)
HAT
MHWS
MLWS
SD
S
GS
G
2015-11
2014-11
2013-09
2012-10
2012-09
2011-11
2010-09
2009-10
2009-09
Profile Envelope
SANDS

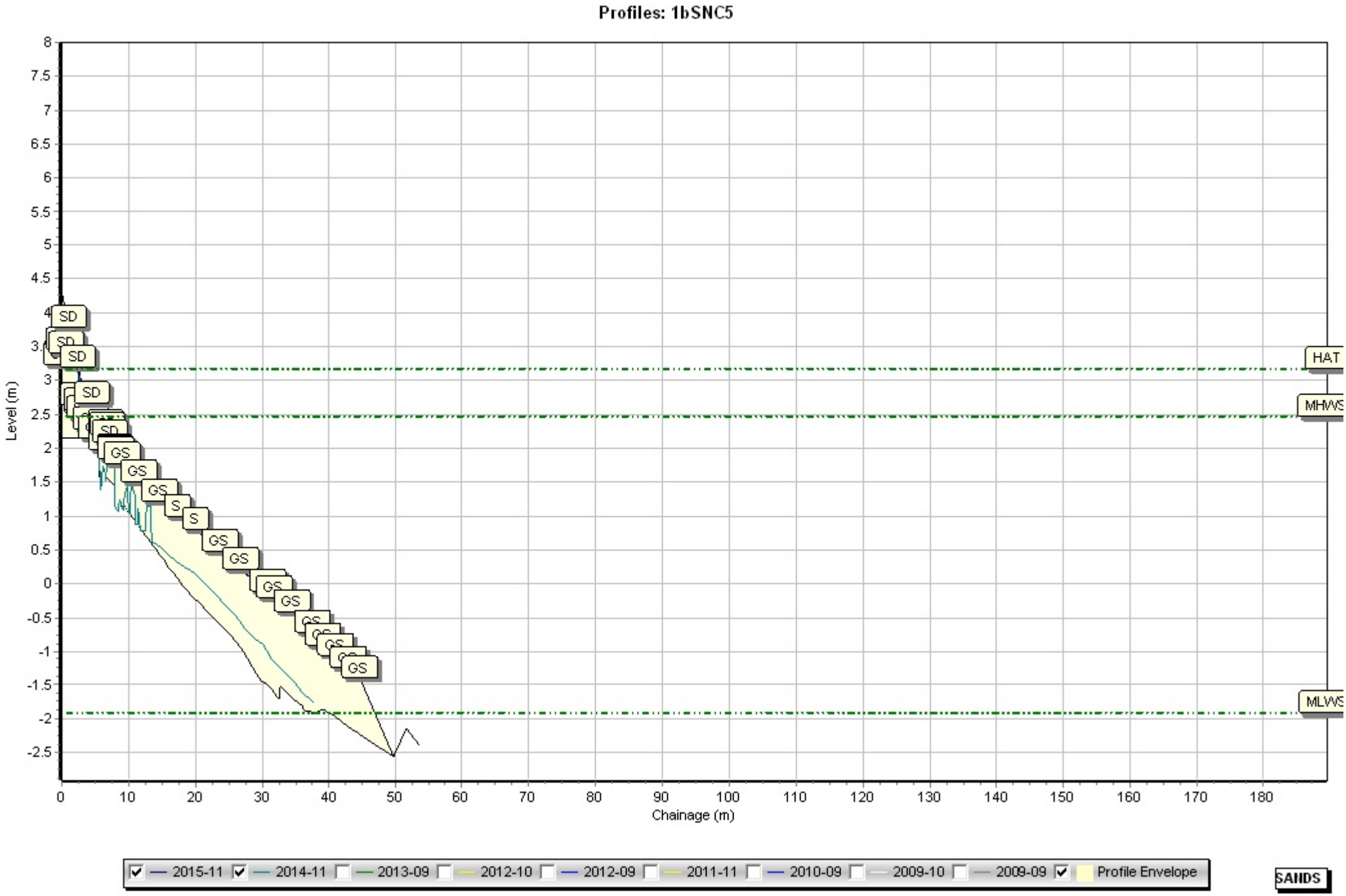

Profiles: 1bSNN13
Level (m)
Chainage (m)
HAT
MHWS
MLWS
ZZ
SD
S
2015-11
2014-11
2013-09
2012-10
2012-09
2011-11
2010-09
2009-10
2009-09
Profile Envelope
SANDS

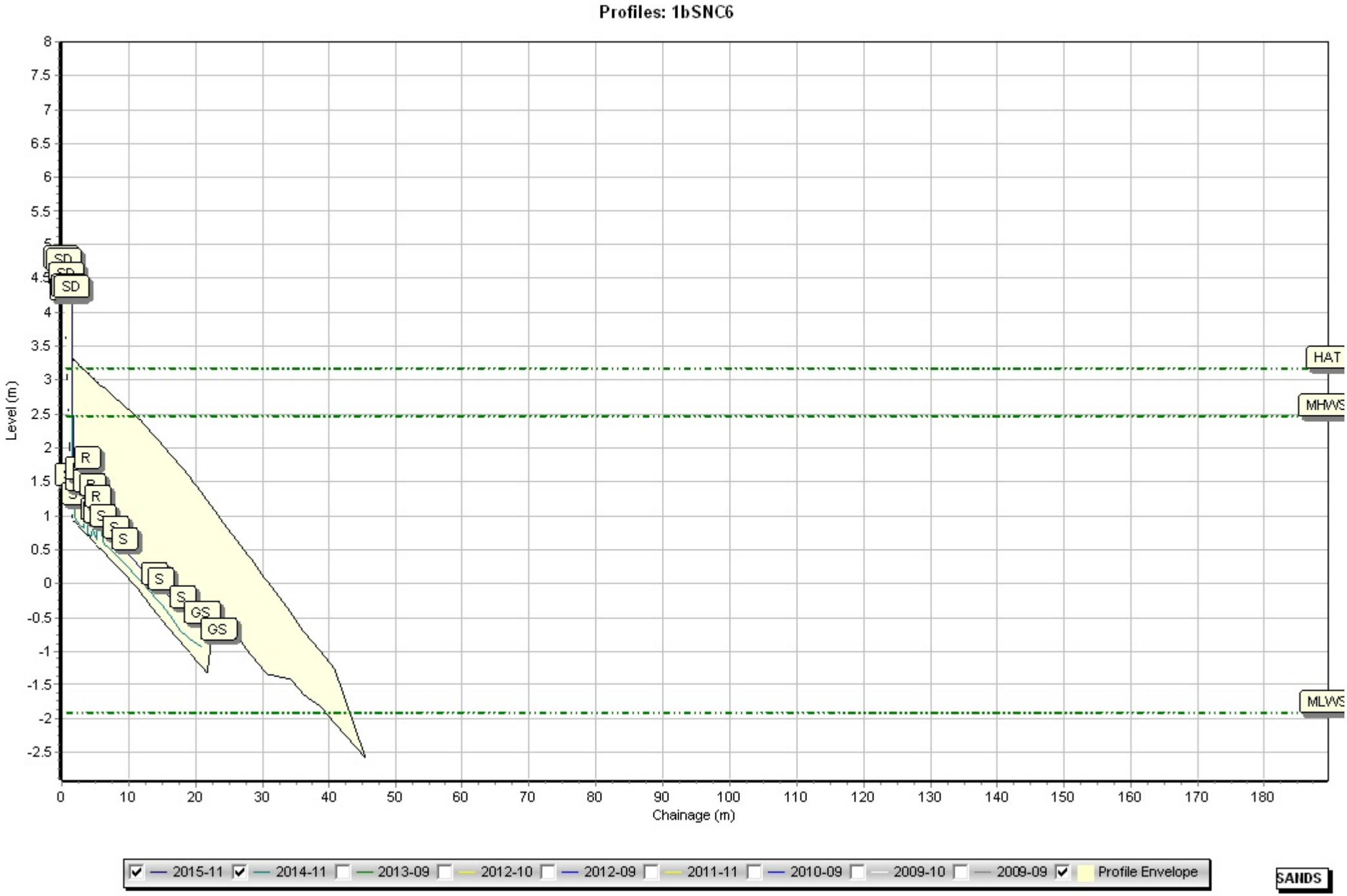

Profiles: 1bSNC1
Level (m)
Chainage (m)
HAT
MHWS
MLWS
GR
ZZ
2015-11
2014-11
2013-09
2012-10
2012-09
2011-11
2010-09
2009-10
2009-09
Profile Envelope
SANDS

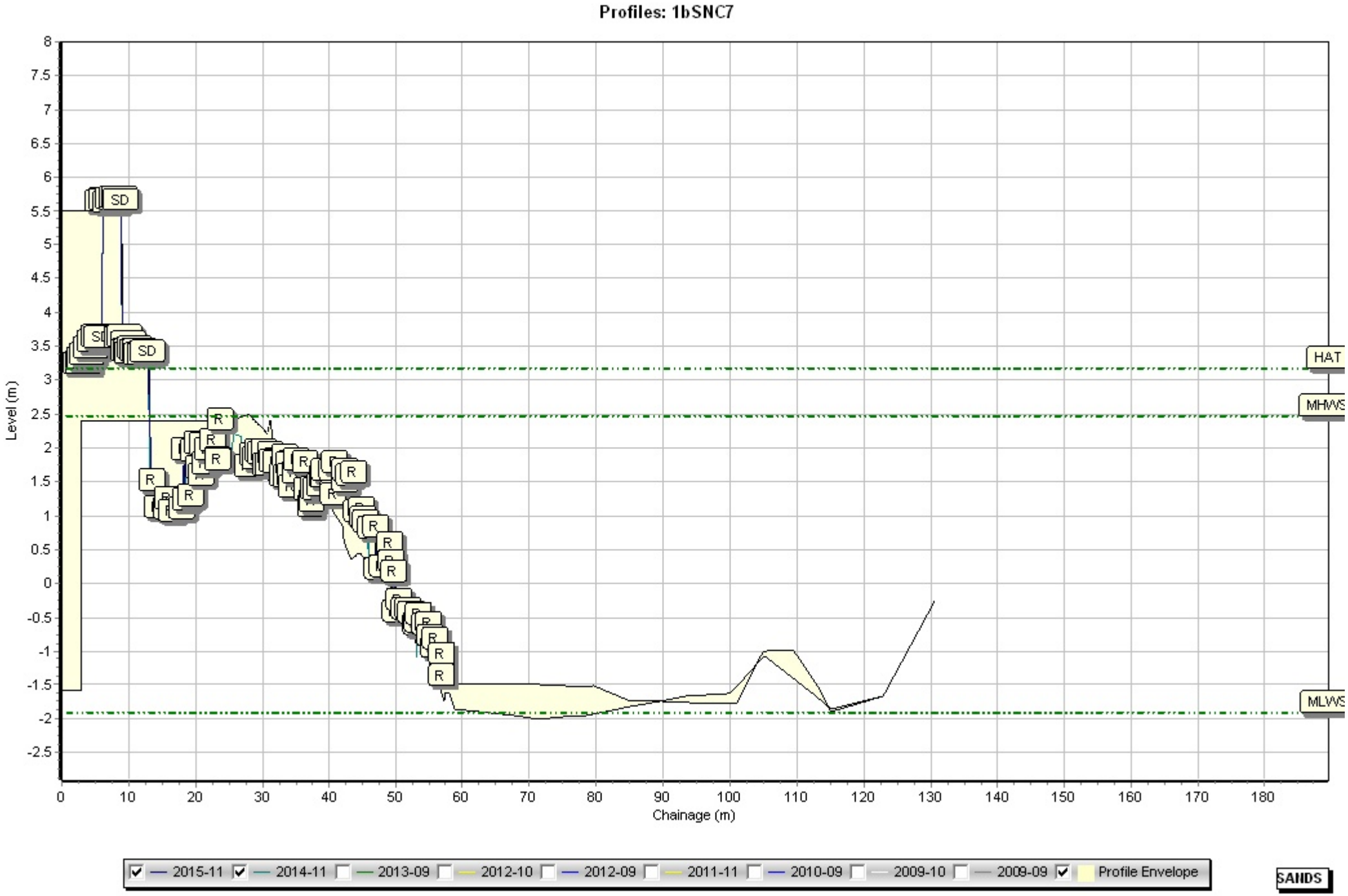

Profiles: 1bSNC2
Level (m)
Chainage (m)
HAT
MHWS
MLWS
ZZ
GS
S
2015-11
2014-11
2013-09
2012-10
2012-09
2011-11
2010-09
2009-10
2009-09
Profile Envelope
SANDS

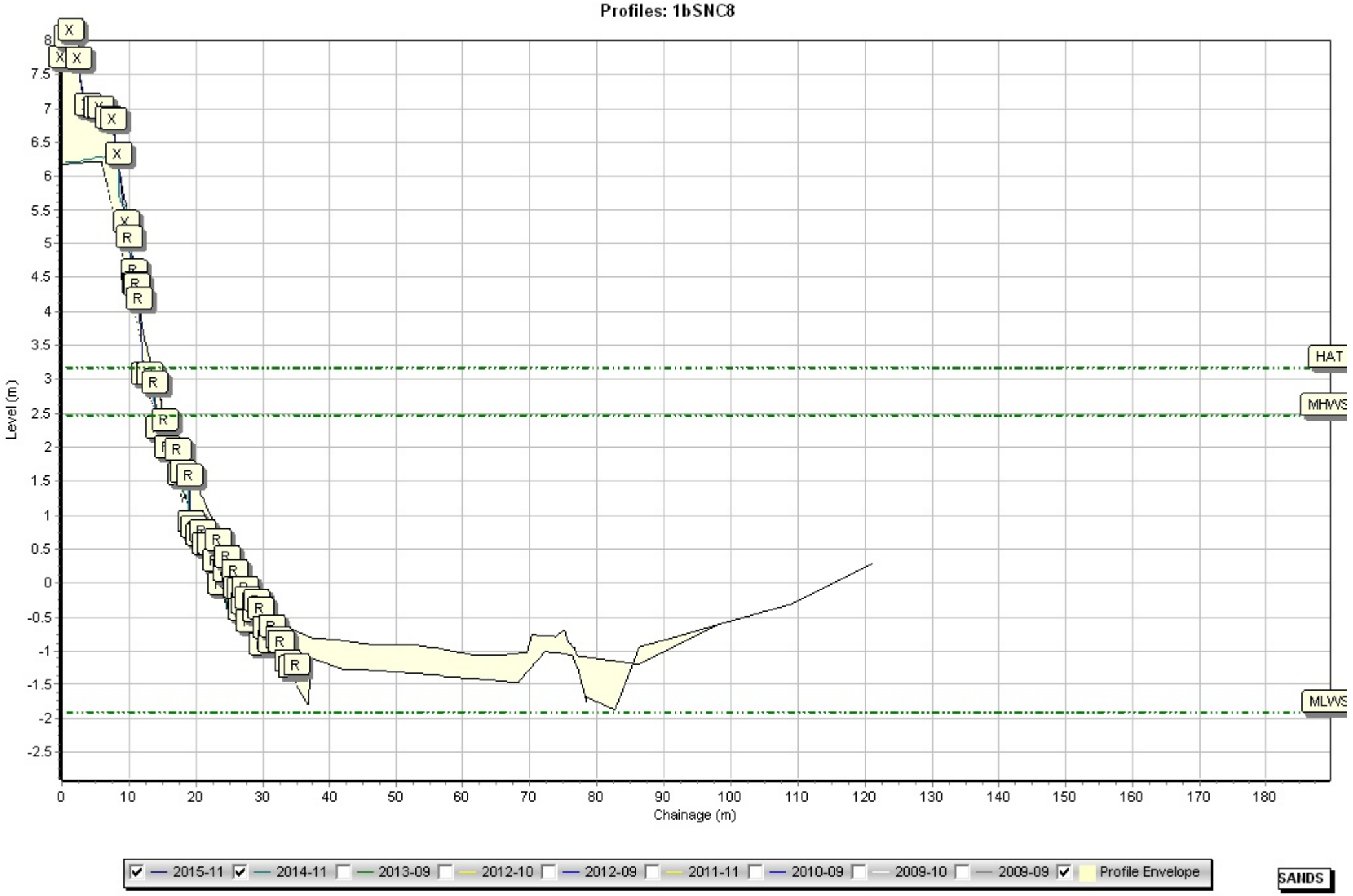

Profiles: 1bSNC3
Level (m)
Chainage (m)
HAT
MHWS
MLWS
2015-11
2014-11
2013-09
2012-10
2012-09
2011-11
2010-09
2009-10
2009-09
Profile Envelope
SANDS

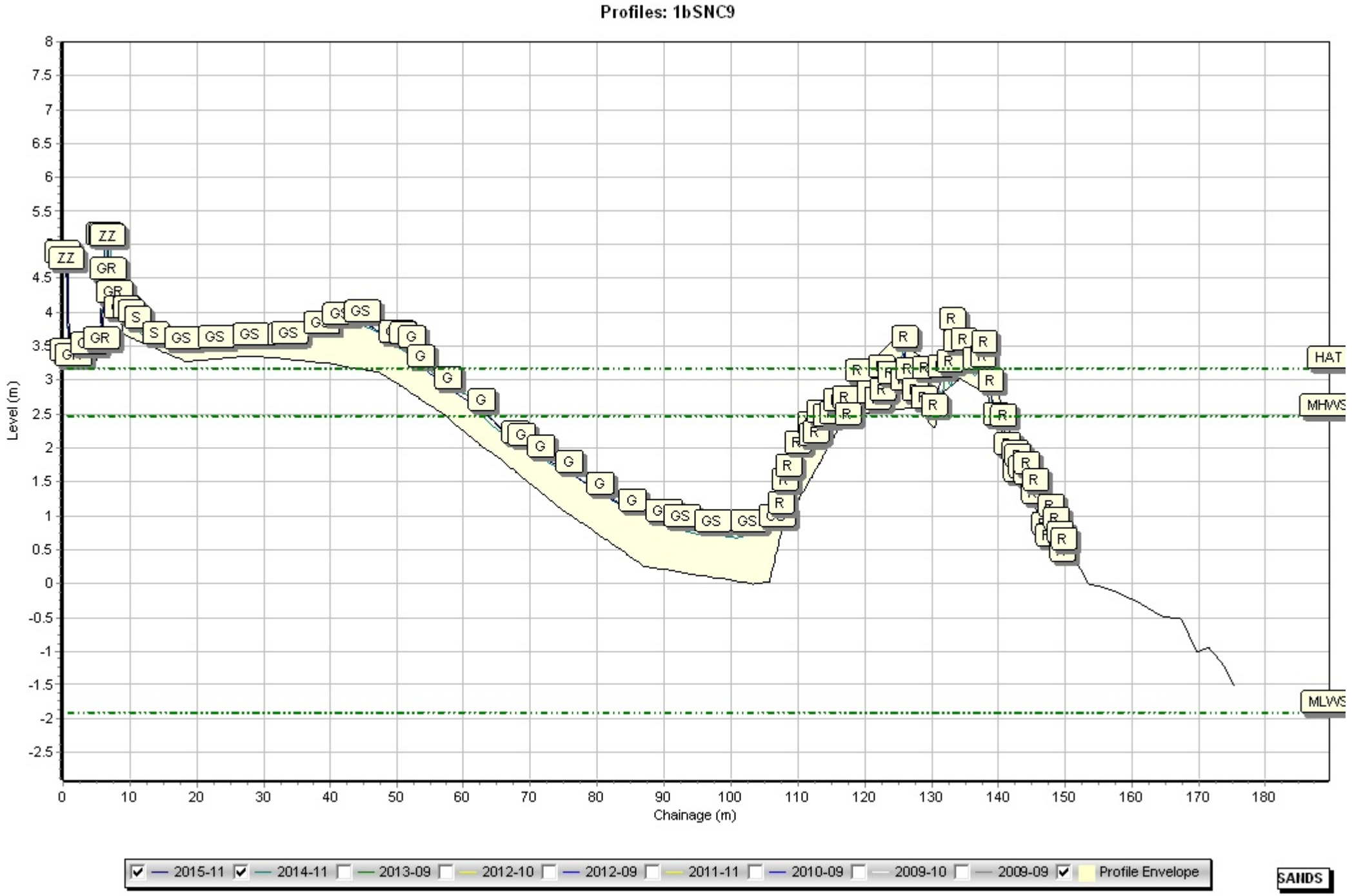

Profiles: 1bSNC4
Level (m)
Chainage (m)
HAT
MHWS
MLWS
GS
2015-11
2014-11
2013-09
2012-10
2012-09
2011-11
2010-09
2009-10
2009-09
Profile Envelope
SANDS

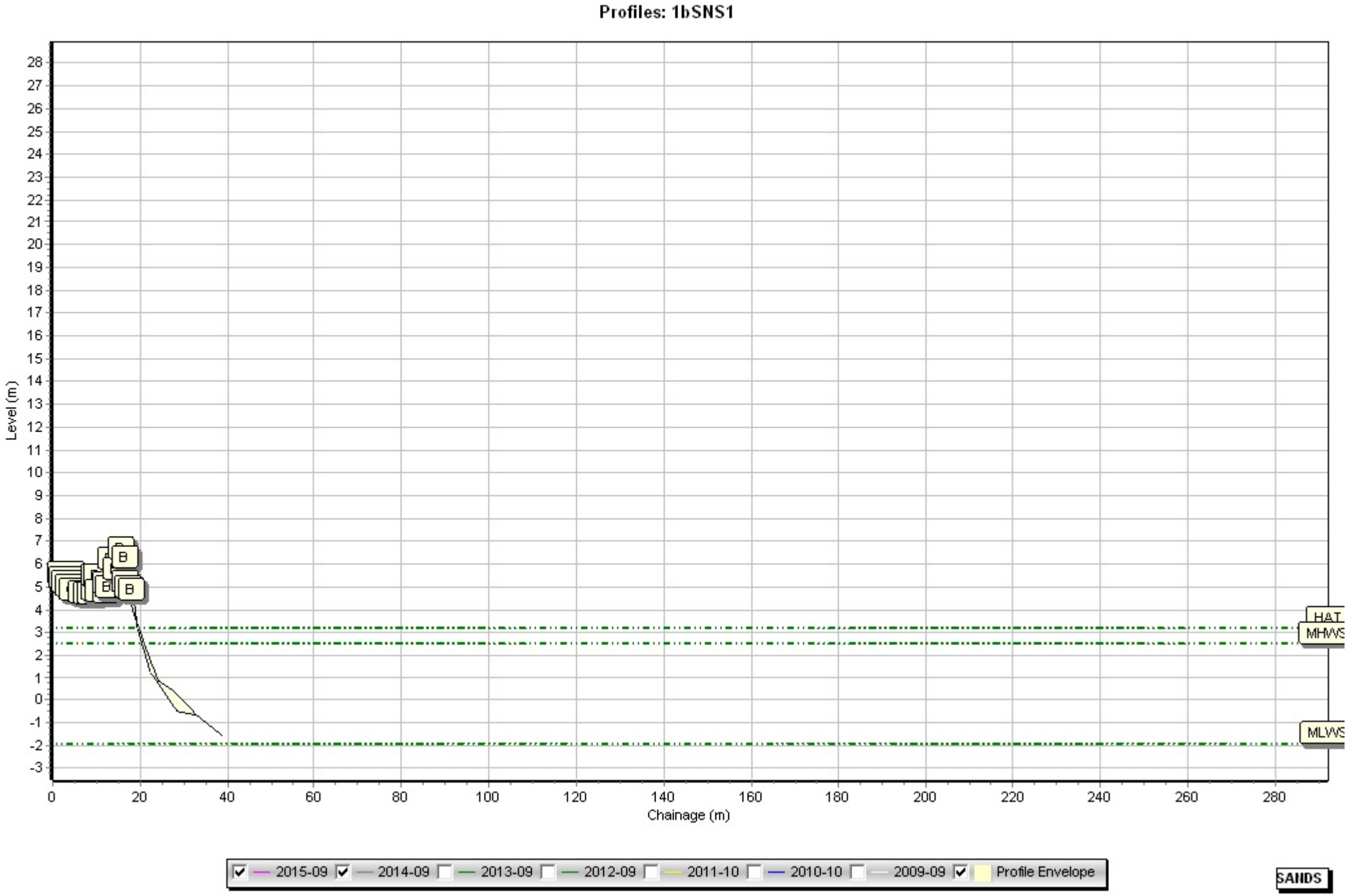

Profiles: 1bSNC5
Level (m)
Chainage (m)
HAT
MHWS
MLWS
SD
GS
S
2015-11
2014-11
2013-09
2012-10
2012-09
2011-11
2010-09
2009-10
2009-09
Profile Envelope
SANDS

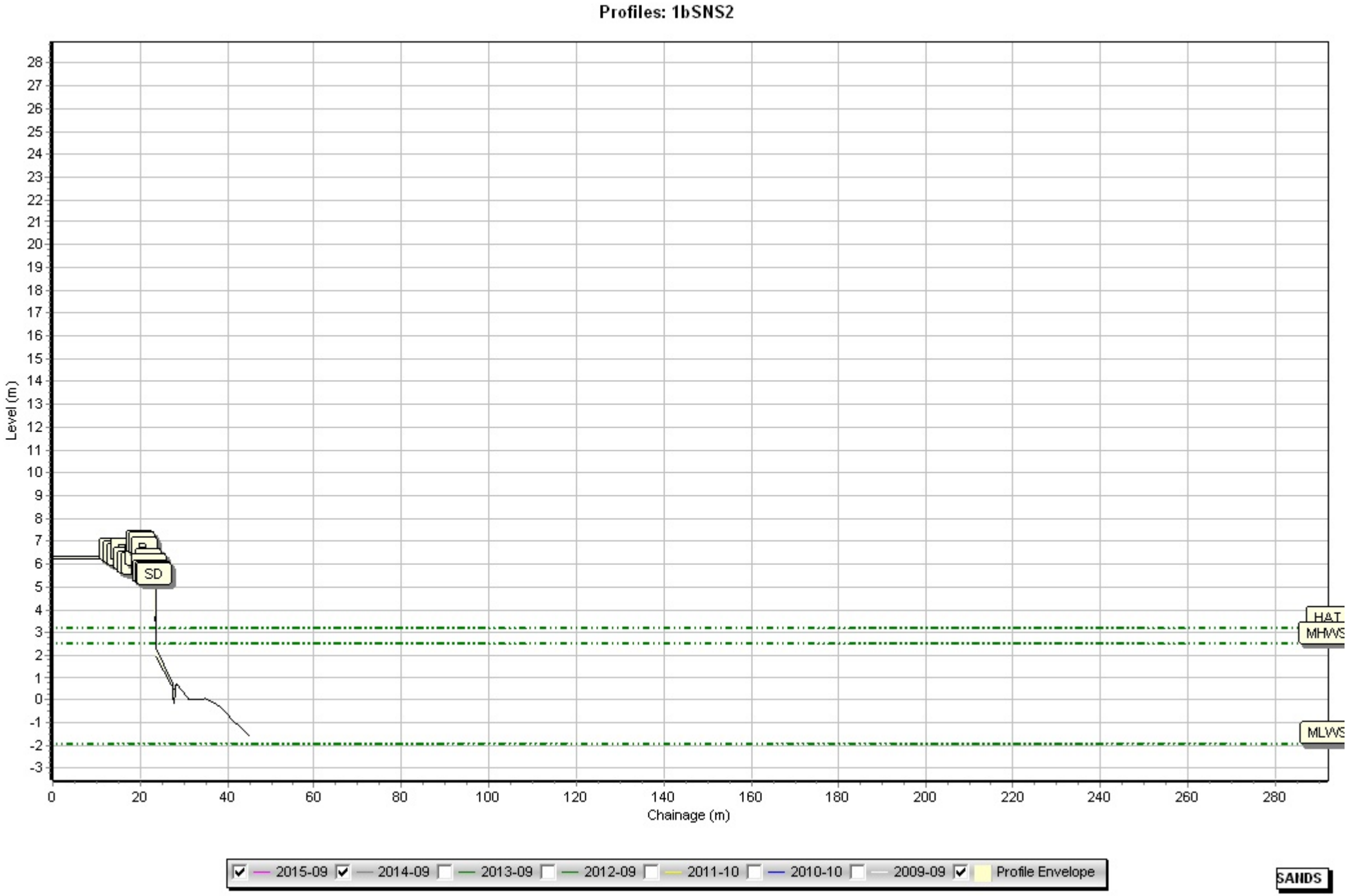

Profiles: 1bSNC6
Level (m)
Chainage (m)
HAT
MHWS
MLWS
SD
R
S
GS
2015-11
2014-11
2013-09
2012-10
2012-09
2011-11
2010-09
2009-10
2009-09
Profile Envelope
SANDS

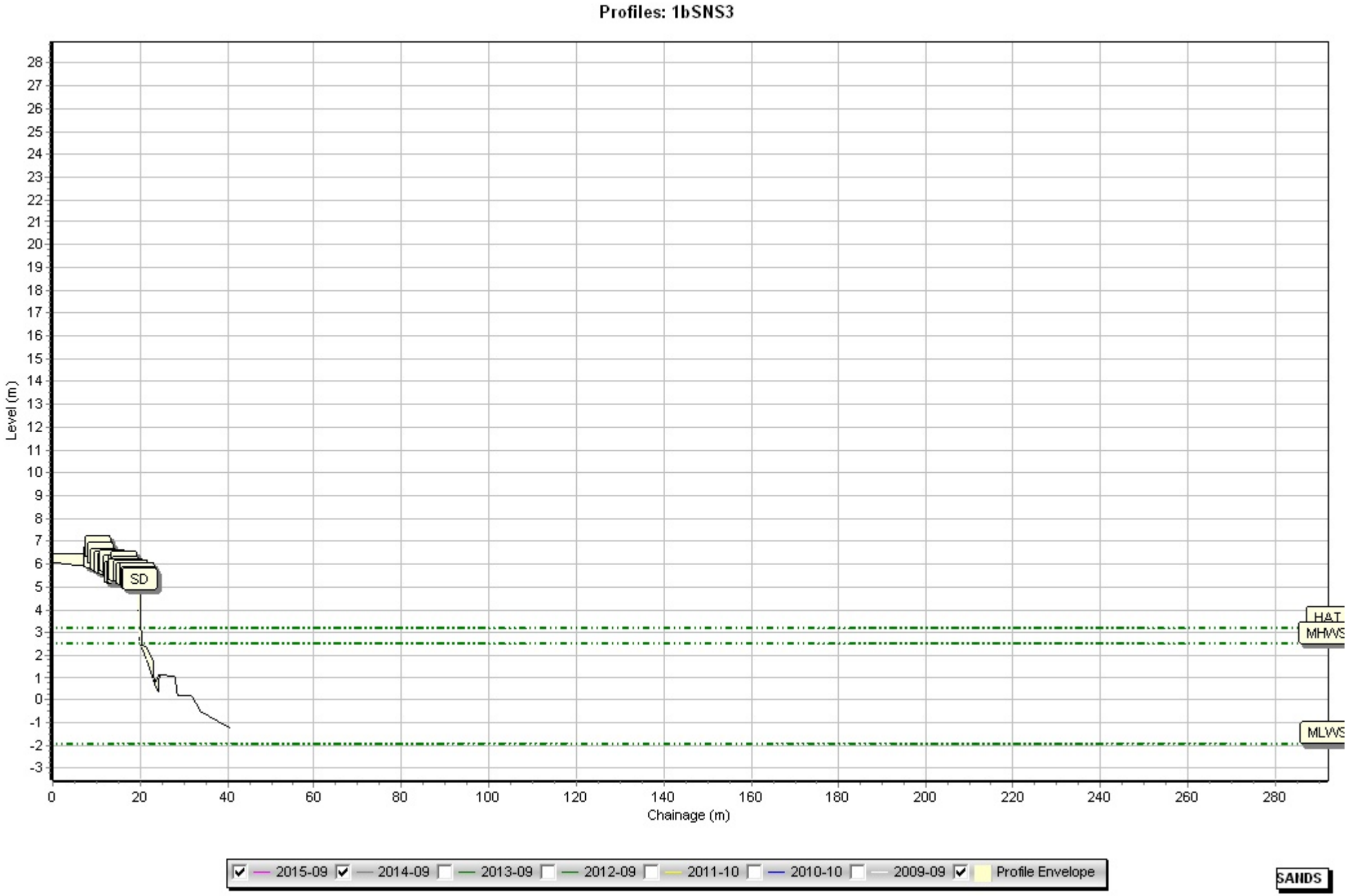

Profiles: 1bSNC7
Level (m)
Chainage (m)
HAT
MHWS
MLWS
SD
R
2015-11
2014-11
2013-09
2012-10
2012-09
2011-11
2010-09
2009-10
2009-09
Profile Envelope
SANDS

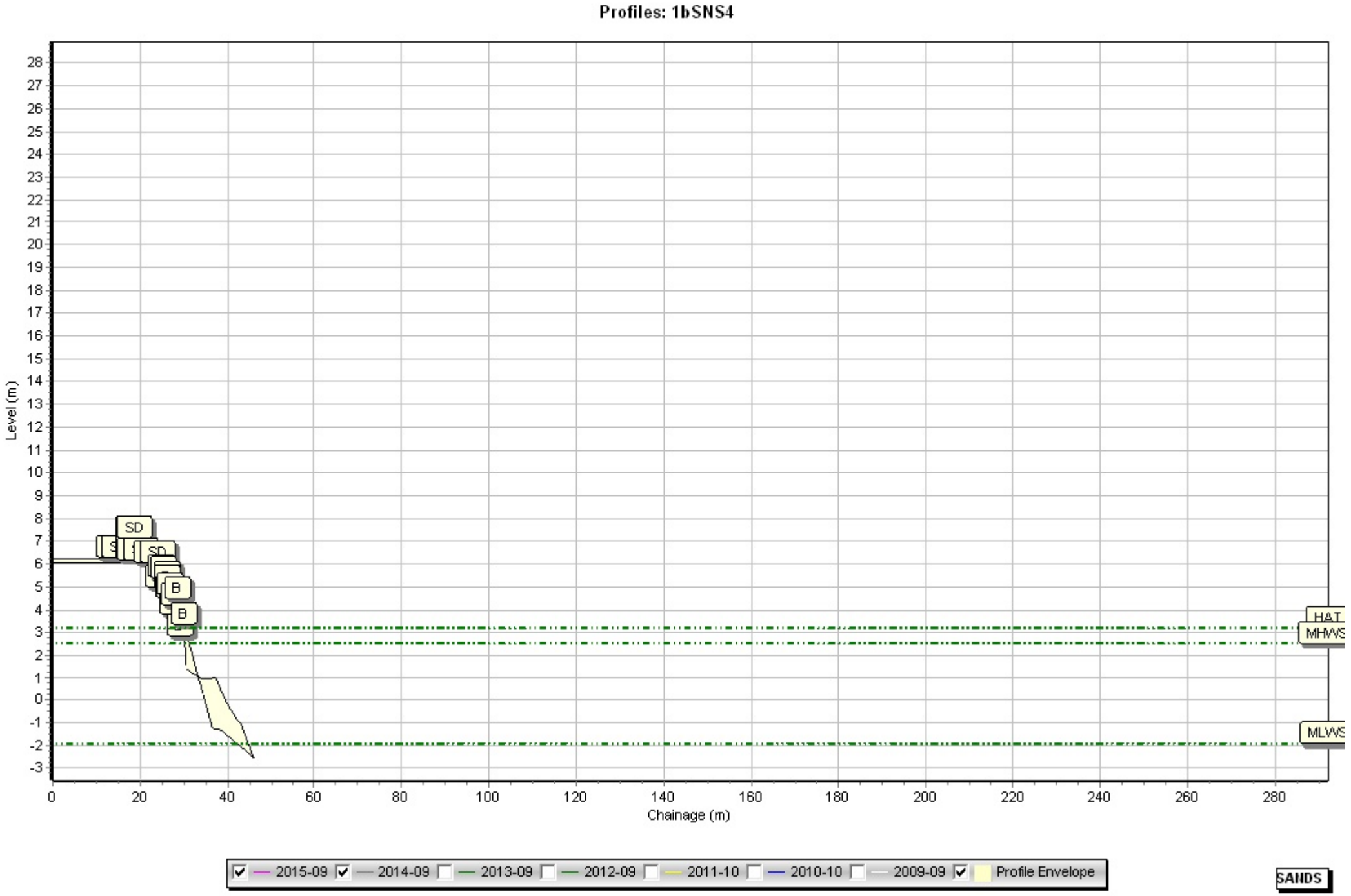

Profiles: 1bSNC8
Level (m)
Chainage (m)
HAT
MHWS
MLWS
2015-11
2014-11
2013-09
2012-10
2012-09
2011-11
2010-09
2009-10
2009-09
Profile Envelope
SANDS

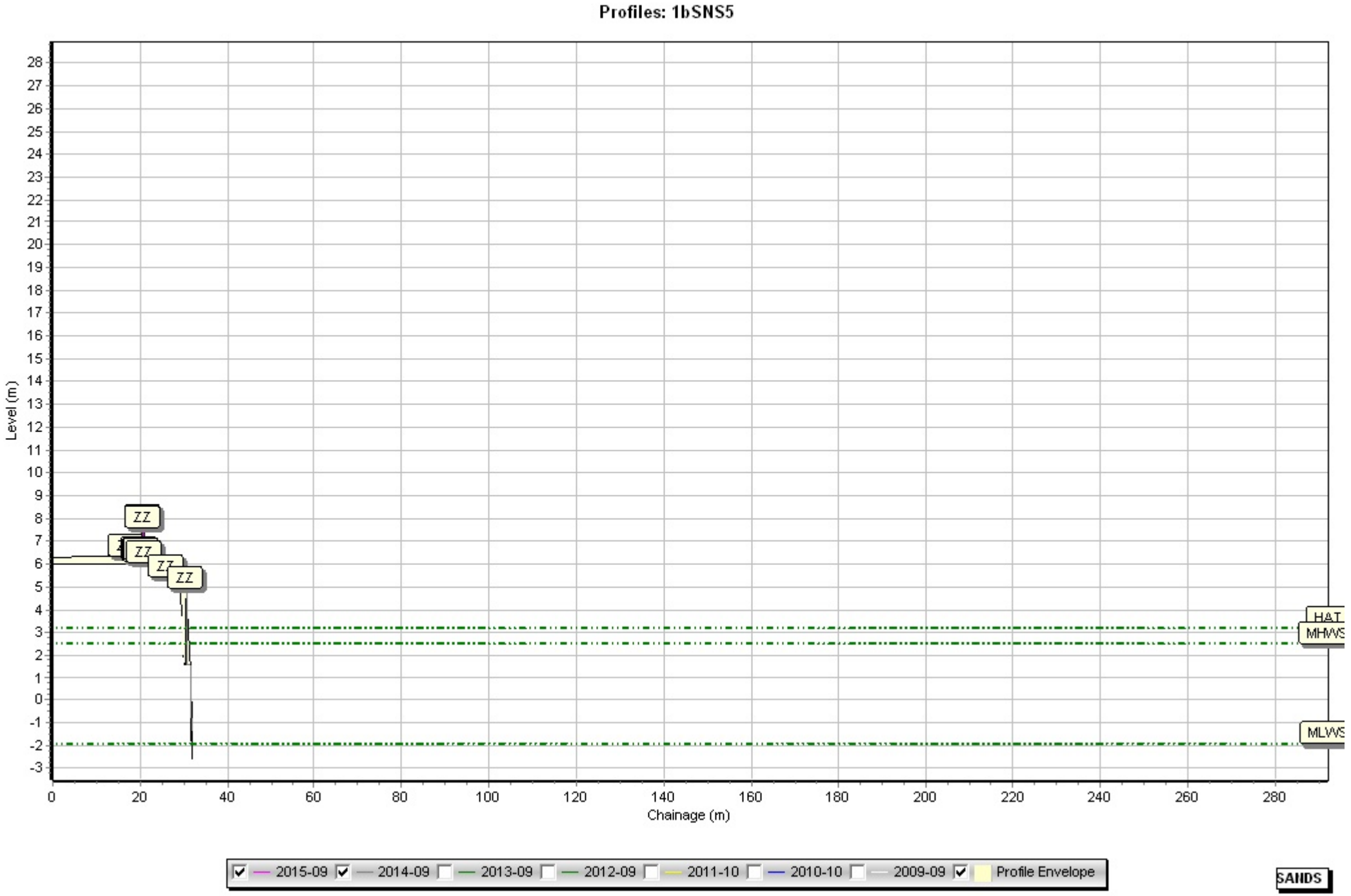

Profiles: 1bSNC9
Level (m)
Chainage (m)
HAT
MHWS
MLWS
2015-11
2014-11
2013-09
2012-10
2012-09
2011-11
2010-09
2009-10
2009-09
Profile Envelope
SANDS

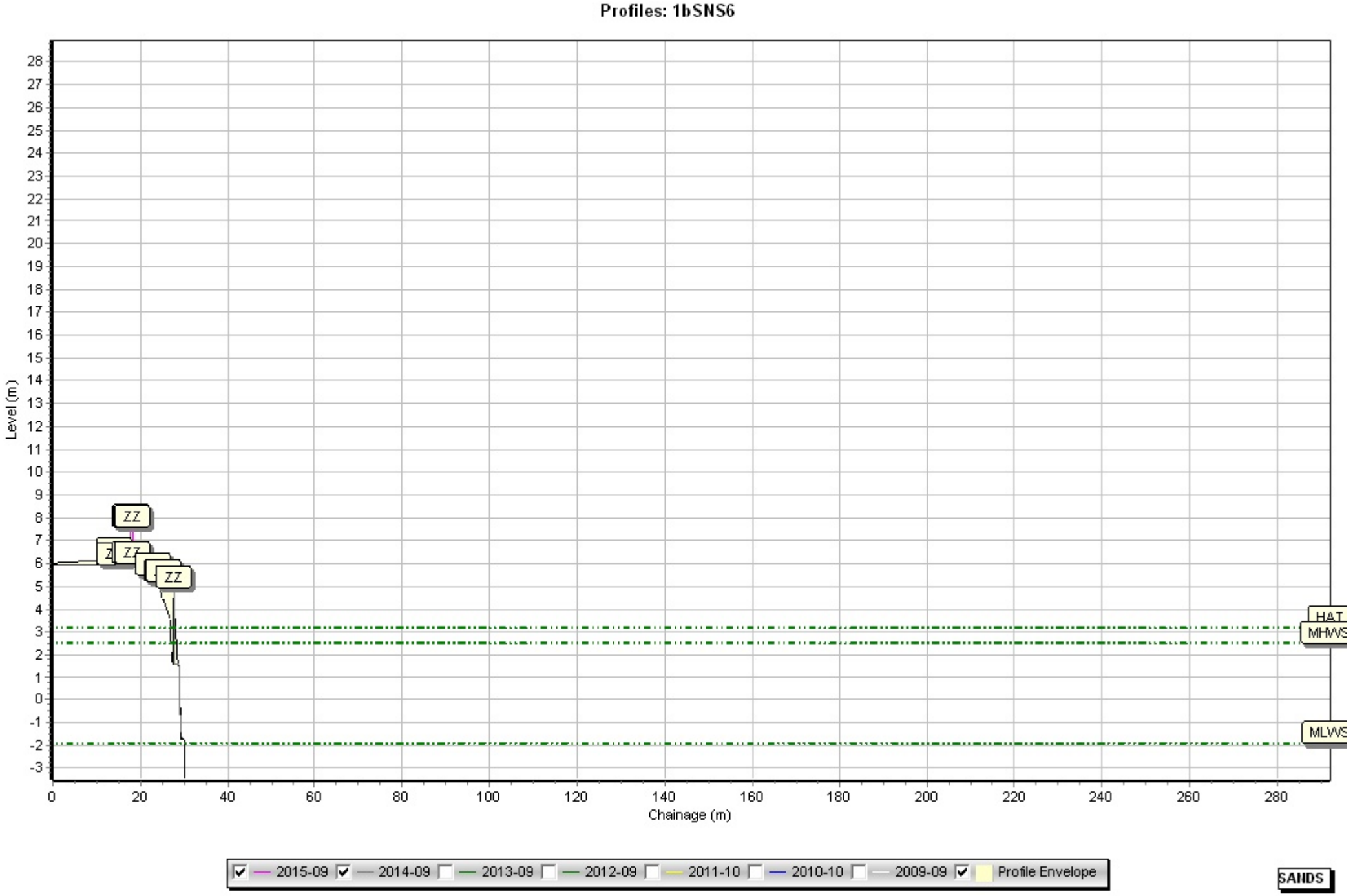

Profiles: 1bSNS1
Level (m)
28
27
26
25
24
23
22
21
20
19
18
17
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
0
-1
-2
-3
0
20
40
60
80
100
120
140
160
180
200
220
240
260
280
Chainage (m)
B
B
B
B
HAT
MHWS
MLWS
2015-09
2014-09
2013-09
2012-09
2011-10
2010-10
2009-09
Profile Envelope
SANDS

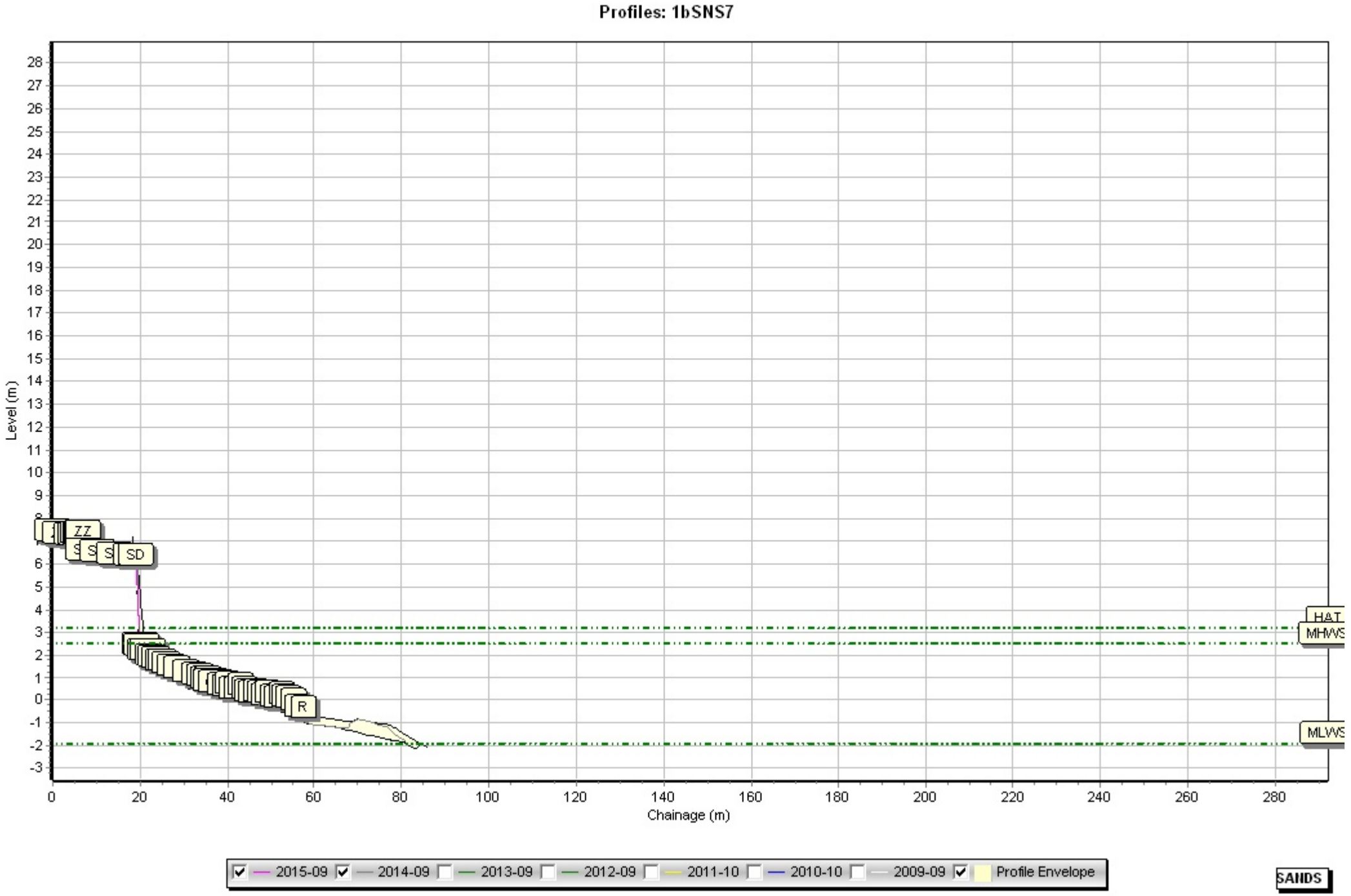

Profiles: 1bSNS2
Level (m)
28
27
26
25
24
23
22
21
20
19
18
17
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
0
-1
-2
-3
0
20
40
60
80
100
120
140
160
180
200
220
240
260
280
Chainage (m)
SD
HAT
MHWS
MLWS
2015-09
2014-09
2013-09
2012-09
2011-10
2010-10
2009-09
Profile Envelope
SANDS

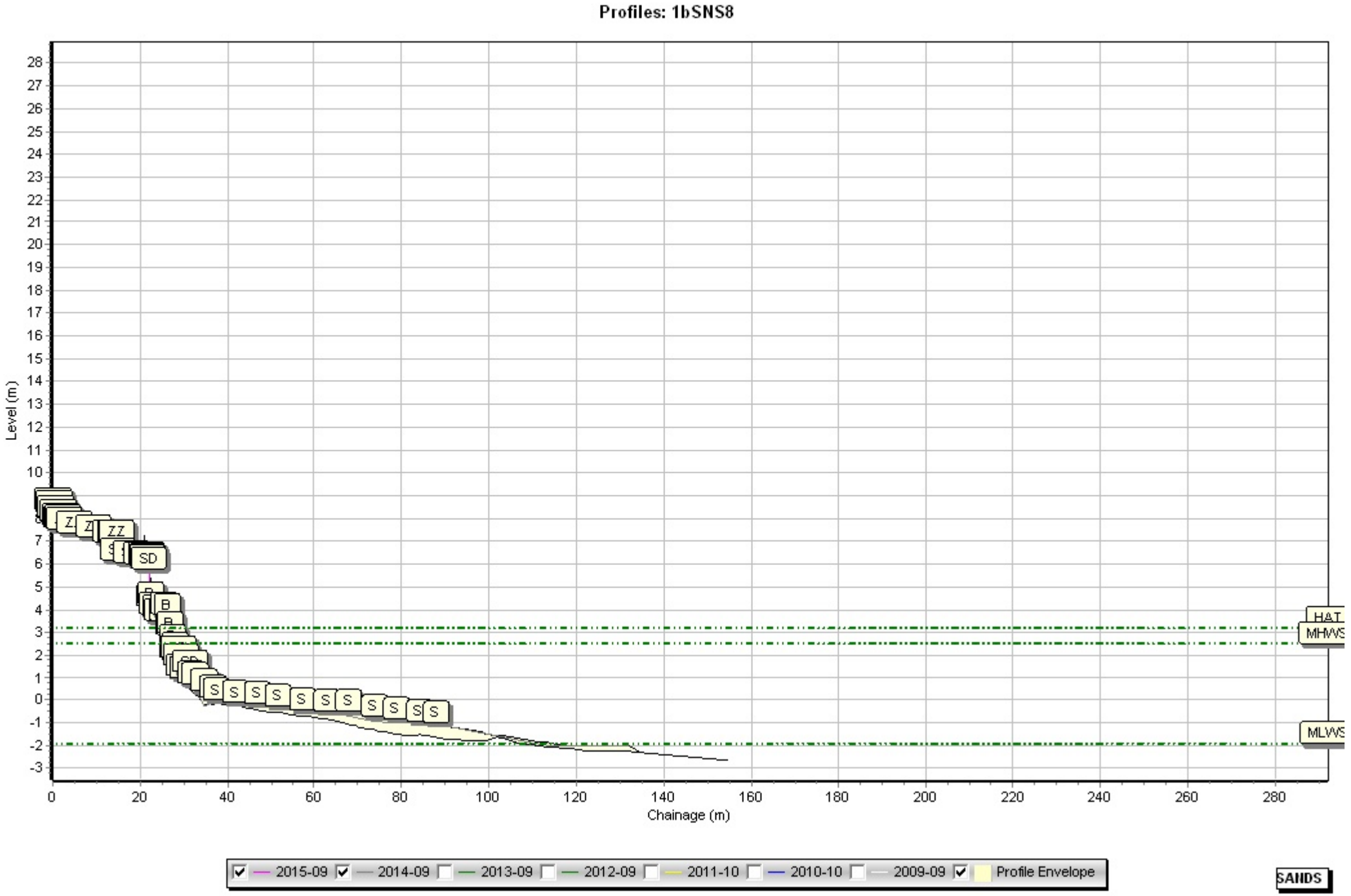

Profiles: 1bSNS3
Level (m)
28
27
26
25
24
23
22
21
20
19
18
17
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
0
-1
-2
-3
SD
HAT
MHWS
MLWS
0
20
40
60
80
100
120
140
160
180
200
220
240
260
280
Chainage (m)
2015-09
2014-09
2013-09
2012-09
2011-10
2010-10
2009-09
Profile Envelope
SANDS

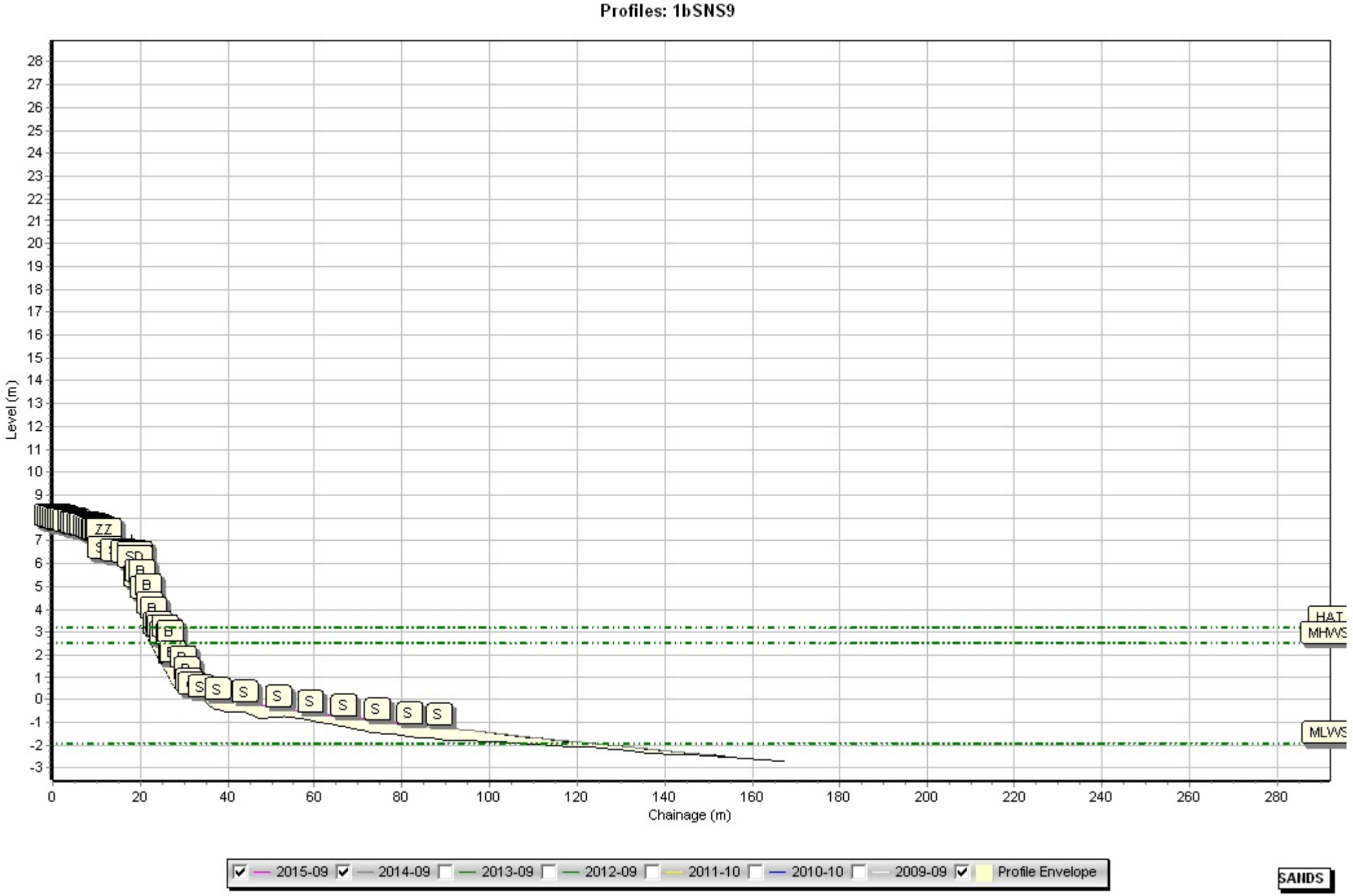

Profiles: 1bSNS4
Level (m)
28
27
26
25
24
23
22
21
20
19
18
17
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
0
-1
-2
-3
0
20
40
60
80
100
120
140
160
180
200
220
240
260
280
Chainage (m)
SD
SD
B
B
HAT
MHWS
MLWS
2015-09
2014-09
2013-09
2012-09
2011-10
2010-10
2009-09
Profile Envelope
SANDS

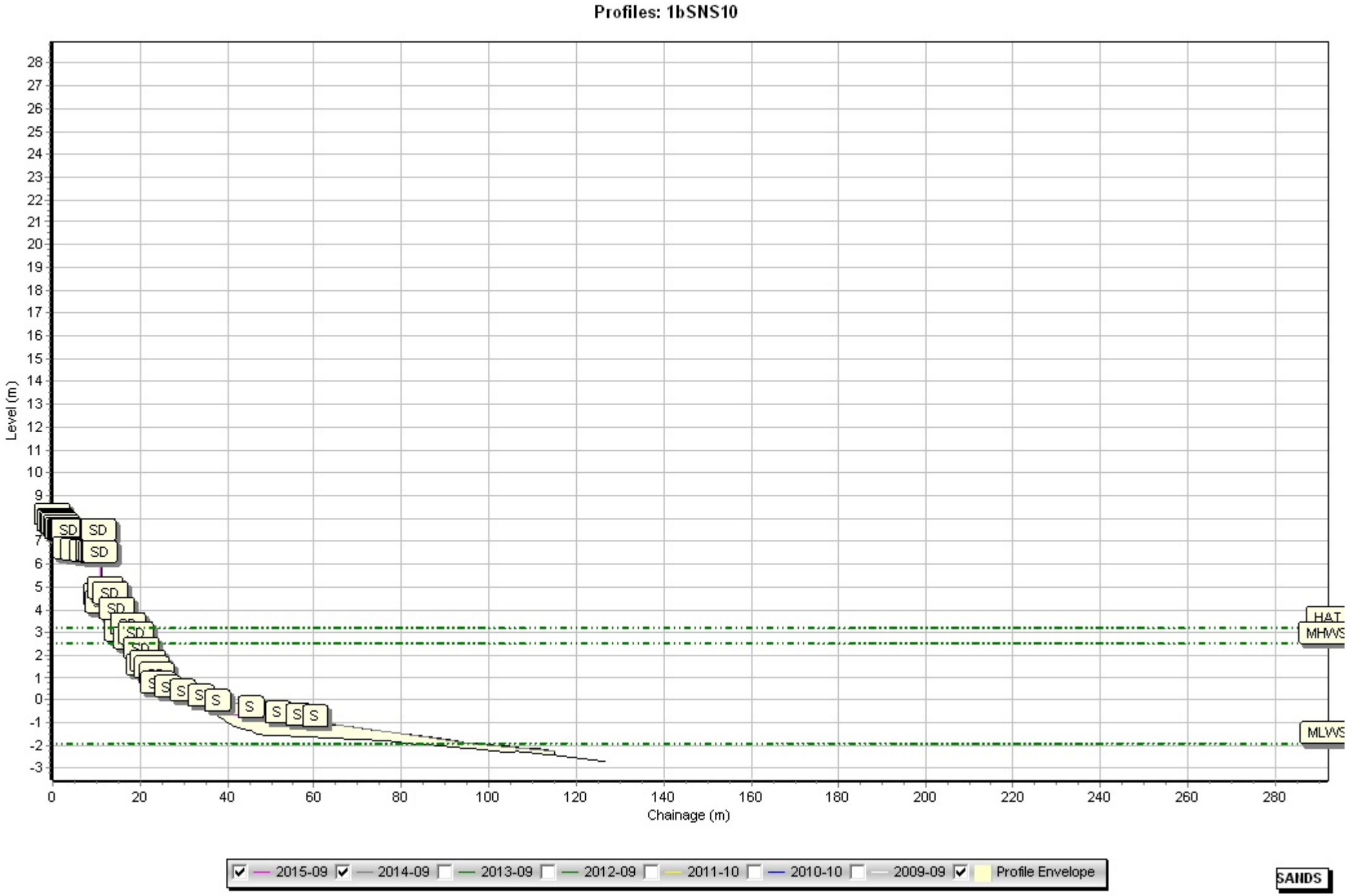

Profiles: 1bSNS5
Level (m)
28
27
26
25
24
23
22
21
20
19
18
17
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
0
-1
-2
-3
0
20
40
60
80
100
120
140
160
180
200
220
240
260
280
Chainage (m)
ZZ
ZZ
ZZ
ZZ
HAT
MHWS
MLWS
2015-09
2014-09
2013-09
2012-09
2011-10
2010-10
2009-09
Profile Envelope
SANDS

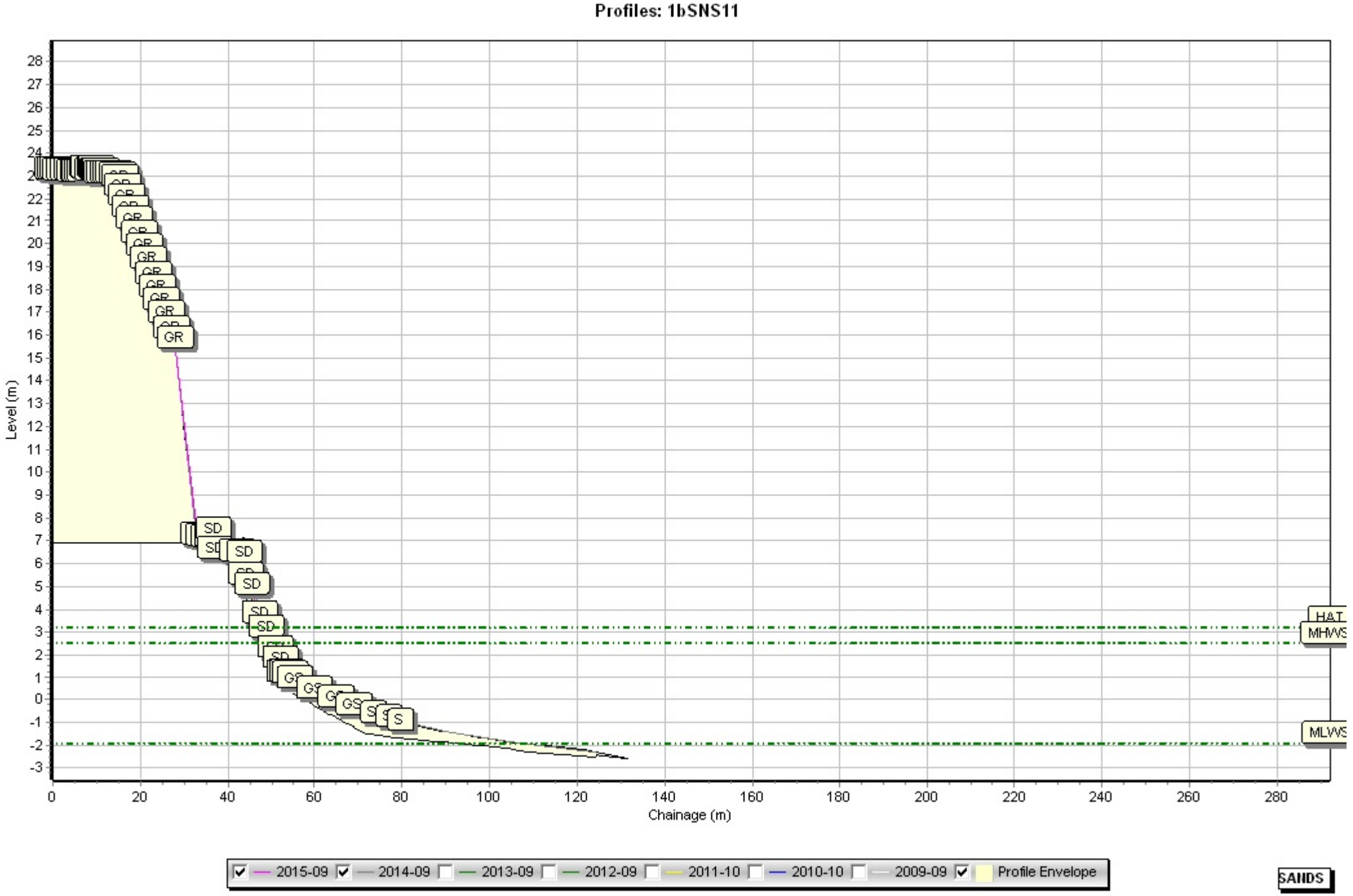

Profiles: 1bSNS6
Level (m)
28
27
26
25
24
23
22
21
20
19
18
17
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
0
-1
-2
-3
ZZ
ZZ
ZZ
HAT
MHWS
MLWS
0
20
40
60
80
100
120
140
160
180
200
220
240
260
280
Chainage (m)
2015-09
2014-09
2013-09
2012-09
2011-10
2010-10
2009-09
Profile Envelope
SANDS

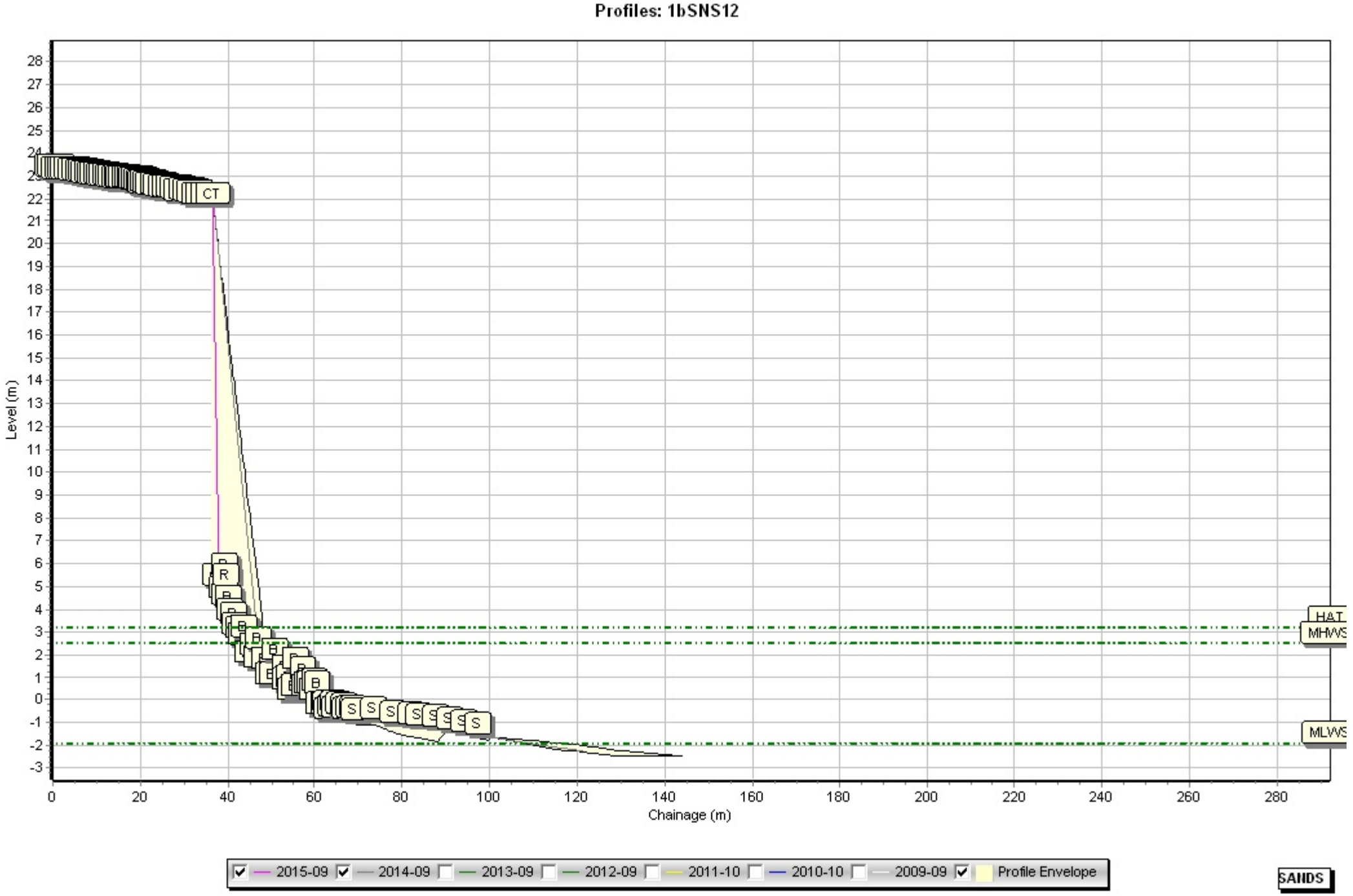

Profiles: 1bSNS7
Level (m)
Chainage (m)
ZZ
SD
R
HAT
MHWS
MLWS
2015-09
2014-09
2013-09
2012-09
2011-10
2010-10
2009-09
Profile Envelope
SAIDS

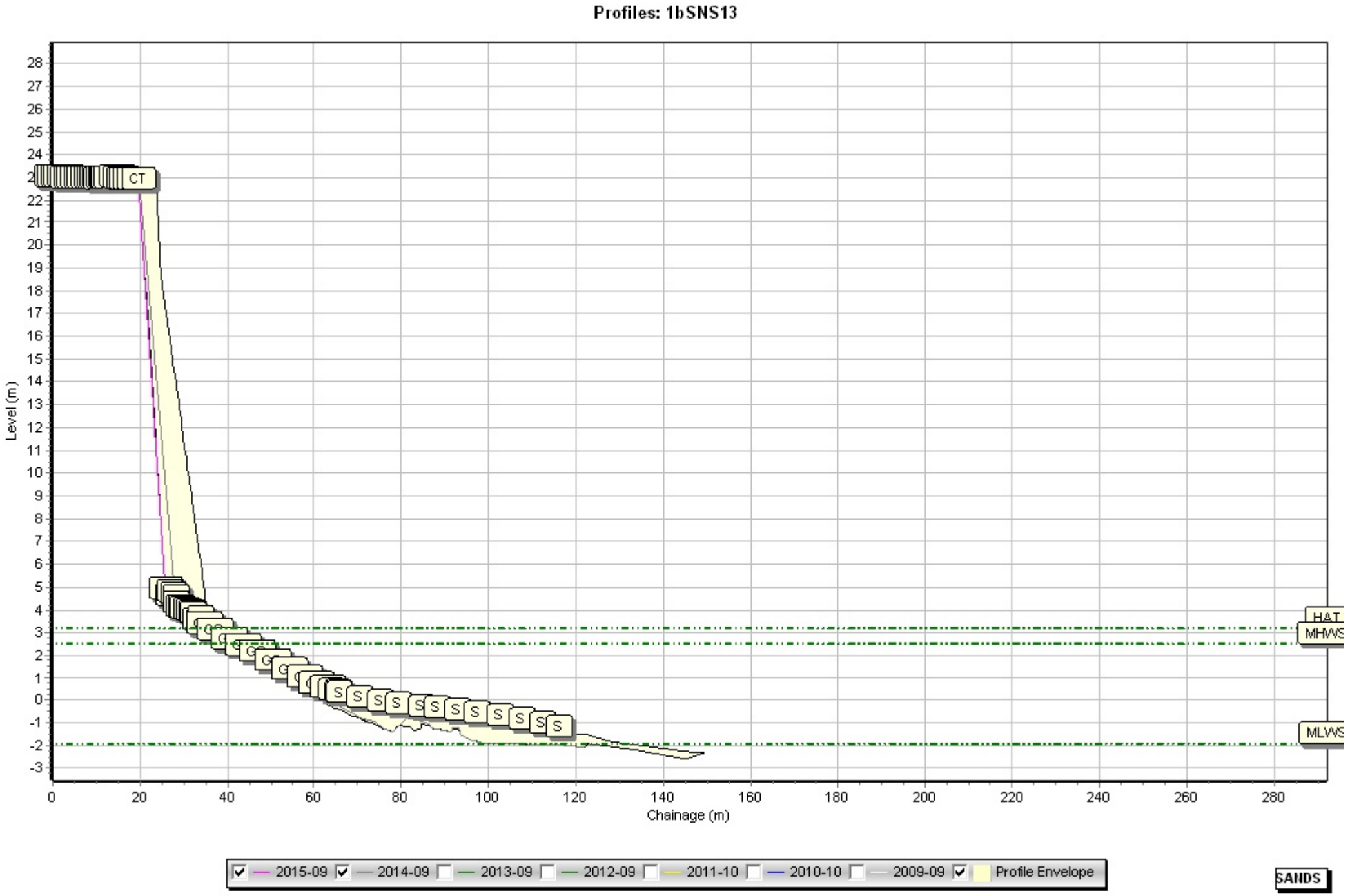

Profiles: 1bSNS8
Level (m)
Chainage (m)
SD
HAT
MHWS
MLWS
2015-09
2014-09
2013-09
2012-09
2011-10
2010-10
2009-09
Profile Envelope
SANDS

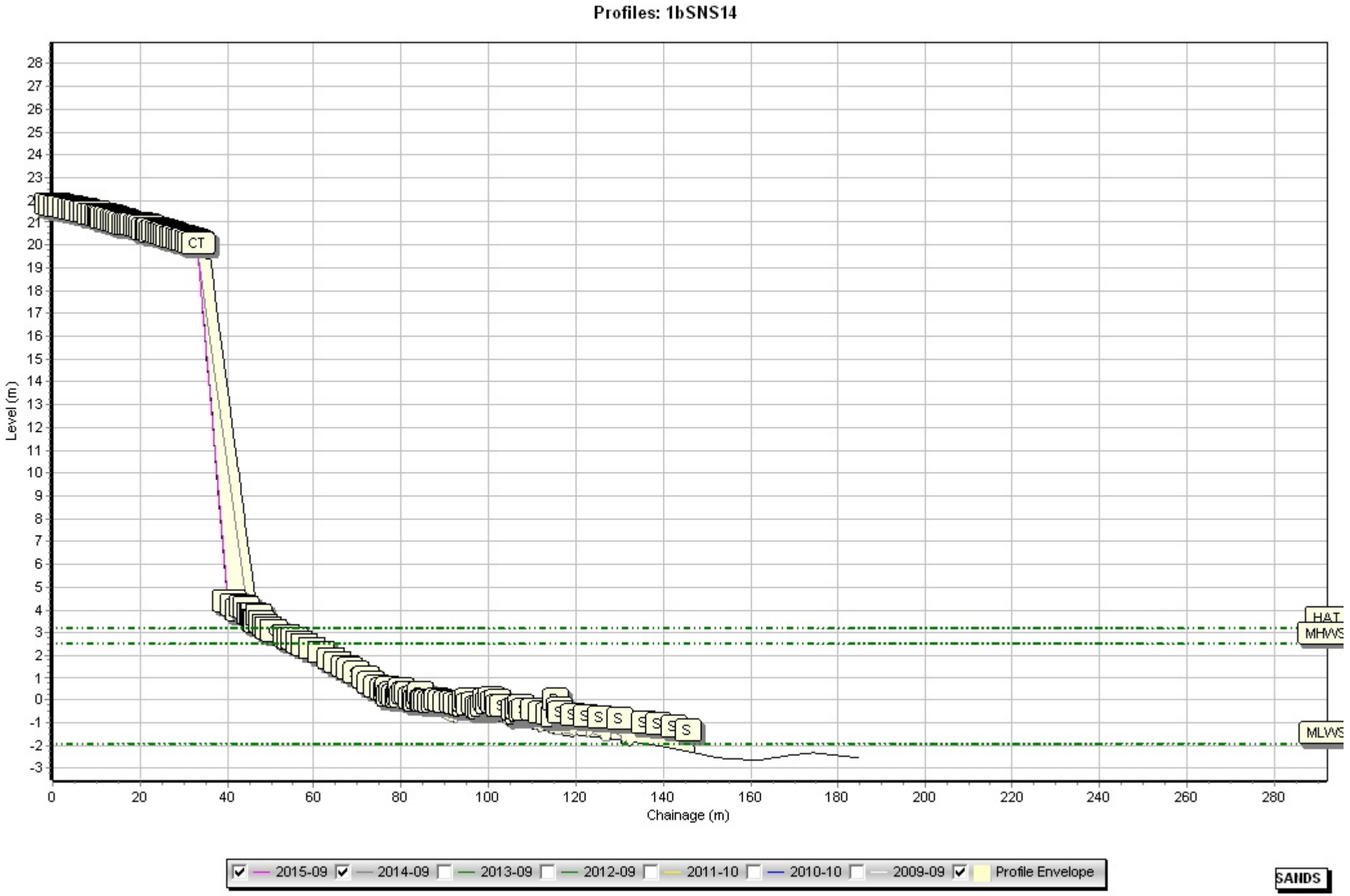

Profiles: 1bSNS9
Level (m)
Chainage (m)
ZZ
SD
B
S
HAT
MHWS
MLWS
2015-09
2014-09
2013-09
2012-09
2011-10
2010-10
2009-09
Profile Envelope
SANDS

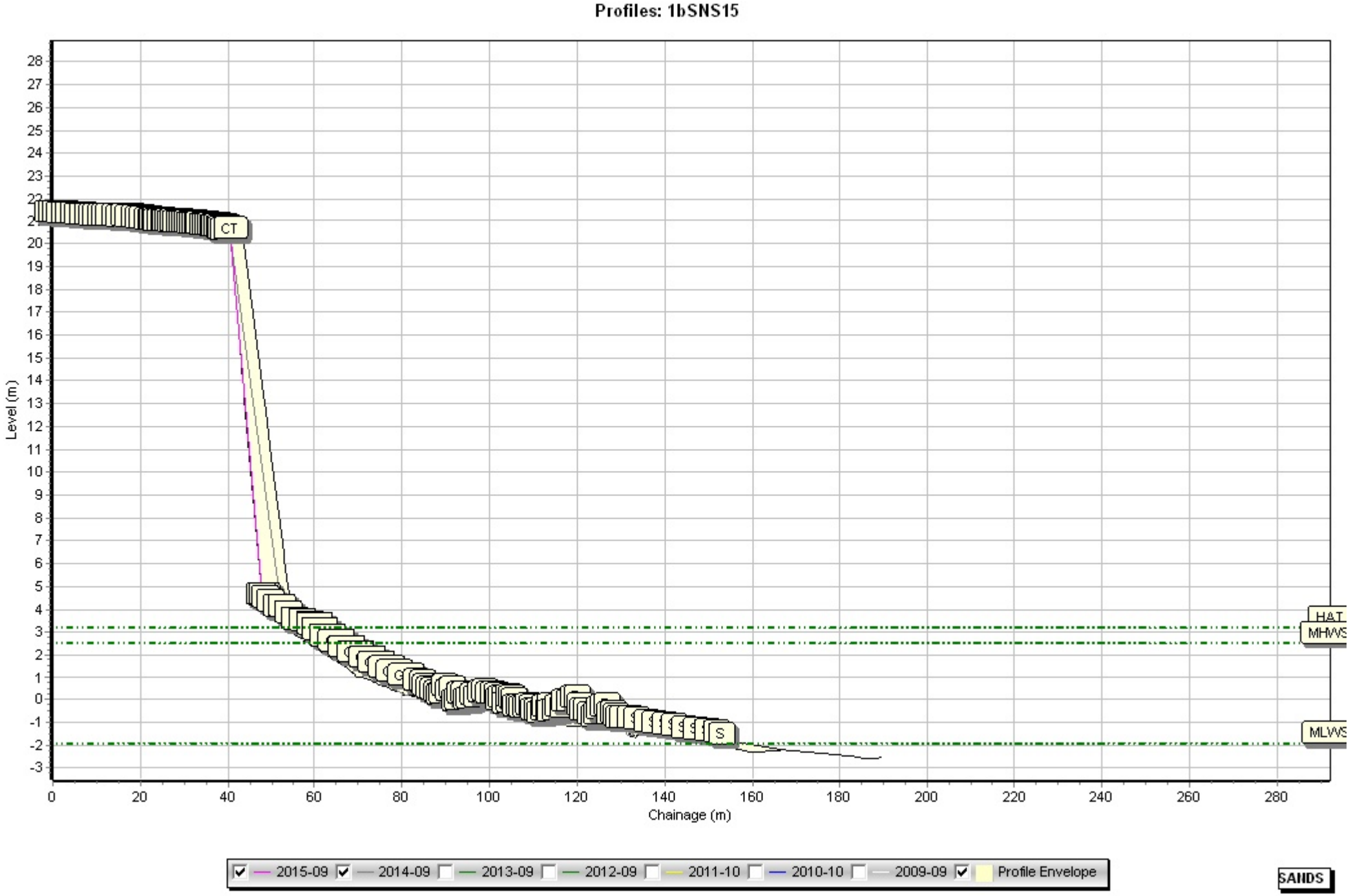

Profiles: 1bSNS10
Level (m)
Chainage (m)
SD
S
HAT
MHWS
MLWS
2015-09
2014-09
2013-09
2012-09
2011-10
2010-10
2009-09
Profile Envelope
SAIDS

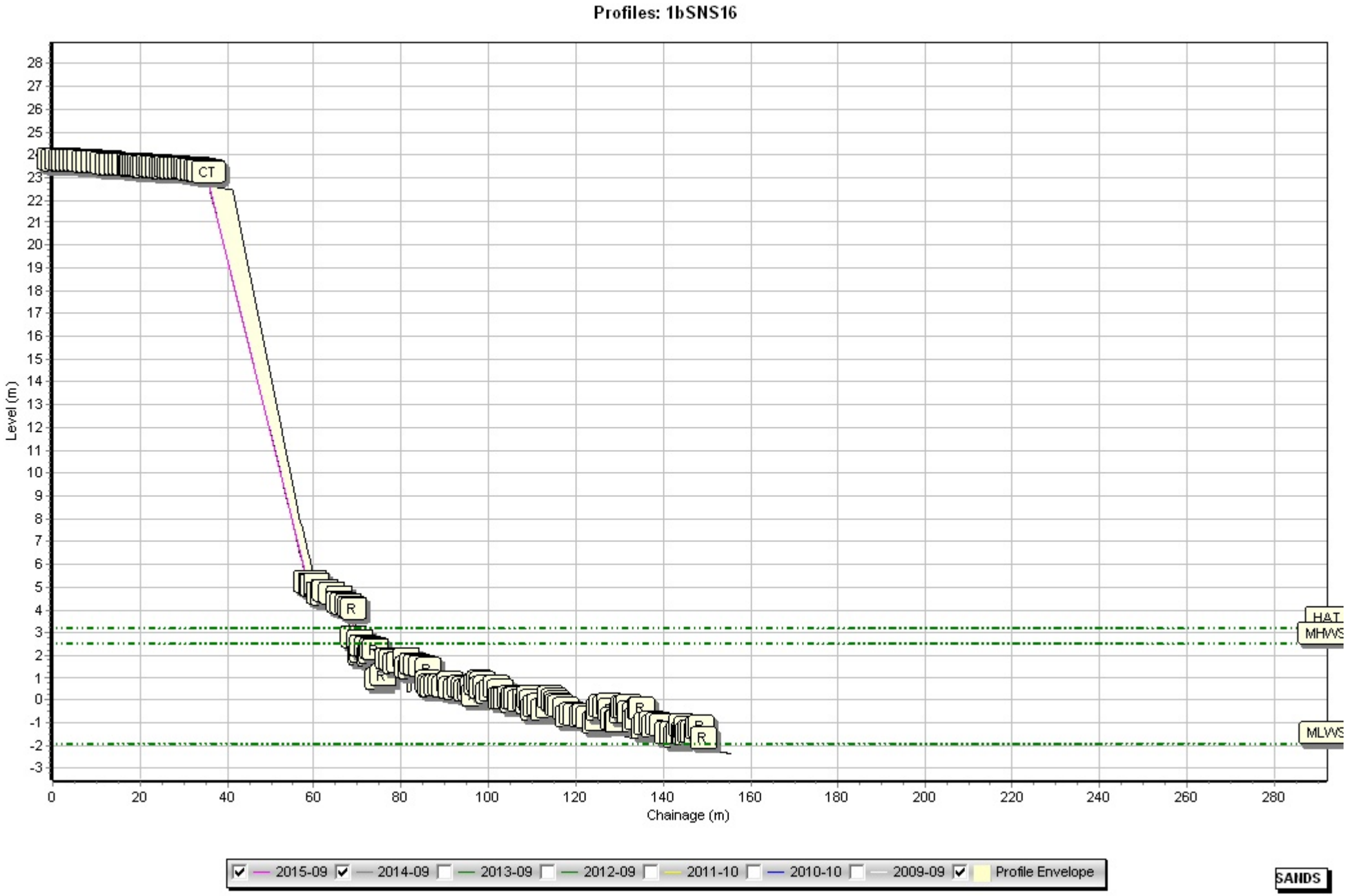

Profiles: 1bSNS11
Level (m)
Chainage (m)
GR
SD
HAT
MHWS
MLWS
2015-09
2014-09
2013-09
2012-09
2011-10
2010-10
2009-09
Profile Envelope
SANDS

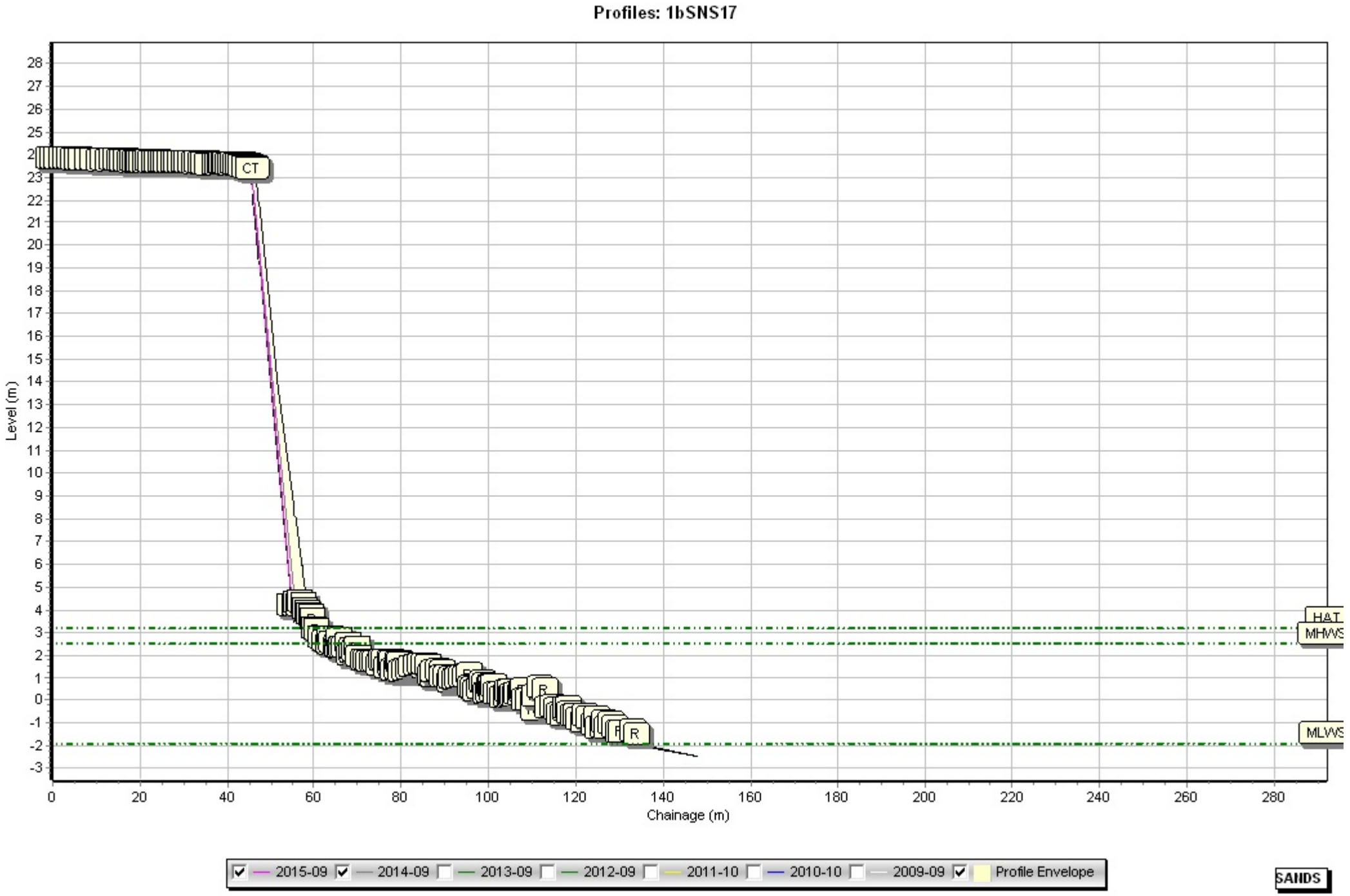

Profiles: 1bSNS12
Level (m)
Chainage (m)
CT
R
B
S
HAT
MHWS
MLWS
2015-09
2014-09
2013-09
2012-09
2011-10
2010-10
2009-09
Profile Envelope
SANDS

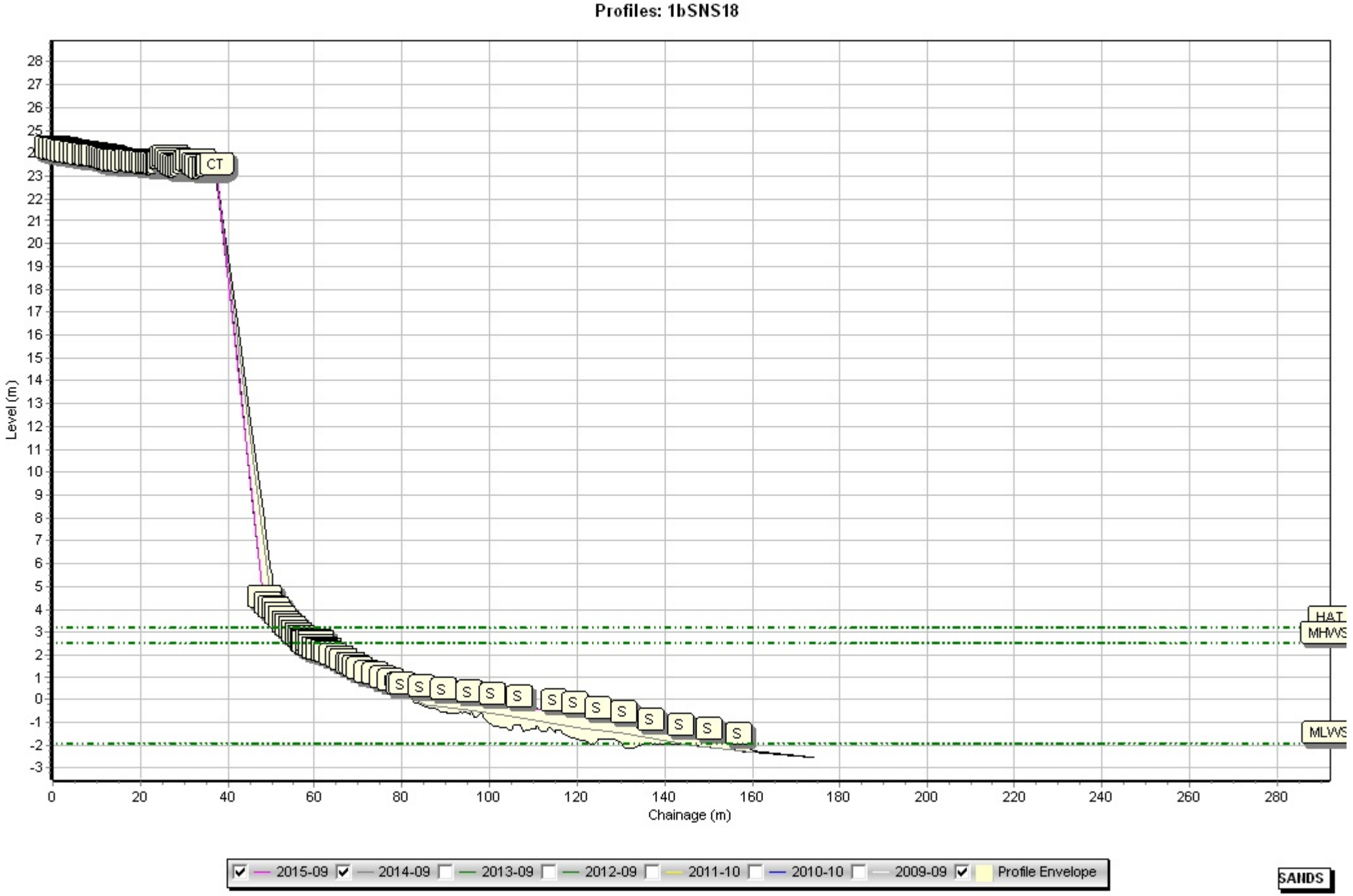

Profiles: 1bSNS13
Level (m)
Chainage (m)
CT
HAT
MHWS
MLWS
2015-09
2014-09
2013-09
2012-09
2011-10
2010-10
2009-09
Profile Envelope
SANDS

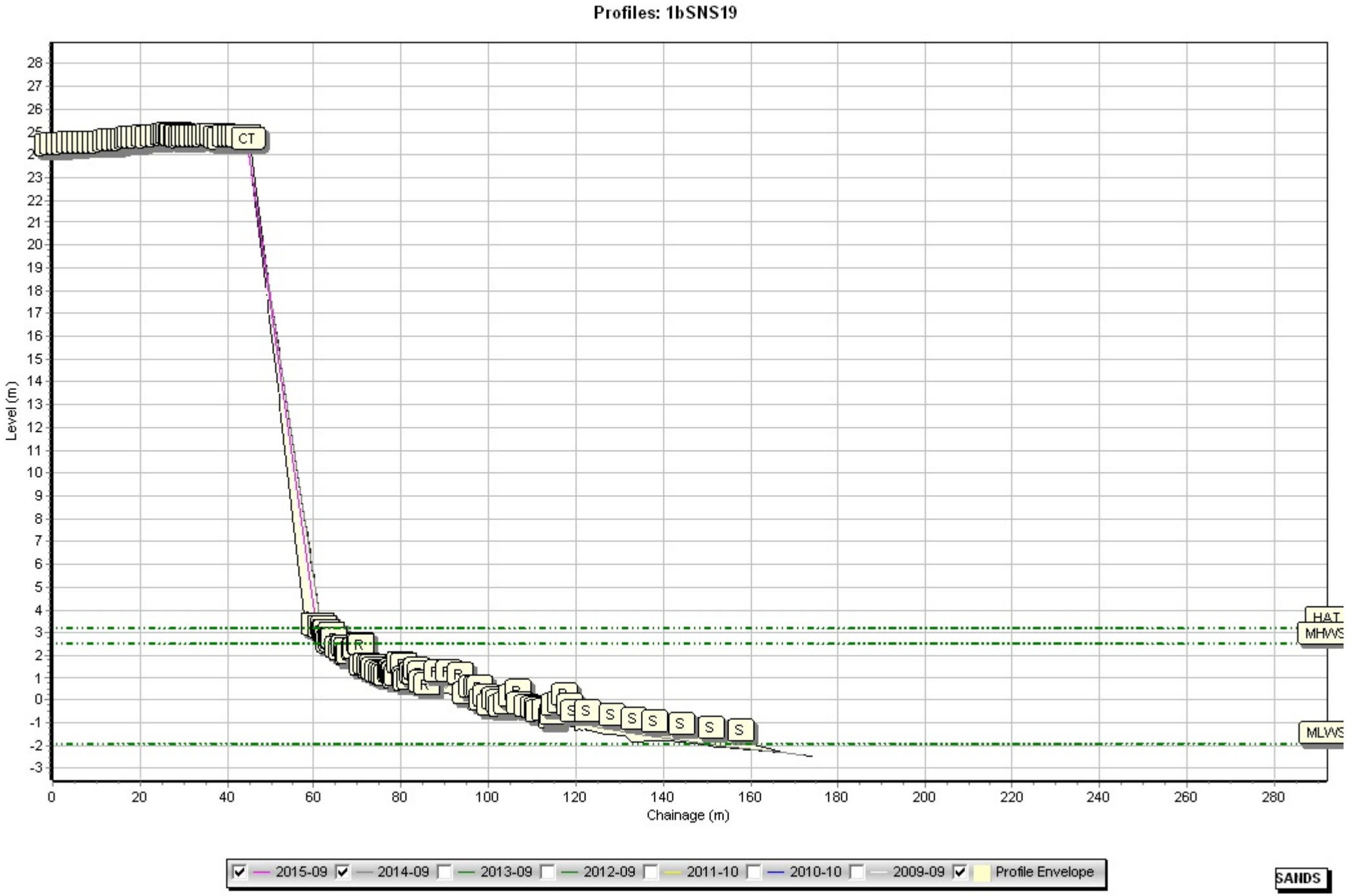

Profiles: 1bSNS14
Level (m)
Chainage (m)
CT
HAT
MHWS
MLWS
2015-09
2014-09
2013-09
2012-09
2011-10
2010-10
2009-09
Profile Envelope
SANDS

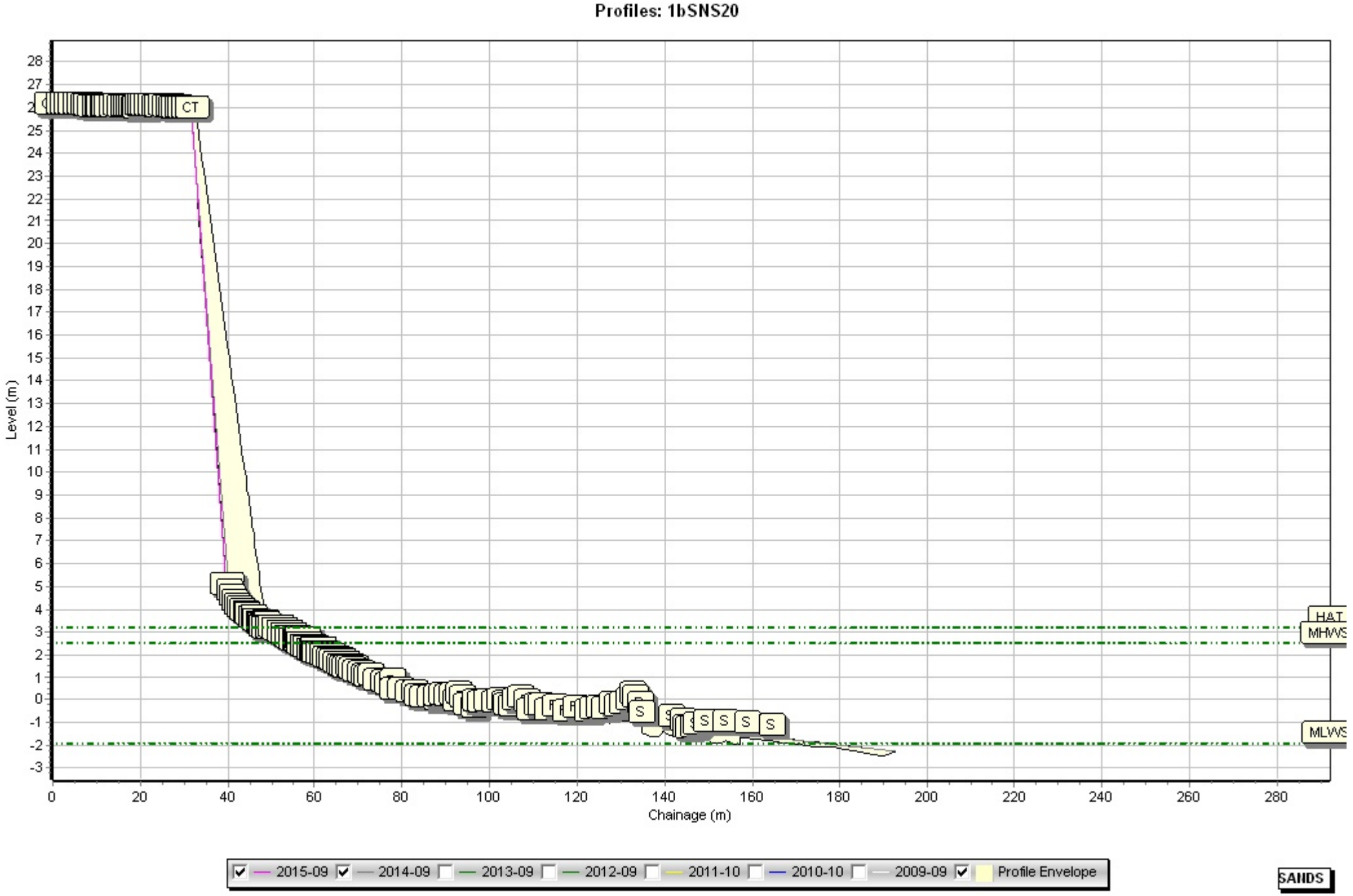

Profiles: 1bSNS15
Level (m)
Chainage (m)
CT
S
HAT
MHWS
MLWS
2015-09
2014-09
2013-09
2012-09
2011-10
2010-10
2009-09
Profile Envelope
SANDS

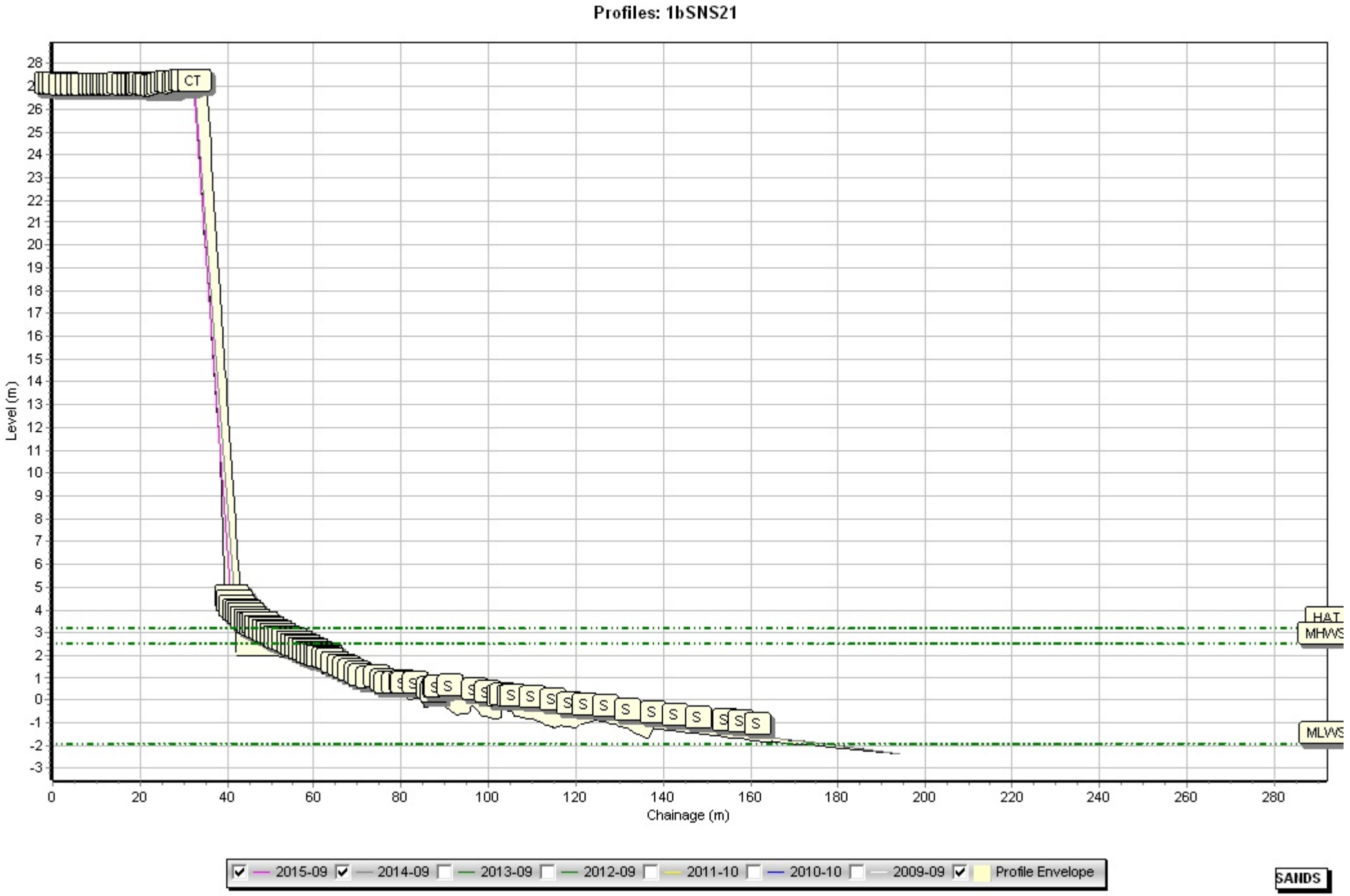

Profiles: 1bSNS16
Level (m)
Chainage (m)
CT
R
HAT
MHWS
MLWS
2015-09
2014-09
2013-09
2012-09
2011-10
2010-10
2009-09
Profile Envelope
SANDS

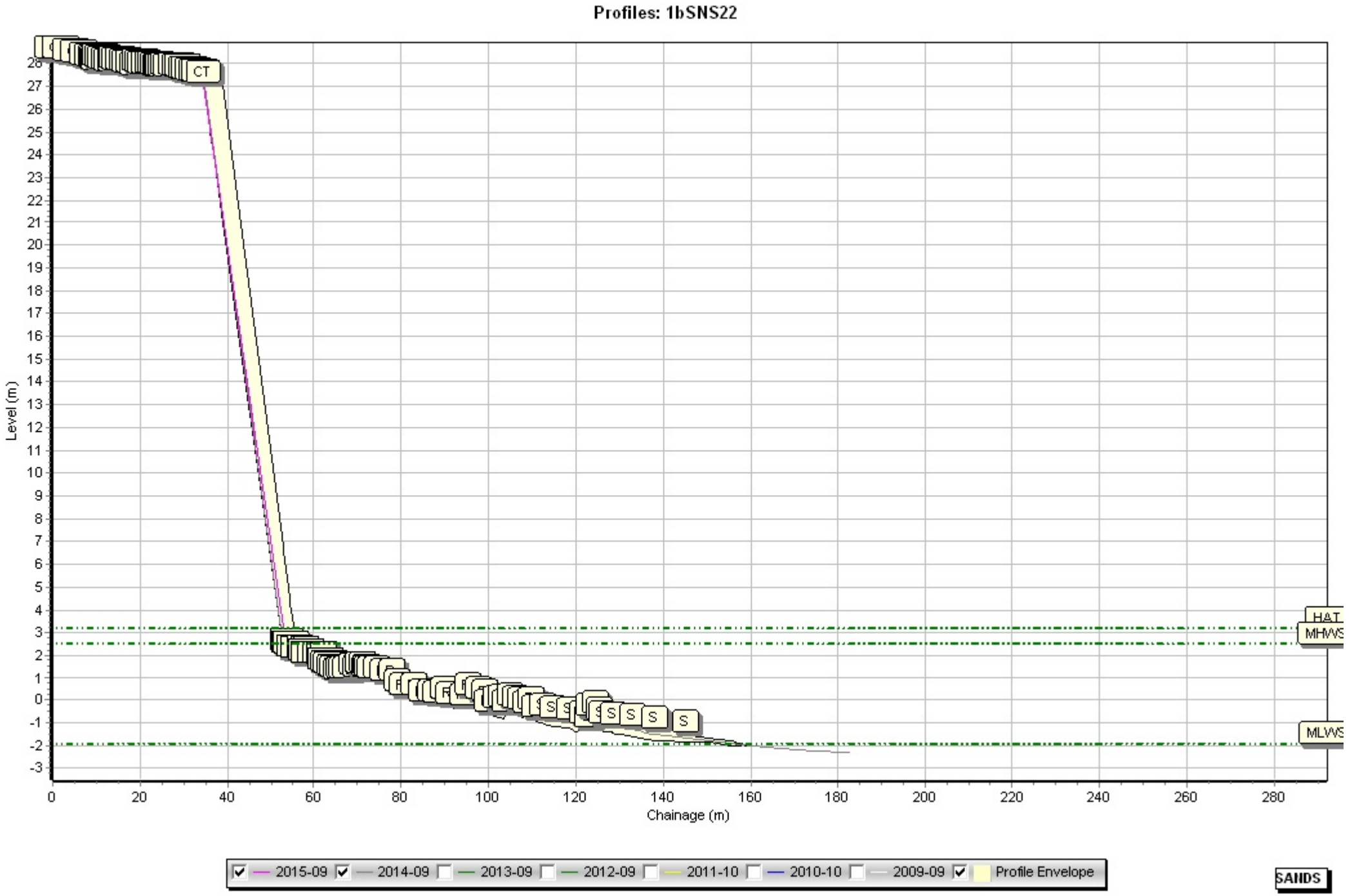

Profiles: 1bSNS17
Level (m)
Chainage (m)
CT
HAT
MHWS
MLWS
2015-09
2014-09
2013-09
2012-09
2011-10
2010-10
2009-09
Profile Envelope
SANDS

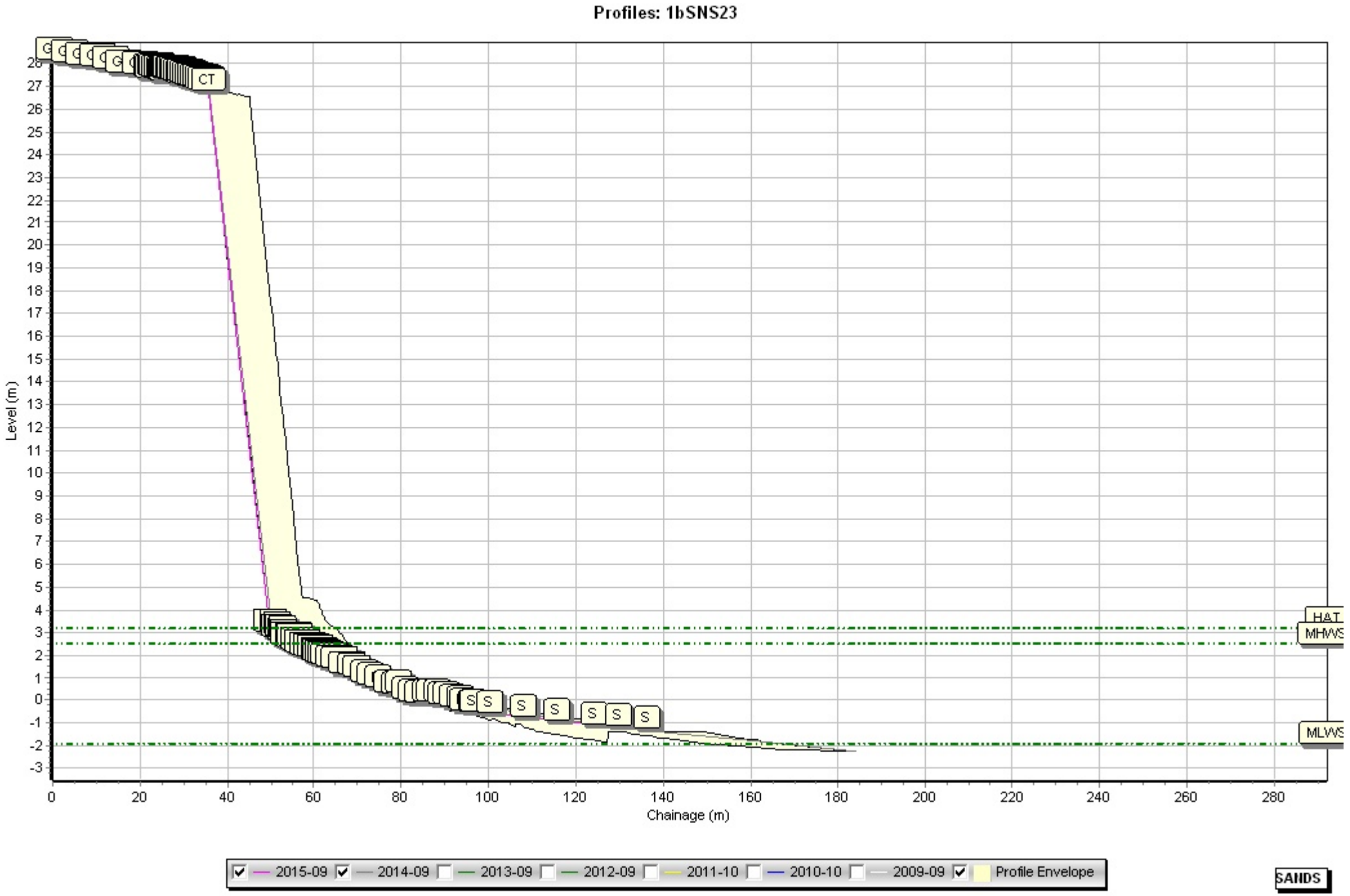

Profiles: 1bSNS18
Level (m)
Chainage (m)
CT
HAT
MHWS
MLWS
2015-09
2014-09
2013-09
2012-09
2011-10
2010-10
2009-09
Profile Envelope
SANDS

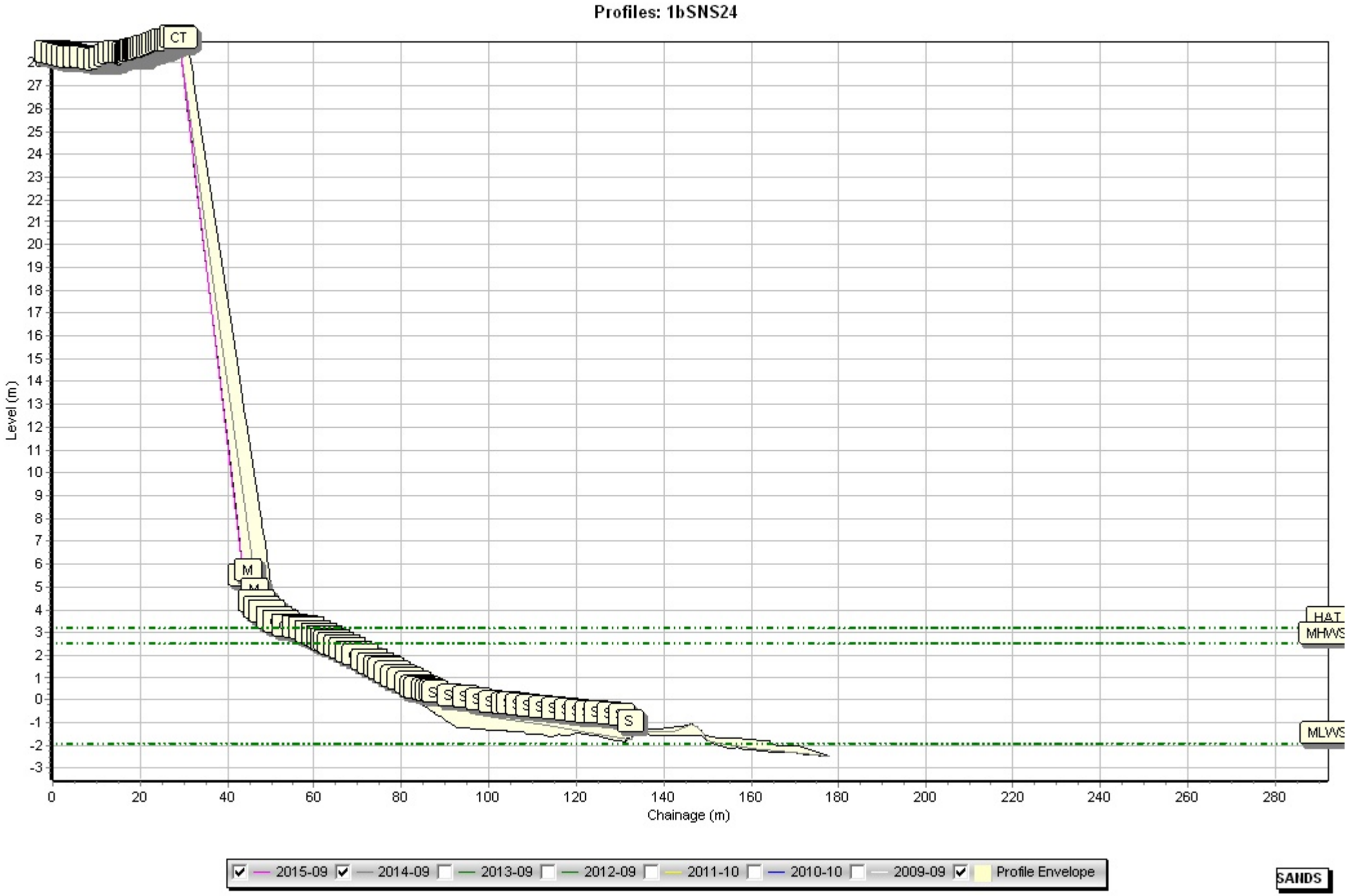

Profiles: 1bSNS19
Level (m)
Chainage (m)
CT
R
S
HAT
MHWS
MLWS
2015-09
2014-09
2013-09
2012-09
2011-10
2010-10
2009-09
Profile Envelope
SANDS

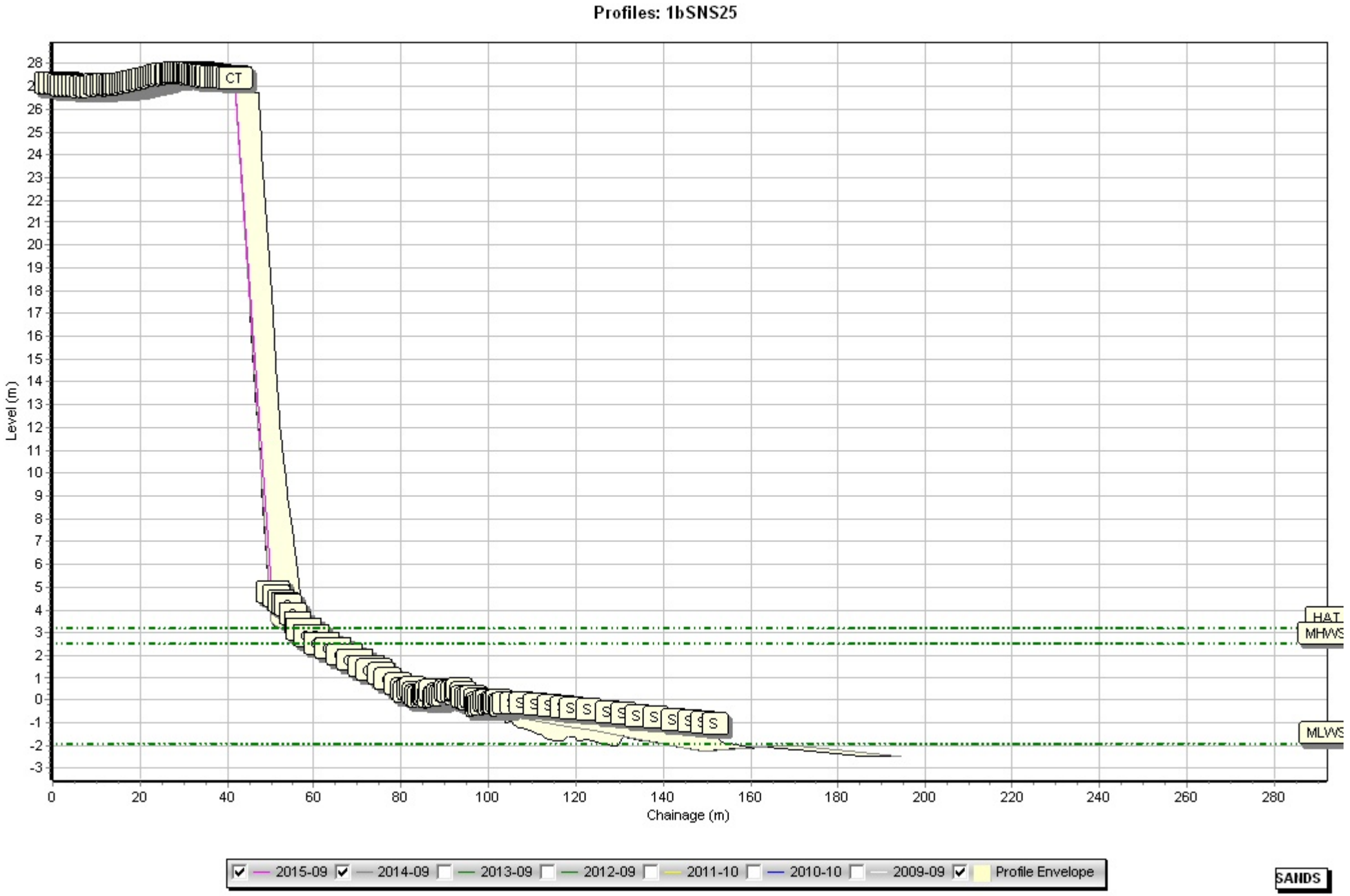

Profiles: 1bSNS20
CT
HAT
MHWS
MLWS
S
Level (m)
Chainage (m)
2015-09
2014-09
2013-09
2012-09
2011-10
2010-10
2009-09
Profile Envelope
SANDS

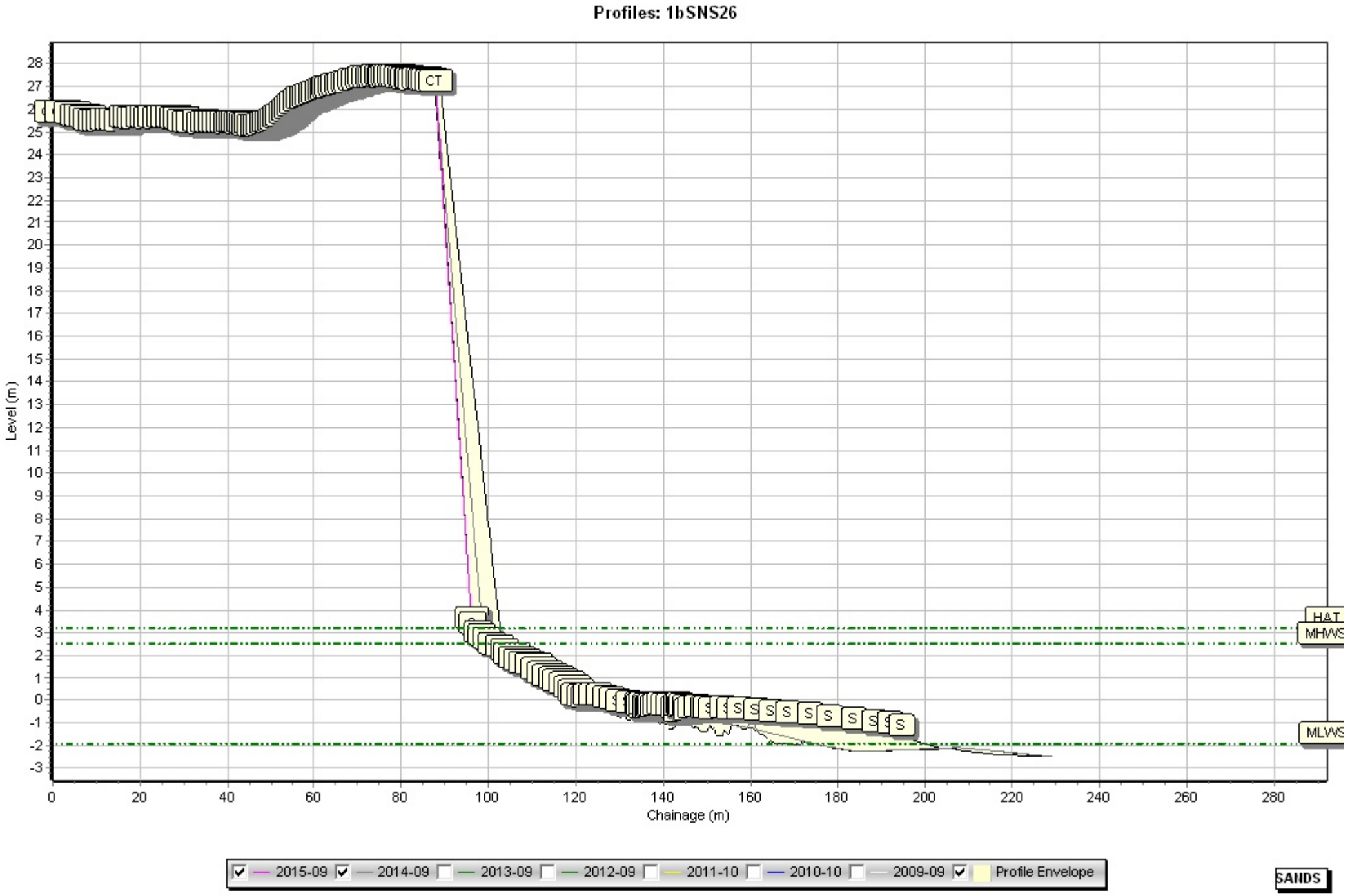

Profiles: 1bSNS21
CT
HAT
MHWS
MLWS
Level (m)
Chainage (m)
2015-09
2014-09
2013-09
2012-09
2011-10
2010-10
2009-09
Profile Envelope
SANDS

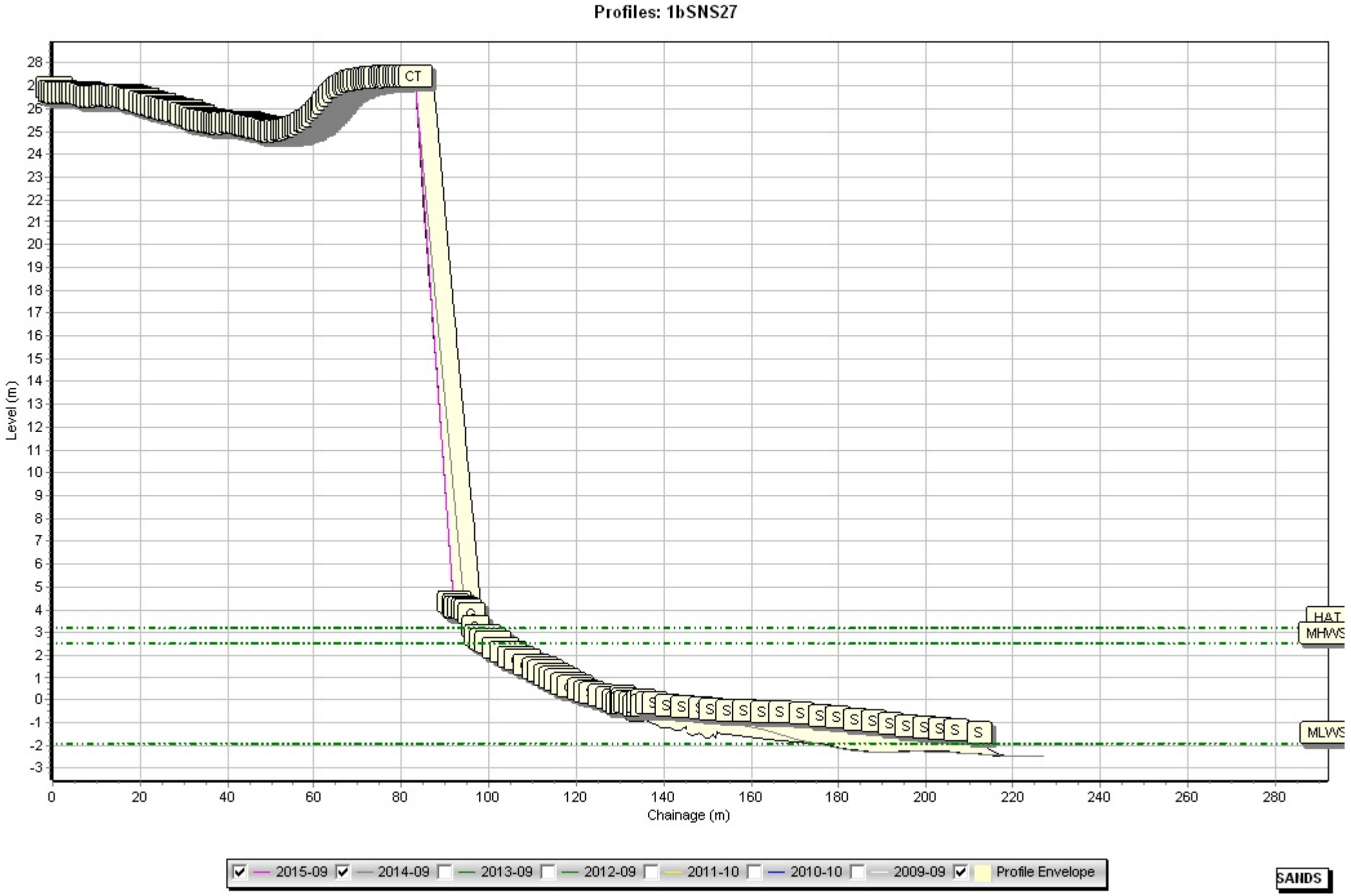

Profiles: 1bSNS22
CT
S
HAT
MHWS
MLWS
Level (m)
Chainage (m)
2015-09
2014-09
2013-09
2012-09
2011-10
2010-10
2009-09
Profile Envelope
SANDS

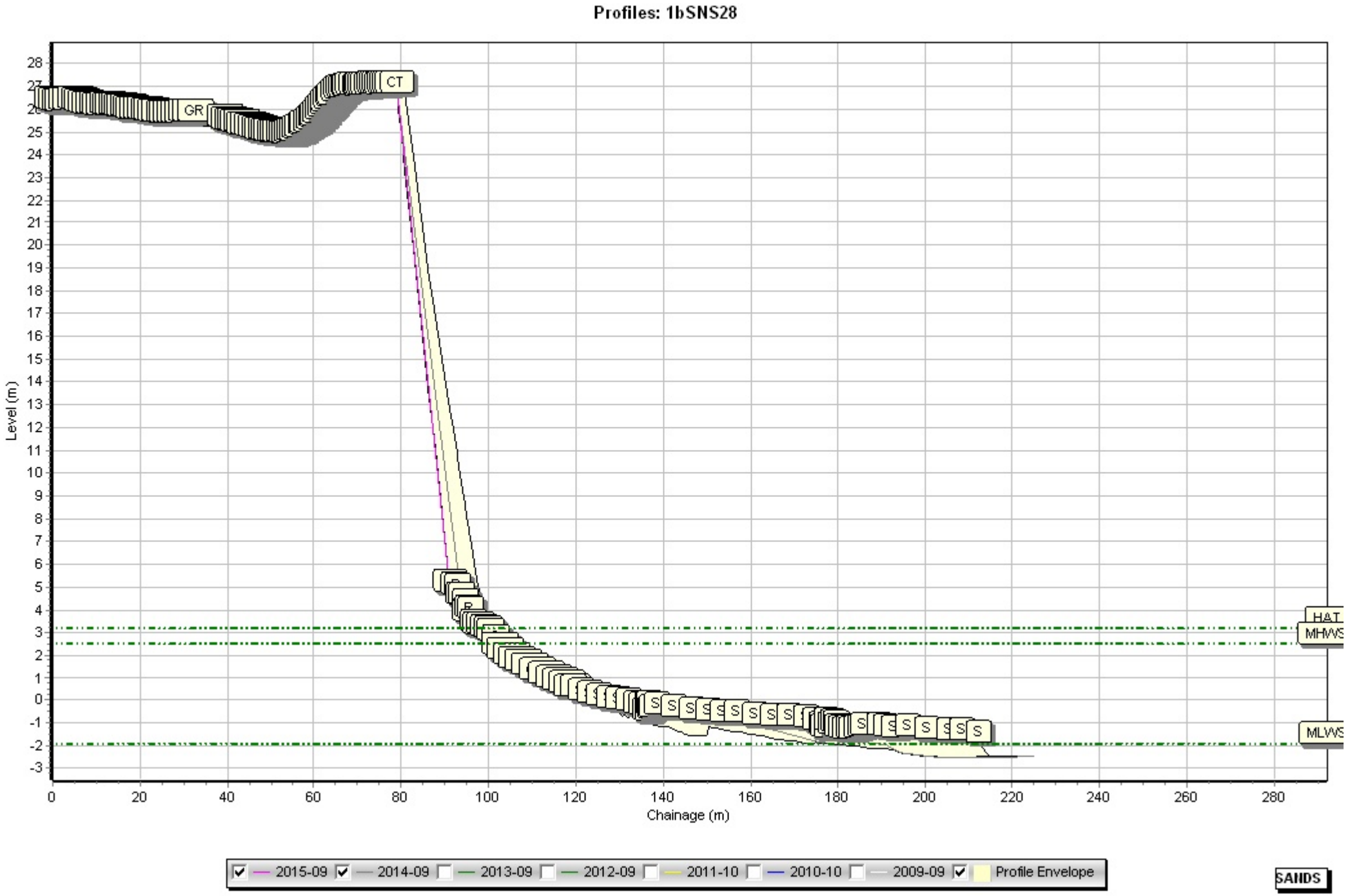

Profiles: 1bSNS23
Level (m)
Chainage (m)
CT
S
HAT
MHWS
MLWS
2015-09
2014-09
2013-09
2012-09
2011-10
2010-10
2009-09
Profile Envelope
SANDS

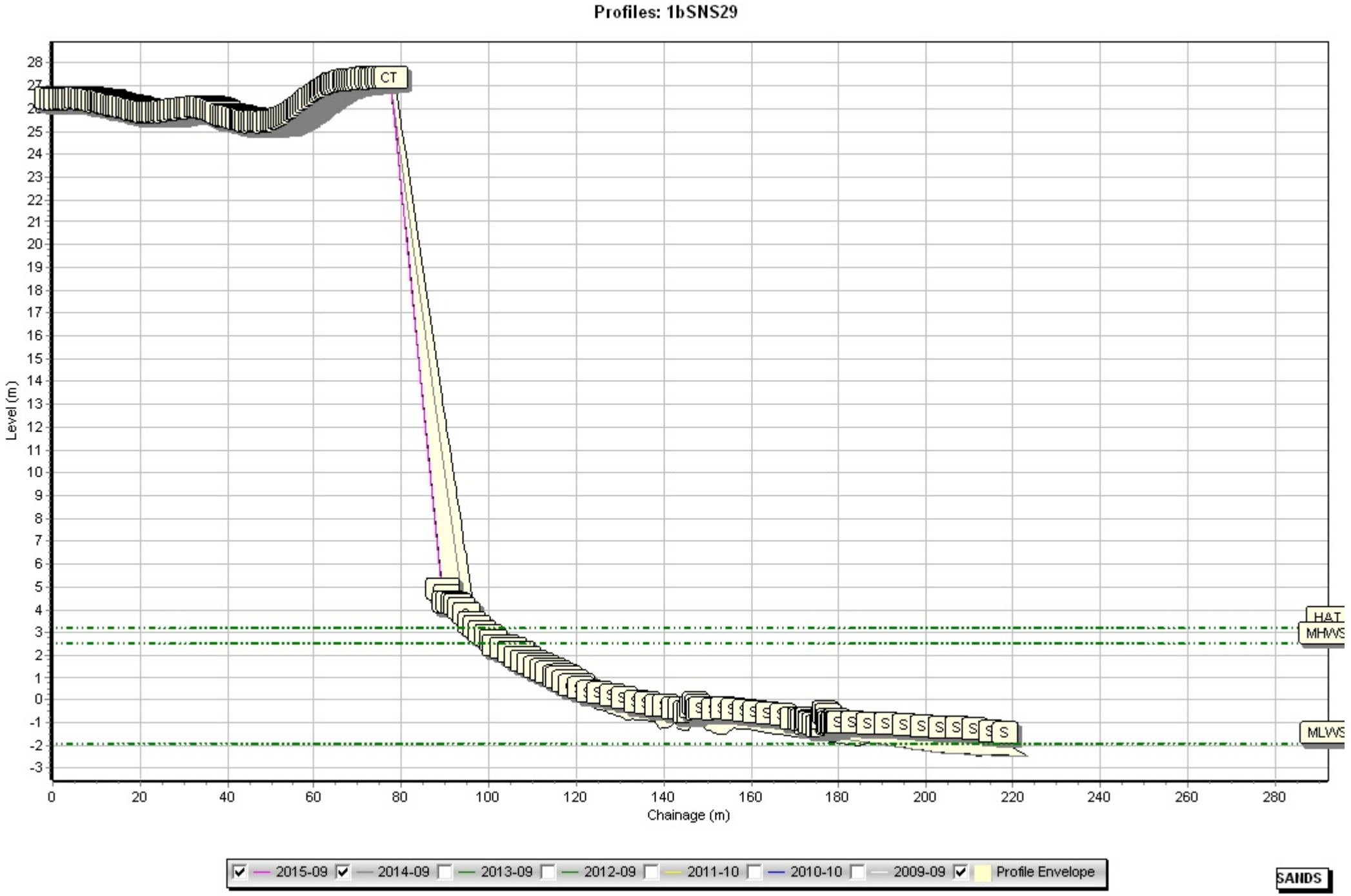

Profiles: 1bSNS24
CT
M
S
HAT
MHWS
MLWS
Level (m)
Chainage (m)
2015-09
2014-09
2013-09
2012-09
2011-10
2010-10
2009-09
Profile Envelope
SANDS

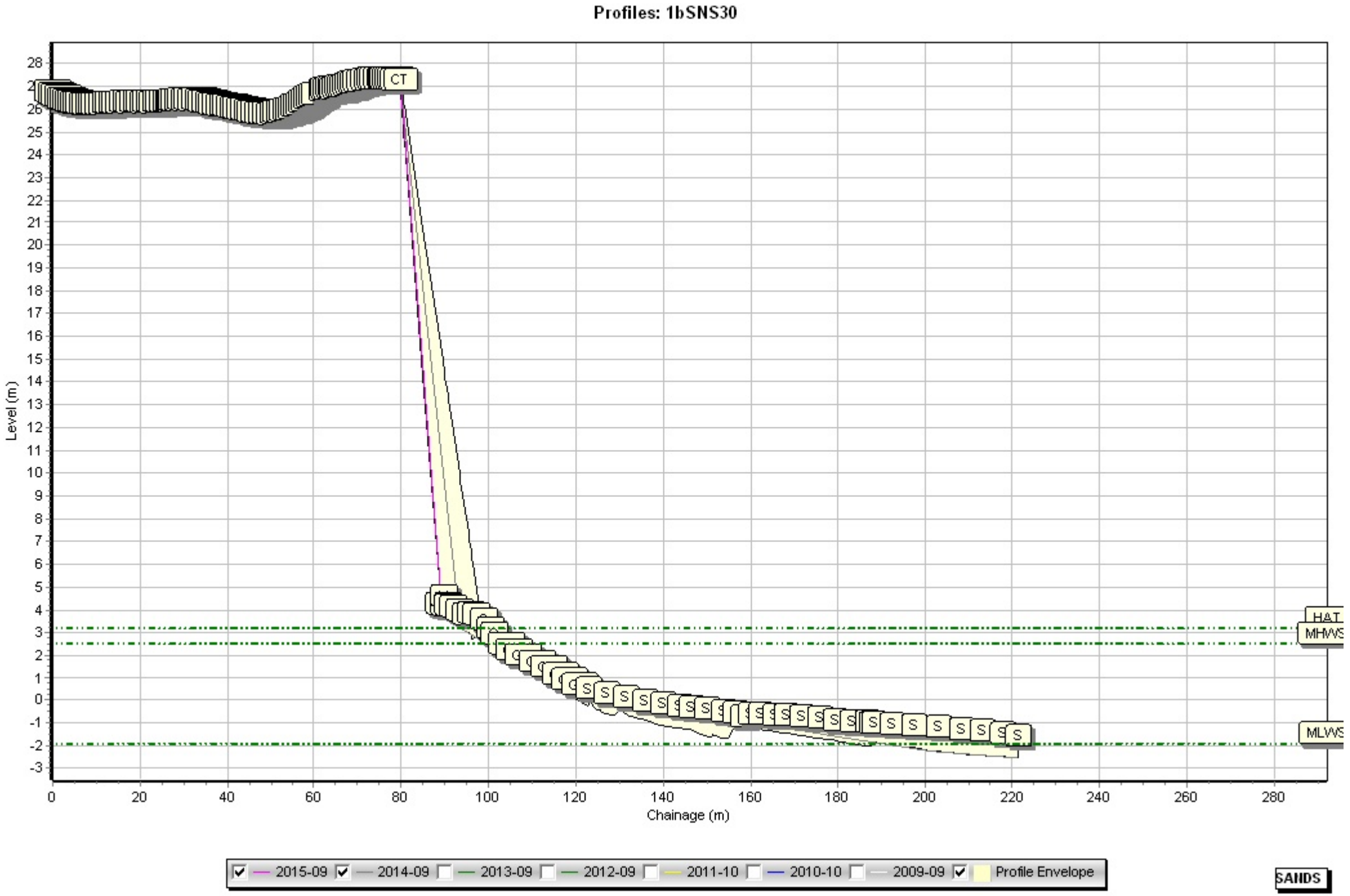

Profiles: 1bSNS25
CT
HAT
MHWS
MLWS
Level (m)
Chainage (m)
2015-09
2014-09
2013-09
2012-09
2011-10
2010-10
2009-09
Profile Envelope
SANDS

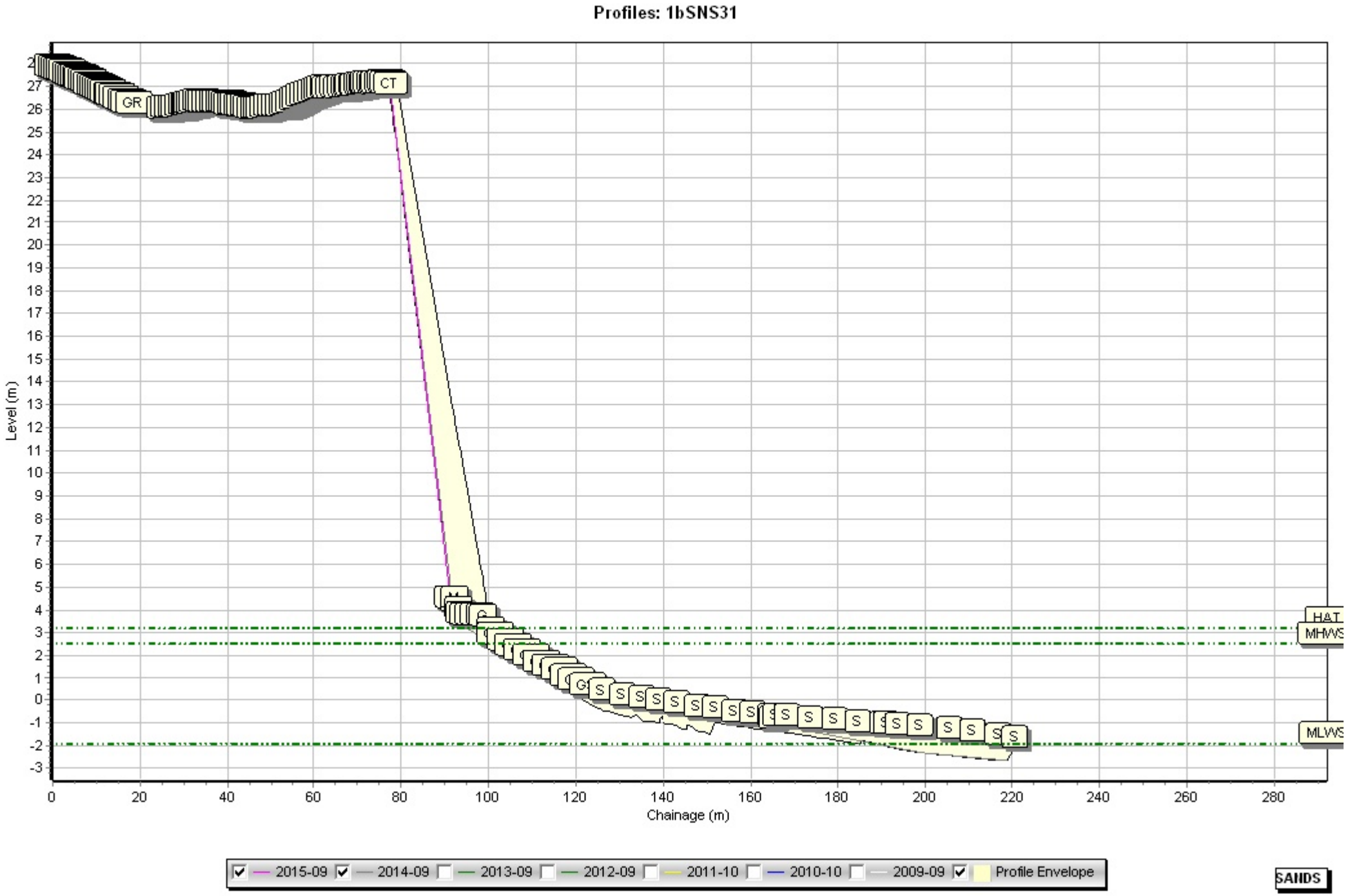

Profiles: 1bSNS26
CT
S
HAT
MHWS
MLWS
Level (m)
Chainage (m)
2015-09
2014-09
2013-09
2012-09
2011-10
2010-10
2009-09
Profile Envelope
SANDS

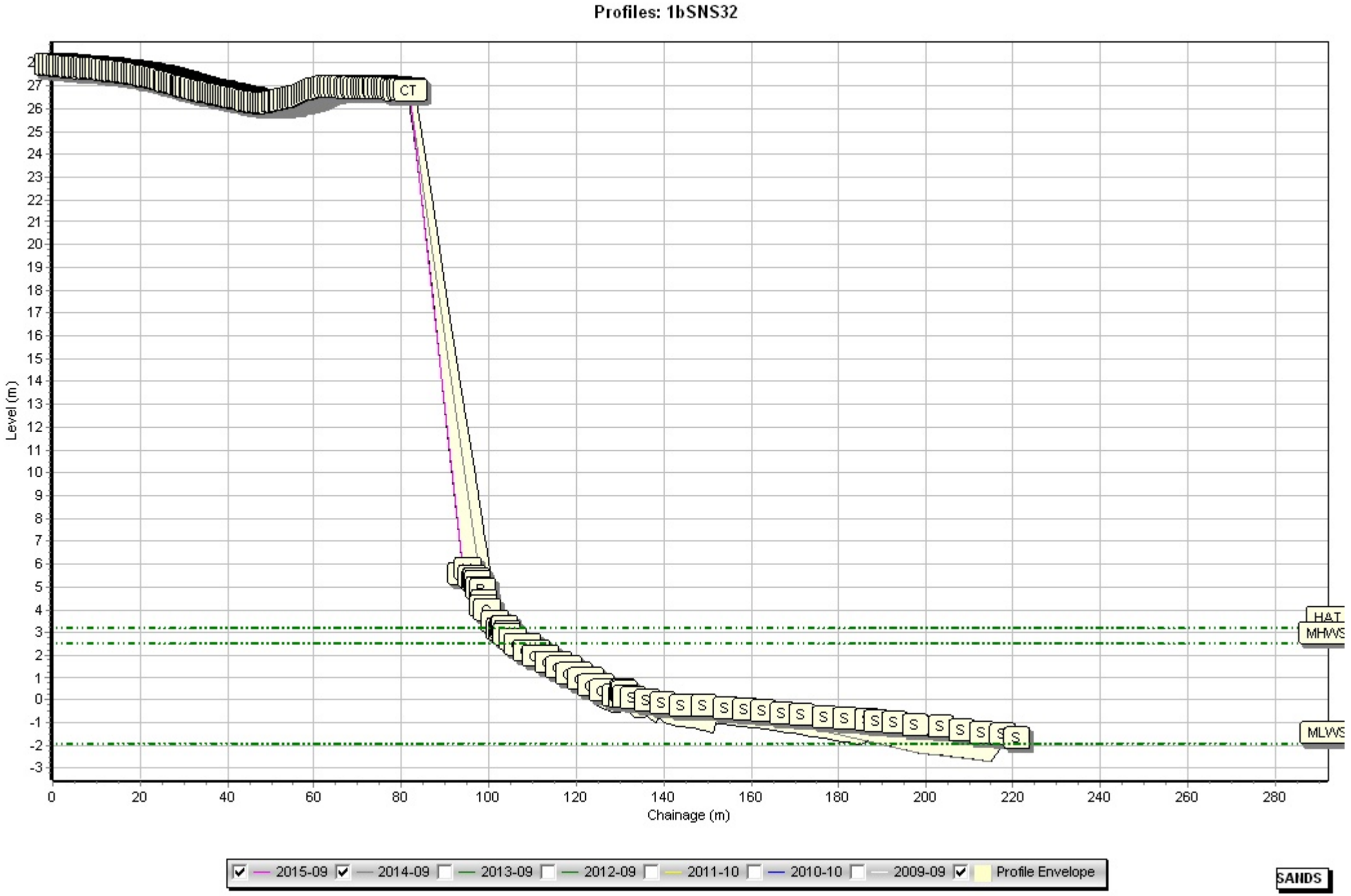

Profiles: 1bSNS27
CT
HAT
MHWS
MLWS
Level (m)
Chainage (m)
2015-09
2014-09
2013-09
2012-09
2011-10
2010-10
2009-09
Profile Envelope
SANDS

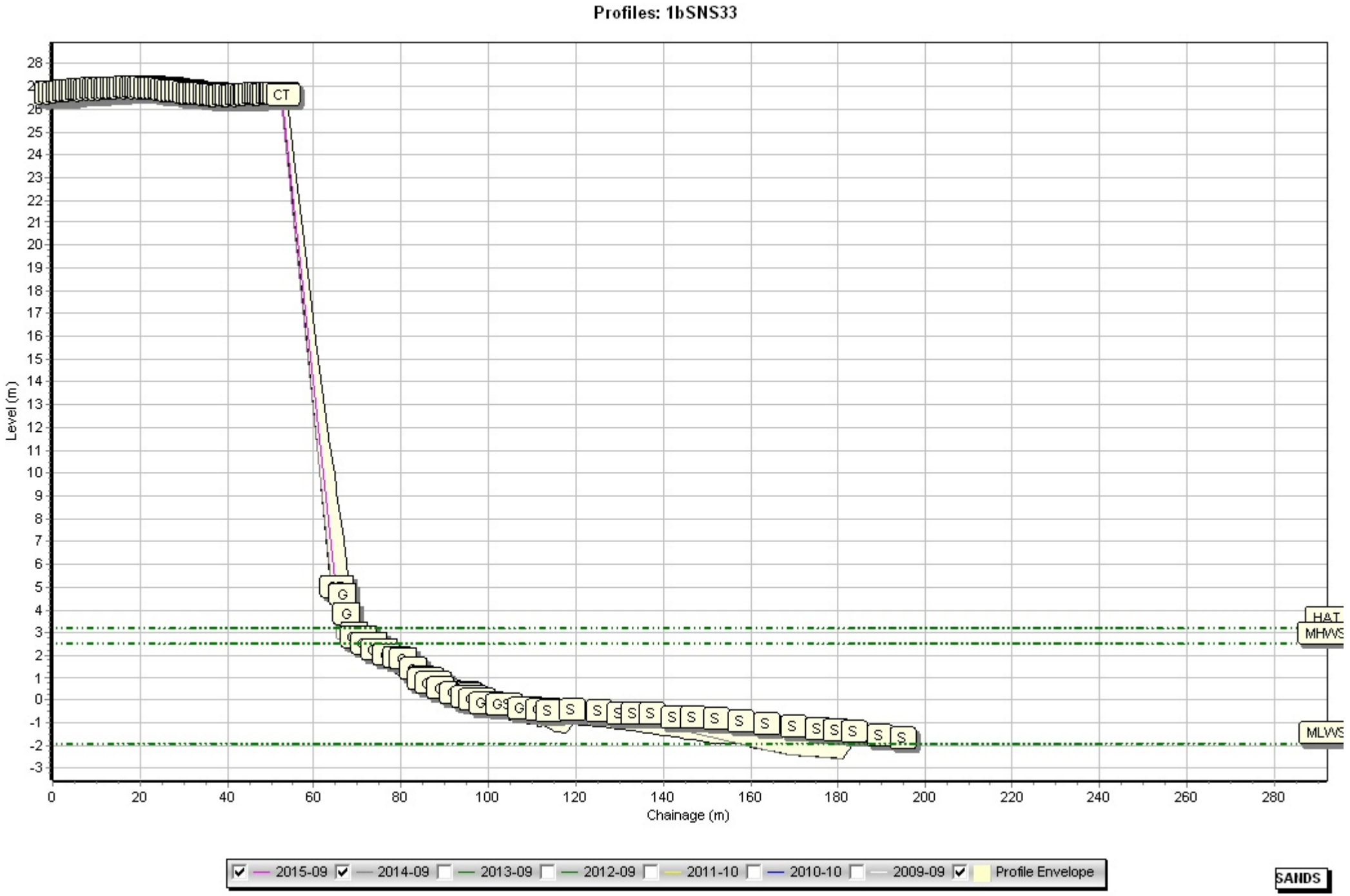

Profiles: 1bSNS28
GR
CT
P
S
HAT
MHWS
MLWS
Level (m)
Chainage (m)
2015-09
2014-09
2013-09
2012-09
2011-10
2010-10
2009-09
Profile Envelope
SANDS

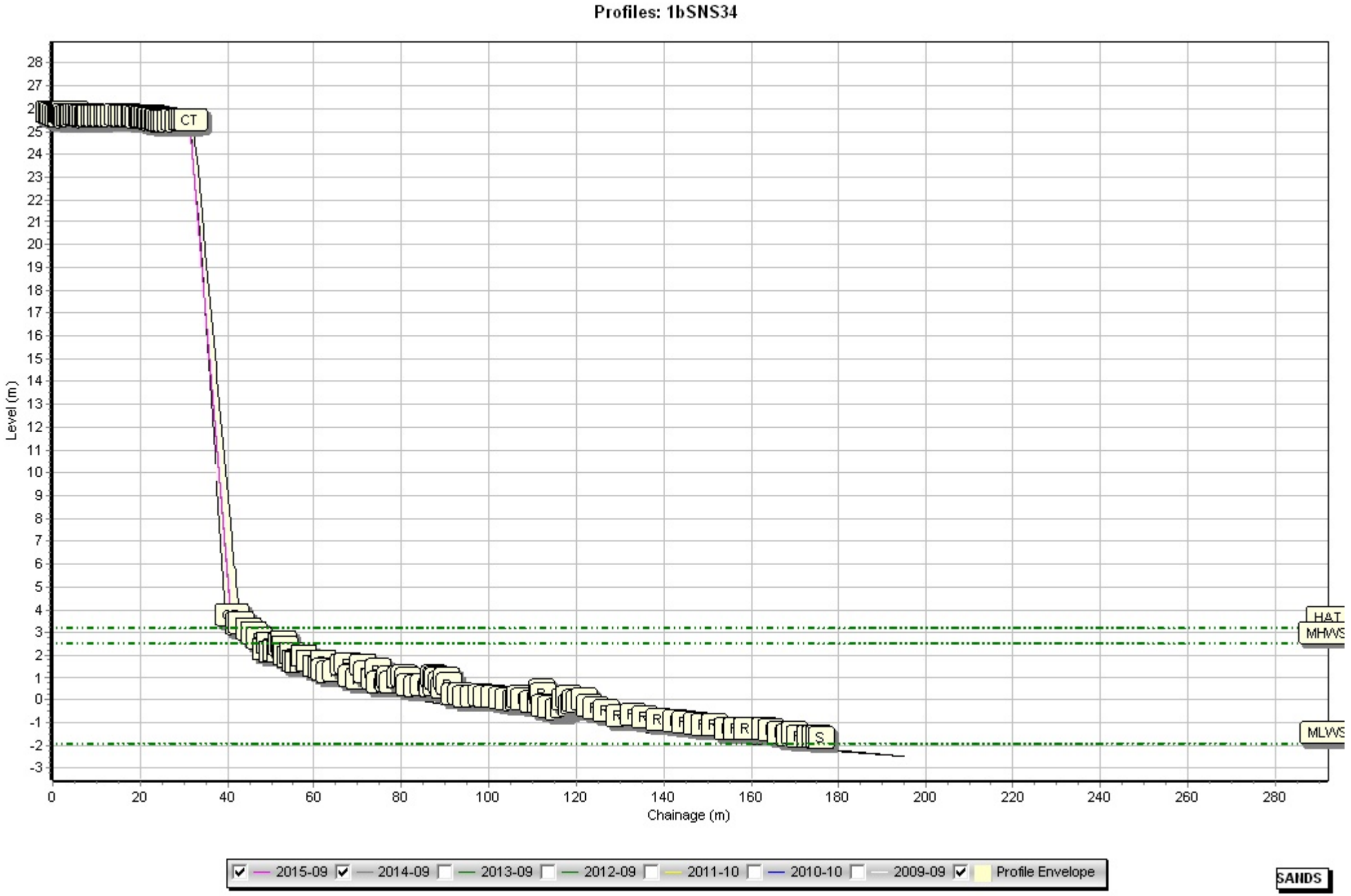

Profiles: 1bSNS29
CT
HAT
MHWS
MLWS
Level (m)
Chainage (m)
2015-09
2014-09
2013-09
2012-09
2011-10
2010-10
2009-09
Profile Envelope
SANDS

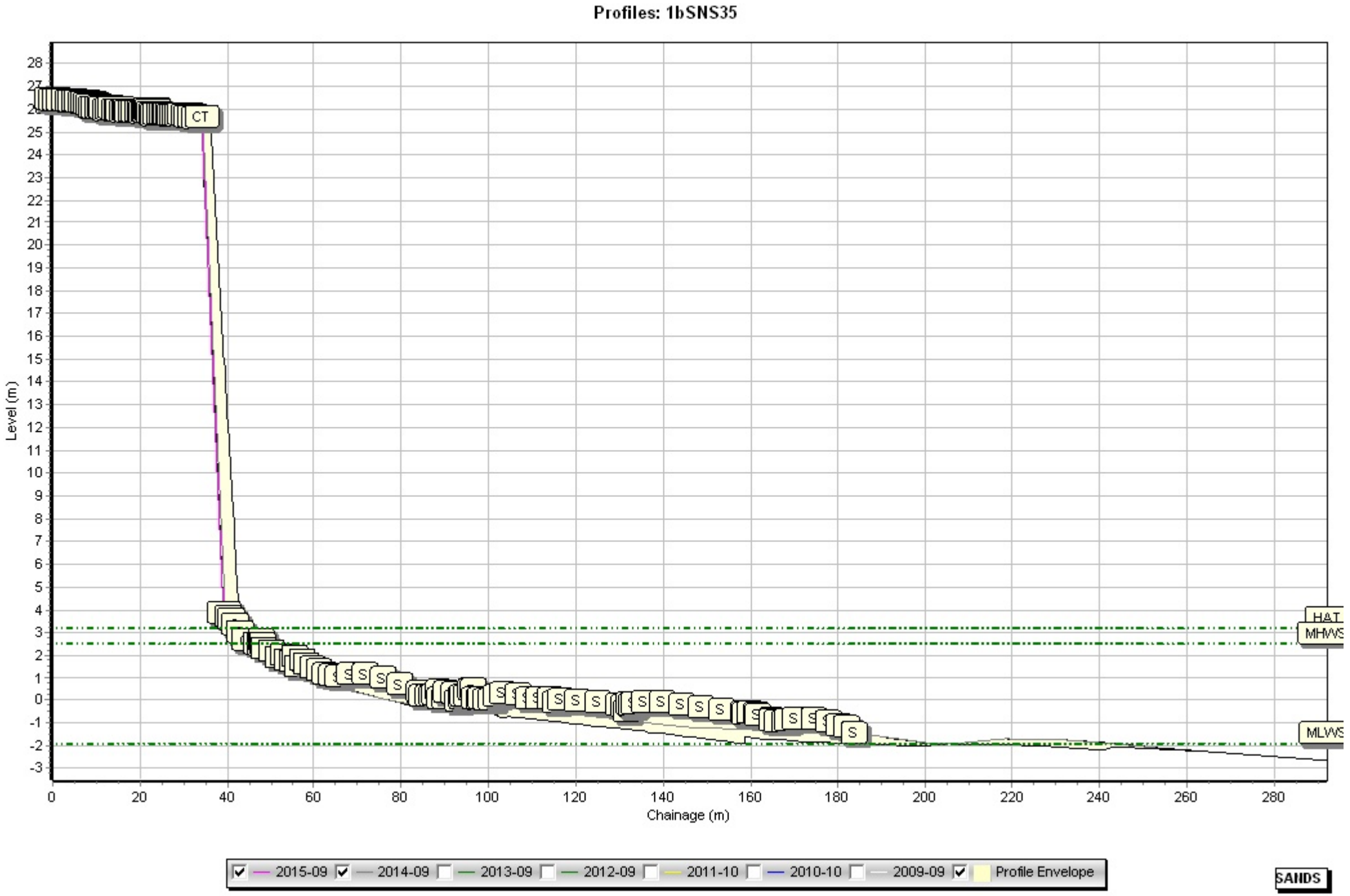

Profiles: 1bSNS30
CT
S
HAT
MHWS
MLWS
Level (m)
Chainage (m)
2015-09
2014-09
2013-09
2012-09
2011-10
2010-10
2009-09
Profile Envelope
SANDS

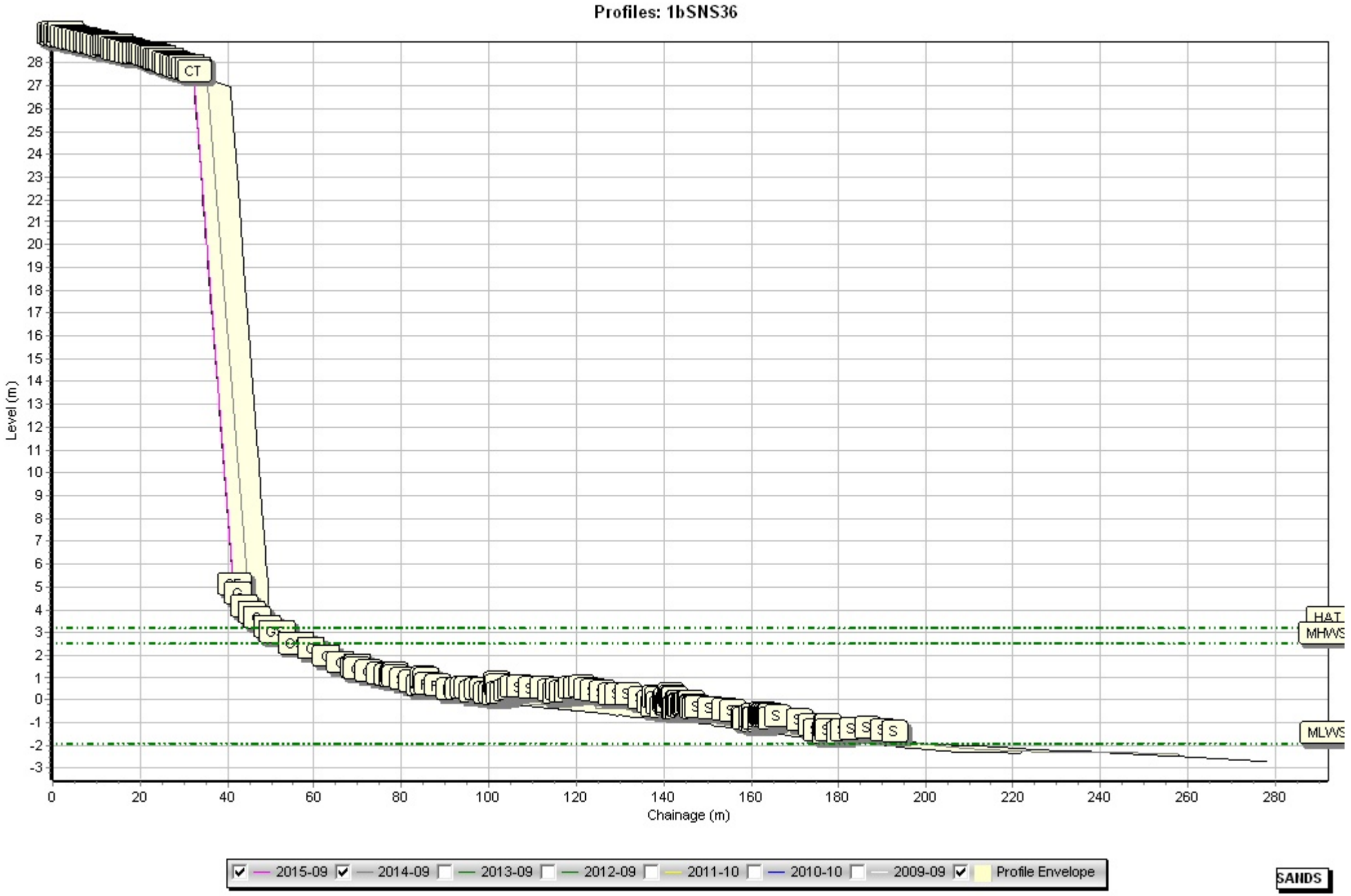

Profiles: 1bSNS31
GR
CT
HAT
MHWS
MLWS
Level (m)
Chainage (m)
2015-09
2014-09
2013-09
2012-09
2011-10
2010-10
2009-09
Profile Envelope
SANDS


Profiles: 1bSNS32
CT
HAT
MHWS
MLWS
Level (m)
Chainage (m)
2015-09
2014-09
2013-09
2012-09
2011-10
2010-10
2009-09
Profile Envelope
SANDS


Profiles: 1bSNS33
Level (m)
Chainage (m)
CT
G
S
HAT
MHWS
MLWS
2015-09
2014-09
2013-09
2012-09
2011-10
2010-10
2009-09
Profile Envelope
SANDS


Profiles: 1bSNS34
Level (m)
Chainage (m)
CT
HAT
MHWS
MLWS
S
2015-09
2014-09
2013-09
2012-09
2011-10
2010-10
2009-09
Profile Envelope
SANDS


Profiles: 1bSNS35
Level (m)
Chainage (m)
CT
HAT
MHWS
MLWS
2015-09
2014-09
2013-09
2012-09
2011-10
2010-10
2009-09
Profile Envelope
SANDS

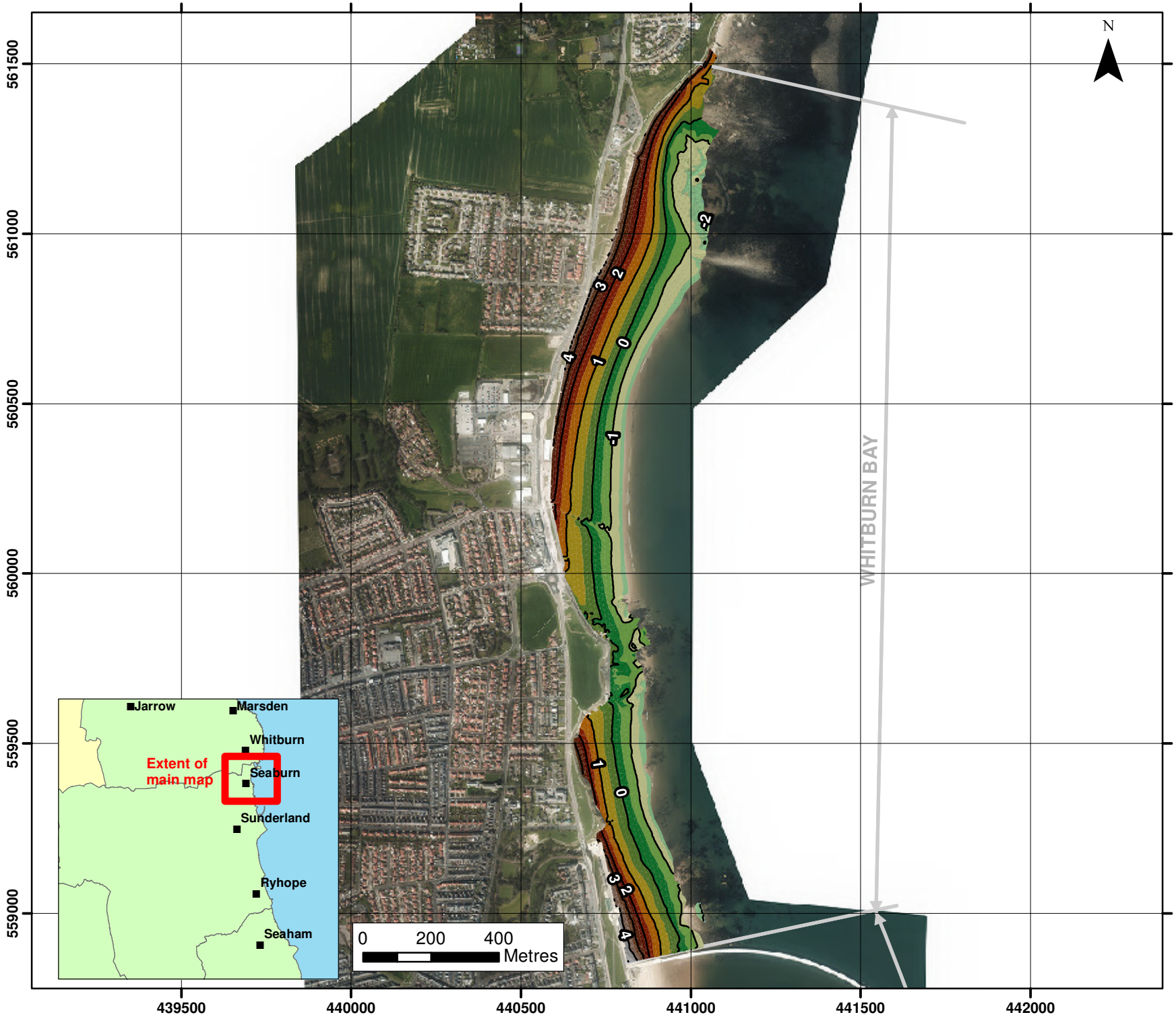

Profiles: 1bSNS36
CT
HAT
MHWS
MLWS
Level (m)
Chainage (m)
2015-09
2014-09
2013-09
2012-09
2011-10
2010-10
2009-09
Profile Envelope
SANDS

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

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

Appendix B

Topographic Survey



KEY

Elevation (m OD)

- 5 - 5.5
- 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
- -2.144 - -2
- Contour 1m

Client: North East Coastal Group

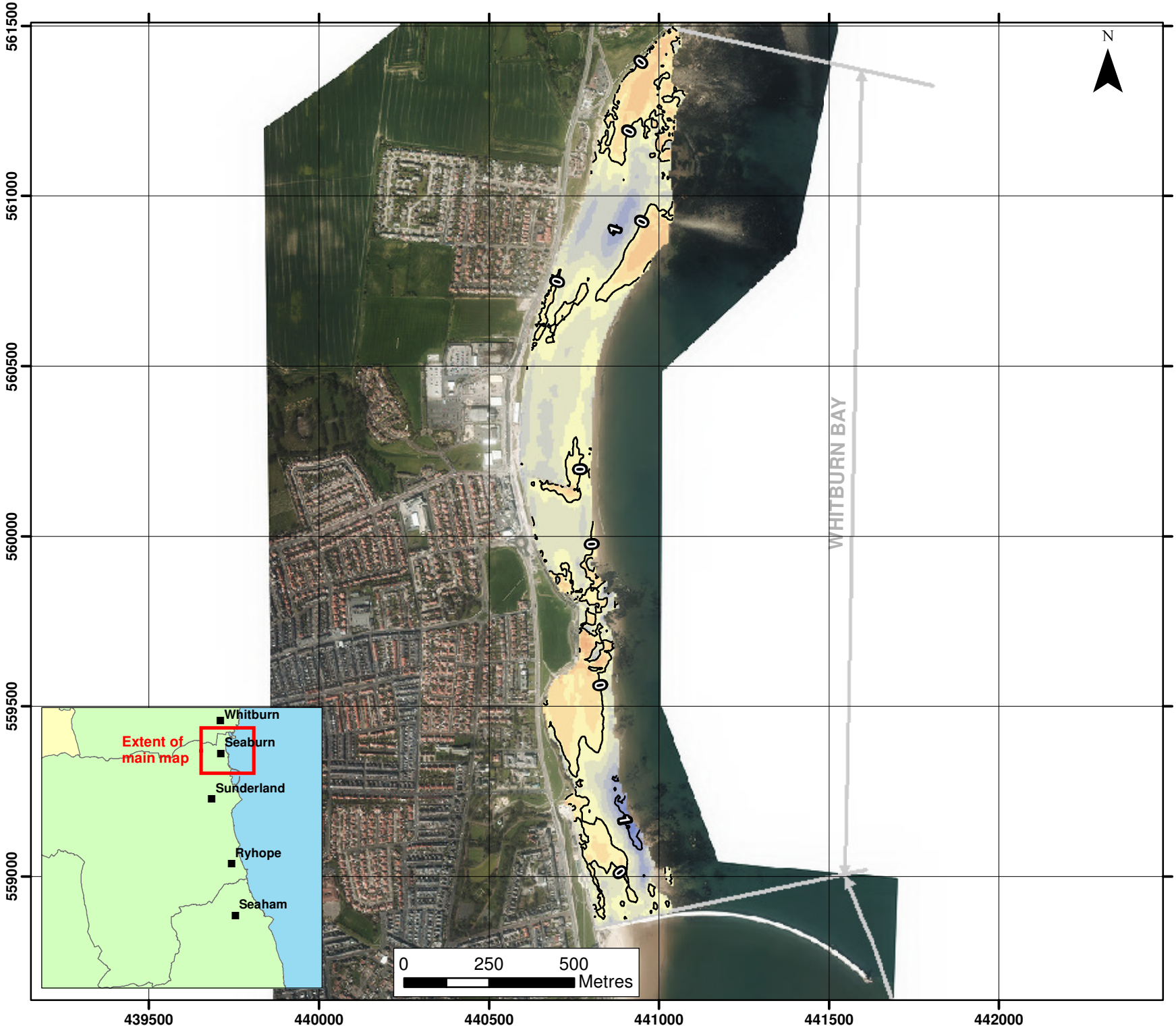
Project: Cell 1 Regional Coastal Monitoring Programme 2011 to 2016

Appendix B - Map 1a
Topographic Survey
Whitburn Bay
Sunderland City Council

Analytical Report 8
Full Measures Survey
Autumn 2015

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

Tel: +44 (0)121 456 2345
Fax: +44(0)121 456 1569
www.ch2m.com



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

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

Loss

Change < 0.1 m

Gain

Contours of change

Client: North East Coastal Group

Project: Cell 1 Regional Coastal Monitoring Programme 2011 to 2016

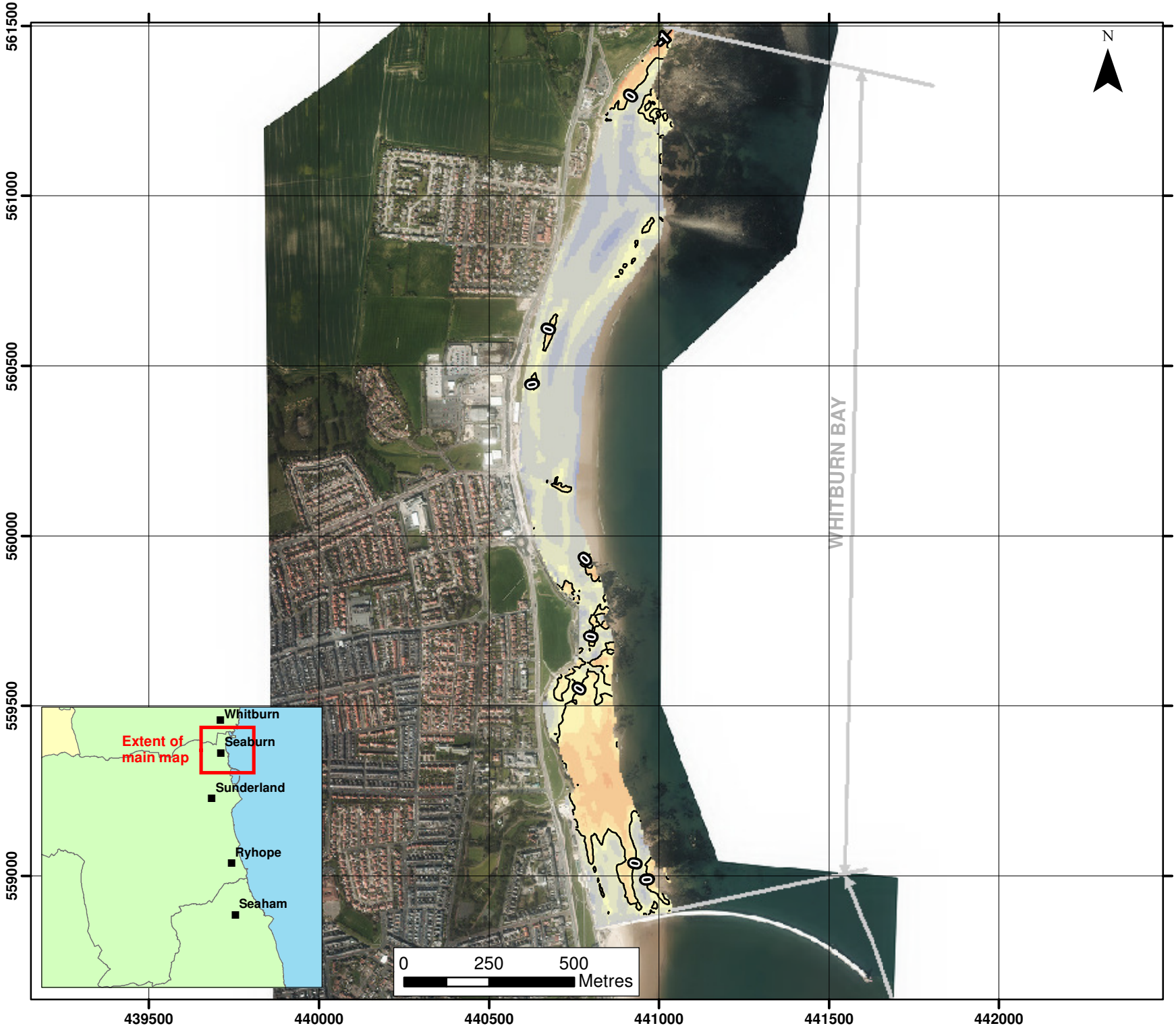
Appendix B- Map 1b Topographic Difference Whitburn Bay Sunderland City Council

Analytical Report 8
Full Measures Survey
Autumn 2015

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

Tel: +44 (0)121 456 2345
Fax: +44(0)121 456 1569
www.ch2m.com

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



KEY Autumn 2009 and Autumn 2015
Change in elevation (m)

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

Contours of change

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

Appendix B- Map 1c
Long-term Elevation change
Whitburn Bay
Sunderland City Council

Analytical Report 8
Full Measures Survey
Autumn 2015

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

Tel: +44 (0)121 456 2345
Fax: +44(0)121 456 1569
www.ch2m.com

KEY

Elevation (m OD)

- 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

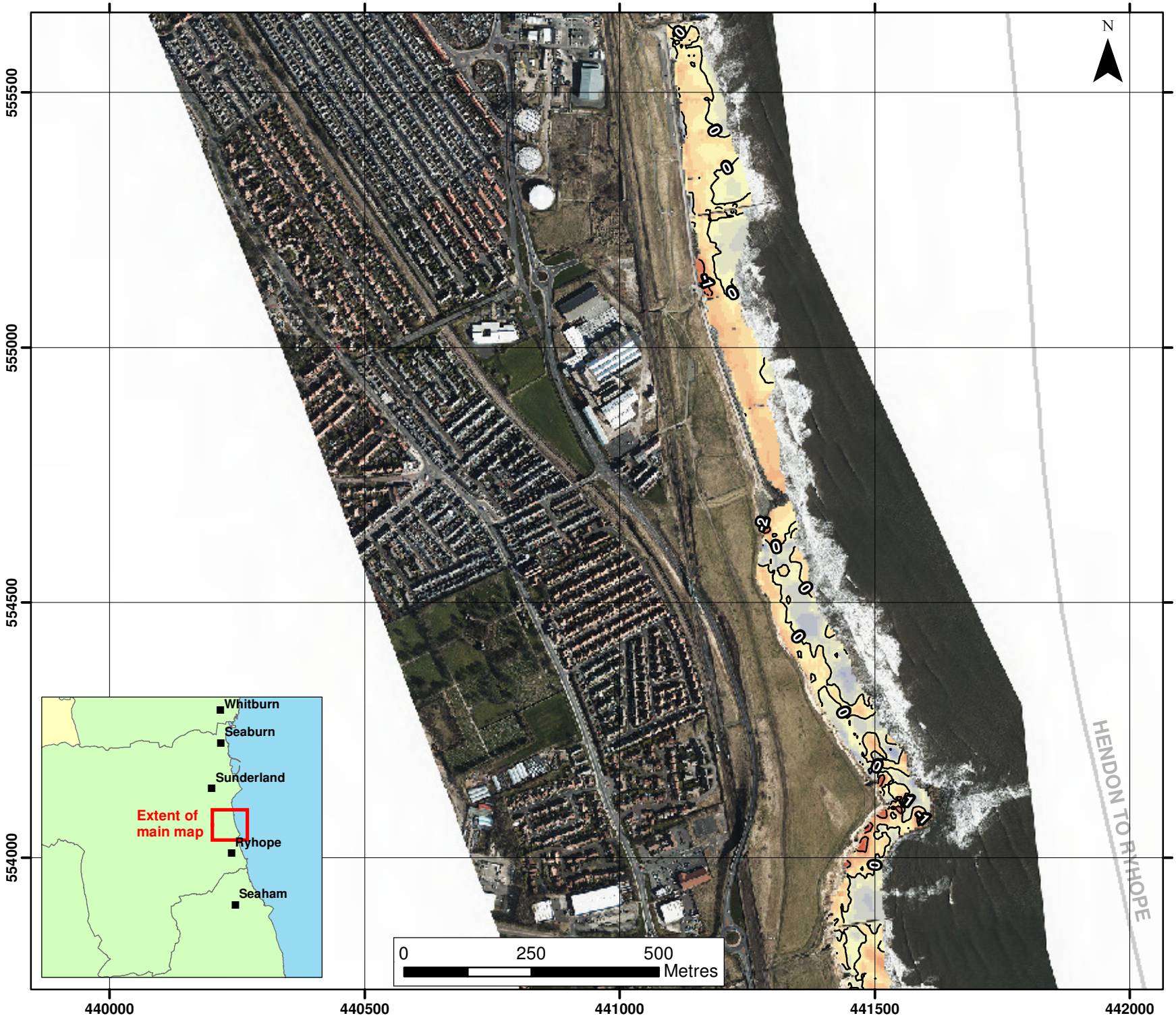
Project: Cell 1 Regional Coastal Monitoring Programme 2011 to 2016

Appendix B - Map 2a
Topographic Survey
Hendon to Ryhope a Sunderland City Council

Analytical Report 8
Full Measures Survey
Autumn 2015

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

Tel: +44 (0)121 456 2345
Fax: +44(0)121 456 1569
www.ch2m.com



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

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

Loss
Change < 0.1 m
Gain

Contours of change

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

Appendix B - Map 2b Short-term Elevation Change Hendon to Ryhope a Sunderland City Council

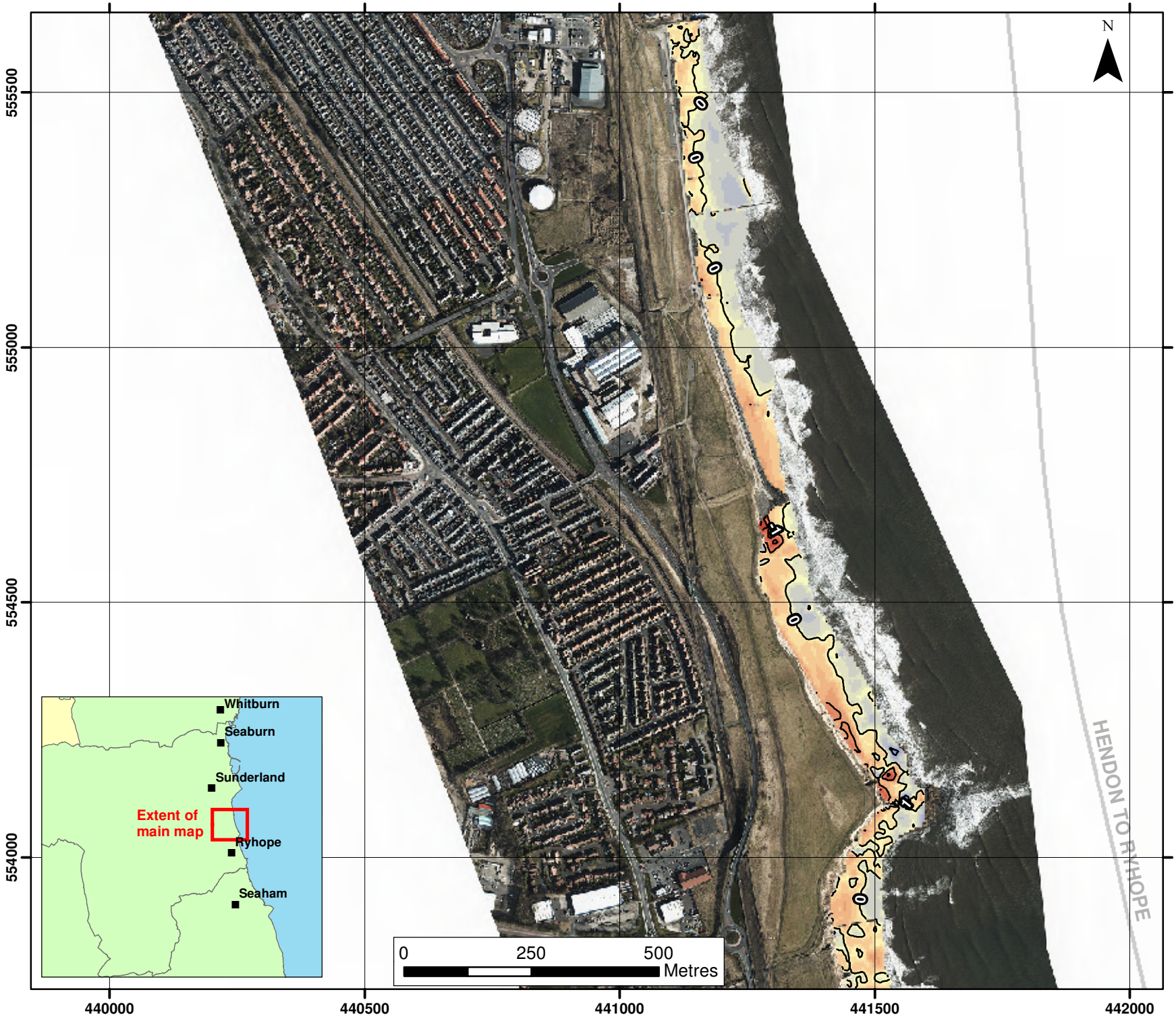
Analytical Report 8
Full Measures Survey
Autumn 2015

ch2m

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

Tel: +44 (0)121 456 2345
Fax: +44(0)121 456 1569
www.ch2m.com

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



KEY Autumn 2009 and Autumn 2015
Change in elevation (m)

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

Contours of change

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

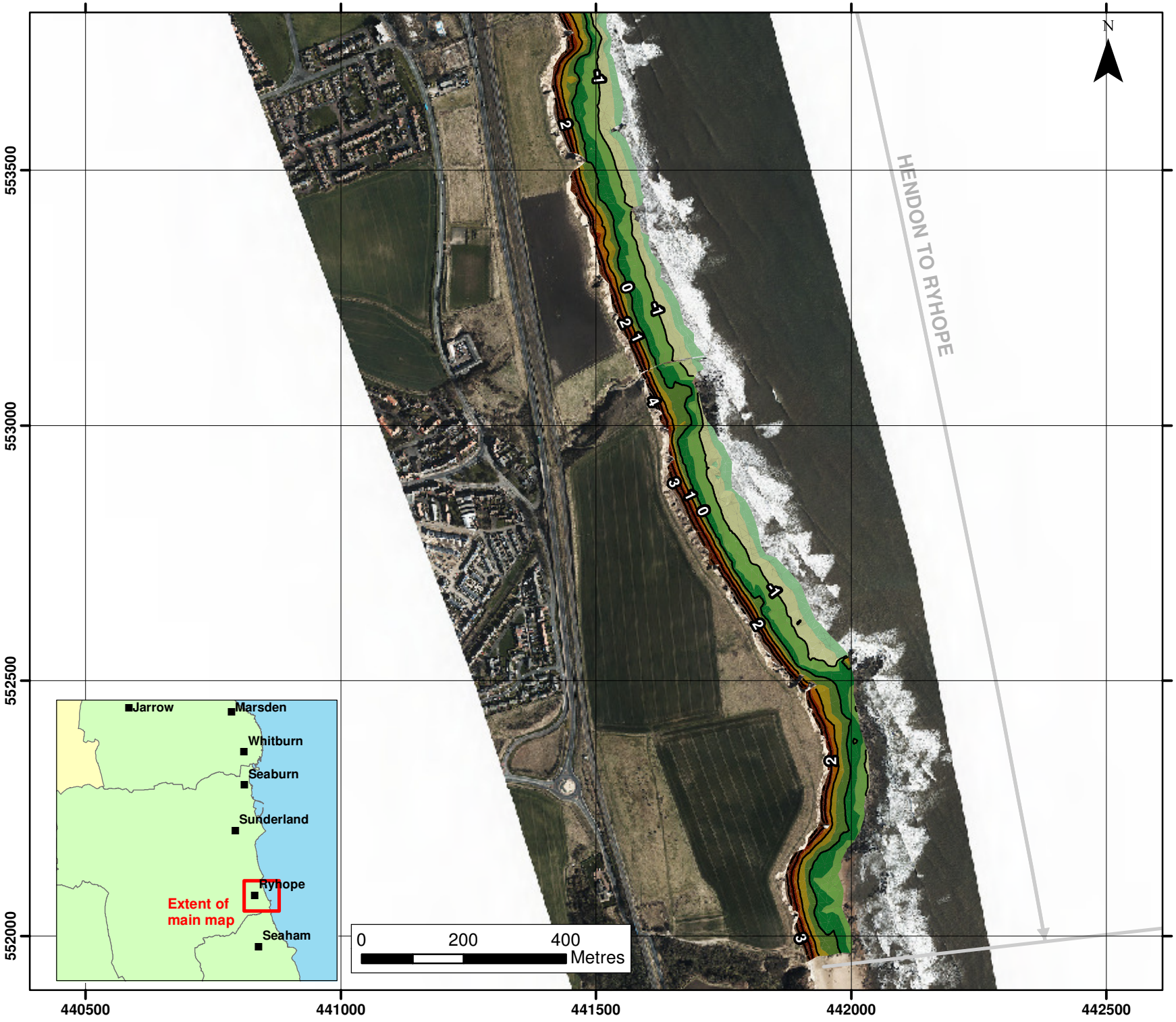
Appendix B - Map 2c Long-term Elevation Change Hendon to Ryhope a Sunderland City Council

Analytical Report 8
Full Measures Survey
Autumn 2015

ch2m.

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

Tel: +44 (0)121 456 2345
Fax: +44(0)121 456 1569
www.ch2m.com



KEY

Elevation (m OD)

- 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

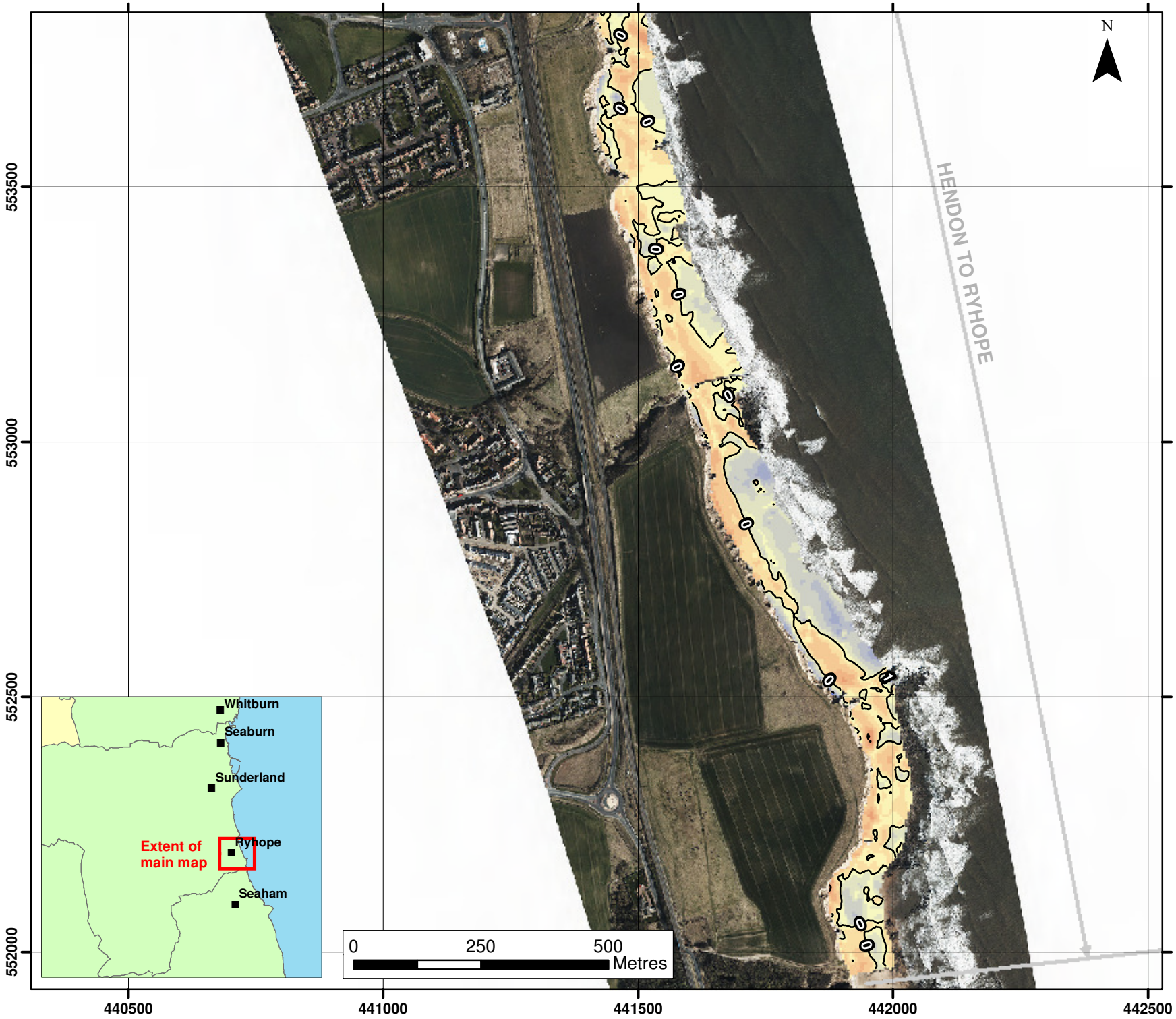
Appendix B - Map 3a
Topographic Survey
Hendon to Ryhope
Sunderland City Council

Analytical Report 8
Full Measures Survey
Autumn 2015

ch2m

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

Tel: +44 (0)121 456 2345
Fax: +44(0)121 456 1569
www.ch2m.com



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

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

Loss

Change < 0.1 m

Gain

Contours of change

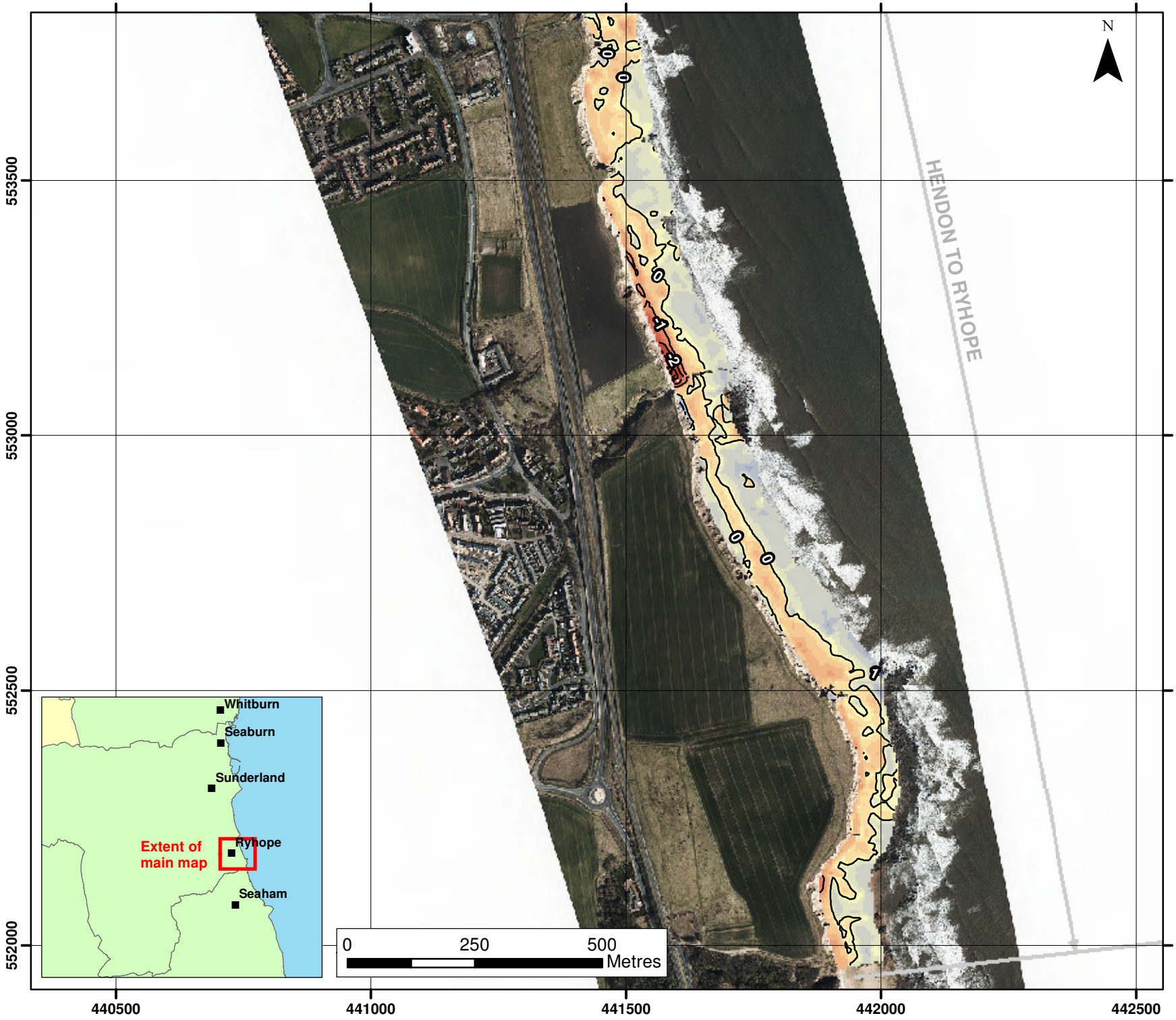
Client: North East Coastal Group
Project: Cell 1 Regional Coastal Monitoring Programme 2011 to 2016

Appendix B - Map 3b
Short-term Elevation Change
Hendon to Ryhope b
Sunderland City Council

Analytical Report 8
Full Measures Survey
Autumn 2015

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

Tel: +44 (0)121 456 2345
Fax: +44(0)121 456 1569
www.ch2m.com



KEY Autumn 2009 and Autumn 2015
Change in elevation (m)

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

Loss
Change < 0.1 m
Gain

Contours of change

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

Appendix B - Map 3c
Long-term Elevation Change
Hendon to Ryhope b
Sunderland City Council

Analytical Report 8
Full Measures Survey
Autumn 2015

ch2m

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

Tel: +44 (0)121 456 2345
Fax: +44(0)121 456 1569
www.ch2m.com

Appendix C

Cliff Top Survey

Cliff Top Survey

Hendon and Ryhope

Thirty-two ground control points have been established between Hendon and Ryhope (Map 1 and Map 2). The maximum separation between any two points varies along the coast, reflecting the degree of risk from the erosion.

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

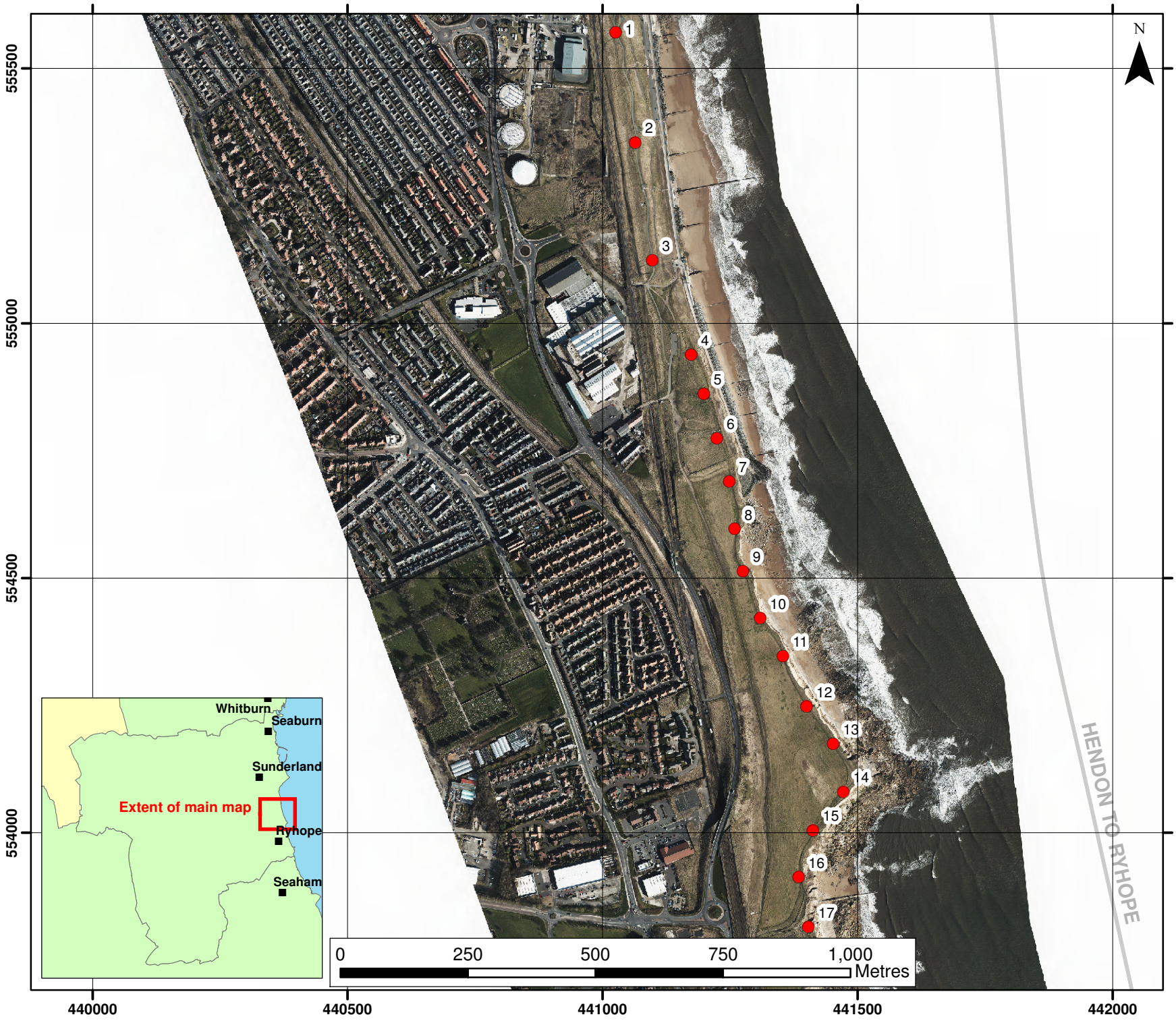
Table B1 provides baseline information about these ground control points and results from the 2009 (baseline) survey showing the position from the ground control point to the edge of the cliff top along the defined bearing. Future reports will show results from subsequent surveys and provide a means of assessing erosion since the baseline survey.

Table B1 – Cliff Top Surveys between Hendon and Ryhope

Ground Control Point Details				Distance to Cliff Top (m)			Total Erosion (m)		Erosion Rate (m/year)
Ref	Easting	Northing	Bearing (º)	Baseline Survey (March 2009)	Previous Survey (March 2015)	Present Survey (Sept 2015)	Baseline (March 2009) to Present (Sept 2015)	Previous (March 2015) to Present (Sept 2015)	Baseline (March 2009) to Present (Sept 2015)
1	441025.7	555571.1	75	8.16	8.4	8.4	0.2	0.0	0.0
2	441064.4	555355.1	85	7.09	5.5	5.6	-1.5	0.0	-0.2
3	441098	555124	82	10.01	10.4	10.3	0.3	0.0	0.0
4	441174	554938.7	65	10.3	10.5	10.5	0.2	0.0	0.0
5	441199.1	554861.1	65	7.71	10.9	7.8	0.1	-3.1	0.0
6	441224.5	554774.2	71	10.83	10.9	10.9	0.0	0.0	0.0
7	441248.4	554690.3	74	10.18	10.4	10.4	0.3	0.0	0.0
8	441259.3	554596.6	101	10.08	9.9	9.9	-0.2	0.0	0.0
9	441275.8	554513.4	66	10.52	6.6	6.5	-4.0	-0.1	-0.6
10	441309.4	554421.3	58	8.77	1.5	1.4	-7.4	-0.1	-1.2
11	441354	554346.5	68	8.2	6.2	6.2	-2.0	0.0	-0.3

12	441400.2	554248.2	56	6.17	6.0	6.1	-0.1	0.1	0.0
13	441452.3	554174.7	63	11.61	8.7	8.5	-3.1	-0.2	-0.5
14	441472.3	554080.5	127	7.33	7.4	7.1	-0.2	-0.3	0.0
15	441413	554005.1	122	7.84	7.9	7.9	0.1	0.0	0.0
16	441384.8	553913.3	90	9.89	7.9	7.8	-2.1	-0.1	-0.3
17	441404.1	553815.5	93	6.32	6.1	6.1	-0.2	0.0	0.0
18	441404.1	553723.6	119	8.1	8.0	8.0	-0.1	0.0	0.0
19	441398.5	553632.8	78	8.23	5.6	5.5	-2.7	-0.1	-0.4
20	441438.3	553452.9	71	10.09	6.5	6.5	-3.6	0.0	-0.6
21	441506.1	553256.1	62	8.57	1.7	1.7	-6.9	0.0	-1.1
22	441550.1	553158.7	103	6.57	3.5	3.6	-2.9	0.1	-0.5
23	441585.2	553076.5	64	8.11	7.9	7.9	-0.2	0.0	0.0
24	441624.4	552870.7	69	7.53	4.4	4.1	-3.4	-0.3	-0.5
25	441689.1	552758	70	14.58	7.0	6.9	-7.7	0.0	-1.2
26	441715	552713.3	54	12.87	11.3	11.2	-1.7	-0.1	-0.3
27	441749.2	552674.4	62	14.56	3.9	3.6	-11.0	-0.3	-1.7
28	441776.6	552629.9	57	8.62	4.3	4.2	-4.4	0.0	-0.7
28A	441798.6	552586.3	56	13.63*	8.2	8.2	-5.4	0.0	-0.9
28B	441817.4	552542.4	64	12.30*	11.3	11.3	-1.0	0.0	-0.2
28C	441852.2	552502.6	52	13.11*	13.0	12.8	-0.3	-0.2	-0.1
29	441880.1	552471.6	83	15.46	15.2	15.1	-0.3	0.0	0.0
30	441921.4	552269	97	8.55	7.6	7.6	-1.0	0.0	-0.1
31	441853.1	552094	75	11.2	6.7	6.5	-4.7	-0.2	-0.7
32	441883.3	551988.5	96	9.82	5.0	5.0	-4.8	0.0	-0.8

*Note that 28a-c baseline is September 2009.



KEY

- Ground Control Points

Client: North East Coastal Group

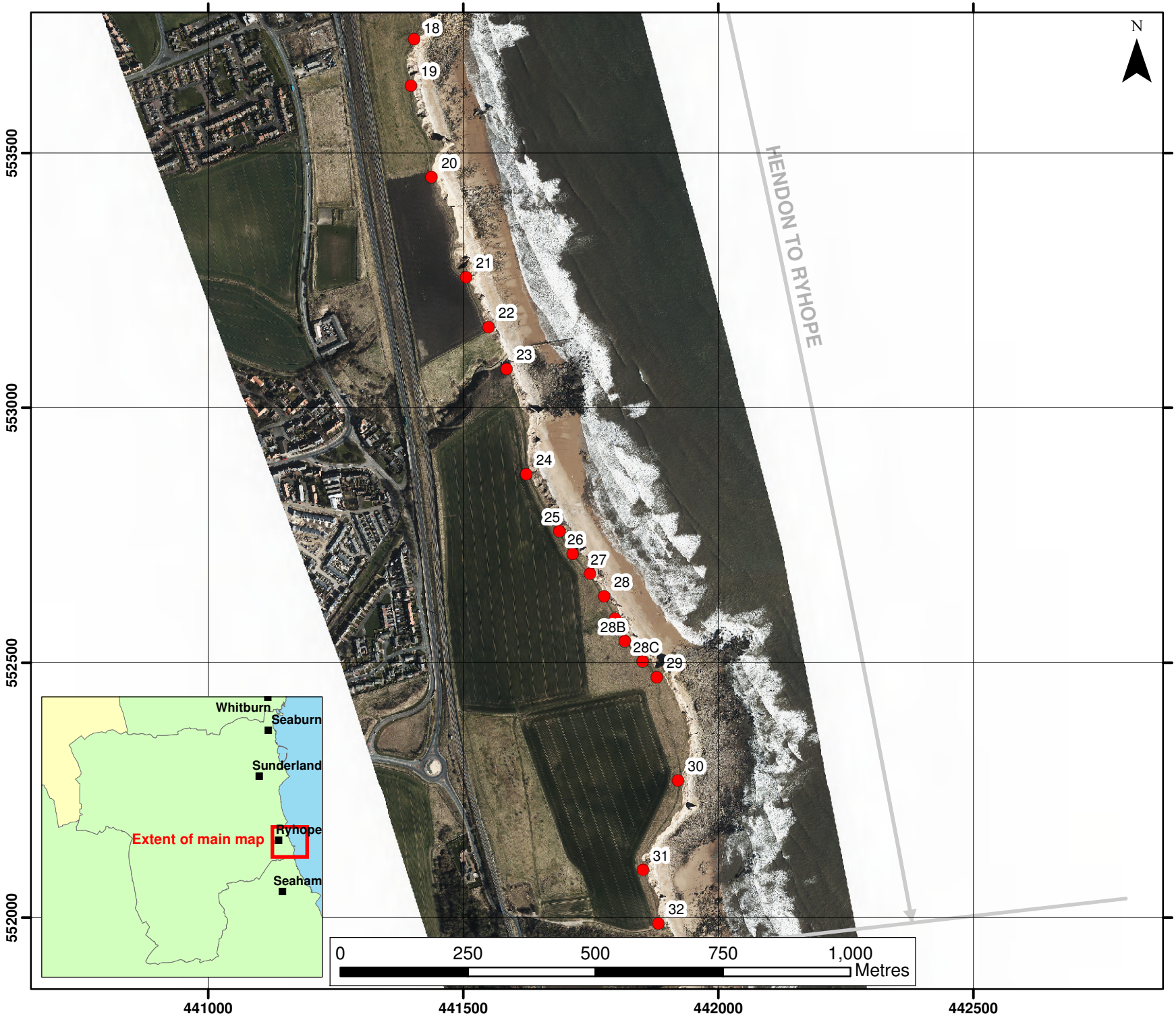
Project: Cell 1 Regional Coastal Monitoring Programme 2011 to 2016

Appendix C - Map 1
Ground Control Points
Hendon to Ryhope North
Sunderland City Council

Analytical Report 8
Full Measures Survey
Autumn 2015

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

Tel: +44 (0)121 456 2345
Fax: +44(0)121 456 1569
www.ch2m.com



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
Hendon to Ryhope South
Sunderland City Council

Analytical Report 8
Full Measures Survey
Autumn 2015

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

Tel: +44 (0)121 456 2345
Fax: +44(0)121 456 1569
www.ch2m.com