Wightlink Ltd.

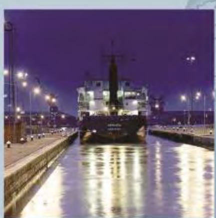
Evaluating Possible Effects of the Lymington to Yarmouth Ferries

Monitoring Report 23 and 7th Report for the Environmental Management Panel

Report R.1556w

December 2014

Creating sustainable solutions for the marine environment





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Date: December 2014

Project Ref: R/3772/06

Report No: R.1556w

Version	Details of Change	Date
1	Version for Client Comment	3 November 2014
2	Version for EMP	4 November 2014
3	Final	8 December 2014

Document Authorisation		Signature	Date
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Summary

This report presents the latest findings of an environmental monitoring programme that is being undertaken to assess the effects of the W-Class ferry service operating between Lymington and Yarmouth. This monitoring has been underway since 2009 and is now a formal requirement of the Section 106 Agreement (S106) that accompanied the consents for the ferry operations.

The monitoring methods were developed by key stakeholders and they involve regular on-site surveys of the mudflat habitat alongside the Lymington Channel in order to accurately describe small-scale changes in the intertidal elevations. The monitoring also includes regular reviews of data collected by the Lymington Harbour Commission (LHC), Environment Agency (EA) and the Channel Coastal Observatory (CCO) which describe the broader morphology of the channel and surrounding marshes.

The aim of the work is to evaluate and understand what contribution the ferries might be having to the existing rates of low-shore mudflat erosion within the Lymington Estuary. This is one element of an adaptive mitigation and monitoring plan which is being overseen by an Environment Management Panel (EMP). The results obtained are used to inform judgements about the requirements for, and effectiveness of, accompanying mitigation initiatives.

From the monitoring work it is clear that conditions within the estuary are dominated by natural processes which make even the worst-case predictions of the ferry effects undetectable. There are substantial areas of marsh that are eroding and much of the mudflat on the eastern side is lowering at the mean low water level. Although erosion is the dominant process in many areas, there are also large sections of the estuary mudflats (especially upstream and on the west side of the channel) which are accreting both intertidally and subtidally. The observations made indicate that the estuary is evolving, narrowing in many places and also possibly seeking a more sinusoidal curve over time.

There is no evidence of any link between ferry activities and the observed changes on the intertidal habitats or subtidal margins. There is evidence that the centre of the subtidal channel initially deepened (possibly to accommodate the large vessels) and then stabilised subsequently. However there is no indication of any effect on the shallow subtidal banks along the channel margins.

There are also several indications which show that no direct relationship exists between estuary form and ferry shape. The absence of this relationship means that the worst-case predicted effects from the operation of the ferry service will not occur. The ferries may make a negligible contribution to observed sediment fluxes but any such effects will be insignificant in the context of the physical evolution and ecological functioning of the estuary. However, in the same way that it is not possible to detect the worst-case scenario, it will not be possible to distinguish any such lower effects in this estuary because natural forces are acting so strongly. Such effects would also be insignificant in the context of the physical evolution and ecological functioning of the estuary.

The results of this work were discussed at a meeting of the EMP which was held on 20 November 2014 (following circulation of a draft copy of this report). At that meeting, it was agreed that there should be a substantial reduction in the monitoring work given the absence of any effects observed. There will be no further on-site surveys and the reporting in 2015 will only involve a brief technical note which will review the available Environment Agency LiDAR data. There will only be a meeting of the EMP in 2015 if these results highlight any issues, otherwise the next meeting will be in November 2016.

Abbreviations

ABPmer	ABP Marine Environmental Research Ltd
AIS	Automatic Identification System
Black and Veatch	Black & Veatch Holding Company
CCO	Channel Coastal Observatory
CD	Chart Datum
DGM	Digital Ground Model
EA	Environment Agency
EMP	Environment Management Panel
ERM	Environmental Resources Management
LHC	Lymington Harbour Commission
LiDAR	Light Detection and Ranging
ODN	Ordnance Datum Newlyn
MLW	Mean Low Water
NE	Natural England
NFDC	New Forest District Council
NFNPA	New Forest National Park Authority
SP	Seymour's Post

Cardinal points/directions are used unless otherwise stated.

SI units are used unless otherwise stated.

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1. Introduction

1.1 Background

At the start of 2009, Wightlink Ltd introduced the new W-Class ferry onto their service operating between Lymington and Yarmouth (Image 1). In that year, a monitoring and data review programme was implemented to understand the possible impacts of this service on the adjacent intertidal habitats of the Lymington Channel. The methods for this ferry monitoring work were developed and agreed in consultation with key stakeholders (including Natural England, Lymington Harbour Commission, Channel Coastal Observatory and Wightlink Ltd.) and were set out in a stand-alone 'monitoring review' report (ABPmer, 2009).

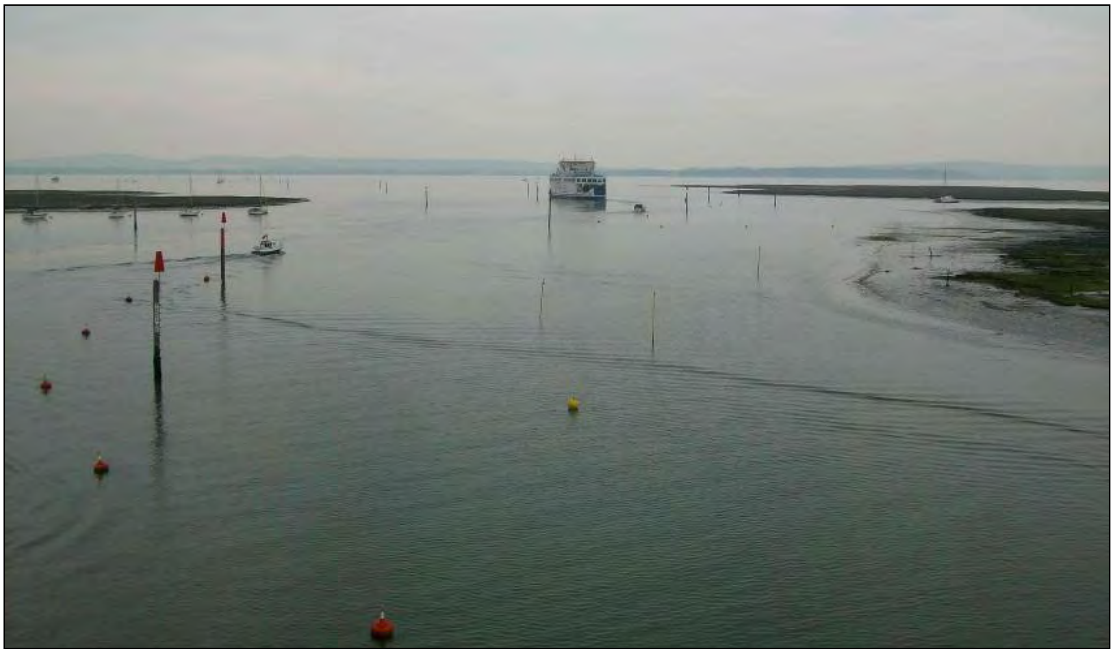

Image 1. View of outer Lymington Estuary

This monitoring programme began in June 2009 and was originally scheduled to be completed in October 2009. However, due to the value of the information being obtained, this timeframe was extended and the work then pursued for over two years (until the end of 2011). During this period, surveys were undertaken on an almost monthly basis and the information obtained was used to underpin the necessary impact assessment and consenting work for this project.

Since the end of 2011, this monitoring and data review work has been continuing as a condition of the Planning Consent for the operation of the ferry service which was granted in December 2011. The monitoring work, which includes on-site surveys on a quarterly basis, is being undertaken to further understand what contribution the ferries might be having on the existing rates of low-shore mudflat erosion within the estuary.

The results obtained can then be used inform judgements about the requirements for, and effectiveness of, separate mitigation initiatives. These mitigation initiatives include operational constraints (especially reduced ferry speed) and a saltmarsh recharge project that Wightlink Ltd. has carried out on the adjacent Boiler Marsh site.

This ferry monitoring work is therefore one element of a larger iterative mitigation and monitoring plan which is being carried out as a consent requirement for the operation of the W Class ferries. The latest results from the sediment recharge mitigation work will be reported separately.

The mitigation and monitoring plan is being overseen by an Environment Management Panel (EMP) as a formal requirement of the Section 106 Agreement (S106) that accompanied the Planning Application and Consents for the ferry operation. The specific requirements for this monitoring are set out in Section 4, Schedule 5 of the Section 106 (S106) Agreement.

1.2 Monitoring Components

One of the two main elements of this monitoring programme involves regular (quarterly) visual/photographic analyses of a series of graduated stakes that have been placed in intertidal areas alongside the Lymington Channel. These are being used to relatively accurately describe the localised changes in sediment elevation that take place on these intertidal areas over time.

Another core monitoring requirement involves regular reviews of bathymetry data that is collected biennially by the Lymington Harbour Commission (LHC) to describe any changes to the subtidal morphology of the Lymington Channel. Separate monitoring of the ferry speeds is also conducted by Wightlink Ltd.

In addition to this core monitoring work, regular reviews are also made of relevant survey data that is collected by other parties. This includes, especially, the Light Detection and Ranging (LiDAR) data that is collected annually by the Environment Agency (EA) and which helps to further describe the wider intertidal and shoreline morphology. More recently the Channel Coastal Observatory (CCO) has also begun collecting survey data at this location. In particular, over the period from late 2012 to the middle of 2013, extra survey work has been undertaken by the CCO which includes the following:

- A laser elevation and photographic survey of the intertidal areas alongside the channel undertaken in late 2012 (as taken from the deck of a W-Class ferry navigating the estuary);
- A swath bathymetry survey of the river from the ferry terminal to the channel mouth as undertaken in July 2013; and
- An aerial photography survey undertaken in summer 2013.

The results of this CCO work will be reviewed within this programme as and when data and reports become available. For this report the aerial image and the data from the July 2013 swath bathymetry survey were available and have been considered.

1.3 Scope of this Report

The results of all the previous monitoring undertaken between June 2009 and July 2013 were described in a series of previous progress reports (ABPmer Report Numbers R.1556a-v). The monitoring work was then continued throughout 2014 (as confirmed at the most recent EMP meeting[1]) and this report reviews the work undertaken over this latest period.

Since the last report was issued (December 2013) three further quarterly graduated stake surveys have been carried out. These were completed on 17 October 2013 (the third quarterly survey of 2013; Survey No. 33), on 15 April 2014 and 16 July 2014 (the first and second quarterly surveys of 2014, Surveys No. 34 and 35 respectively).

This report presents a review of the results obtained up to and including these latest surveys. The results are designed to inform discussions at the next annual EMP meeting which will be held on 20 November 2014. A further survey was also undertaken on 7 October 2014 and the results from this work, once analysed, will be reported separately.

In addition during April 2014, the LHC carried out a new bathymetry survey of the Lymington Estuary and the data from the CCO's July 2013 swath bathymetry survey were published online earlier this year. The latest Environment Agency LiDAR survey was also flown in March 2013. The results from all these surveys have been made available to ABPmer and used for this review.

The LHC has also, in the past, undertaken separate surveys of the upper estuary intertidal habitats using the same graduated stake approach that is being applied for this ferry monitoring work (see Section 2). The last survey undertaken by the LHC was in August 2012 and the results reported in October 2012 (Black and Veatch, 2012). The findings from this work have been considered within past reports and are again reproduced here to provide a context for this analysis.

1.4 EMP Reporting Process

This report represents the 23rd document issued under the overall ferry monitoring programme and the seventh report to be formally issued to the EMP. Including this document, the full list of documents issued to the EMP is as follows:

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1 So far EMP meetings have been held on four occasions on the following dates: 6 June 2012, 7 November 2012, 19 June 2013 and, most recently, on 13 November 2014.

- 1st report for EMP) Ferry Monitoring Progress Report 19: Final Issued February 2012 (ABPmer 2012a) - ABPmer Report No. R1556s;
- 2nd report for EMP) Ferry Monitoring Progress Report 20: Final Issued December 2012 (ABPmer 2012b) - ABPmer Report No R1556t;
- 3rd report for EMP) Recharge Mitigation Progress Report 1: Final Issued December 2012 (ABPmer 2012c) - ABPmer Report No R2007;
- 4th report for EMP) Ferry Monitoring Progress Report 21: Final Issued June 2013 (ABPmer 2013a) - ABPmer Report No R1556u;
- 5th report for EMP) Ferry Monitoring Progress Report 22: Final Issued December 2013 (ABPmer 2013b) – ABPmer Report No R1556v;
- 6th report for EMP) Recharge Mitigation Progress Report 2: Final Issued December 2013 (ABPmer 2013c) - ABPmer Report No R2142;
- 7th report for EMP) Ferry Monitoring Progress Report 23: (this report).

2. Methods

Details about the methods used for the graduated stake deployment work and for all the follow up surveys were described in detail in the original monitoring agreement report (ABPmer, 2009) as well as in the subsequent monitoring Progress Reports Nos. 1 to 12 (ABPmer Report Numbers R.1556a-l).

The current and historical locations of the graduated stakes are shown in Figure 1. This includes the stake deployed for the Wightlink survey work in June 2009 as well as those deployed by the LHC in September 2010.

Table 1 also summarises all the Wightlink stake monitoring surveys which have been conducted to date. The exact positions and dates of deployment of these stakes were described in the previous reports.

Table 1. Stake monitoring surveys conducted to date in the Lymington River

Year	Survey Date	Survey Number	Survey Type
2009	10 June	1	Initial stake deployment
	26 June	2	Follow-up survey
	10 July	3	Follow-up survey
	24 July	4	Follow-up survey
	10 August	5	Follow-up survey
	8 September	6	Follow-up survey
	5 October	7	Follow-up survey
2010	5 March	8	Follow-up survey
	15 March	9	Follow-up survey
	15 April	10	Follow-up survey
	18 May	11	Follow-up survey
	15 June	12	Follow-up survey
	15 July	13	Follow-up survey
	13 August	14	Follow-up survey
	8 September	15	Follow-up survey
	7 October	16	Follow-up survey
	4 November	17	Follow-up survey
2011	18 February	18	Follow-up survey
	18 March	19	Follow-up survey
	18 April	20	Follow-up survey
	17 May	21	Follow-up survey
	16 June	22	Follow-up survey
	18 July	23	Follow-up survey
	16 August	24	Follow-up survey
	13 September	25	Follow-up survey
	11 October	26	Follow-up survey
	9 November	27	Follow-up survey
2012	21 April	28	Follow-up Survey
	23 July	29	Follow-up Survey
	1 October	30	Follow-up Survey
2013	10 April	31	Follow-up Survey
	26 July	32	Follow-up Survey
	17 October	33	Follow-up Survey
2014	15 April	34	Follow-up Survey
	16 July	35	Follow-up Survey
	7 October	36	Follow-up Survey

3. Results

3.1 Graduated Stake Survey Results

The results of the 33rd, 34th and 35th graduated stake surveys are summarised in Table 2 (the results of the latest 36th survey will be reviewed separately once the data has been analysed). This table shows the overall change in the vertical elevation of the substratum that has been observed at each stake location over the five years of the monitoring programme (as assessed by visual comparison of the digital photographs). Table 3 additionally summarises the direction of net change in intertidal elevation since deployment.

To describe the temporal changes over the survey period, the readings that have been obtained from all the graduated stakes to date are presented as time-series plots in Figures 2 to 5. These show the changes in intertidal elevation at each stake, relative to baseline, for each survey during the full monitoring period to date. This now covers five complete years from June 2009 to July 2014.

In addition to considering the net elevation changes at each stake location, Figures 6a and 6b show the changes in substratum height that were recorded between each subsequent survey as the 'rate of change in substratum height per year', calculated using the equation:

$$\text{Rate of change winter (mm/yr)} = \frac{\text{(height difference between last and first survey of subsequent monitoring periods)} \times 365}{\text{number of days between the two surveys}}$$

These plots show the rate of change (in mm/year) and hence facilitate an understanding about the broad dynamics of sediment change within any given survey area.

For most of the sites, the changes in substratum height expressed in these tables and figures are presented relative to the 'baseline' height that was measured during the first survey (on 10 June 2009). In some cases a photograph was unavailable from Survey 1, in which instance the change is shown relative to the earliest survey for which a photograph is available for comparison. In particular, it should be noted that Stakes CH3-CH6 were deployed later than the others (in May/June 2010) as replacements for the loss of the original Stakes CH1 and CH2 which were located at, and near, to the LHC Phase 1 Rock Armour Breakwater which was subsequently constructed in April/May 2010 (see Figure 1).

As shown in Table 2, during the latest surveys, clear photographs and subsequent measurements were obtained from the majority of locations. There were however a number of stakes during the Survey 33 (October 2013) where no information could be obtained (these were stakes CB1, CB2, CB4, CB9 and TB1). This was because many sites on the low shore remained under water during this survey due to the particular climatic conditions on the day.

Table 2. Change in substratum elevation at each graduate stake position from to Survey 35

Stake	Date of Baseline Measurement	17 October 2013 Change in Elevation Compared to Baseline (mm)	Comments	15 April 2014 Change in Elevation Compared to Baseline (mm)	Comments	16 July 2014 Change in Elevation Compared to Baseline (mm)	Comments
CB1	26 June 2009	-	Not assessed, stake underwater.	-2	Scour around base of stake, height estimated from water level in photograph.	17	Scour around base of stake, height estimated from water level in photograph.
CB2	10 June 2009	-	Not assessed, stake underwater.	-35	Scour around base of stake, height estimated from water level in photograph.	-32	Scour around base of stake, height estimated from water level in photograph.
CB3	10 June 2009	-55	Mud in front of stake, height estimated from mud level at nearest point	-84	Scour around base of stake, height estimated from water level in photograph.	-75	Scour around base of stake, height estimated from water level in photograph.
CB4	26 June 2009	-	Not assessed, stake underwater.	-4	Height estimated through scaling of digital photograph.	11	Height estimated through scaling of digital photograph.
CB5	10 June 2009	-56	Height estimated through scaling of digital photograph.	-74	Height estimated through scaling of digital photograph.	-69	Height estimated through scaling of digital photograph.
CB6	10 June 2009	-66	Change estimated from visual comparison of graduated scale.	-88	Change estimated from visual comparison of graduated scale.	-86	Shells and algae in front of stake, height estimated from lowest point
CB7	10 July 2009	-	Not assessed, stake underwater.	-38	Scour around base of stake, height estimated from water level in photograph.	-36	Scour around base of stake, height estimated from water level in photograph.
CB8	10 June 2009	-37	Scour around base of stake, height estimated from water level in photograph.	-59	Change estimated from visual comparison of graduated scale.	-71	Scour around base of stake, height estimated from water level in photograph.
CB9	10 June 2009	-	Not assessed, stake underwater.	-96	Scour around base of stake, height estimated from water level in photograph.	-83	Scour around base of stake, height estimated from water level in photograph.
CB10	10 June 2009	-163	Change estimated from visual comparison of graduated scale	-191	Height estimated through scaling of digital photograph.	-224	Height estimated through scaling of digital photograph.
TB1	10 June 2009	-	Not assessed, stake underwater.	-144	Scour around base of stake, height estimated from water level in photograph.	-127	Scour around base of stake, height estimated from water level in photograph.
TB2	10 June 2009	-64	Change estimated from visual comparison of graduated scale.	-131	Mud in front of stake, height estimated from mud level at nearest point	-125	Mud and algae in front of stake, height estimated from mud level at nearest point
SP1	10 June 2009	-36	Change estimated from visual comparison of graduated scale.	-39	Change estimated from visual comparison of graduated scale.	-18	Scour around base of stake, height estimated from water level in photograph.
SP2	10 June 2009	+7	Scour around base of stake, height estimated from water level in photograph.	-12	Scour around base of stake, height estimated from water level in photograph.	32	Scour around base of stake, height estimated from water level in photograph.
SP3	10 June 2009	-36	Change estimated from visual comparison of graduated scale.	-59	Scour around base of stake, height estimated from water level in photograph.	-49	Change estimated from visual comparison of graduated scale.
SP4	10 June 2009	-43	Change estimated from visual comparison of graduated scale.	-42	Change estimated from visual comparison of graduated scale.	-26	Scour around base of stake, height estimated from water level in photograph.
SP5	10 June 2009	-17	Change estimated from visual comparison of graduated scale	-38	Scour around base of stake, height estimated from water level in photograph.	-23	Scour around base of stake, height estimated from water level in photograph.
SP6	10 June 2009	-27	Scour around base of stake, height estimated from water level in photograph.	-18	Scour around base of stake, height estimated from water level in photograph.	8	Scour around base of stake, height estimated from water level in photograph.
SP7	10 June 2009	-	Stake removed.	-	Stake removed.	-	Stake removed.
SP8	10 June 2009	-2	Scour around base of stake, height estimated from water level in photograph.	-19	Scour around base of stake, height estimated from water level in photograph.	-4	Scour around base of stake, height estimated from water level in photograph.
SP9	10 June 2009	-5	Scour around base of stake, height estimated from water level in photograph.	-3	Scour around base of stake, height estimated from water level in photograph.	8	Scour around base of stake, height estimated from water level in photograph.
SP10	10 June 2009	-16	Scour around base of stake, height estimated from water level in photograph.	6	Scour around base of stake, height estimated from water level in photograph.	34	Scour around base of stake, height estimated from water level in photograph.
CH3	18 May 2010	-	Not able to assess, no safe access.	-	Not able to assess, no safe access.	-	Not able to assess, no safe access.
CH4	15 June 2010	-	Not able to assess, no safe access.	-	Not able to assess, no safe access.	-	Not able to assess, no safe access.
CH5	15 June 2010	-33	Change estimated from visual comparison of graduated scale	-28	Scour around base of stake, height estimated from water level in photograph.	-16	Scour around base of stake, height estimated from water level in photograph.
CH6	15 June 2010	+37	Scour around base of stake, height estimated from water level in photograph.	43	Scour around base of stake, height estimated from water level in photograph.	91	Scour around base of stake, height estimated from water level in photograph.

These readings are considered to be accurate to around ±3mm

It has also not been possible to obtain readings from stakes CH3 and CH4 since September 2011. This is because these sites are covered in seaweed and it is not possible to safely access them to clean them due to the depth and softness of the mud in this western side of the estuary. For these reasons it is likely that no further readings will be taken from these sites. Finally, stake SP7 is no longer present.

As noted previously (e.g. ABPmer 2012b 2nd Report for EMP) regular surface sediment movements occur across the mudflat so that on some surveys there is an overlying layer of soft mud while in others there is a more heterogeneous mix of harder exposed clays and patches of mud deposits. This spatial and temporal variation of the substratum has been experienced throughout the survey programme and is a reflection of the dynamic nature of the environment which is characterised by frequent erosion and accretion events. Such sediment movements will be an ongoing regular factor in the environment but the largest individual movements will be particularly prevalent on large tides, storm events and during high freshwater discharges.

Given the dynamic nature of the environment it is important that the temporal changes occurring at each of the survey locations are considered over the full monitoring period and that key trends over time are described, where possible, from these overall results. The full time-series plots are likely to show patterns and trends which average out environmental variations and inherent survey accuracies. Some brief observations relating to the recent results are summarised below. Also the results of the separate LHC stake monitoring are considered.

3.1.1 Seymour's Post and Cocked Hat Post Area (West Side of Channel)

On this western side of the outer estuary several sites have been exhibiting a net background trend of erosion (Figures 2a-d and 3). However the patterns of change in this region are very unclear and, in fact, by July 2014 six of the 11 remaining stake locations actually have bed levels that are higher than (SP3, SP6, SP9, SP10 and CH6) or very close to (i.e. only a 4mm net drop at SP8) the levels they were when the work started in June 2009. Also, when all these sites are considered together there has been a net accretion of 0.1cm overall after 5 years.

The time-series data continues to show that cyclic patterns of erosion and accretion are occurring at all sites with the net result of that cycling varying across the different locations after five years of monitoring. For example some sites such as SP2 and SP9 show a cyclic pattern around the original baseline elevations leading a slight net accretion over the full 5 years of the project (a similar pattern was in evidence at SP7 before that stake was lost).

At other sites, sediment cycling is also in evidence but over different timescales. For instance at some sites (especially at SP1) there are signs of relatively distinct intervals of winter erosion followed by summer accretion while at others there is a more general background trend of erosion (e.g. at SP3 and to a lesser degree at SP5). At Stakes SP6, SP8, SP10 and CH5 there was net erosion during the first half of the work and there has been net accretion subsequently. Finally, and distinctively, there is a trend of progressive net accretion occurring at Stake CH6.

Overall, therefore, there is no indication of any distinct spatial correlations between these observations and the stake positions. This is especially true for the Seymour's Post (SP) sites where the absence of any such pattern underlies the inherently dynamic and variable nature of the sediment fluxes taking place. However, the area covered by the Cocked Hat (CH) posts further upstream is generally more silt rich and appears to be subject to net deposition.

This deposition at the more upstream sites was in evidence at Sites CH1 and CH2 before they were lost and is now illustrated quantitatively by the data from Site CH6. It is also qualitatively demonstrated by the fact that it is no longer possible to access Sites CH3 or CH4 due to the soft deep sediments in this area. This accretion will probably be because they are positioned in the less exposed centre of the estuary and are shielded to the west by the marshes. The LHC Phase 1 breakwater to the north will also be contributing, possibly quite significantly, to this effect.

One change which is quite clear is that all the sites have shown a substantial amount of net accretion in the several months prior to the July 2014 survey. This occurred during the inter period (October 2013 to April 2014) when other areas of the estuary were eroding and it occurred again over the summer between April and July 2014. On average all sites accreted by around 2cm between April and July 2014 alone.

There was clearly a flux of sediment into the area during the past spring/summer which is probably due to a greater amount of sediment that has been in the water column after the storms of the 2013/14 winter. This change has been most evident at Site CH6 which was accreting previously but has shown an increase by 5cm between April and July 2014 alone (Figure 3). It is also very clear at the nearby Site SP2 which accreted by 4.4cm over the same period.

Table 3. Net change in elevation after deployment at time of Survey 35

Area	Stake	Net Change Since Deployment
Cage Boom	CB1	Accretion
	CB2	Erosion
	CB3	Erosion
	CB4	Accretion
	CB5	Erosion
	CB6	Erosion
	CB7	Erosion
	CB8	Erosion
	CB9	Erosion
	CB10	Erosion
Cocked Hat	CH3	-
	CH4	-
	CH5	Erosion
	CH6	Accretion
Seymour's Post	SP1	Erosion
	SP2	Accretion
	SP3	Erosion
	SP4	Erosion
	SP5	Erosion
	SP6	Accretion
	SP7	-
	SP8	Erosion
	SP9	Accretion
	SP10	Accretion
Tar Barrel	TB1	Erosion
	TB2	Erosion

3.1.2 Tar Barrel Area

At these two outer estuary sites there has been clear trend of continuing net erosion. These sites are both now around 13cm lower than they were in June 2009 (Figure 4).

Although there have been some periods when accretion has occurred, this erosion has been on a very consistent basis. At TB1, in particular, it has occurred throughout both the summer and winter months. At TB2, which is higher up the shoreline, the typical pattern involves winter erosion followed by relatively stable periods during the summer.

This relatively clear erosive trend has continued from 2013 into 2014 with the elevation of the substratum decreasing at both locations over the last year (and with no indication of higher rates occurring from the 2013/14 winter storms). However at both sites there was accretion over the last summer which may well be a symptom of the greater amount of sediment in suspension (as described above for the SP and CH sites).

This trend of erosion in the outer estuary reflects the greater exposure of this area (especially to prevailing southerly winds). This erosion has been consistently observed throughout all the different monitoring surveys that have been undertaken including the bathymetry and LiDAR work (see Sections 3.3 and 3.4).

3.1.3 Cage Boom Area

At the majority of the sites on the eastern side of the estuary (8 out of 10) there has been relatively clear net erosion over the 5-year period of the monitoring programme (Figure 5a-d). There is, however, an inherent temporal variability in the observations, with cycles of accretion and erosion occurring over time. In general there does appear to be a spatial distinction between the north and the south of this area.

To the south at Site CB10 (Figure 5d), which is the most downstream and exposed location in this area, there has been the highest rate of erosion at any location. This site is now 22cm lower than it was in June 2009 (4.4cm/year erosion on average). By contrast the upstream lower shore locations sites CB1 and CB4 (Figures 5a and b) have shown a high level of stability and net accretion of around 1cm over 5 years. The EA LiDAR data (Section 3.4) also indicates that accretion is likely to be occurring in this northern part of area (probably as a consequence of sediment being swept from the adjacent marsh creek system).

Overall the majority of sites at the Cage Boom Area are exhibiting higher and clearer levels of erosion than the western side of the estuary. This will be due to the greater exposure of this side of the estuary to wind and wave conditions.

3.1.4 LHC Stake Surveys (Upper Estuary)

In addition to the Wightlink surveys, the LHC has previously provided ABPmer with the reported results from their separate graduated stake survey work. This work was carried out by Black and Veatch, on behalf of the LHC, to assess the effects of the new breakwater (Black and Veatch, 2011). The graduated stakes for these surveys were located in the upstream sections of the estuary (they are coloured orange in Figure 1). These Black and Veatch/LHC surveys were undertaken quarterly (eight surveys in total) over the two years from September 2010 to August 2012.

After two years of monitoring, the results showed that there has been accretion along the sheltered and exposed side of the breakwater on the western/southern side of the channel (LHC sites labelled 'WB' on Figure 1) thus indicating the benefit of the structure. The physical changes observed to the south in the area of the Wightlink survey stakes (qualitatively at Sites CH3 and CH4 sites and quantitatively at Site CH6) suggest that the depositional effects related to the breakwater (see next section) may well be extending into this area. The 2014 LHC bathymetry survey (Section 3.3) and the 2014 Environment Agency LiDAR data (Section 3.4) also indicates that accretion is occurring in this area.

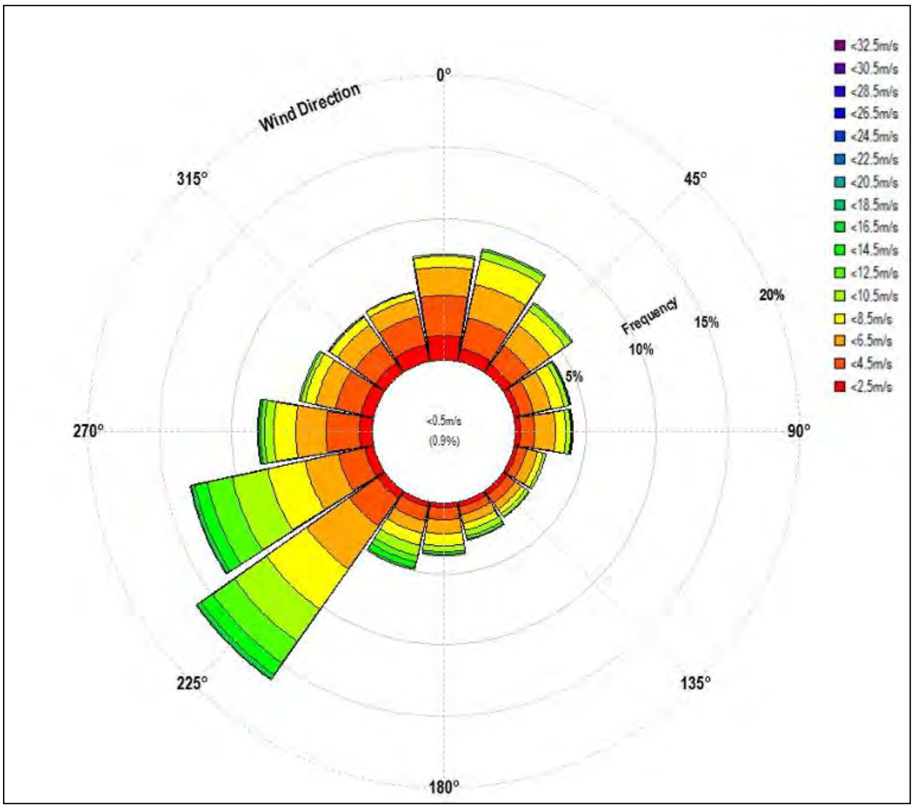
On the eastern/northern side of the channel, where the Phase 1 breakwater has no influence, the conditions are similar to those that have been recorded for the Wightlink surveys. There is a net erosional trend but also temporal and spatial variations in erosion and accretion over time. These observed changes are attributed to the fact that "the inter tidal mud is responding to weather conditions and continuing to follow historical erosion trends rather than the presence of the breakwater" (Black and Veatch, 2013).

The Phase 2 stage of breakwater work has also now been constructed (between April and October 2014) on the east side of the channel. This will now have an effect on the mudflats and marshes in this area.

3.2 Summary of Wightlink and LHC Stake Surveys

To provide a broad estuary-wide overview of the findings from this survey work, the combined results of the ongoing Wightlink stake monitoring and the previous LHC stake surveys are presented in Figure 7. This shows the net elevation change at each of the survey stakes during these two monitoring programmes. Together these results indicate that there is net erosion in most areas and there is a clear and intuitive spatial relationship between the observed rate of mudflat erosion and the degree of exposure to wind waves.

The more exposed eastern shoreline are lowering faster than those on the western side and, also, the rate of erosion at the exposed mouth of the estuary is much greater (again most significantly on the eastern shore) than the upstream sites. This is in keeping with the fact that the main wind direction and the strongest wind speeds are from the south and west. To illustrate this point, wind data from Lymington the period June 2009 to December 2012 was downloaded from the CCO website (www.channelcoast.org) and used to create a wind rose (as shown in Image 2).



(Source CCO website: www.channelcoast.org)

Image 2. Wind direction at Lymington monitoring station (Jun 2009 to Dec 2012)

To further illustrate the spatial patterns described by the data, the average changes in each of the main areas of the channel are shown in Figure 8[2]. Taking account of the fact that the Wightlink work has been underway for five years (while two years' of data are available for the LHC work) the system can be broken down, in order of the net relative erosion rate, as follows:

- Highly exposed eastern marsh edge (Wightlink Site CB10) which has eroded by 22.4cm over five years which equates to around -4cm/year;
- Highly exposed eastern outer estuary (Wightlink Sites TB1 and TB 2) which has eroded on average by 13cm over 5 years which equates to around -2.5cm/year;
- Moderately exposed eastern middle estuary which has eroded on average by 5cm over 5 years (Wightlink Sites CB1 to CB9) or 2cm over 2 years (LHC data) which equates to around -1cm/year;
- Less exposed western outer estuary has accreted by 0.3cm over 5 years which equates to < +0.1cm/year (Wightlink Sites SP1 to SP10, CH5 and CH6). This value is influenced by the accretion that occurred in the Summer of 2014 (especially at Site CH6);

2 Figure 8 also identifies the 1km zone (see orange line) of the Lymington Channel in which possible ferry effect may theoretically occur (to the adjacent low shore mudflats) based on the worst-case predictive model.

- More sheltered western middle estuary and, specifically the area in the immediate lee of Phase 1 LHC breakwater, which has accreted by 1cm over 2 years (LHC Data) which equates to +0.5cm/year (NB even before the breakwater was put in place the Wightlink Sites CH1 and CH2 in this section of the estuary accreted by 2cm over the one year period from June 2009 to May 2010 and accretion has probably occurred at Sites CH3 and CH4 which is making sampling at these locations impossible, as described above); and
- Most sheltered western upper estuary (also shielded to some degree by Phase 1 LHC) which has accreted by 3cm over 2 years which equates to +1.5cm/year.

3.3 LHC and CCO Bathymetry Data Review

As discussed in the introduction, bathymetric data was collected by the LHC in April 2014 and a separate swath bathymetry survey was completed by the CCO in July 2013 which is now available for analysis. Both of these datasets have been reviewed here and, where possible the data has been compared to historical survey results and trends.

The mapped results from the LHC April 2014 bathymetric survey are shown in Appendix A in the form of four maps. These illustrate the conditions experienced during the 2014 survey and they are expressed as the difference between the interpolated[3] depth readings since the previous LHC survey in March 2012 and since the LHC survey that was undertaken in June 2008 before the W-Class ferry service began. These charts cover the area from the Royal Lymington Yacht Club (which lies downstream of the Wightlink Ferry Terminal) to the mouth of the estuary where it is marked by navigation Post 8 (i.e. equivalent to the seaward limit of the area shown in Figure 1).

The mapped outputs in Appendix A, illustrate that in 2014 there was little significant change across the bulk of the estuary area. Most of the readings taken indicate a net accretion although that is at levels that are below the accuracy of the data interpolations and therefore they cannot necessary be taken as indicative of a change. Such areas with no definitive change are shown as blue readings.

Some changes are, however, large and definitive enough to indicate a change and these are coloured in green text (areas that are ‘shallower’ through erosion/excavation) or red text (areas that are deeper through accretion/deposition). Focussing on these areas it is possible to clearly see the outcome of the LHC’s dredging work around the toe end of the Phase 1 breakwater (as carried out during the 2013/14 winter). This resulted in depth increases of around 1m.

There are signs also of accretion of around 30cm along the full length of the western side of the channel’s subtidal margins. This is in keeping with the changes indicated by the stakes for the

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3 i.e. the readings that are predicted across a 10m x 10m grid (based on hydrographic processing software) between the *in situ* measurements (that are taken along survey lines but which are not in exactly the same location between years).

adjacent intertidal areas. This is also the section of the channel which the LHC intends to dredge during the 2014/15 winter period to maintain safe navigation.

The centre navigable channel was previously shown to have deepened (by around 10 to 40cm) along its length from the Wightlink Ferry terminal to the estuary mouth over the period from 2010 to 2012 (ABPmer 2012b). This is also indicated by the comparison made here between 2008 and 2012 (see Appendix A). However, over the most recent two year period (from 2012 to 2014) there is no indication that the central channel has deepened further. Therefore, it is possible that over the initial 2 to 3 years of its operations, the W-Class ferry prompted this subtidal deepening effect after which conditions have stabilised to a new equilibrium.

Some of this observed deepening will be due to inherent variations in the accuracy of the survey reading and the fact that bathymetry of the channel will naturally change over the course of a year as a result of the winter dredging programme and natural processes. To better understand the estuary's morphology, and compare the latest findings with those from the past, the 2014 bathymetric data is reviewed against a range of past survey data in the following sections. The relevant data sources are as listed in Table 4 and Section 3.3.1 considers the changes to subtidal and intertidal areas based on selected lateral cross-sections while Section 3.3.3 describes the changes to the Mean Low Water (MLW) position and the Chart Datum positions along the full length of the estuary.

Table 4. Historical bathymetric data sources

Date	Data Source (Provided By)
1866/1870	OS 2nd edition 6" maps, for study coastline (Hampshire County Council)
1907	OS 3rd edition 6" maps, for study coastline, except sheet 65NE (Hampshire County Council Records Office)
1975	1:10,000 OS Raster tiles for study area (Environment Agency)
1993	Maps scanned and geo-referenced from LHC map library
1994	Bathymetric chart provided by LHC 1:1250 (CPLYM002)
March 2005	Contour produced from DGM of LIDAR data (NFDC/Channel Coastal Observatory, Regional Monitoring Programme)
October 2006	Charts and X, Y, Z data provided by LHC (PRO Surveys Ltd., 2006)
June 2008	Charts and X, Y, Z data provided by LHC (Shoreline Surveys Ltd., 2008)
July 2009	Charts and X, Y, Z data provided by LHC (Shoreline Surveys Ltd., 2009)
May 2010	Charts and X, Y, Z data provided by LHC (Shoreline Surveys Ltd., 2010)
March 2012	Charts and X, Y, Z data provided by LHC (Shoreline Surveys Ltd., 2012)
April 2014	Charts and X, Y, Z data provided by LHC (Shoreline Surveys Ltd., 2014)
NB for the May 2010 surveys the need for an 8cm correction (deepening) was identified Shoreline Surveys Ltd subsequent to the initial survey. This correction has been made	

3.3.1 Long-Term Changes in the Subtidal Channel Shape

To compare the historical data describing the estuary channel shape, complete cross-sections were plotted through the locations of Harpers Post South, Cocked Hat, Bag of Halfpence and Seymour's Post. These cross-sections, which are shown in Figures 9 to 12, were previously analysed as part of the impact assessment work (ERM and ABPmer 2010) and the subsequent review of the LHC 2012 bathymetric surveys (ABPmer 2012b). In this case the 2014 LHC bathymetric data has been added.

These diagrams indicate that the intertidal areas (above CD) are generally stable within the accuracies of the bathymetric survey monitoring. Changes to the subtidal channel have been observed with the following historical trends being in evidence at each profile:

- At Cocked Hat (Figure 10): historically the whole profile has been stable over time, particularly since 1993. The most significant change was a deepening of the base of the channel by about 0.5m between 1988 and 1993. For the rest of time the changes were within the maximum resolution of the survey. In 2010 and 2012, since the W-Class ferries came into service, the channel has continued to remain stable. The results of the 2014 survey show the outcome of dredging work on the west side of the channel as undertaken by LHC in the 2013/14 winter. It also shows substantial accretion of the intertidal upstream of the rock armour. There is no indication of any central subtidal channel deepening here in 2012 or 2014.

- At Harpers Post South and Bag of Halfpence (Figures 9 and 11): the most significant historical changes occurred here between the 1988 and 1999[4] surveys and the channel has been more stable subsequently. The magnitude of the past changes, compared to recent years, suggests either direct or indirect anthropogenic change(s) occurred, or that there was a response to a major perturbation. At Harpers Post South in 2010, the shape remained relatively stable and in 2012 there was a slight deepening by a few centimetres of the central subtidal channel on its northern side (possibly influenced by the ferry service). This depth was maintained, with no further deepening, in 2014. Otherwise no change from past years is in evidence and the intertidal areas have remained stable. At the Bag of Halfpence in 2012 the subtidal channel also deepened (by up to 40cm) particularly in the centre. Once again this depth was subsequently maintained in 2014. The intertidal area has also remained stable and there are signs of accretion on the western lower shore and shallow subtidal section between 2012 and 2014 (as shown in the maps presented in Appendix A) in the area to be dredged next winter (2014/15). Accretion on the eastern side is also in evidence and this area may be subject to future dredging to maintain the navigation channel.

- At Seymour's Post (Figure 12): historically, the cross-sectional area of the channel has remained relatively stable but evidently exhibited a general movement of about 10m to the east in the late 1980s or early 1990s. The base of the channel also deepened most during this period. In recent years, since the W-Class ferries began operating, there may have been some deepening of the subtidal channel base with the depths being marginally higher in 2012. By 2014, however, the depths had become slightly shallower in the centre of the channel indicating that there has been no clear deepening of the bed in this outer channel area. The intertidal has remained stable and there are also signs of some accretion of the shallow subtidal area on the western side of the channel between 2012 and 2014.

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4 The 1993 data set would appear to have a horizontal scaling problem as the changes relative to the other surveys do not look consistent and the magnitude of change indicated does not appear realistic. This survey was also identified as the 'odd one out' from the CD and MLW analysis and therefore should be considered less reliable than the other surveys.

Overall the depth reading from the 2014 bathymetric survey generally fall within the 'noise' of all the datasets and, once all the data are considered together, the channel morphology (especially of the intertidal) is shown to be relatively stable. The results reinforce the findings from the plotted maps (in Appendix A) and show evidence of a deepening of the channel base in 2012 (at Seymour's Post, Bag of Halfpence and, to a lesser degree, at Harpers Post South). No subsequent deepening is in evidence in 2014. There are signs of accretion along the shallow subtidal areas along the western subtidal flank of the estuary.

3.3.2 Long-Term Changes in Mean Low Water and Chart Datum

Using the 2014 LHC data, the Mean Low Water (MLW) and Chart Datum (CD) alignments were contoured and are shown, alongside the alignments from previous data, in Figures 13 and 14. The MLW is used here as an indicator of the changes that have occurred over time and is also used as a level for determining qualitative habitat change by Natural England. The SAC boundary in Lymington River is defined by the location of the navigation posts, which are approximately positioned along the CD alignment.

Historically, the MLW has moved landward over time both within the channel and also on the open coast (see Image 3). The highest rates of retreat were observed at the exposed mouth (as also clearly indicated by the graduated stake results). Generally there is also more erosion on the outside of the bend above Pylewell (between Enticott to Cage Boom posts) than on the inside of the bend, at Cocked Hat. This suggests that there is a migration of the channel at the bend and possibly a slight meandering of the channel.

Since 1993 the position of MLW has been more stable than it was prior to the mid-1990s (following the trends that are also observed subtidally). However it has also 'varied in position' across a 30m wide zone in an inconsistent manner which makes measuring a net rate of landward movement very difficult if not impossible from this information (this applies to the main estuary channel but not the estuary mouth where trends are very clear).

This variation across 30m of the intertidal is due to differences in between-survey accuracies (as described above). It is also due to the very flat morphology of the intertidal areas which exacerbates differences in the horizontal positioning on the MLW alignment (i.e. the shallow intertidal gradients mean that even small vertical differences (of a few centimetres) in the depth readings can lead to relatively large horizontal differences (of several metres) in the recorded MLW alignment).

The extent to which the position of MLW can 'vary' has been demonstrated in the period since the W-class ferries came into service in early 2009. In 2009, the results indicated that the MLW position was lying to the landward side of the position observed in all other years. However in 2014 it was mainly lying on the seaward side when compared to the results from other years (see Figure 13). Thus the 2009 and 2014 results encompass this 30m-wide 'zone of variability' and, if taken literally, they would indicate that there has been a seaward movement of the MLW (accretion of the intertidal) throughout almost the entire main channel. This is clearly an inaccurate conclusion as the more detailed on-site survey work has shown areas of erosion and accretion in the estuary (as described above). This is therefore, a clear indication of the relatively accuracies of between-survey measurements using this technique and a demonstration that this data should not be treated as actual change for levels below the accuracy of the technique (i.e. < ±15cm).

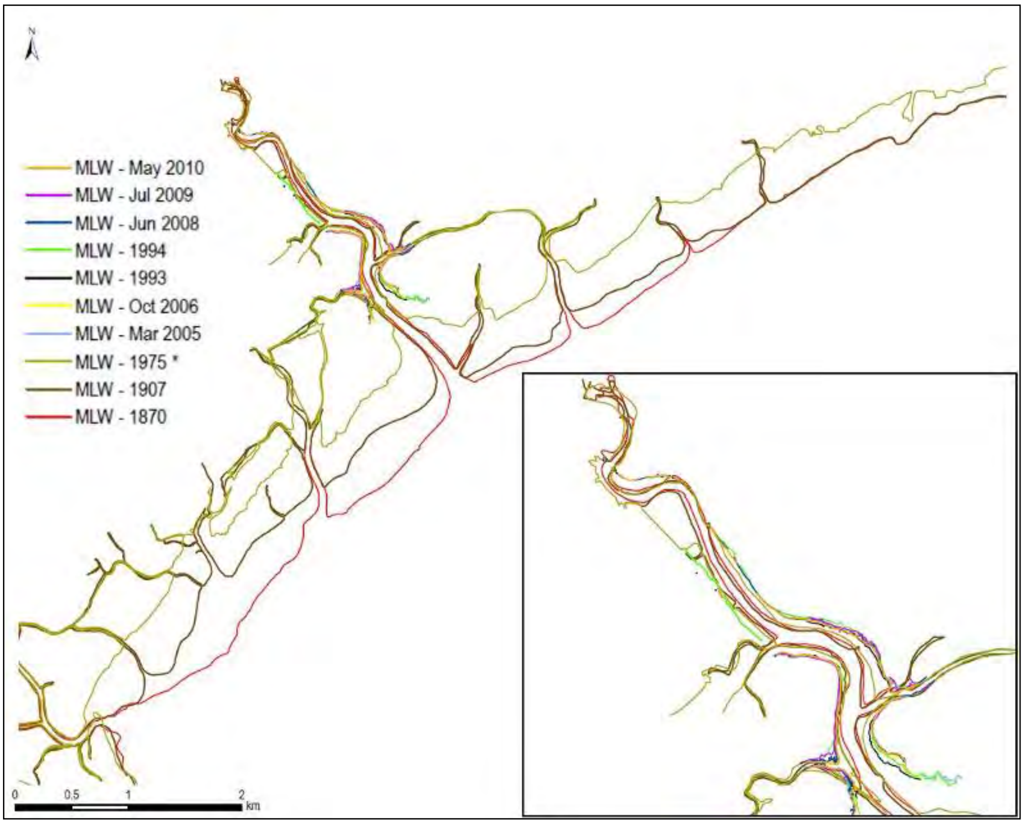

Image 3. Alignment of mean low water showing progressive retreat especially of exposed areas

The results undertaken since the W-Class ferry began operating therefore indicate that there has still been no clear unidirectional erosion or accretion trends at the scale that can be inferred from these measurements. While smaller scale changes are occurring (and this is confirmed by the findings of the stake monitoring which have been reviewed above in Section 3.1) these are not resolved by analysis of the available bathymetric data. The 2014 data does however provide assurances that the MLW in the main channel has not been subject to any significant retreat and, in this respect, verifies the results obtained from graduated stake surveys.

Although clear changes in the MLW are not detectable along the main estuary channel, the historical results consistently confirm that there is a spatially-distinct pattern of erosion at the mouth (the eastern side up to Pylewell Post especially). This is again confirmed by the 2014 data which shows that the MLW from this latest survey lies to landward of all previous MLW alignments on the eastern side of the estuary mouth. On the western side of the estuary mouth erosion is also occurring but over a smaller area (mainly up to navigation Post 8) and over a reduced distance. These observations are all in keeping with the findings from other monitoring work and shows that where distinct morphological trends occur they are clearly described by this data.

Similar to the findings for the MLW alignment, the position of the CD level (which is shown in Figure 14) indicates that the main channel has also been relatively stable, although there have been signs of a migration of the channel over the longer term[5]. Like the MLW positions, the location of the CD contour varies between surveys but the horizontal distance is considerably less variable at CD because of steeper shoreline profile at this point. Within the main channel the 2014 CD alignment generally lies within the range of past variation but on the seaward side. This provides assurances that there has been no erosion/retreat of this alignment. Conversely, it is actually likely to reflect accretion in some areas. This is especially true along the western flank of the estuary where the position of the CD alignment in 2014 (some 5m to seaward of recent years) reflects the fact that accretion that has occurred along here as indicated by the other analyses reviewed previously.

At the exposed mouth of the estuary there has historically been a clear retreat of the CD line over the longer-term (early 1980s to the present). Between 2012 and 2014 however there has been a slight advancement of the line in this area. This will particularly be a function of measurement variability over the flat low shore area. However, as indicated by the observations of accretion in the western intertidal areas, it is also likely to reflect the fact that major fluxes of sediment would have occurred into the estuary over the winter and summer 2014 (after the storms of the 2013/14 winter). This sediment will have settled in the lower intertidal and shallow subtidal having been eroded from the marshes and from fronting subtidal bank. When the April 2014 survey was carried out this sediment may well have been mobile and transiting towards the central estuary.

This inward movement of the sediments has been described with a recent MSc study that was undertaken at the University of Southampton (de Castro Silva 2014) which assessed morphodynamic evolution of Lymington Estuary. This study included the development of the sediment budget for the Lymington Estuary based on a detailed review of historical bathymetric data. The conclusion of this work was the sources of sediment in the estuary were the naturally eroding saltmarshes and the subtidal banks outside. The estuary then imports these locally-derived sediments.

3.3.3 CCO Swath Bathymetry Data

In July 2013, the CCO carried out a very detailed swath ('multibeam') bathymetry survey of the subtidal Lymington estuary channel (see Image 4 and Figure 15). This survey provides a new high-resolution view of the channel shape. As this is the first multibeam survey of this channel it is not possible to compare the results with findings from a comparable preceding survey to detect temporal trends. However, it is possible to examine this detailed one-off description for any distinct spatial patterns which might signal a ferry effect.

[5] This migration of the channel has also been indicated by the need to change the location of the navigation posts. In April 2010, LHC relocated the navigation posts at 'Cocked Hat', 'Bag of Halfpence' and 'Seymour's Post' on the west bank to better mark the deep water channel. Two of these, at Seymour's and Bag of Halfpence, were above CD with the Cocked Hat post being close to CD line. It is assumed by LHC that when they were first driven in, the posts marked the margins of the deep water and the west bank has subsequently accreted over a prolonged period of time as the channel has migrated east. More recently, this migration is also indicated by accretion along the western subtidal margins of the channel as described by the 2014 bathymetry data.

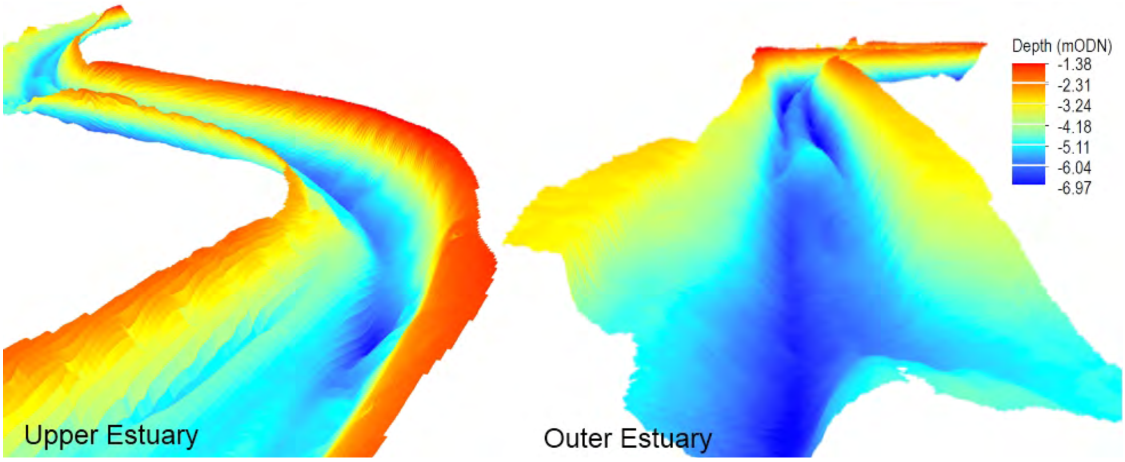

Image 4. Two 3D views of the subtidal estuary channel from the CCO survey data

From this review, two observations are made which provide evidence that there is no detectable effect from ferry operation and that the worst-case effects, which have formed the basis of the assessment and mitigation, are not occurring. These two observations are as follows:

- The channel narrows despite ferry operations: There is a distinct narrowing of the channel around the toe of the Phase 1 breakwater by around 10m. This is the area where the LHC carried out dredging in the 2013/14 winter to maintain the navigable channel. The worst-case prediction of the ferry effect is based on the principle that the W-Class ferry operations could force a widening of the whole channel width along the full 1km length of the channel. This survey indicates that that cannot be occurring if the channel can narrow in this manner.

- The channel doesn't widen at the passing area. According to the worst-case prediction of the ferry effect, it was argued that there was a sensitive relationship between the extra underwater blockage that is presented by the new W-Class and the overall channel shape along the full 1km length of the channel. On this basis, and given the expectation that the W-Class ferry operations could force a widening of the whole channel width, a greater widening effect should occur in the subtidal and shallow intertidal areas where the ferries pass on each transit (because at this point the two passing vessels will double the value of the extra blockage and double the theoretical effect). This CCO multibeam survey shows no indication (even at the high detail shown) that channel widening is occurring in this area.

3.4 Environment Agency LiDAR Data

In addition to the results of the LHC and CCO bathymetric results described above, the Environment Agency's latest LiDAR can also be used to interpret changes to the channel morphology. In this case, because it is aerial remote sensing data, it only describes the intertidal areas with the extent of the coverage being dictated by the elevation of the tide at the time of the survey. The coverages of the LiDAR images for 2008 and 2014, which were taken on a relatively low tide, are shown in Image 5.

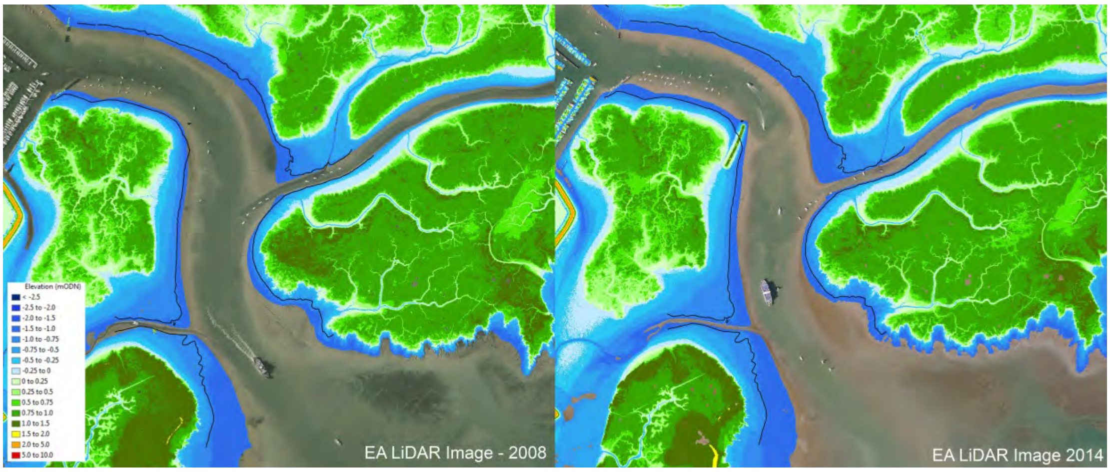

Image 5. Environment Agency LiDAR Images from 2008 and 2014

The results of these EA surveys are presented in Figures 16 to 18. Figure 16 includes two plots showing elevation differences/changes between 2008 and 2014 (encompassing the five-year operational phase of the W-Class ferries) and also the changes over the last year between 2013 and 2014. Figure 17 presents the same analysis for the wider shoreline and has been included because the EMP requested equivalent data for areas away from the ferry navigation route. Figure 18 also presents the interpreted MLW alignment along the channel length for those recent LiDAR data sets where the low shore was exposed and clear elevation readings were obtained (years 2008 to 2014).

The results presented in Figure 16 show that there has been very little detectable change in the mudflat elevation. This is to be expected because any changes that have occurred (as measured by the stake surveys) are typically lower than the vertical measurement accuracy of the LiDAR technique. That accuracy is around ±15cm for one survey and, for this reason, any ‘changes’ of this order expressed by the data have been excluded from this plot.

What is evident from Figures 16 and 17 is that accretion of sediments is continuing to occur around the Phase 1 breakwater. This was identified from previous LiDAR analyses and also indicated by the LHC stake monitoring work (Black and Veatch 2012). However, this LiDAR data shows that it has also continued through the 2013 to 2014 period. There are also some signs of accretion to the south of the breakwater and the northern part of the Cocked Hat post area which is in keeping with the observations made from the stake surveys (e.g. at Stake CH6, CB1 and CB2).

Figure 16 clearly shows how the saltmarsh edges are continuing to retreat at the mouth of the estuary particularly, but also within the channel itself. This erosion is visible on the LiDAR comparison because it is marked by a clear vertical ‘cliff’ as compared to the flattened mudflat morphology. As expected, the results shown in Figure 16 directly mirror the results from the stake monitoring and describe the inter-relationship between erosion rate and exposure. They show how the outer marshes within the estuary are eroding fastest and are retreating by around 2-3m/year in the outer estuary (from Pylewell seawards) while the inner marshes are retreating by around 1-2m near Cage Boom.

The most sheltered section of the channel and the one showing the least erosion is on the southern/western upstream bank. Here there has been <0.5m of erosion in the last 5 years and very little detectable change over the one year period from 2013 to 2014. In Figure 16, not only is there mudflat accretion on both sides of the breakwater there is no clear sign of marsh erosion 100m upstream or downstream of the breakwater.

For context, Figure 17 indicates how the external seaward marshes are also eroding. The most exposed locations away from the estuary are eroding at rates of up to 5m/year. The relative rates of change on the more exposed and more sheltered marshes are directly comparable with the results from New Forest District Council (NFDC) studies as presented in Image 6. This image show the rates of channel edge erosion as illustrated within the NFDC online presentation and report on ‘Summary Notes of NFDC Coastal Group’s research relating to the Lymington saltmarshes’ (NFDC, October 2007).

The LHC and Wightlink recharges that took place in 2012 and 2013 are also both clearly visible in Figure 17.

(Source: NFDC, 2007)

Image 6. Annual average saltmarsh edge erosion rates – Lymington River

Figure 18 shows the MLW alignment from 2008 to 2014 and, in common with the LHC bathymetry data, indicates clear lateral erosion in the outer estuary and into the Solent but no clear trends within the inner estuary. Also as indicated by the LHC bathymetry data the MLW is typically located seaward of previous year's MLW alignments thus further indicating that there is no indication of landward migration of the MLW based on this data alone.

In a number of cases the LiDAR data describes the MLW alignment as a variable position across a zone that is several metres wide (often these distances are greater than the full predicted worst case effect of the ferry (see Section 4). This is again due to the flat topography of the shoreline.

4. Discussion

As observed during past surveys, the results obtained from the graduated stake survey work continue to indicate that regular movements of sediment are occurring in the estuary leading to cycles of accretion and erosion over the mudflat habitat. As a result there have been high levels of between-site and between-survey variability in the observed bed levels at each of the stake locations throughout the monitoring period.

Against this variation, however, clear spatial trends are in evidence from the five years of graduated stake survey work and from the other data sources reviewed. This trend is directly related to the degree of wave exposure of the habitats. Erosion has been observed at many of graduated stakes and is most pronounced on the exposed eastern side of the estuary. By contrast, the western bank is accreting in the sheltered upper estuary and along much of the central estuary. The LHC Phase 1 rock armour breakwater is making a key contribution to this process.

In 2014 there was evidently a ‘pulse’ of sediment deposition even over the most exposed areas of the western bank in the outer estuary. This may well be due to the greater amount of sediment that was in suspension after the severe storms of the 2013/14 winter. As a result there has now been a net rise in the bed levels in this area after five years when the results are averaged across all the stake positions. This is notwithstanding the fact that many of the sites along this part of the shoreline had been exhibiting background trends of erosion (but at a lower rate than the eastern bank).

This distinction between the western and eastern banks is an ongoing indication that the channel is evolving, narrowing in many places and also possibly seeking a more sinusoidal curve over time. This ongoing evolution of estuary is also reinforced by the observation from the LHC 2014 that the western margins of the subtidal channel have accreted over recent years. It is also indicated by the pattern of proposed dredging that LHC has undertaken and is planning to undertake to maintain navigable depths in the estuary (as illustrated in Image 7).

The Environment Agency LiDAR data also illustrates that there is a similar relationship with respect to saltmarsh erosion with progressive marsh retreat occurring throughout all wave exposed sections of the channel. For both mudflat and marsh, erosion is most substantial in the outer estuary and is lowest in the sheltered upstream sections especially around the new breakwater where accretion trends are evident.

The results of the monitoring continue to demonstrate firmly that natural processes (marsh erosion, sediment flows and wave exposure) are having a dominant effect on the morphology of the estuary. They also provide no indication that the W-Class ferries are having any effect on the estuary system even against the worst-case predictions provided by HR Wallingford, (2012).

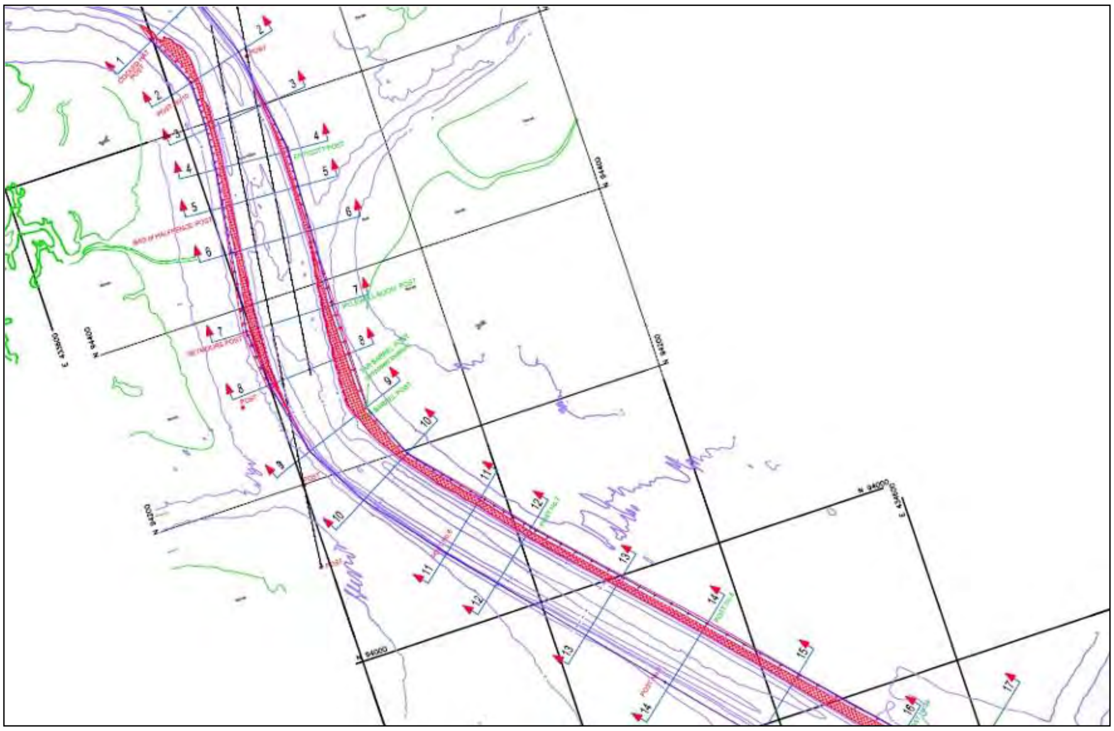

Image 7. Channel margins which LHC propose to dredge to maintain navigable depths

It has been agreed that these worst-case effects are uncertain, small and dwarfed by natural processes (Wightlink Ltd., NFDC, NFNPA and NE 2011) and therefore such effects were always likely to be undetectable against (or distinguishable from) natural change. However, now that the ferry service has been operating for nearly six years (from 2009 through 2014) there are a number of findings which help verify that the worst case effects have not materialised and to confirm that the ferry service is not adversely affecting the adjacent intertidal habitats.

To understand these assurances it is first necessary to understand the worst-case prediction/model itself[6]. No maps of this worst-case model exist and the analysis and reviews of it are relatively complex but, for the EMP, we have sought to try to simplify this in the nine points below. These points set out the basic premises of the original model (Points 1 to 4) as well as the subsequent interpretations (Points 5 to 9) that are needed to convert the modelled predictions into a value for vertical sediment elevation changes against which the results of the stake monitoring can be compared and interpreted:

6 During the June 2013 meeting the EMP specifically requested that "comparisons between the observed reality and the predicted/modelled worst-case effects be included within future reports".

Premises of the Original Model:

1. The ferries acts on both sides of the channel equally and along a 1km stretch of the estuary downstream of the wooden wave breaks (see Figure 8);

2. Without mitigation the ferries contribute to a widening of the channel cross-section of the channel (including the low-shore intertidal) to the extent that is proportionally equivalent to the change in underwater blockage that is posed by the new W-Class ferry as compared against the C-Class ferry. Thus a predicted worst case 30% increase in ferry blockage causes a 30% change to the full cross-section of the whole estuary;

3. Wave effects are dominant south of Pylewell Post and here 25% of change is deemed to be ferry effect; to the north of this point the ferry effects are identified as being dominant and contribute 75% of change;

4. Without operational mitigation, and with the effect inherently declining over time (year by year) as the channel widens, there will be an average recession of about 2.1ha of low shore mudflat (around 0.7ha at CD and 1.4ha at MLW) but no effect on saltmarsh habitat;

Subsequent Interpretations with Operational Mitigation:

5. Given the mitigation undertaken to date (and projected for 2015), this model now corresponds to an average recession of about 1.33ha (see Table B1 in Appendix B) over the full 30 year lifespan of the project;

6. This 'with operational mitigation scenario' now equates to an estimated retreat of around 3.3m at CD and 6.7m at MLW seaward of the wave screen on both sides of the channel over 30 years;

7. Given the flat topography of the shoreline where a 1:100 slope is typical[7], this equates to a vertical change of less than 7cm at MLW over 30 years

8. This would then equate to less than 0.88ha or 4.4cm at MLW over 30 years if the ferry speeds were maintained at 5 knots for their lifetime (see Appendix B);

9. Given the operational mitigation undertaken to date (and also that projected for 2015) around 30% of the worst-case modelled effects or 0.42ha of loss should already have been observed which equates to a retreat of around 1m at CD and 2m at MLW which equates to a vertical change of 2cm at MLW.

[7] Spatial variations along the estuary occur but given the unmapped and theoretical nature of this analysis, detailed section-by-section evaluations are not thought to be necessary/valuable and this review seeks to try and keep the analysis relatively simple.

Therefore, from the modelled worst case effect, it is estimated that a reduction in MLW tidal elevation of between 4.4 and 7cm could occur over 30 years (depending upon whether ferry speeds are maintained at 5 knots or increased to 6 knots). On this understanding, the relevant assurances that this is not occurring and that the ferries are having no adverse effect is provided through the following observations against the monitoring results and also other evidence:

- By now, after nearly six years of service, and with operational mitigation measures in place, we should have seen around 2cm of erosion at the MLW due to the ferries according to modelled prediction. In reality we have (very approximately) seen average changes of nearly this order on an annual or biennial basis (with this average varying greatly with position in the estuary and wave exposure as shown on Figure 8);

- The natural spatial and temporal variability of the recorded changes are high with the levels of change at any given site (whether erosion or accretion) ranging by up to an order of magnitude (±20cm (see Figure 7)) after either 2 to 5 years of monitoring (i.e. for LHC and Wightlink surveys respectively) when compared to the predicted 2cm of erosion;

- Along at least a 500m stretch in the upper estuary (south/west side) accretion rather than erosion is occurring over the intertidal and this is in an area where natural forces are at their weakest and where ferry effects (predicted to be 75% of the change in this area) are most likely to be observed and yet there is no evidence of any such effect;

- Along a 400m stretch in the outer estuary (east side), where natural forces are at their strongest, erosion is so great that it is substantially outstripping the modelled prediction. After 5 years there has been 12cm of erosion at TB1 and TB2 and 22cm of erosion at the CB10 sites (which equates to 2.5cm/year and 4cm/year). There has therefore been two or three times as much erosion here has is anticipated for the full 30 year lifespan of the ferry service. There can be no material ferry effect in this area;

- Along a 400m stretch in the central and outer estuary (about 800m when taking both sides together) the margins of the navigation channel are silting up with the shallow water believed to be encroaching on the channel (Ryan Willegers LHC Pers. Comm. - minutes of EMP meeting of 19 June 2013). The LHC is undertaking phased dredging of these areas to maintain the channel[8] (Black and Veatch 2013) (see Image 8). These shallow subtidal areas are much more likely to be affected by the ferries than the more distant MLW areas and yet they are encroaching on the channel. This very strongly indicates that the intertidal habitats are not affected by the ferries;

- In the area near Pylewell Post where ferry passing occurs (see Figure 15) it would be expected that double the ferry effect would occur, there has been no evidence of an effect (e.g. from the bathymetric work) and no indication from the LHC navigation maintenance proposal of a need for reduced subtidal dredging in these areas. This has been further indicated by the July 2013 swath bathymetry data provided by CCO;

[8] This siltation of the channel margins also led, in April 2010, to a number of navigation posts being moved down the shore to the 1m contour to better mark the deep water and supports the theory that the shoreline is changing in profile rather than simply retreating.

- The subtidal channel margins are accreting on the western side (as indicated by the LHC 2014 data). In addition at the bend in the estuary, at the location of Phase 1 breakwater, the channel narrows (as indicated most clearly by the CCO bathymetry work. These are the areas where the first phases of dredging have been and will be undertaken by the LHC. The worst-case model is predicated on the principle that there is close association between channel shape and ferry blockage. The occurrence of channel accretion and the narrowing of the channel indicates that this sensitive association between the ferry and channel does not exist; and
- There was evidence from the 2012 bathymetric surveys of a trend of deepening towards the centre of the subtidal channel downstream from the ferry terminal (ABPmer 2012b). No further deepening is in evidence for the 2014 survey. Therefore the ferry may well have caused deepening directly below the route of their navigation but the channel appears to have achieved a new equilibrium and there is no evidence that the ferries are acting on the more distant intertidal or even shallow subtidal areas.

In conclusion therefore, it is clear from the monitoring work carried out to date, that the estuary is subject to natural change and a process of gradual evolution throughout much of its length. There are substantial areas of marsh that are eroding and much of the mudflat on the eastern side is lowering at the mean low water level. This lowering, reflects a slight progressive retreat as well as a process of continued gradual intertidal flattening as the marshes retreat.

Although erosion is the dominant process, there are large areas of the estuary mudflats (especially upstream and on the west side of the channel) which are accreting both intertidally and subtidally. The trends seen and observations made indicate that the morphology of the estuary is generally evolving and the channel narrowing over time.

There is no evidence of any link between the observed changes on the intertidal habitats or subtidal margins and ferry activities. There is evidence of the central channel having deepened (possibly to accommodate the large vessels) and then having stabilised subsequently. However there is no indication of any effect on the shallow subtidal banks along the channel margins.

There are also several indications to show that no direct relationship exists between estuary form and ferry shape. The absence of this relationship means that the worst-case predicted effects will not occur.

These points together illustrate that the ferries make only a negligible contribution to observed sediment fluxes at a level well below the small worst-case predictions. However, in the same way that it is not possible to detect the worst-case scenario, it will not be possible to identify or detect any such lower effects in this estuary because natural forces are acting with significantly greater magnitude of change. Such effects would in any case be insignificant in the context of the physical evolution and ecological functioning of the estuary. For the same reasons it is not possible to determine what contribution the operational mitigation measures (slower speeds and reduced trippage) may have had to any observed changes.

5. Further Work

The results of this work were discussed at a meeting of the EMP which was held on 20 November 2014 (following circulation of a draft copy of this report). At that meeting, it was agreed that there should be a substantial reduction in the monitoring work given the absence of any effects observed. There will be no further on-site surveys and the reporting in 2015 will only involve a brief technical note which will review the available Environment Agency LiDAR data. There will only be a meeting of the EMP in 2015 if these results highlight any issues, otherwise the next meeting will be in November 2016.

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ABPmer (2012b) Wightlink - Replacement Lymington to Yarmouth Ferries: Monitoring Possible Short-term Effects of the W-Class Ferries - Progress Report 20, December 2012. ABP Marine Environmental Research Ltd, Report No. R.1556t.

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6.3 Previous Ferry Monitoring Progress Reports (2009 to 2011)

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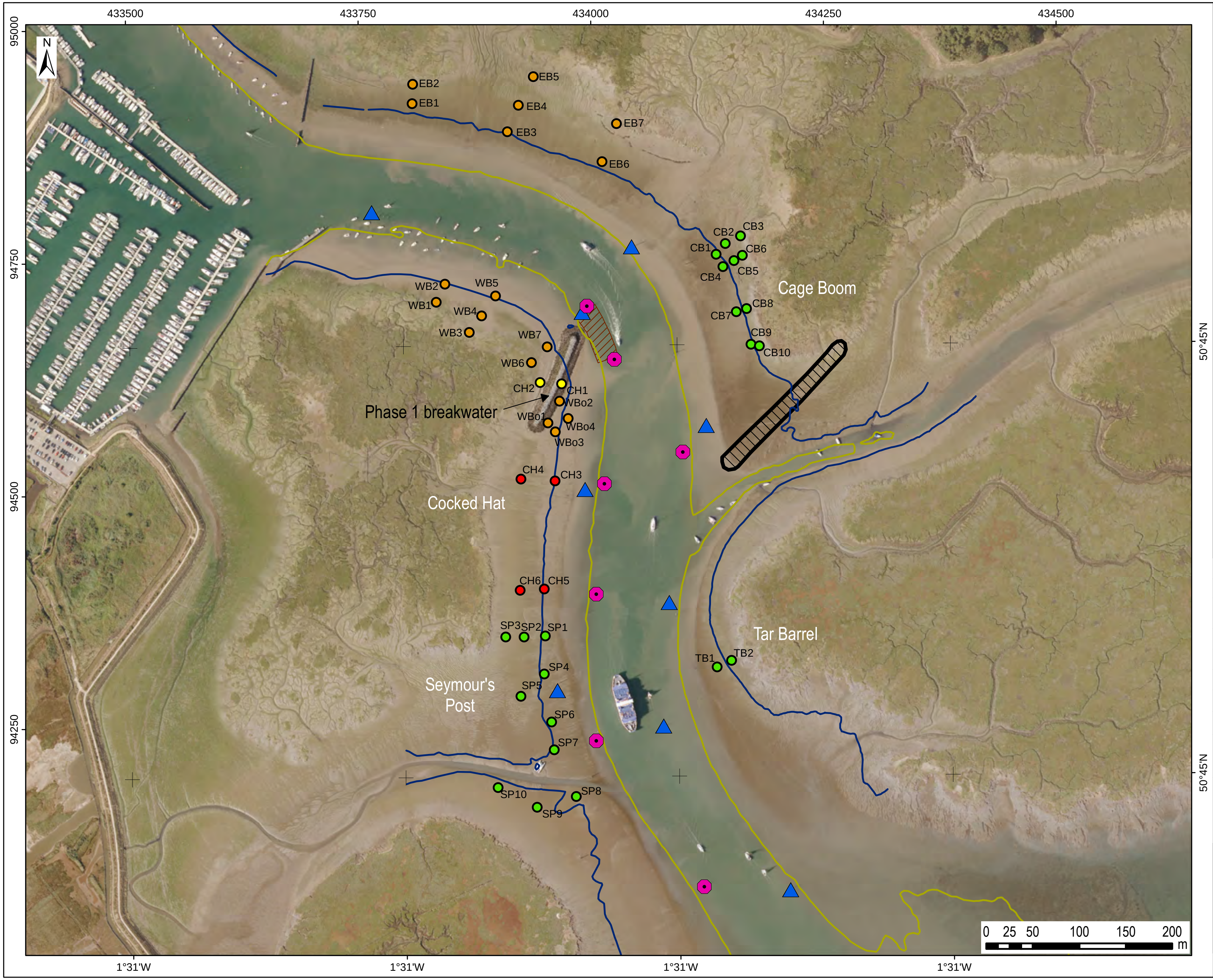
ABP Marine Environmental Research Ltd, Report No. R.1556r. Wightlink - Replacement Lymington to Yarmouth Ferries: Monitoring Possible Short-term Effects of the W-Class Ferries - Progress Report 18, October 2011.

Figures



- Wightlink stakes CH3-CH6 (added in May & June 2010 to replace CH1 & CH2)
- Wightlink stake positions June 2009 to date
- Wightlink stakes CH1 & CH2 (abandoned from May 2010 because of breakwater)
- New and revised navigation posts (from April 2010)
- Previous navigation posts
- LHC stake positions deployed as part of the Phase 1 breakwater monitoring (added Sept 2010)
- CD (April 2014)
- MLW (April 2014)
- Phase 2 indicative breakwater location
- LHC 2013/14 winter channel dredge

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Produced by ABPmer			

Data Sources: Image/Data courtesy of the Channel Coastal Observatory, 2013; Lymington Harbour Commissioners

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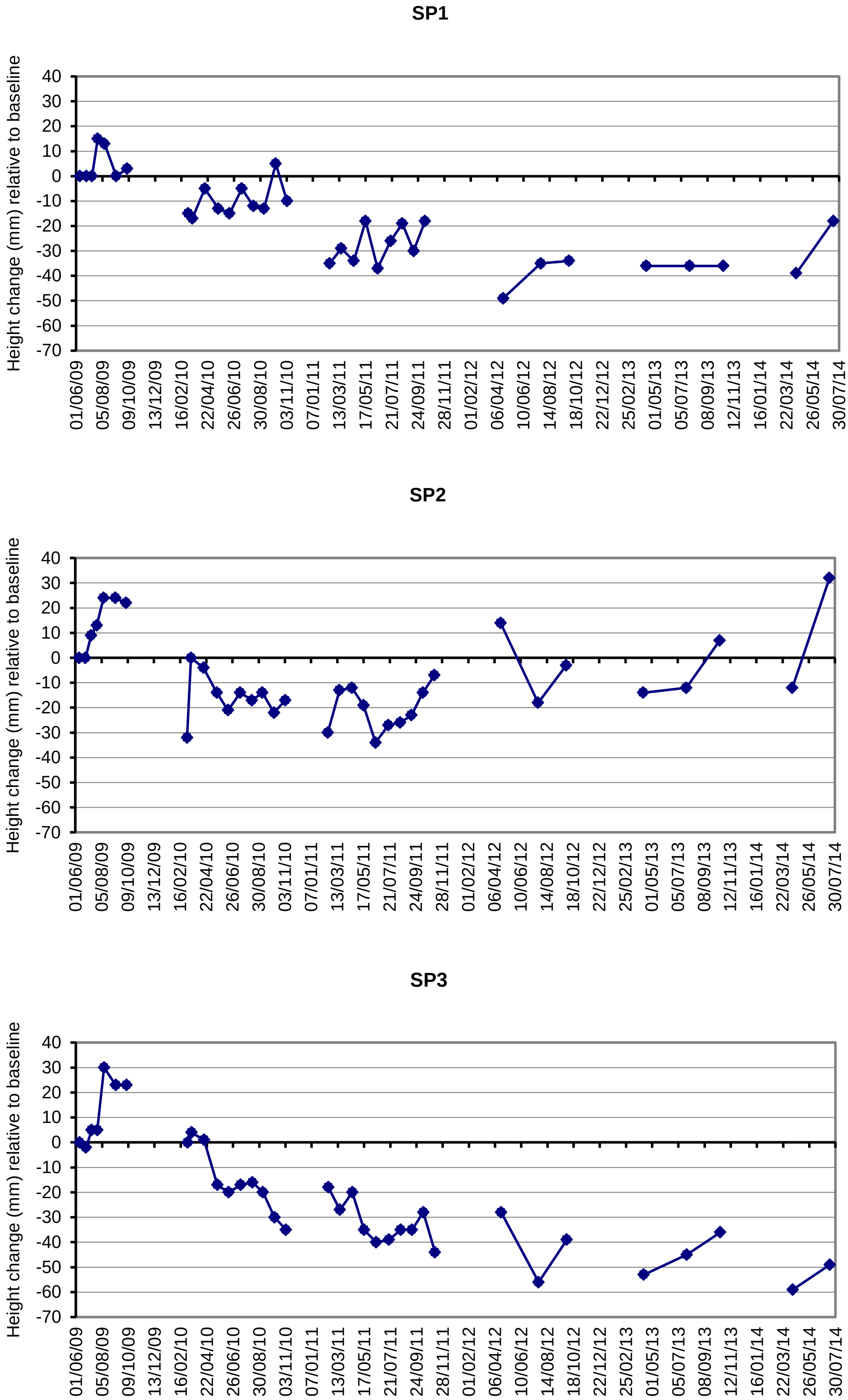
Locations of graduated stakes as used for sediment elevation monitoring

Figure 1



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Produced by ABPmer			

Sediment elevation change (mm) measured at each stake (SP1, SP2, SP3)

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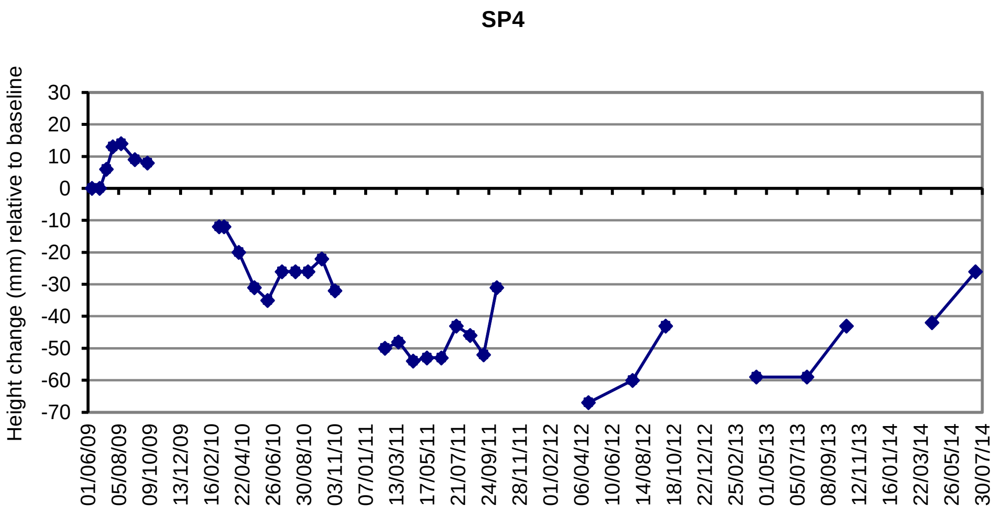
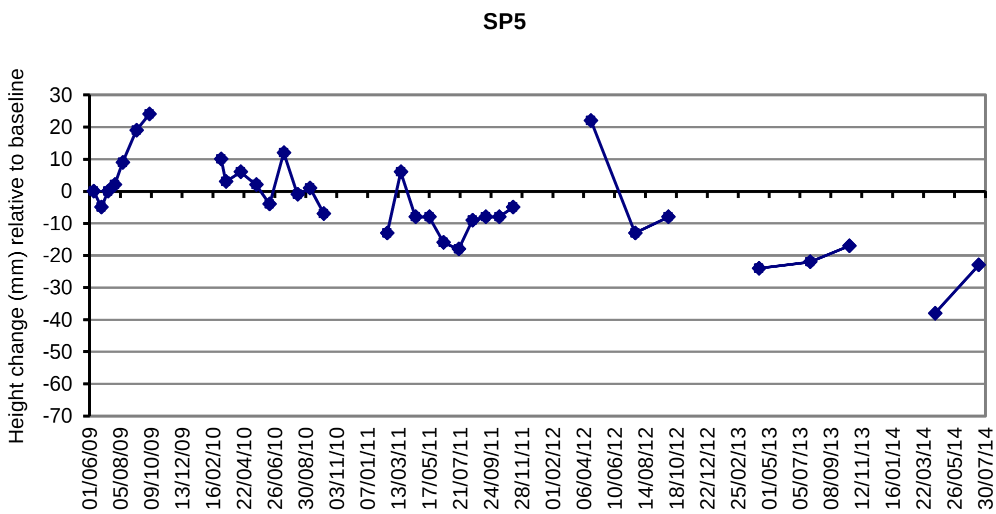
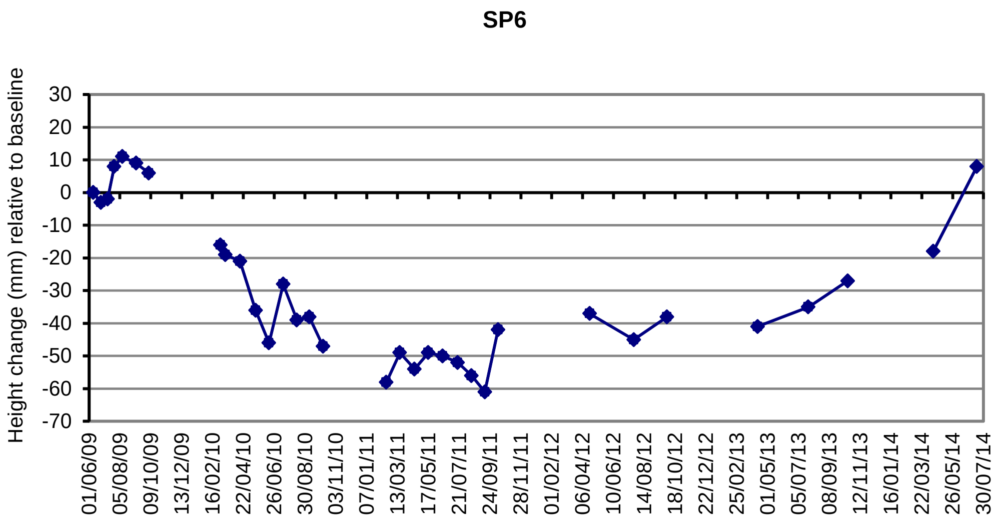
Sediment elevation changes in the Seymour's Post Area (SP1-3)

Figure 2a







Sediment elevation change (mm) measured at each stake (SP4, SP5, SP6)

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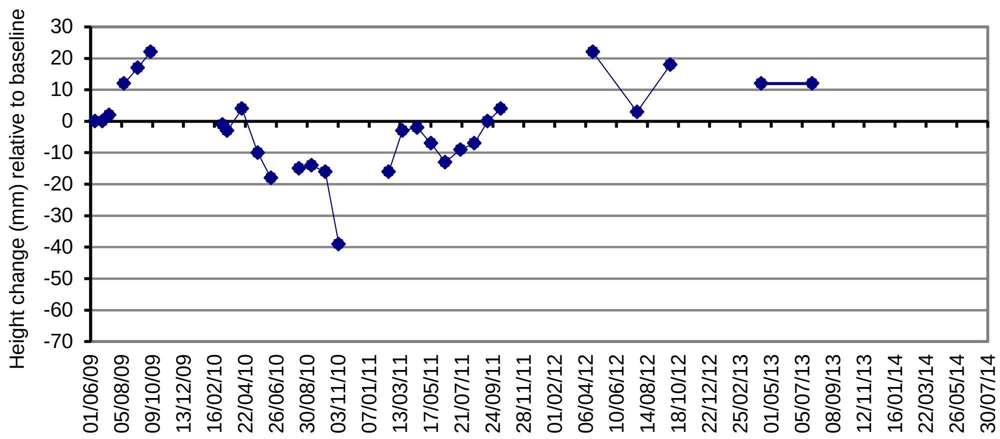
Sediment elevation changes in the Seymour's Post Area (SP4-6)

Figure 2b

SP7



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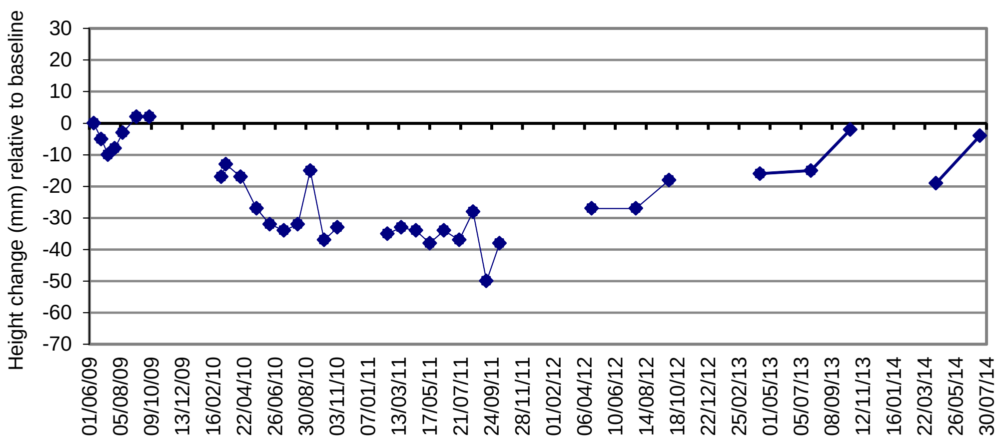

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Produced by ABPmer			

Sediment elevation change (mm) measured at each stake (SP7, SP8)

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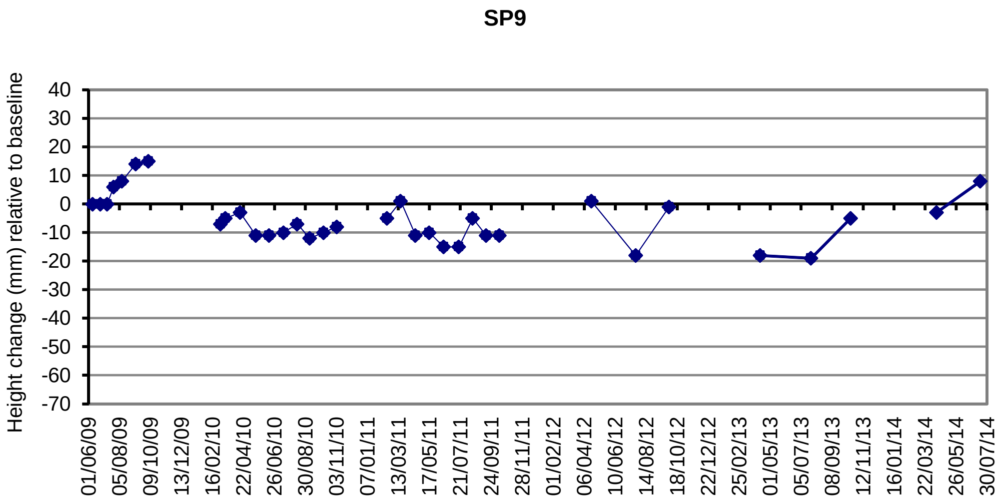
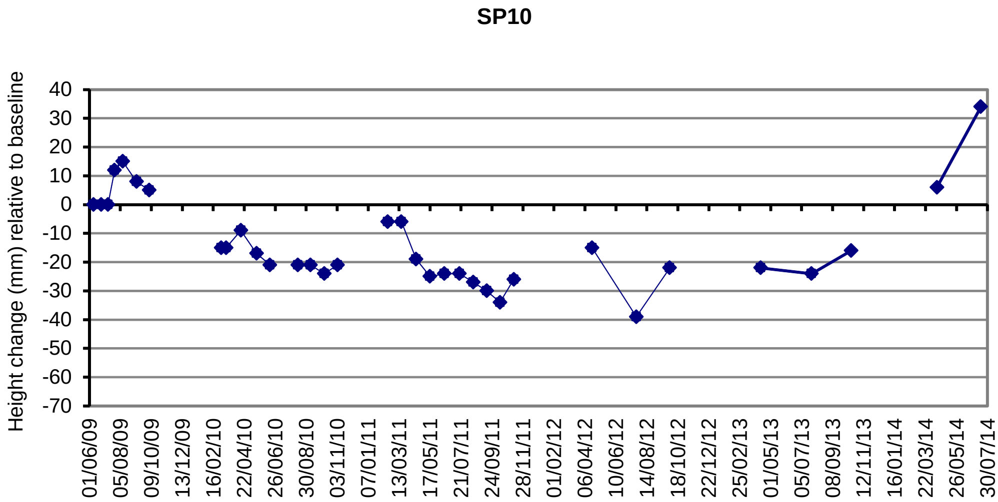
Sediment elevation changes in the Seymour's Post Area (SP7-8)

Figure 2c





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Sediment elevation change (mm) measured at each stake (SP9, SP10)

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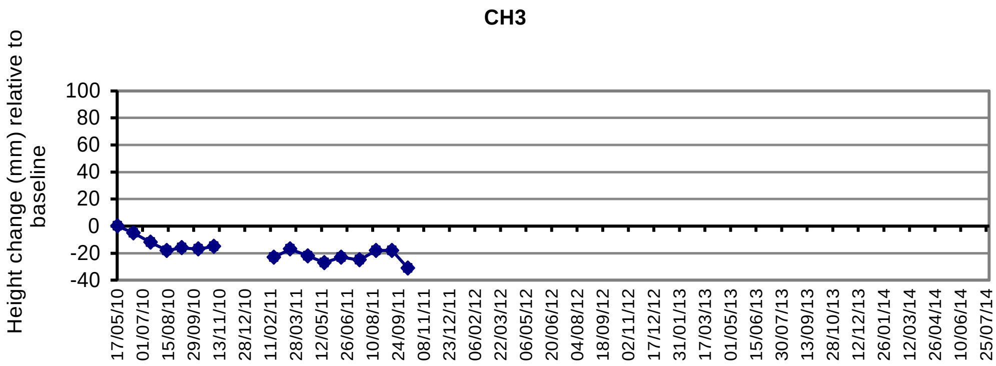
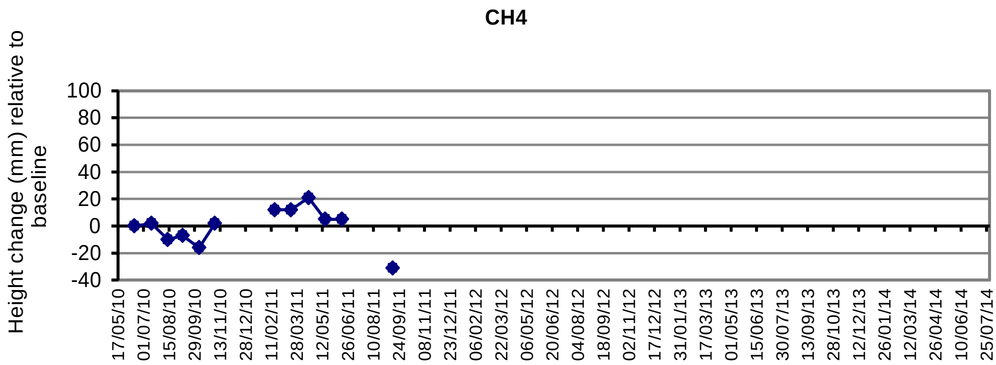
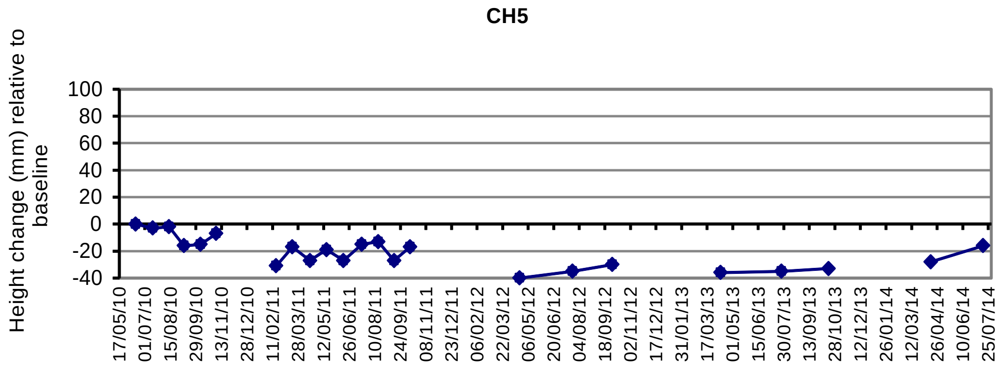
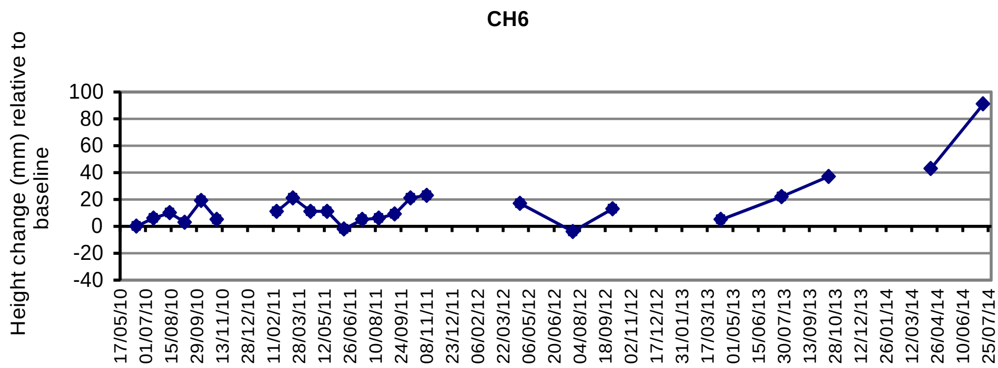
Sediment elevation changes in the Seymour's Post Area (SP9-10)

Figure 2d









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Sediment elevation change (mm) measured at each stake (CH3, CH4, CH5, CH6)

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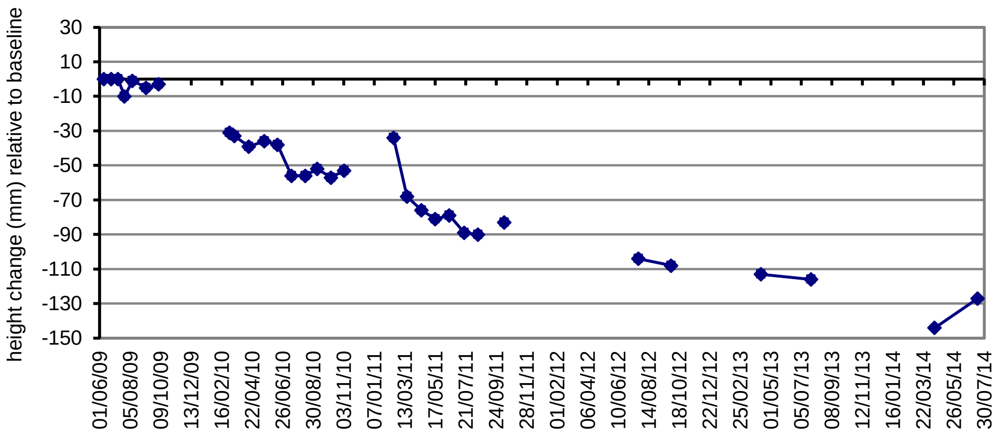
Sediment elevation changes in the Cocked Hat Area (CH3-CH6)

Figure 3

TB1



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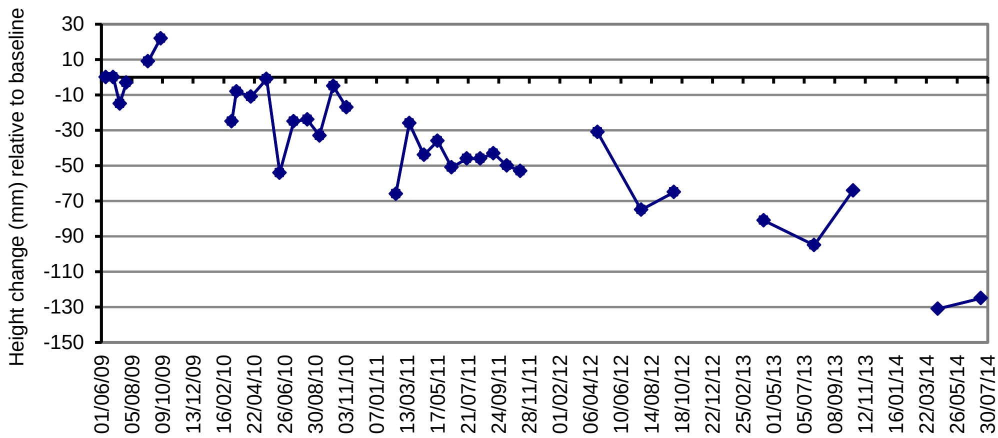

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Produced by ABPmer			

Sediment elevation change (mm) measured at each stake (TB1, TB2)

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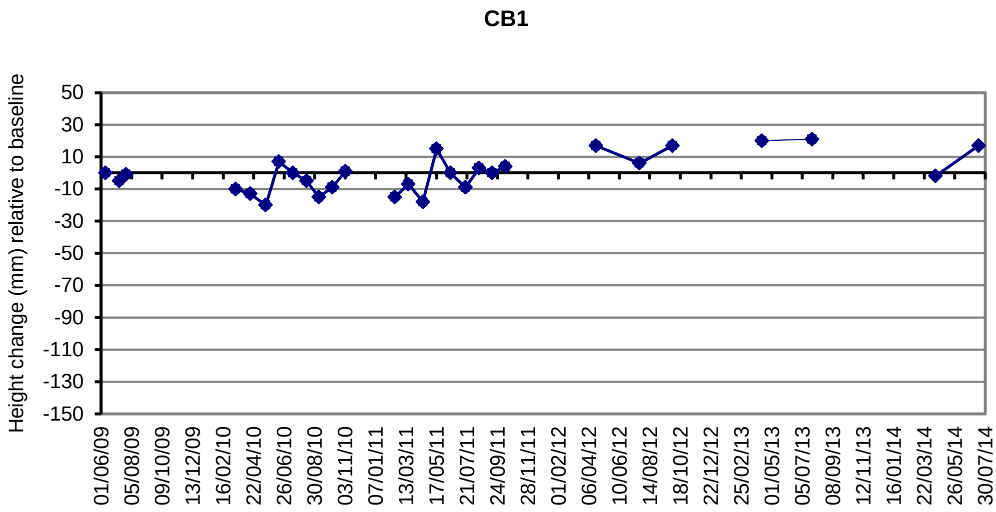
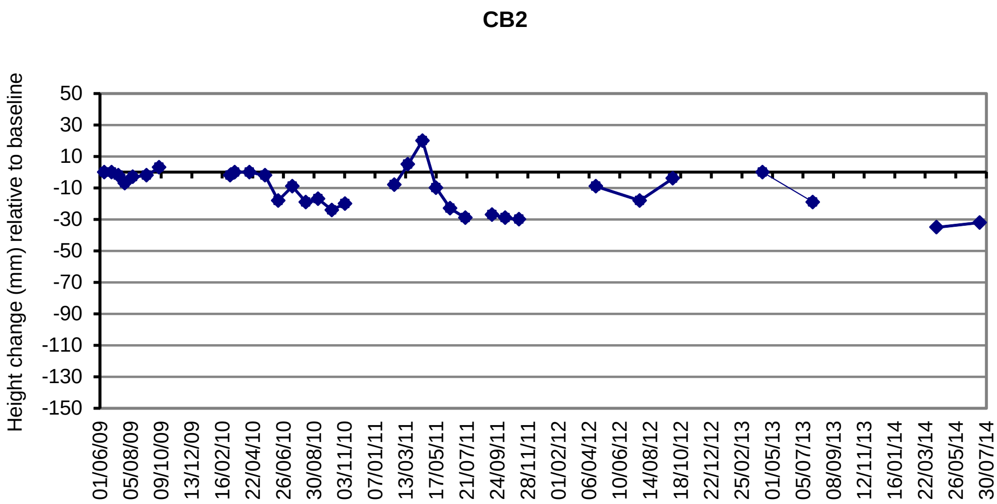
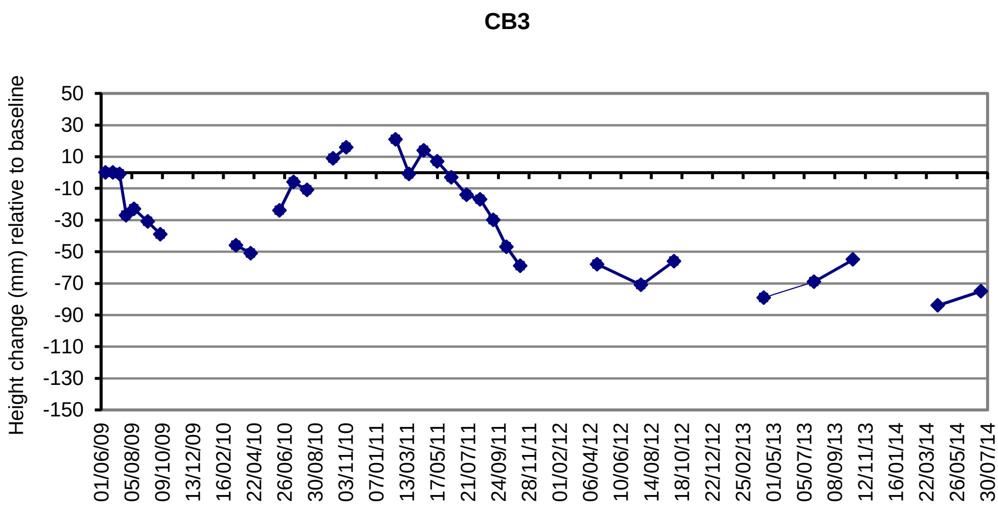
Sediment elevation changes in the Tar Barrel Area (TB1-2)

Figure 4







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Sediment elevation change (mm) measured at each stake (CB1, CB2, CB3)

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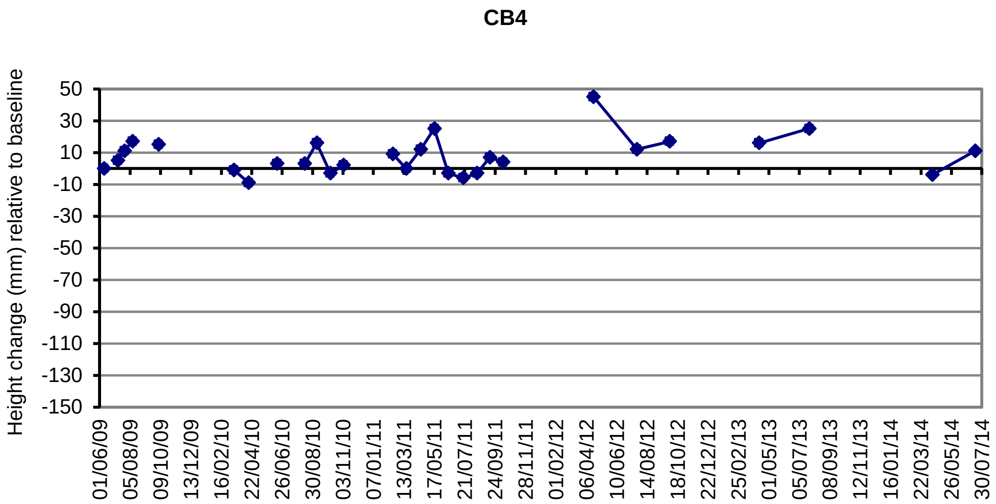
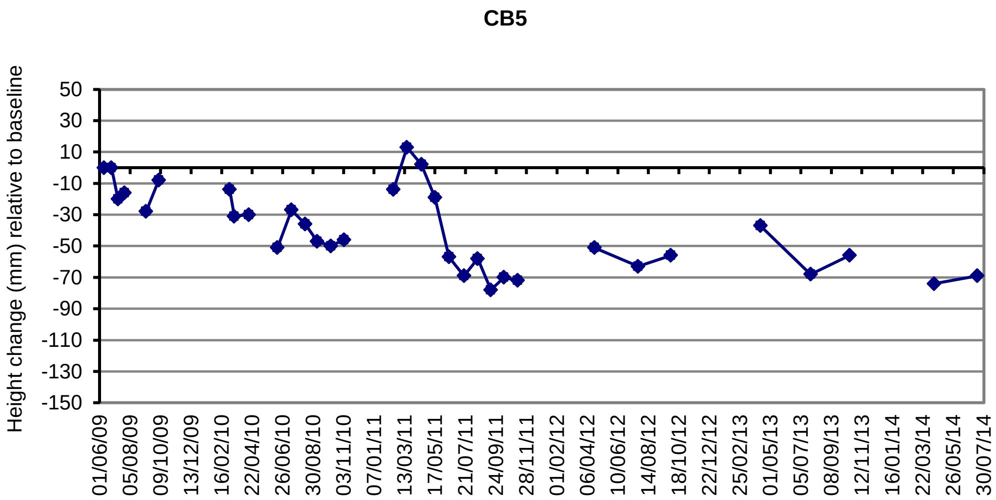
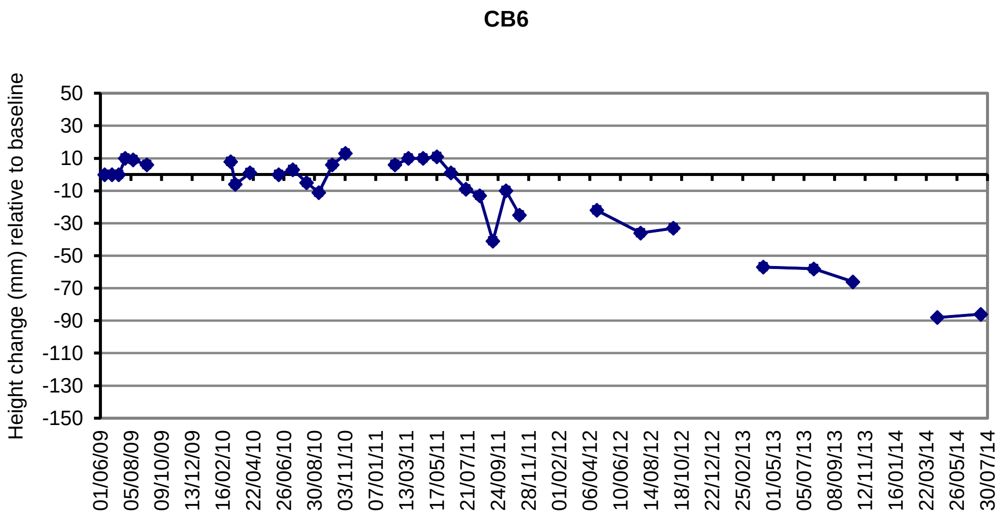
Sediment elevation changes in the Cage Boom Area (CB1-CB3)

Figure 5a







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Produced by ABPmer			

Sediment elevation change (mm) measured at each stake (CB4, CB5, CB6)

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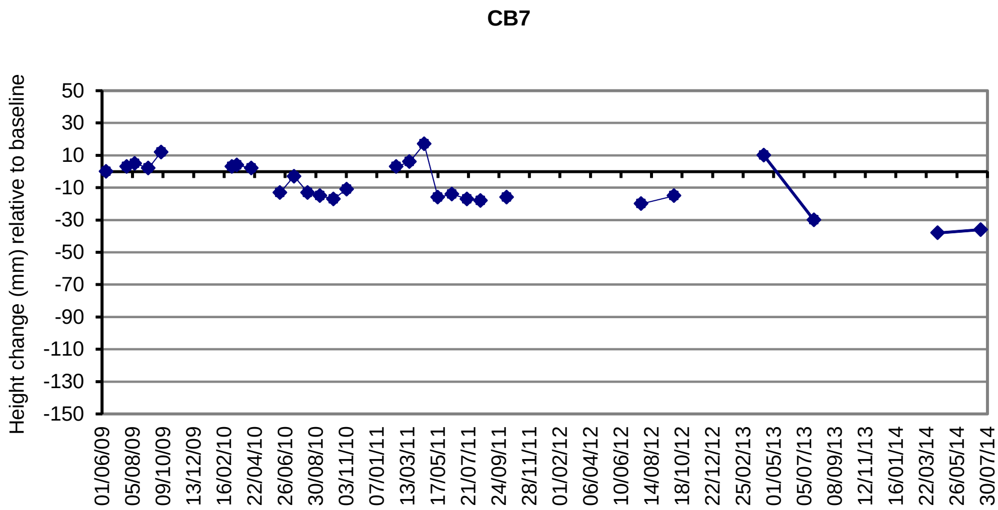
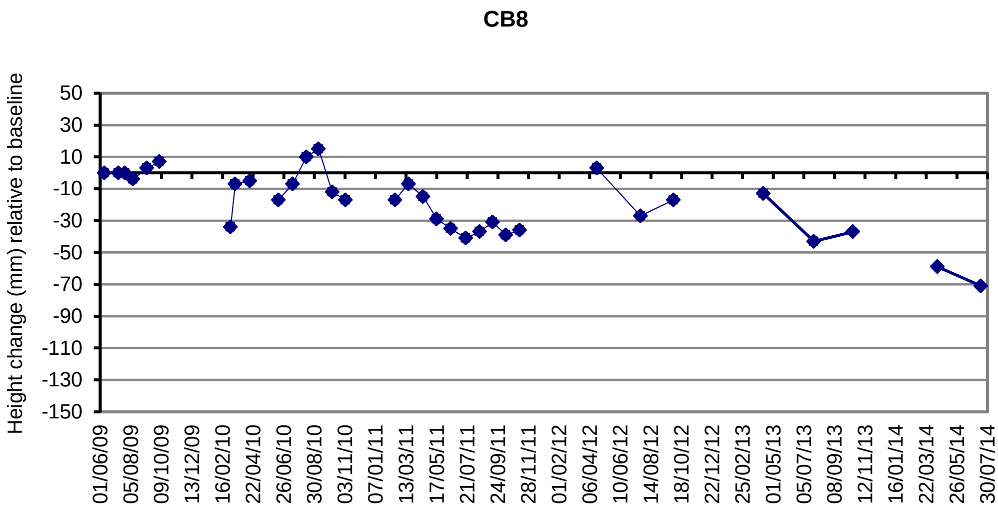
Sediment elevation changes in the Cage Boom Area (CB4-CB6)

Figure 5b





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Produced by ABPmer			

Sediment elevation change (mm) measured at each stake (CB7, CB8)

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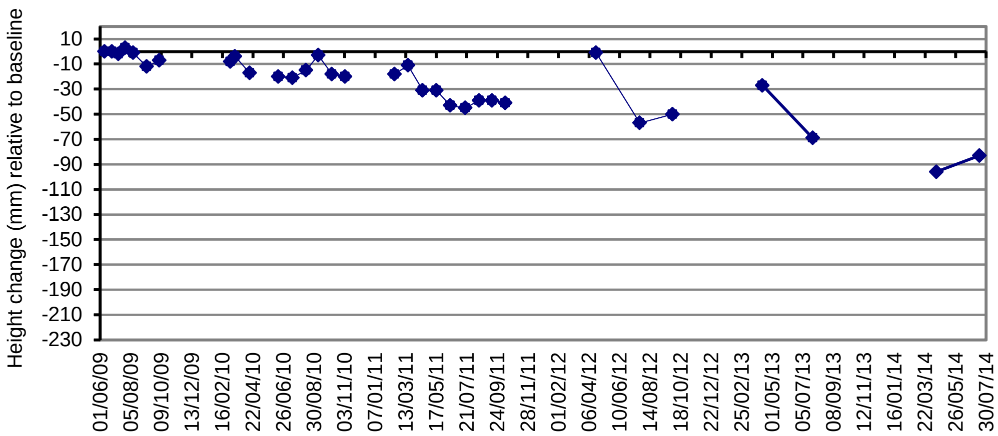
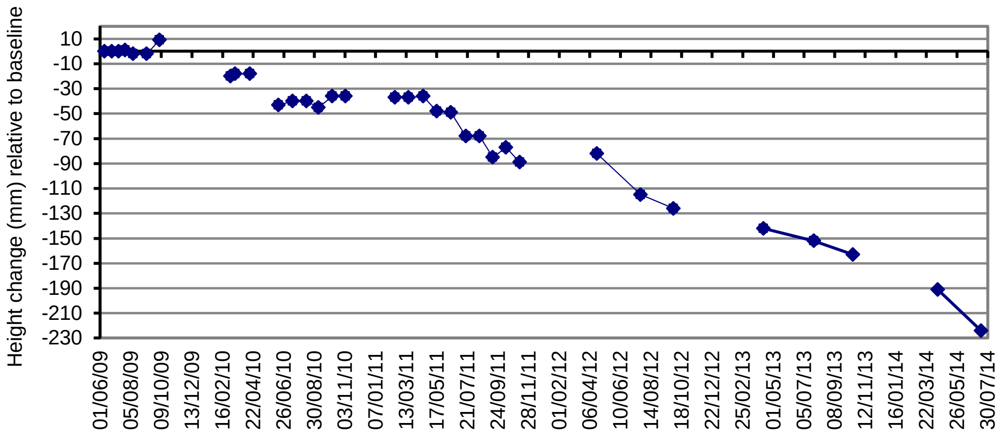
Sediment elevation changes in the Cage Boom Area (CB7-CB8)

Figure 5c

CB9



CB10



Date	By	Size	Version
Oct 14	TAP	A4	1
Coordinate System		N/A	
Projection		N/A	
Scale		N/A	
QA		NKD	
3772_005_R1556w_Fig5d.mxd			
Produced by ABPmer			

Sediment elevation change (mm) measured at each stake (CB9, CB10)

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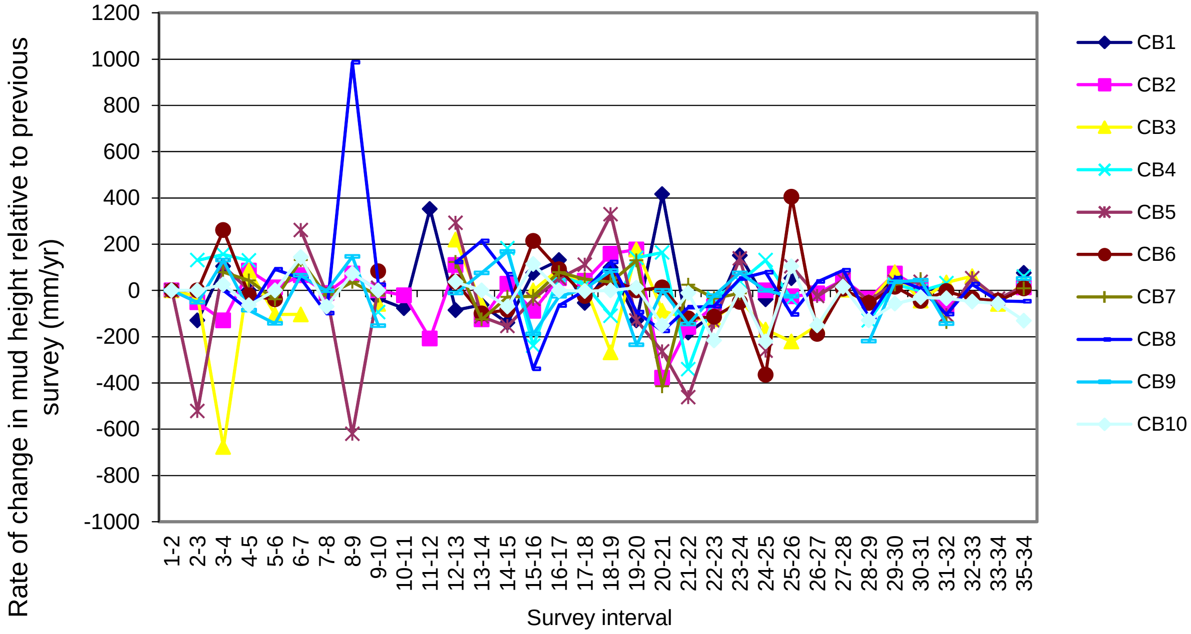
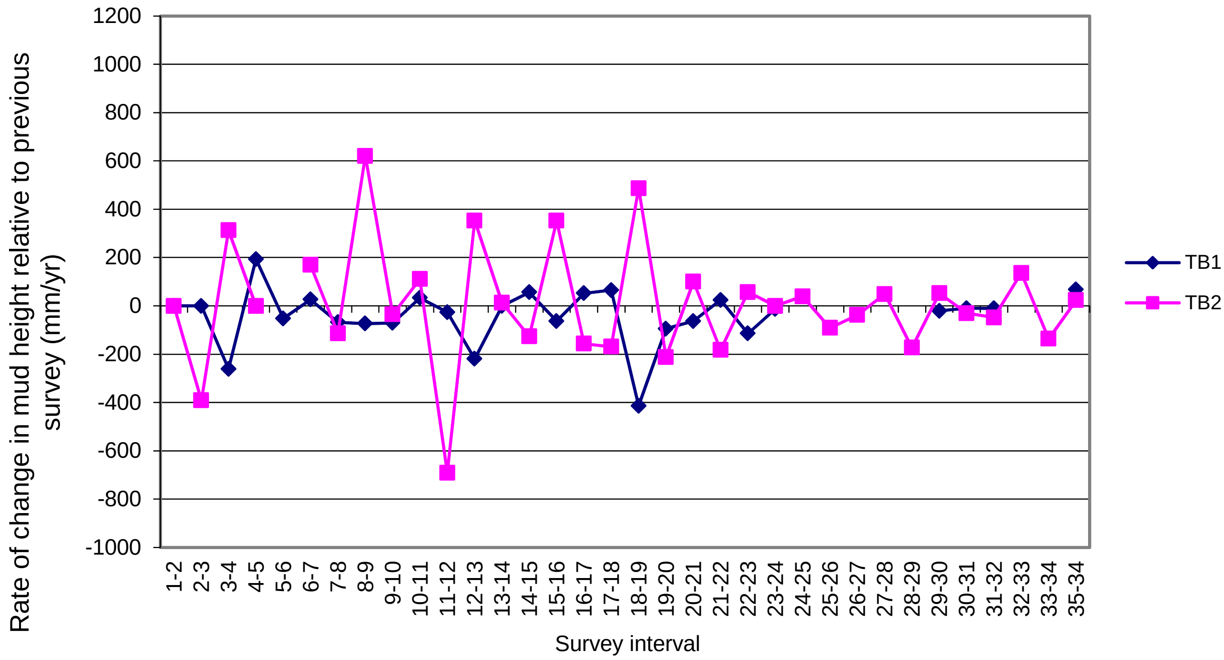
Sediment elevation changes in the Cage Boom Area (CB9-CB10)

Figure 5d

Cage Boom



Tar Barrel



Date	By	Size	Version
Oct 14	NKD	A4	1
Coordinate System	N/A		
Projection	N/A		
Scale	N/A		
QA	TAP		
3772_005_R1556w_Fig6a.mxd			
Produced by ABPmer			

Rate of change in substratum height (mm/year) measured at each stake in the Cage Boom and Tar Barrel Areas between the current survey (shown on x-axis by survey number) and the previous survey. Refer to Table 1 in Section 2 for actual dates of each survey.

As these plots show the rate of change (mm/year) rather than the difference between surveys (as shown in Figures 2 to 5), they provide a better description of the dynamics of sediment change within any given survey area. In particular, they show how at Site TB1 the rate of change is usually negative and this reflects the progressive nature of the erosion at this site (as seen in Figure 3). At most other sites (even the exposed TB2 and CB10) temporal changes in accretion and erosion are evidence against which the overall net erosion, accretion or stability should be viewed. These plots therefore reflect the dynamic nature of the environment and, in some cases, possibly the shift of sediment from one location to another within each survey area.

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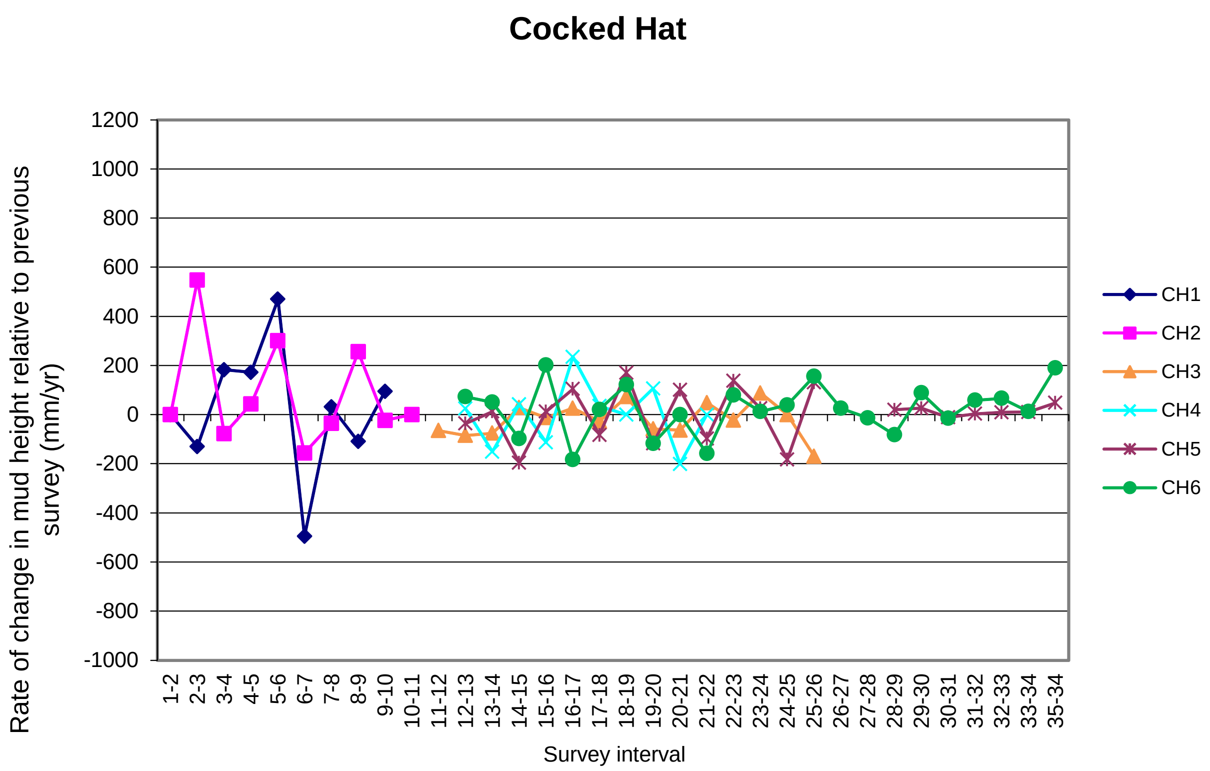
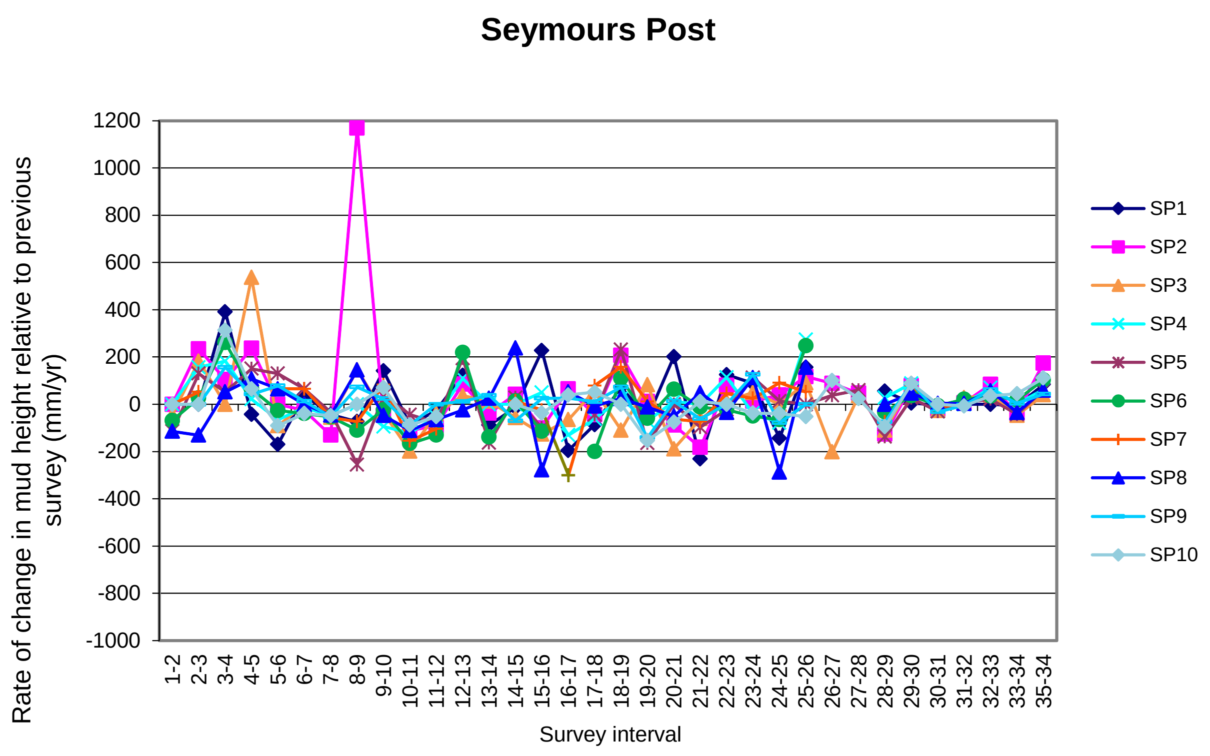
Rate of change in substratum height per year in Cage Boom and Tar Barrel

Figure 6a





Date	By	Size	Version
Oct 14	NKD	A4	1
Coordinate System		N/A	
Projection		N/A	
Scale		N/A	
QA		NMW	
3772_005_R1556w_Fig6b.mxd			
Produced by ABPmer			

Rate of change in substratum height (mm/year) measured at each stake in the Cocked Hat and Seymour's Post Areas between the current survey (shown on x-axis by survey number) and the previous survey. Refer to Table 1 in Section 2 for actual dates of each survey.

As these plots show the rate of change (mm/year) rather than the difference between surveys (as shown in Figures 2 to 5), they provide a better description of the dynamics of sediment change within any given survey area. In particular, they show how at Site TB1 (see Figure 6a) the rate of change is usually negative and this reflects the progressive nature of the erosion at this site (as seen in Figure 3). At most other sites (even the exposed TB2 and CB10) temporal changes in accretion and erosion are evidence against which the overall net erosion, accretion or stability should be viewed. These plots therefore reflect the dynamic nature of the environment and, in some cases, possibly the shift of sediment from one location to another within each survey area.

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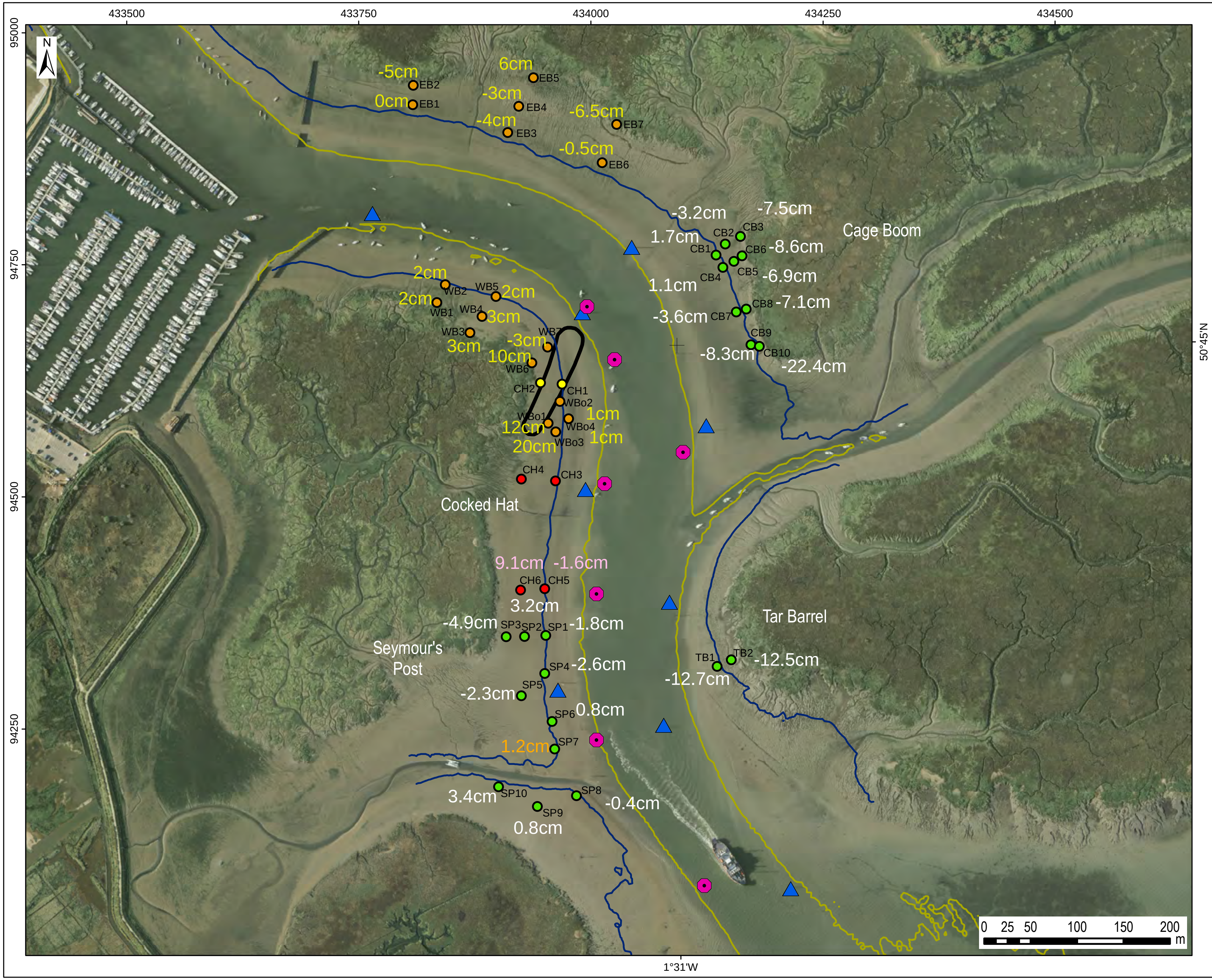
Rate of change in substratum height per year in Cocked Hat and Seymours Post

Figure 6b



- Wightlink stake positions June 2009 to date
- Wightlink stakes CH1 & CH2 (abandoned from May 2010 because of breakwater)
- Wightlink stakes CH3-CH6 (added in May & June 2010 to replace CH1 & CH2)
- LHC stake positions deployed as part of the Phase 1 breakwater monitoring (added Sept 2010)
- New and revised navigation posts (from April 2010)
- Previous navigation posts
- CD (May 2010)
- MLW (May 2010)
- Phase 1 breakwater location

Note: The colour of each elevation value indicates the monitoring period:-
Yellow = 2 years
Orange = 3 years
Pink = 4 years
White = 5 years

Date	By	Size	Version
Oct 14	TAP	A4	1

Coordinate System	British National Grid
Projection	Transverse Mercator
Scale	1:5,565
QA	NKD
3772_005_R1556w_Fig7_sed_elev	
Produced by ABPmer	

Data Sources: Image/Data courtesy of the Channel Coastal Observatory, 2008; Lymington Harbour Commissioners

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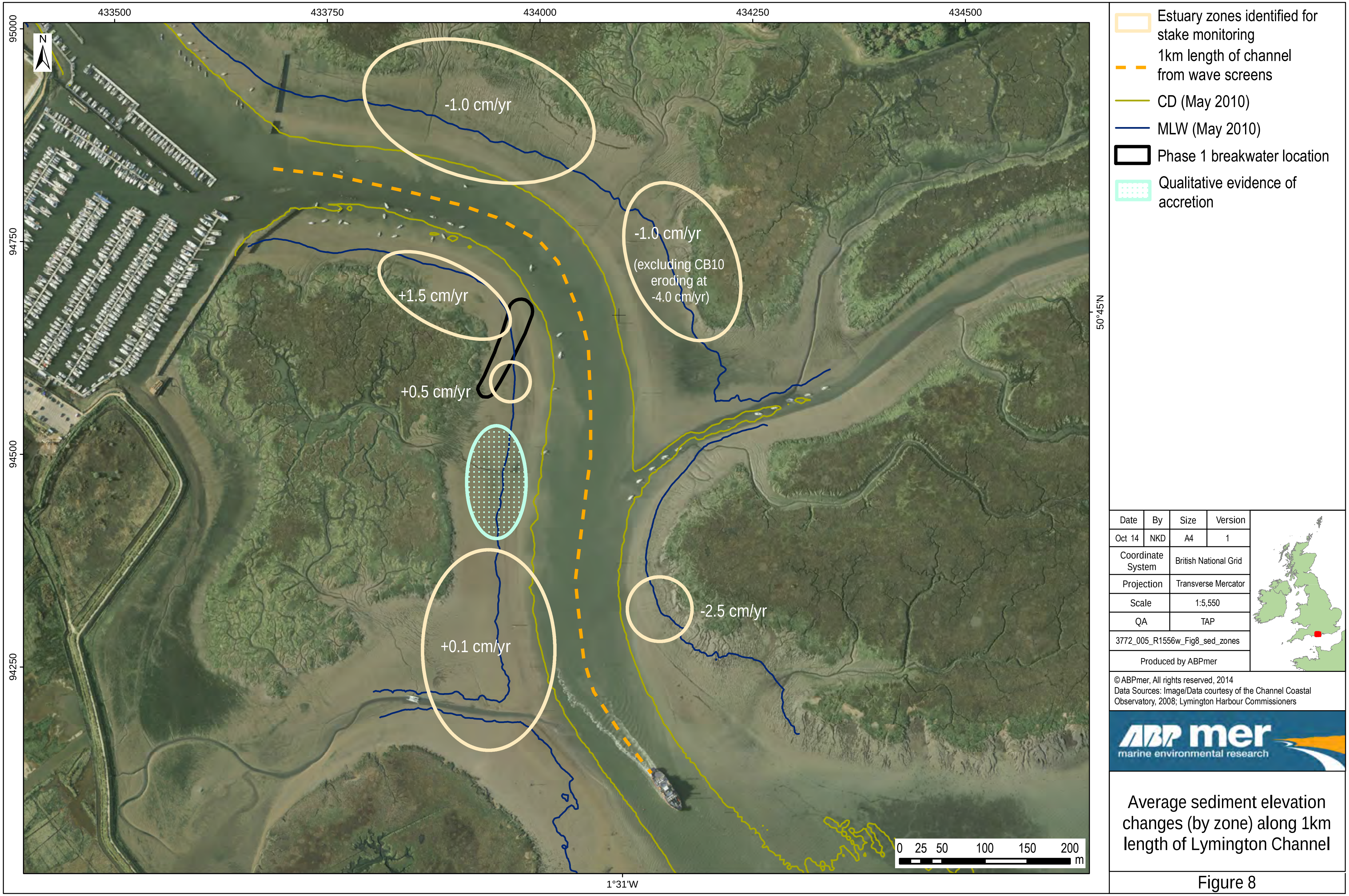
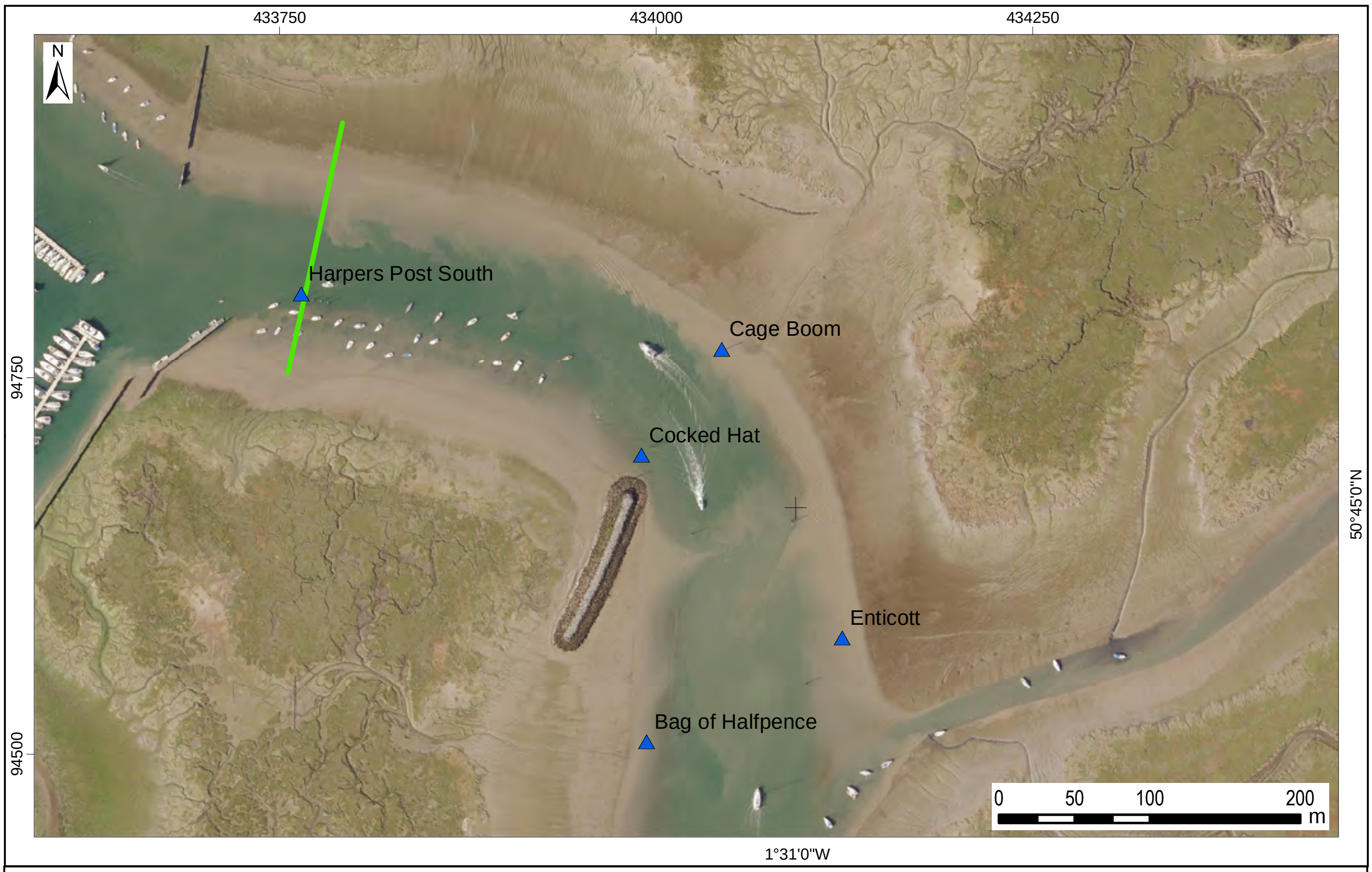
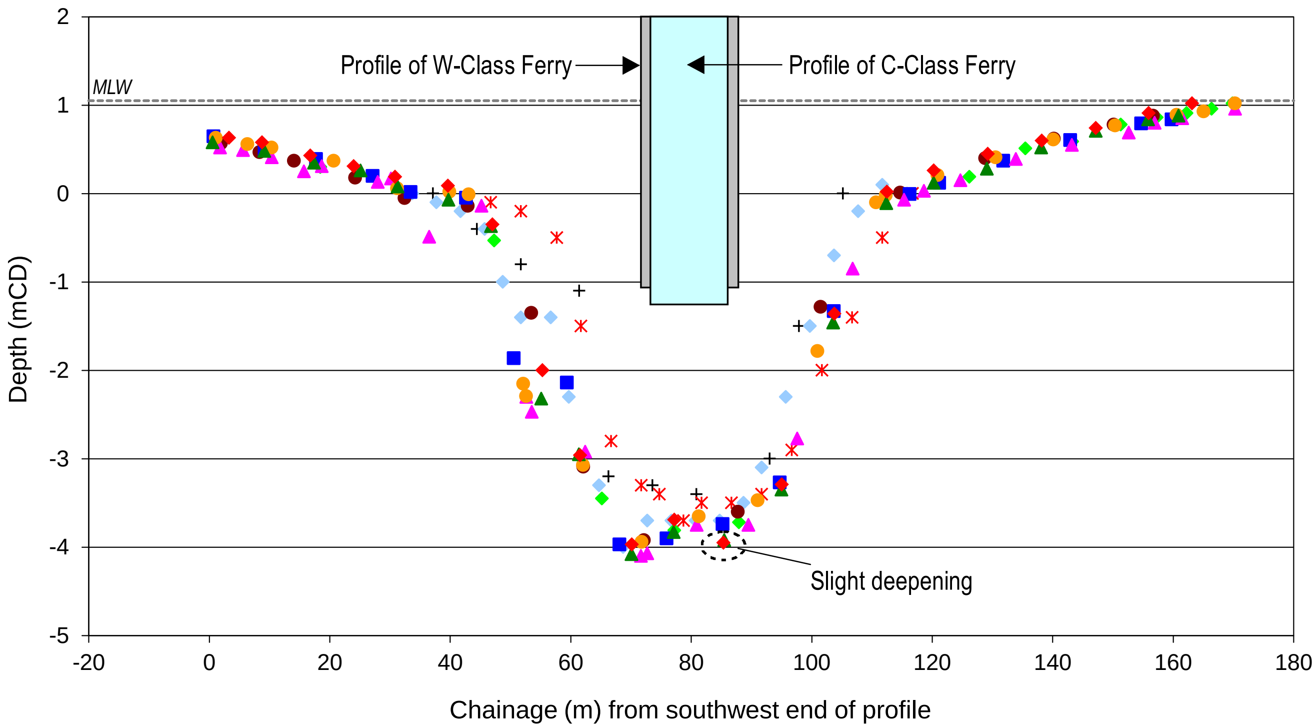
Net sediment elevation change at each stake location after five years

Figure 7


433500
433750
434000
434250
434500
95000
94750
94500
94250
50°45'N
1°31'W
-1.0 cm/yr
-1.0 cm/yr
(excluding CB10 eroding at -4.0 cm/yr)
+1.5 cm/yr
+0.5 cm/yr
+0.1 cm/yr
-2.5 cm/yr
0 25 50 100 150 200 m
Estuary zones identified for stake monitoring
1km length of channel from wave screens
CD (May 2010)
MLW (May 2010)
Phase 1 breakwater location
Qualitative evidence of accretion
Date | By | Size | Version
Oct 14 | NKD | A4 | 1
Coordinate System | British National Grid
Projection | Transverse Mercator
Scale | 1:5,550
QA | TAP
3772_005_R1556w_Fig8_sed_zones
Produced by ABPmer
©ABPmer, All rights reserved, 2014
Data Sources: Image/Data courtesy of the Channel Coastal Observatory, 2008; Lymington Harbour Commissioners
marine environmental research
Average sediment elevation changes (by zone) along 1km length of Lymington Channel
Figure 8





Date	By	Size	Version
Dec 14	NKD	A4	2
Coordinate System	British National Grid		
Projection	Transverse Mercator		
Scale	1:5,000		
QA	TAP		
3772_005_R1556w_Fig9_XSection_HP			
Produced by ABPmer			

Harpers Post South Profile

Navigation Posts (prior to revisions in April 2010)

1988	2008
1993	2009
1999	2010
2005	2012
2006	2014

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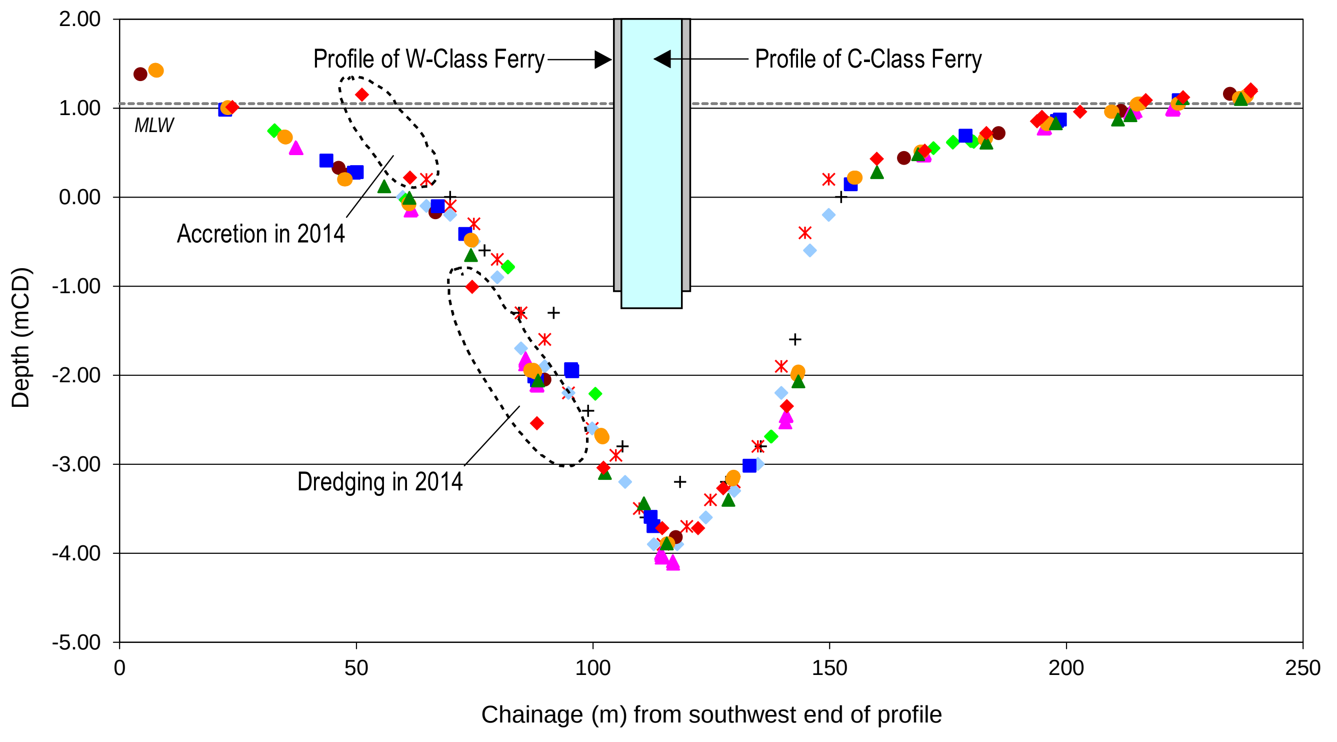
Channel Cross Section near Harpers Post South

Figure 9



Date	By	Size	Version
Dec 14	NKD	A4	2
Coordinate System	British National Grid		
Projection	Transverse Mercator		
Scale	1:5,000		
QA	TAP		
3772_005_R1556w_Fig10_XSection_CH			
Produced by ABPmer			

Cocked Hat Profile

Navigation Posts (prior to revisions in April 2010)

1988 2008
1993 2009
1999 2010
2005 2012
2006 2014

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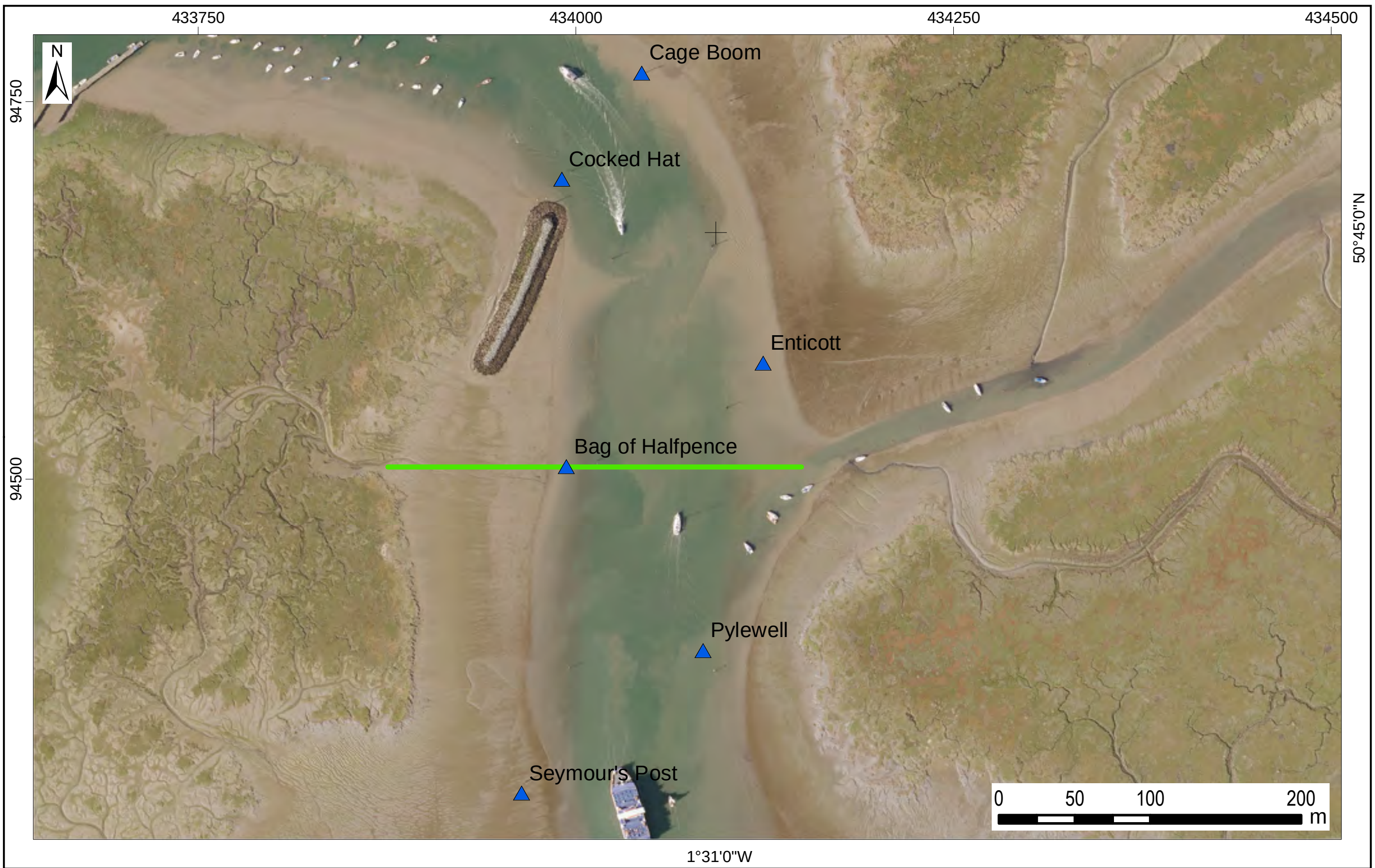
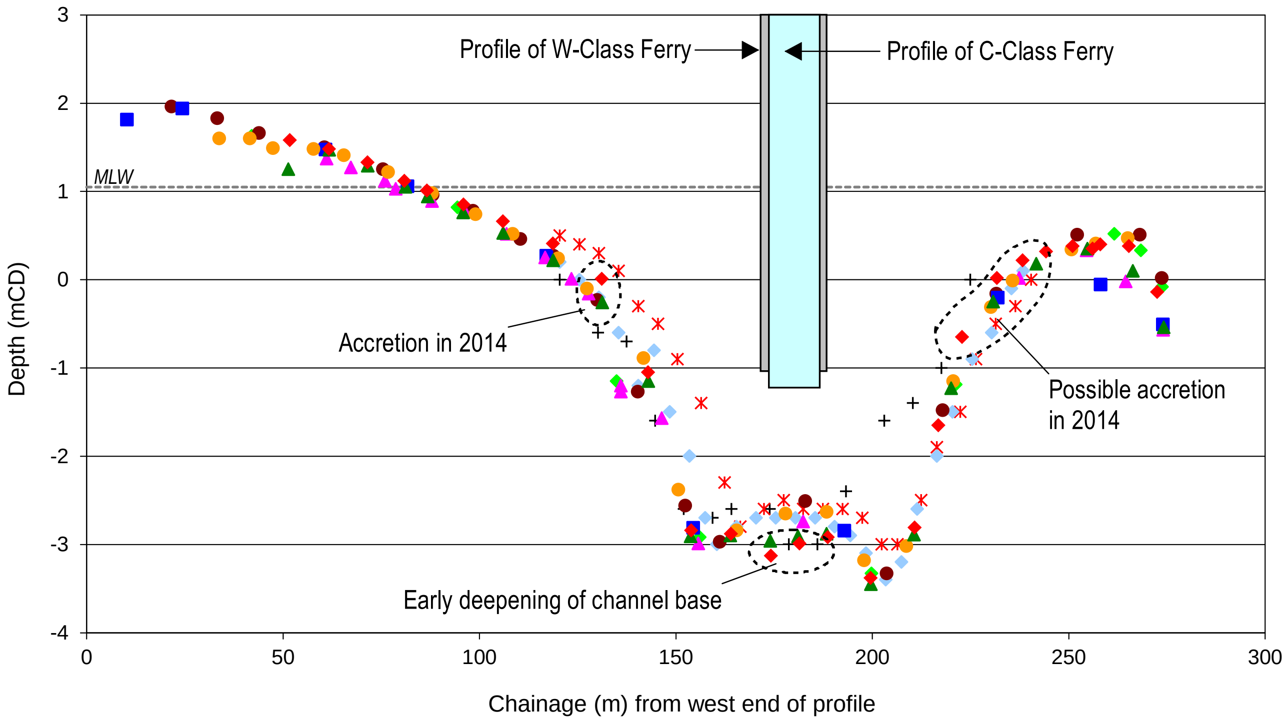
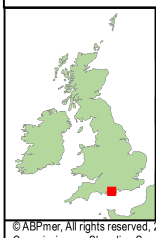
Channel Cross Section near Cocked Hat Post

Figure 10







Date	By	Size	Version
Dec 14	NKD	A4	2
Coordinate System	British National Grid		
Projection	Transverse Mercator		
Scale	1:5,000		
QA	TAP		
3772_005_R1556w_Fig11_XSection_BH			
Produced by ABPmer			

Bag of Halfpence Profile
Navigation Posts (prior to revisions in April 2010)
+ 1988 ■ 2008
× 1993 ▲ 2009
◆ 1999 ● 2010
◆ 2005 ▲ 2012
● 2006 ◆ 2014

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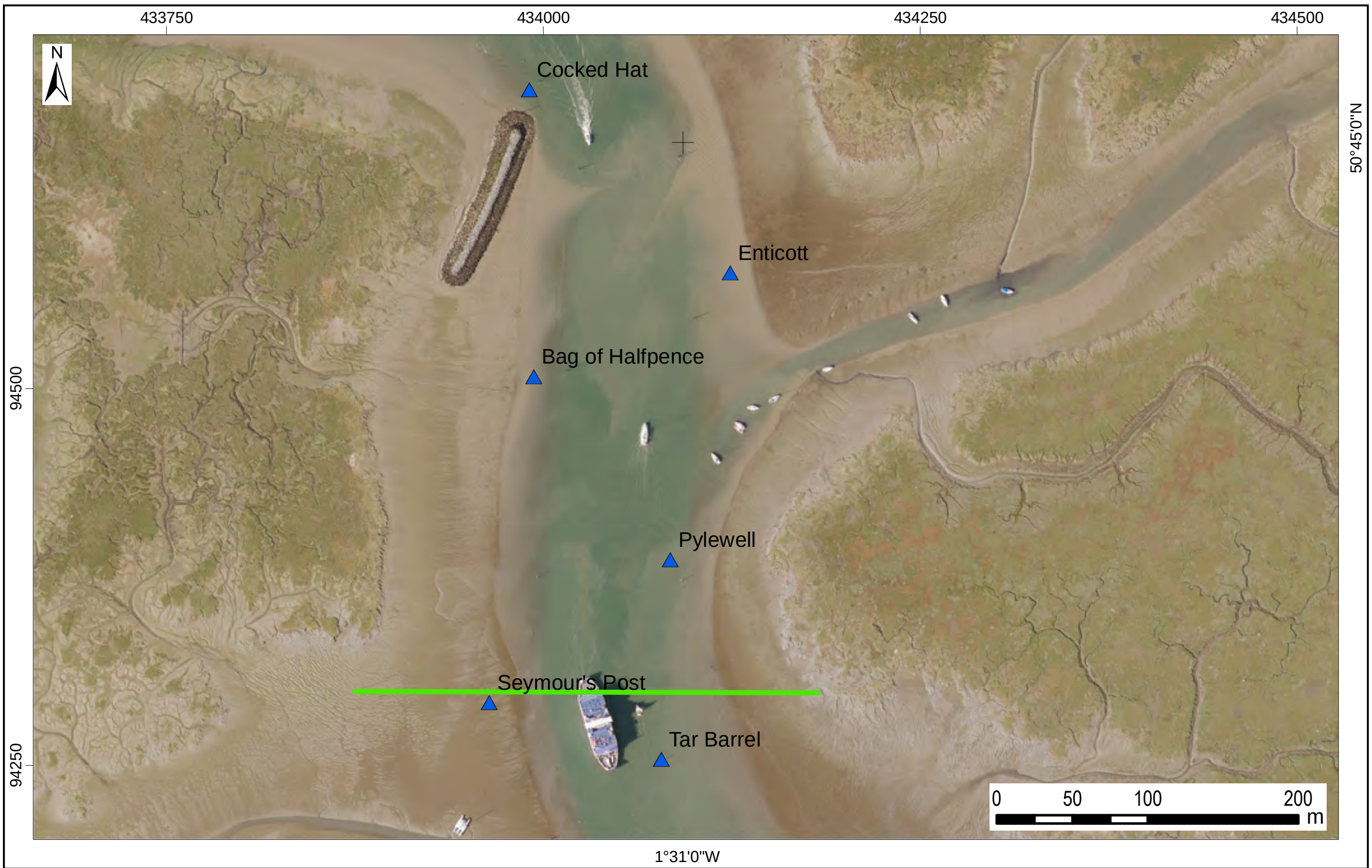
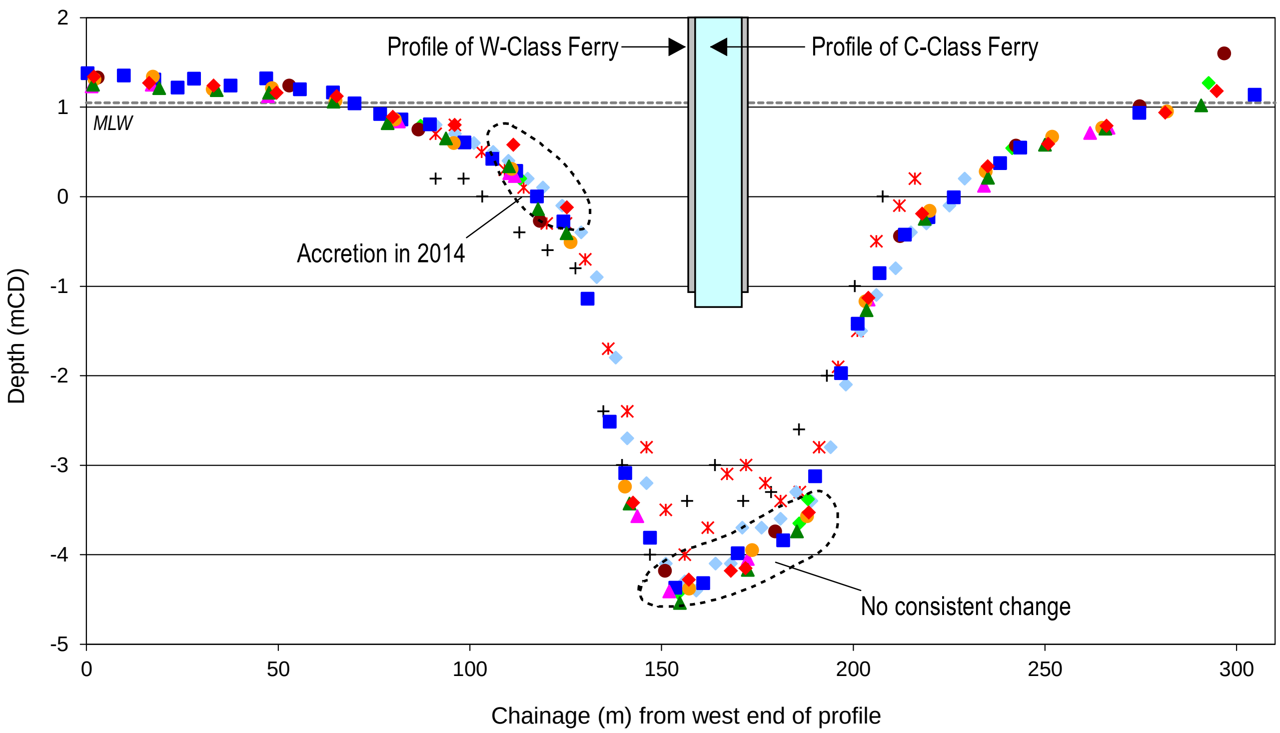
Channel Cross Section near Bag of Halfpence Post

Figure 11





Date	By	Size	Version
Dec 14	NKD	A4	2
Coordinate System	British National Grid		
Projection	Transverse Mercator		
Scale	1:5,000		
QA	TAP		
3772_005_R1556w_Fig12_XSection_SP			
Produced by ABPmer			

Seymour's Post Profile
Navigation Posts (prior to revisions in April 2010)
1988, 1993, 1999, 2005, 2006, 2008, 2009, 2010, 2012, 2014

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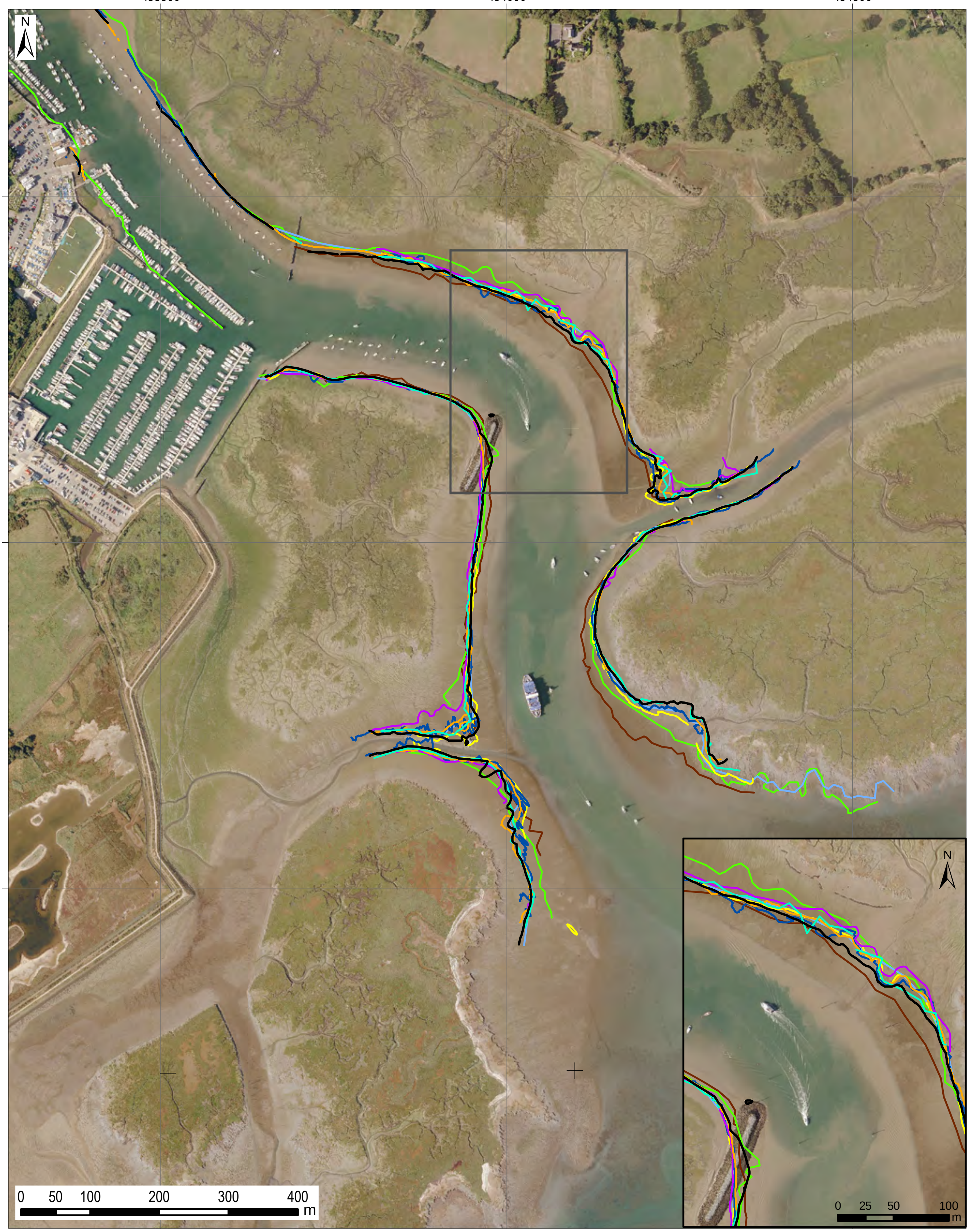
Channel Cross Section near Seymour's Post

Figure 12



Date	By	Size	Version
Dec 14	NKD	A4	2
Coordinate System	British National Grid		
Projection	Transverse Mercator		
Scale	1:8,000		
QA	TAP		
3772_005_R1556w_Fig13_MLW			
Produced by ABPmer			

 Data Sources: Lymington Harbour Commissioners, Shoreline Surveys Ltd., 2014; Aerial photographs courtesy of the Channel Coastal Observatory, 2013.

- MLW - Apr 2014
- MLW - Mar 2012
- MLW - May 2010
- MLW - Jul 2009
- MLW - Jun 2008
- MLW - Oct 2006
- MLW - Mar 2005
- MLW - 1994
- MLW - 1993
- Extent of zoom view (scale: 1:5,000)

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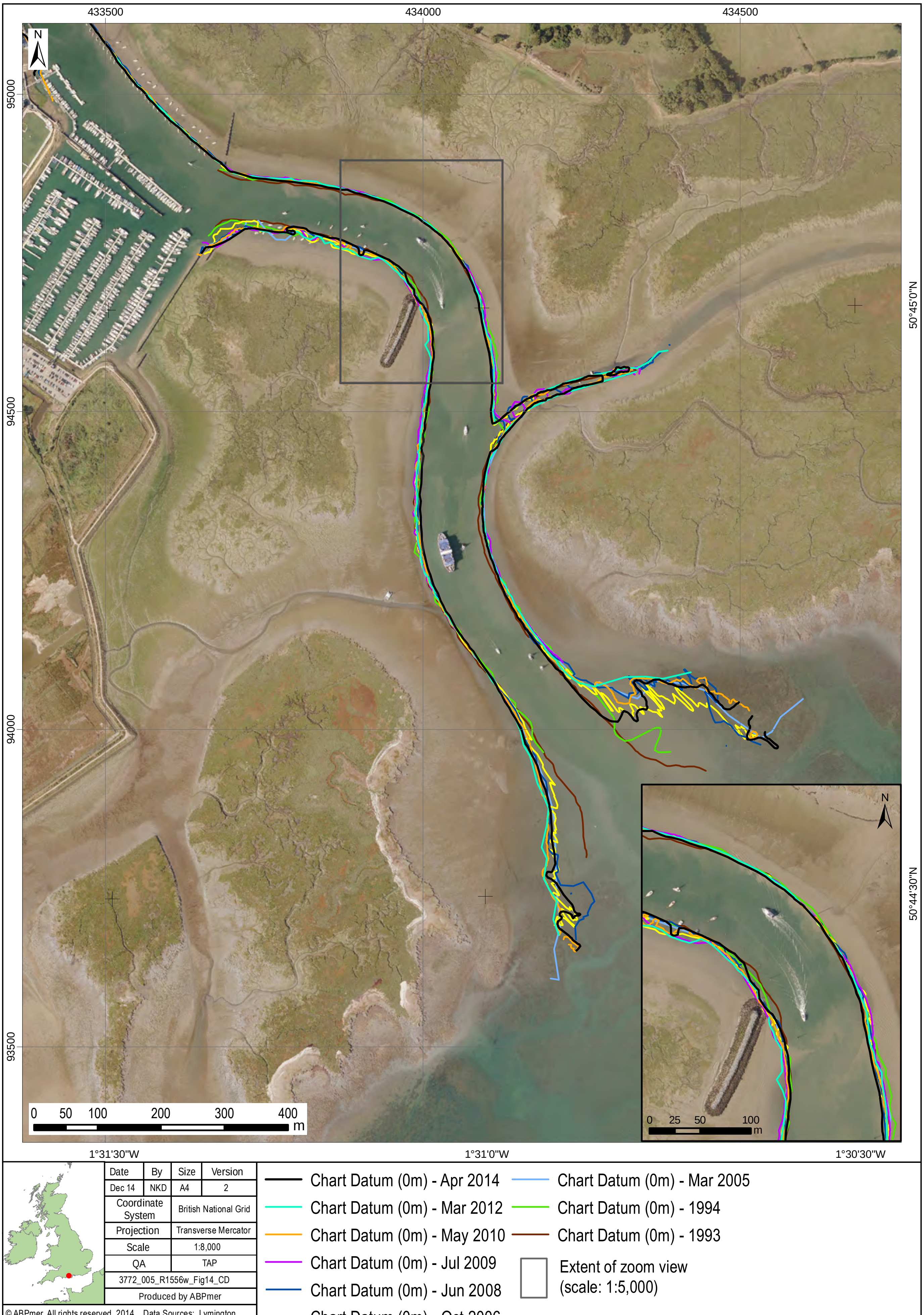
Changes in MLW alignment based on bathymetry data 1993 to 2014

Figure 13



Date	By	Size	Version
Dec 14	NKD	A4	2
Coordinate System		British National Grid	
Projection		Transverse Mercator	
Scale		1:8,000	
QA		TAP	
3772_005_R1556w_Fig14_CD			
Produced by ABPmer			

 Data Sources: Lymington Harbour Commissioners, Shoreline Surveys Ltd., 2014; Aerial photographs courtesy of the Channel Coastal Observatory, 2013.

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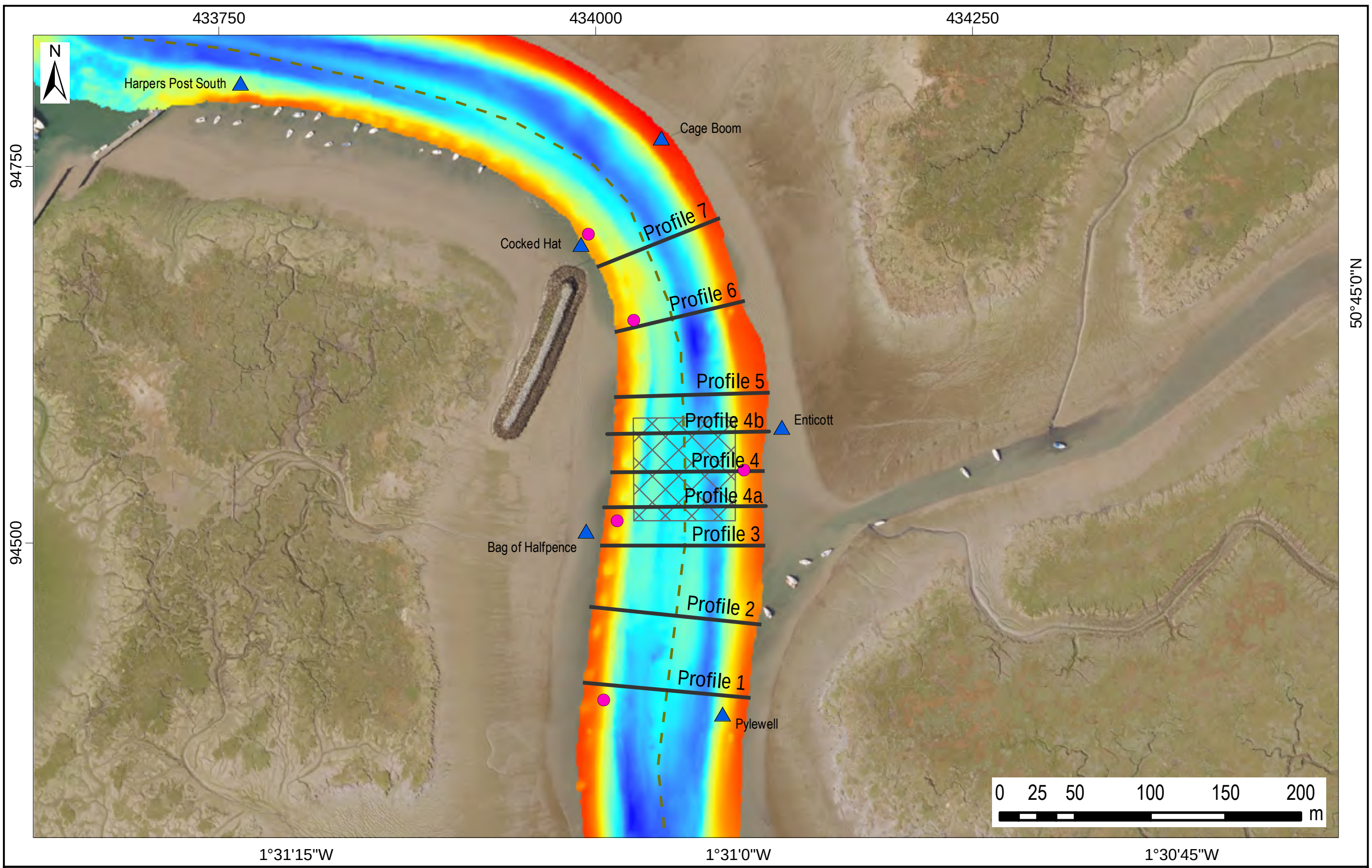
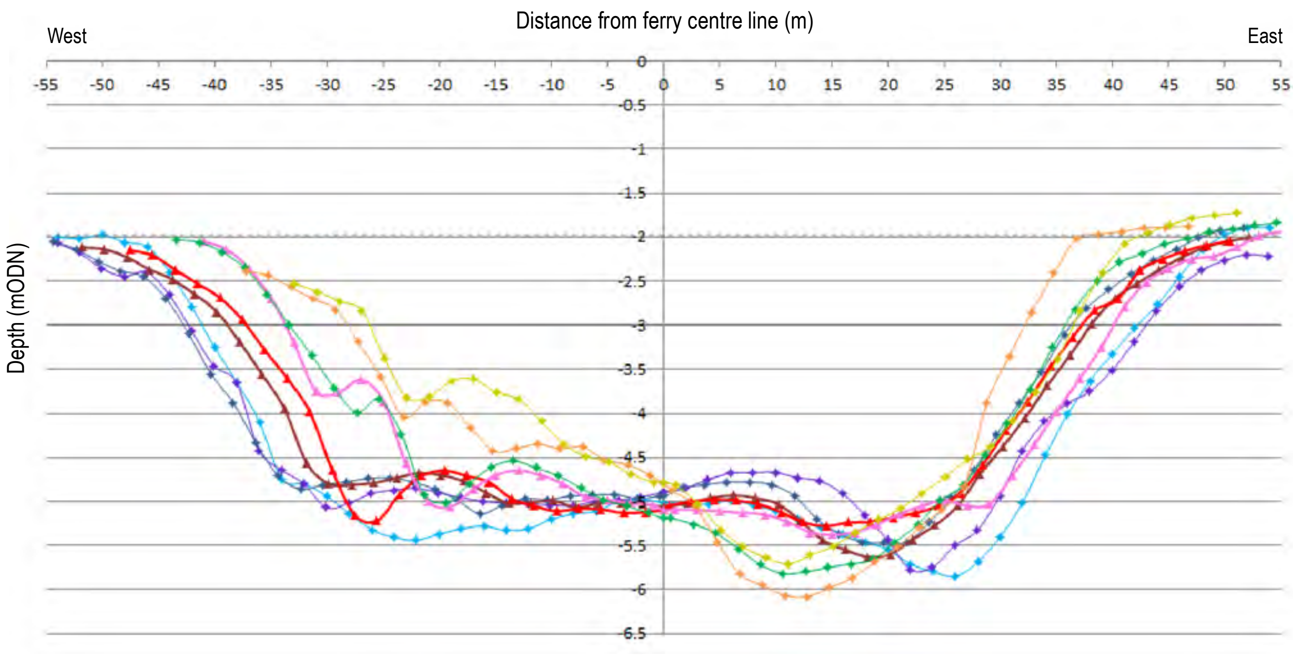
Changes in CD alignment based on bathymetry data 1993 to 2014

Figure 14





Note: Chart Datum (CD) is 1.98m below Ordnance Datum Newlyn (ODN).

Date	By	Size	Version
Oct 14	NKD	A4	1
Coordinate System	British National Grid		
Projection	Transverse Mercator		
Scale	1:50,000		
QA	TAP		
3772_005_R1556w_Fig15_XSections			
Produced by ABPmer			

Swath bathymetry data and aerial photographs courtesy of the Channel Coastal Observatory, 2013.

Profile locations
Ferry passing place
Ferry centre line
New and revised navigation posts (from April 2010)
Previous navigation posts

Depth (mODN)
-1.38
-2.31
-3.24
-4.18
-5.11
-6.04
-6.97

Profile 1
Profile 2
Profile 3
Profile 4a
Profile 4
Profile 4b
Profile 5
Profile 6
Profile 7
Chart Datum

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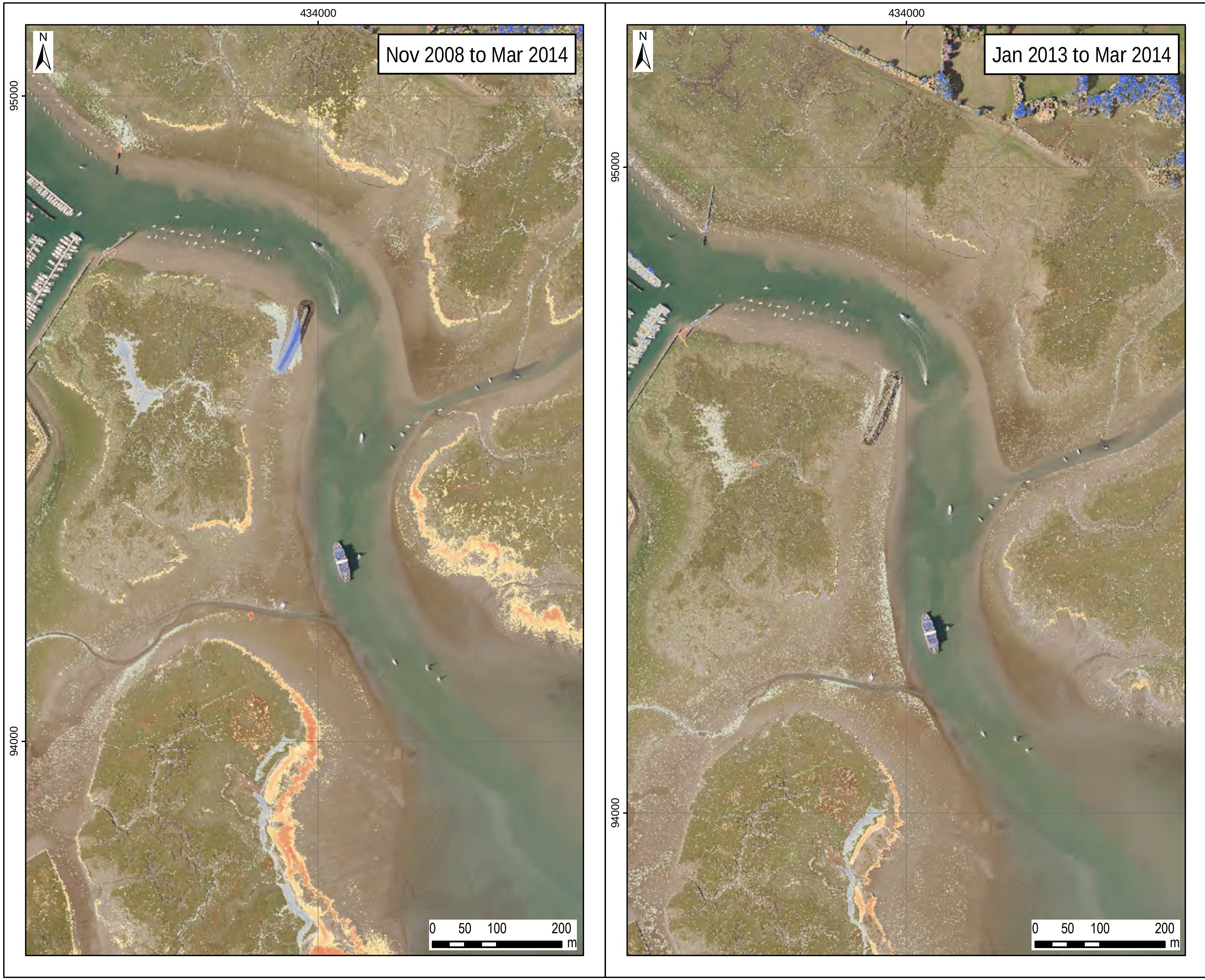
Cross channel cross-sections near the ferry passing area based on CCO swath bathymetry data

Figure 15



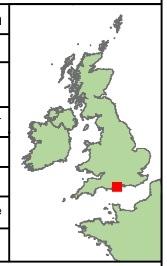
Change in elevation (m)

- < -5
- -4.9 to -4
- -3.9 to -3
- -2.9 to -2
- -1.9 to -1.5
- -1.4 to -1
- -0.99 to -0.75
- -0.74 to -0.5
- -0.49 to -0.25
- -0.24 to -0.15
- -0.14 to 0
- 0 to 0.15
- 0.16 to 0.25
- 0.26 to 0.5
- 0.51 to 0.75
- 0.76 to 1
- 1.1 to 1.5
- 1.6 to 2
- 2.1 to 3
- 3.1 to 4
- 4.1 to 5

Erosion

Accretion

Date	By	Size	Version
Nov 14	NKD	A4	1
Coordinate System	British National Grid		
Projection	Transverse Mercator		
Scale	1:8,000		
QA	TAP		
3772_005_R1556w_Fig16_Lidar_Elev_Change			
Produced by ABPmer			



Data Source: Environment Agency 2008, 2013, 2014
Aerial photos courtesy of Channel Coastal Observatory, 2013

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Changes in habitat elevation along the Lymington Channel based on EA LiDAR data

Figure 16

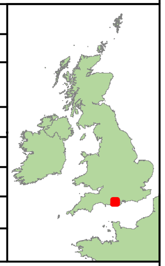
Change in elevation 2008 to 2014 (metres)

- < -3.0
- -2.99 to -2.5
- -2.49 to -2.0
- -1.99 to -1.5
- -1.49 to -1.0
- -0.99 to -0.5
- -0.49 to -0.4
- -0.39 to -0.3
- -0.29 to -0.2
- -0.19 to -0.1
- -0.09 to 0.1
- 0.11 to 0.2
- 0.21 to 0.3
- 0.31 to 0.4
- 0.41 to 0.5
- 0.51 to 1.0
- 1.01 to 1.5
- 1.51 to 2.0
- 2.01 to 2.5
- 2.51 to 3.0

Erosion

Accretion

Date	By	Size	Version
Nov 14	NKD	A4	1
Coordinate System	British National Grid		
Projection	Transverse Mercator		
Scale	1:14,000		
QA	TAP		
3772_005_R1556w_Fig17_Lidar_Diff.mxd			
Produced by ABPmer			



LiDAR data: EA, 2008, 2014. Aerial photographs courtesy of Channel Coastal Observatory, 2013

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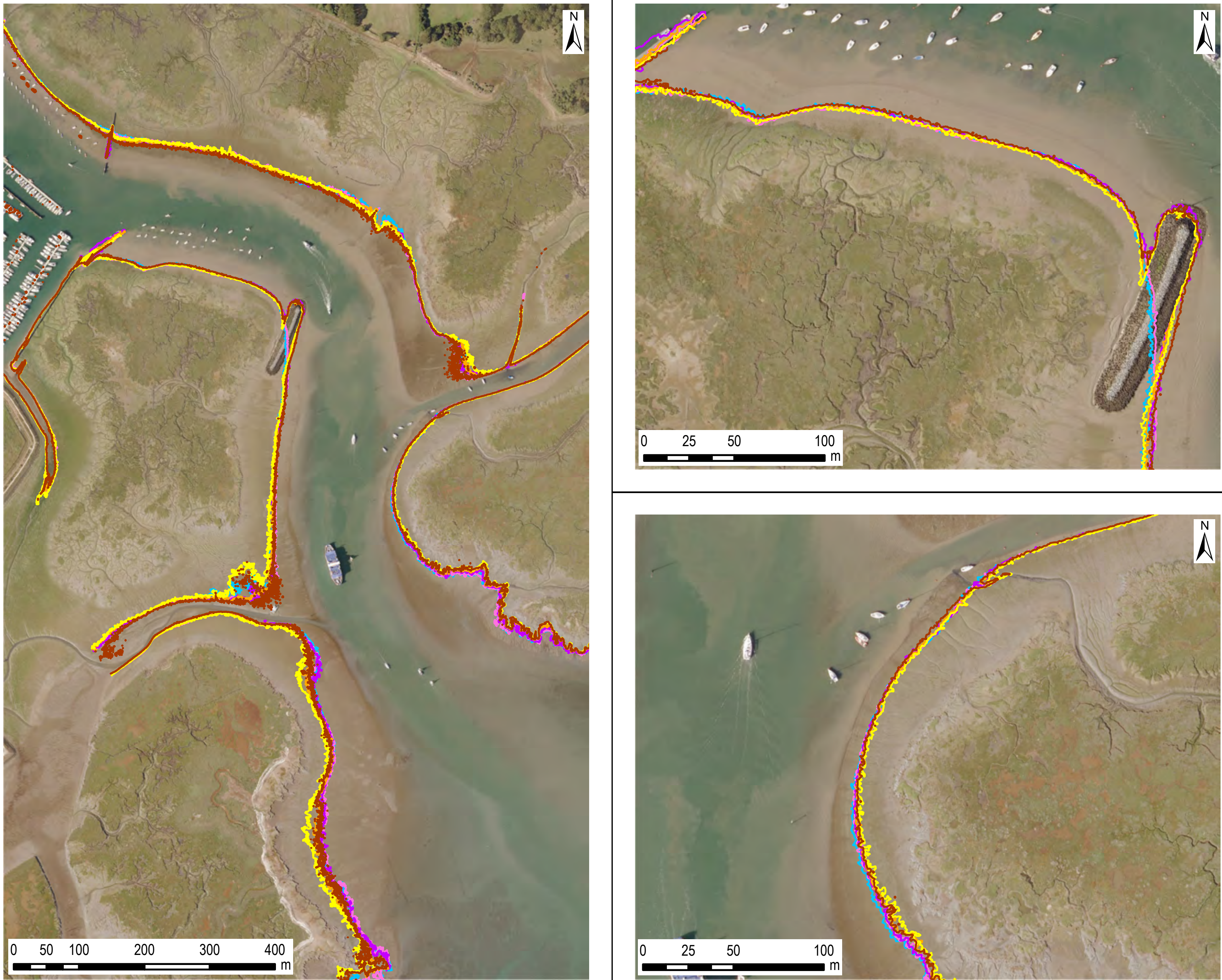
Changes in habitat elevation along the Lymington frontage based on EA LiDAR data

Figure 17



MLW - March 2014
MLW - January 2013
MLW - January/February 2012
MLW - November 2010
MLW - October 2009
MLW - November 2008

Date	By	Size	Version
Oct 14	NKD	A4	1
Coordinate System	British National Grid		
Projection	Transverse Mercator		
Scale	various		
QA	TAP		
3772_005_R1556w_Fig18_mlw_cont			
Produced by ABPmer			

Data Source: Environment Agency 2008, 2009, 2010, 2012, 2013, 2014. Aerial photos courtesy of Channel Coastal Observatory, 2013.

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Changes in MLW alignment based on EA LiDAR data 2008 - 2014

Figure 18

Appendices

Appendix A

Charts from the 2014 Lymington Bathymetry Survey (Comparing 2008 with 2014 and 2012 with 2014 Survey Results)

A. Charts from the 2014 Lymington Bathymetry Survey (Comparing 2008 with 2014 and 2012 with 2014 Survey Results)

- Chart A1 Residual Comparison April 2014 with March 2012 (Royal Lymington Yacht Club to Cocked Hat Post)
- Chart A2 Residual Comparison April 2014 with June 2008 (Royal Lymington Yacht Club to Cocked Hat Post)
- Chart A3 Residual Comparison April 2014 with March 2012 (Cocked Hat Post to No.7 Post)
- Chart A4 Residual Comparison April 2014 with June 2008 (Cocked Hat Post to No.7 Post)

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Hydrographic — Geophysical — Topographic

Green Meadows, Affpuddle, Dorchester, Dorset DT2 7HH
Telephone: +44 1305 848821 or +44 7950 038317
email@shorelinesurveys.com — www.shorelinesurveys.com

TITLE: Residual Comparison: April 2014 with March 2012 (Royal Lymington Yacht Club to Cocked Hat Post)

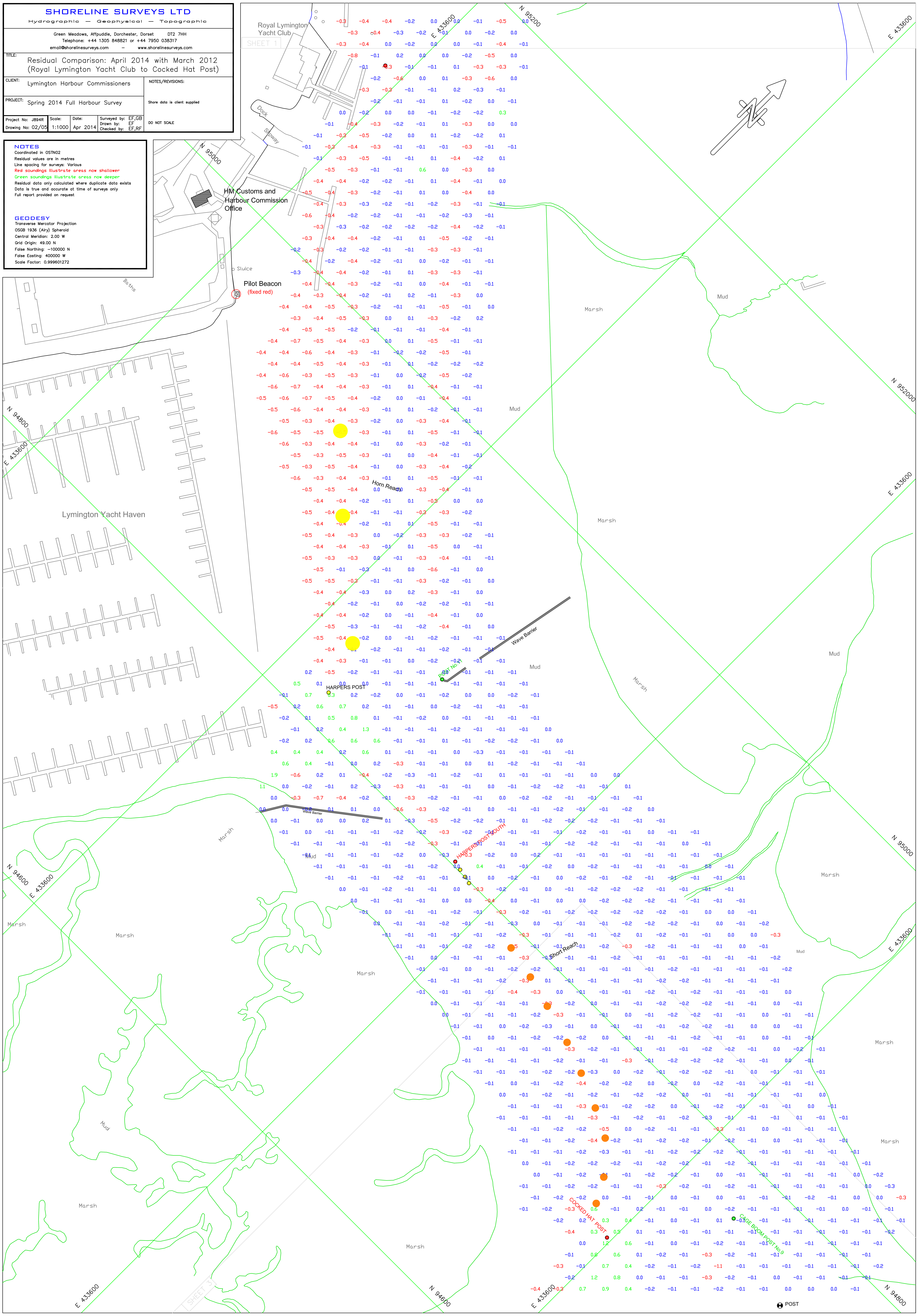
CLIENT: Lymington Harbour Commissioners	NOTES/REVISIONS:
PROJECT: Spring 2014 Full Harbour Survey	Shore data is client supplied
Project No: J894R; Drawing No: 02/05 / Scale: 1:1000 / Date: Apr 2014 / Surveyed by: EF,GB; Drawn by: EF; Checked by: EF,RF	DO NOT SCALE

NOTES

Coordinated in OSTN02
Residual values are in metres
Line spacing for surveys: Various
Red soundings illustrate areas now shallower
Green soundings illustrate areas now deeper
Residual data only calculated where duplicate data exists
Data is true and accurate at time of surveys only
Full report provided on request

GEODESY

Transverse Mercator Projection
OSGB 1936 (Airy) Spheroid
Central Meridian: 2.00 W
Grid Origin: 49.00 N
False Northing: −100000 N
False Easting: 400000 W
Scale Factor: 0.999601272



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Telephone: +44 1305 848821 or +44 7950 038317
email@shorelinesurveys.com — www.shorelinesurveys.com
TITLE: Residual Comparison: April 2014 with June 2008 (Royal Lymington Yacht Club to Cocked Hat Post)
CLIENT: Lymington Harbour Commissioners
PROJECT: Spring 2014 Full Harbour Survey
NOTES/REVISIONS:
Shore data is client supplied
DO NOT SCALE
Project No: J894R
Drawing No: 02/05
Scale: 1:1000
Date: Apr 2014
Surveyed by: EF,GB
Drawn by: EF
Checked by: EF,RF
NOTES
Coordinated in OSTN02
Residual values are in metres
Line spacing for surveys: Various
Red soundings illustrate areas now shallower
Green soundings illustrate areas now deeper
Residual data only calculated where duplicate data exists
Data is true and accurate at time of surveys only
Full report provided on request
GEODESY
Transverse Mercator Projection
OSGB 1936 (Airy) Spheroid
Central Meridian: 2.00 W
Grid Origin: 49.00 N
False Northing: −100000 N
False Easting: 400000 W
Scale Factor: 0.999601272
Royal Lymington Yacht Club
HM Customs and Harbour Commission Office
Pilot Beacon
(fixed red)
Sluice
Baths
Dock
Slipway
Lymington Yacht Haven
Horn Reach
Wave Barrier
POST No.11
HARPERS POST
HARPERS POST SOUTH
Short Reach
CAGE BOOM POST No.9
COCKED HAT POST
POST
Marsh
Mud
N 95200
N 95000
N 94800
N 94600
N 952000
E 433600

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Telephone: +44 1305 848821 or +44 7950 038317
email@shorelinesurveys.com — www.shorelinesurveys.com
TITLE: Residual Comparison: April 2014 with March 2012 (Cocked Hat Post to No.7 Post)
CLIENT: Lymington Harbour Commissioners
PROJECT: Spring 2014 Full Harbour Survey
Project No: J894R
Drawing No: 03/05
Scale: 1:1000
Date: Apr 2014
Surveyed by: EF,GB
Drawn by: EF
Checked by: EF,RF
NOTES/REVISIONS:
Shore data is client supplied
DO NOT SCALE
NOTES
Coordinated in OSTN02
Residual values are in metres
Line spacing for surveys: Various
Red soundings illustrate areas now shallower
Green soundings illustrate areas now deeper
Residual data only calculated where duplicate data exists
Data is true and accurate at time of surveys only
Full report provided on request
GEODESY
Transverse Mercator Projection
OSGB 1936 (Airy) Spheroid
Central Meridian: 2.00 W
Grid Origin: 49.00 N
False Northing: -100000 N
False Easting: 400000 W
Scale Factor: 0.999601272
E 434000
E 434200
E 434400
N 94600
N 94400
N 94200
Marsh
Mud
Lymington River
Short Reach
COCKED HAT POST
CAGE BOOM POST
POST No.10
POST
ENTICOTT POST
BAG of HALFPENCE POST
SEYMOURS POST
PYLEWELL BOOM POST
TAR BARREL POST
POST No.8


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email@shorelinesurveys.com — www.shorelinesurveys.com
TITLE: Residual Comparison: April 2014 with June 2008 (Cocked Hat Post to No.7 Post)
CLIENT: Lymington Harbour Commissioners
PROJECT: Spring 2014 Full Harbour Survey
NOTES/REVISIONS:
Shore data is client supplied
DO NOT SCALE
Project No: J894R
Drawing No: 03/05
Scale: 1:1000
Date: Apr 2014
Surveyed by: EF,GB
Drawn by: EF
Checked by: EF,RF
NOTES
Coordinated in OSTN02
Residual values are in metres
Line spacing for surveys: Various
Red soundings illustrate areas now shallower
Green soundings illustrate areas now deeper
Residual data only calculated where duplicate data exists
Data is true and accurate at time of surveys only
Full report provided on request
GEODESY
Transverse Mercator Projection
OSGB 1936 (Airy) Spheroid
Central Meridian: 2.00 W
Grid Origin: 49.00 N
False Northing: −100000 N
False Easting: 400000 W
Scale Factor: 0.999601272
E 434000
E 434200
E 434400
N 94600
N 94400
N 94200
Lymington River
Short Reach
Marsh
Mud
COCKED HAT POST
CAGE BOOM POST No.9
POST
POST No.10
ENTICOTT POST
BAG of HALFPENCE POST
SEYMOURS POST
PYLEWELL BOOM POST
TAR BARREL POST
POST No.8
POST No.7
SHEET 2
SHEET 4

Appendix B

Conceptual Model of Ferry Impacts
Updated October 2014

B. Conceptual Model of Ferry Impacts Updated October 2014

B.1 Introduction

The impacts of the ferry service are small, uncertain and dwarfed by the effects of natural processes. In reality, therefore, it is unlikely that any contributory effect of the ferries to the changing intertidal habitats within the Lymington Channel will be measured. This is evident from the first five years' of monitoring along the Lymington Estuary which has confirmed how natural processes are a dominant factor and that the marshes are continuing to erode throughout the length of the estuary with relatively large-scale fluxes of sediment are occurring.

A clear relationship is evident between the levels of wind-wave exposure at any given location and the rates of erosion of the marshes and lowering of the mean low water. Erosion is therefore most prevalent on the eastern wave-exposed outer seaward areas and lowest on the sheltered western upstream sections of the estuary. There is no evidence from the work that has been undertaken and reviewed so far which would indicate that the effects of the ferries can be, or will ever be, distinguished from all other natural as well as man-made forcing factors.

Given the absence of detectable effects that can be attributed to the ferries it is necessary to refer to the original conceptual model of the ferry impacts and make informed judgements against that. This model describes the worst-case impacts as predicted by Natural England and are based on a series of underlying assumptions. This model was based on principles originally developed prior to the W-Class coming into service in February 2009 and, among other aspects it is theoretically influenced by the frequency and speed of the ferry trips.

An original worst-case model predicted a 2ha (hectares) effect. However, following the discussions that informed the Planning Application and the Appropriate Assessment Information report (ERM and ABPmer 2010; ABPmer 2011), this was reduced to 1.4ha after the trippage reduction effects (identified by Natural England as 24%) and temporary ferry speed reduction effects (identified by Natural England as 25% for speeds reduced to 5.5 knots) were taken into account. This value then increased slightly to 1.43ha when HR later re-reviewed the model on Natural England's behalf in 2012 (see footnote following).

It is now possible to update the model predictions based on the actual number of ferry trips and actual average speeds that have been recorded to the present (up to the end of August 2014) and with revised forecasting on this basis. This includes a projection into 2015 based on an understanding of the number of trips proposed and the existing average speed of the ferries being preserved. This update of the model prediction is presented below.

B.2 Trippage Overview

In the conceptual model the baseline trippage rate was 21,000 trips and the impact to trippage relationship is a linear one. Therefore the following trips and conceptual impact reductions are relevant for the periods 2009 to 2015 based on completed and scheduled trips:

- 2009 - 16,646 trips representing a 21% reduction in the conceptual erosion rate;
- 2010 - 17,516 trips representing a 17% reduction in the conceptual erosion rate;
- 2011 - 16,828 trips representing a 20% reduction in the conceptual erosion rate;
- 2012 - 16,456 trips representing a 22% reduction in the conceptual erosion rate;
- 2013 - 14,000 trips representing a 33% reduction in the conceptual erosion rate;
- 2014 - 11,550 trips representing a 45% reduction in the conceptual erosion rate; and
- 2015 - 11,000 trips (estimate) which represents a 48% reduction in the conceptual erosion rate.

As is clear from this summary, in 2013, 2014 and again in 2015 substantial sequential reductions in annual trippage have been and will be made against the baseline. Then assuming a continued 20% reduction throughout the residual life of the ferries this reduces the theoretical projected/modelled ferry impacts from the original 2ha to 1.53ha.

B.3 Ferry Speeds Overview

In the conceptual model, the baseline ferry speed was 6 knots (only the 1km section below the wave screens is relevant) and the impact to speed relationship is non-linear and is derived from the difference between the fourth-root of the speed change (HR Wallingford, 2011). This non-linear relationship is illustrated in Image B1.

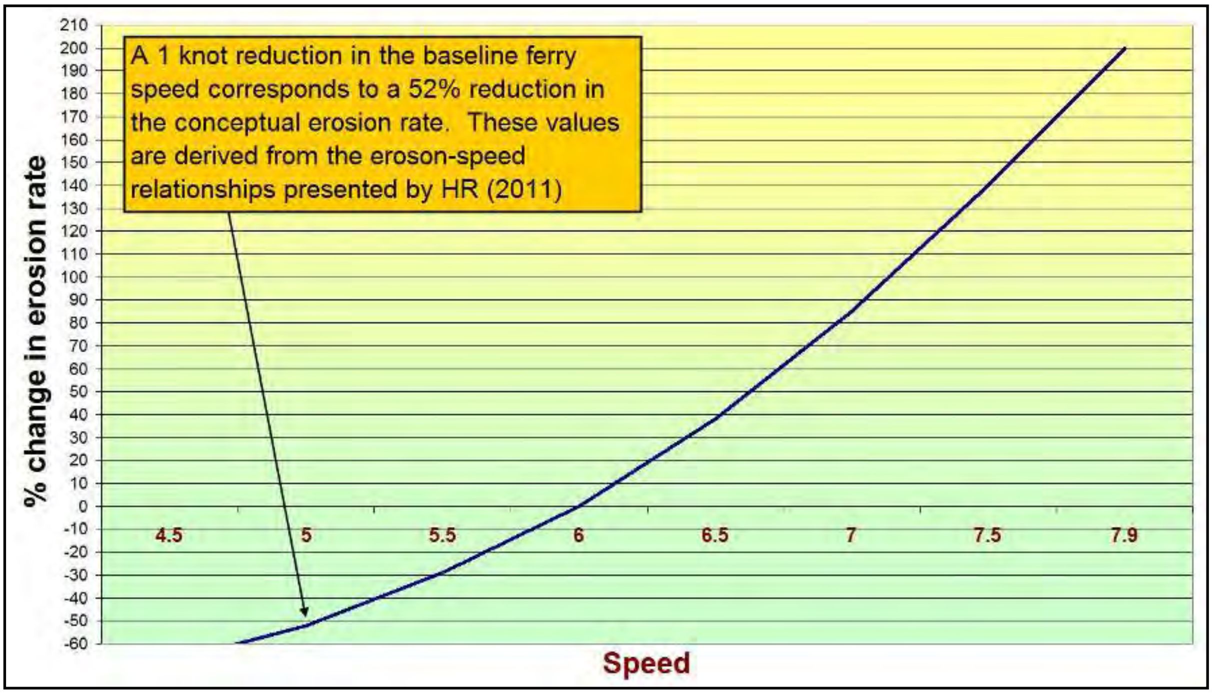

Image B1. Projected relationship between erosion and ferry speed as used within the conceptual impact model

From this relationship, the conceptual impact reductions that are relevant for the periods 2009 to 2015 (based on the average speeds as recorded using Automatic Identification System (AIS)) are as follows:

- 2009 - average speed 6 knots representing a 0% reduction in the conceptual erosion rate;
- 2010 - average speed 6 knots representing a 0% reduction in the conceptual erosion rate;
- 2011 - ferry speed was formally reduced in early 2011 and monitoring of the speeds formally began on 21 June 2011. This monitoring was intermittent to start with due to the software needing to be refined. However from the 21 June to 31 December 2011 (when data were obtained from 140 days), the average speed below the wave screen was 5 knots. This represents a 52% reduction in the conceptual erosion rate;
- 2012 - average speed from 1 January to 30 September 2012 was 5 knots (the monthly average ranged very little from 4.9 to 5.2 knots) this again represents a 52% reduction in the conceptual erosion rate;
- 2013 - average speed from 1 January to 30 August 2013 was 5 knots (the monthly average again ranged very little from 4.9 to 5.2 knots) this also represents a 52% reduction in the conceptual erosion rate; and
- 2014 - average speed from 1 January to 30 August 2013 was 5.2 knots this represents a 45% reduction in the conceptual erosion rate; and
- 2015 – it is assumed that ferry speeds will be preserved at around 5 knots representing a 52% reduction in the conceptual erosion rate.

B.4 Revised Conceptual Prediction

The above results show, that there have been, and will be, 17 to 48% reductions in annual trippage with the larger reductions occurring in recent years due to reduced demand and trippage. The ferry speed has been consistently around 5 or 5.2 knots (representing a 52% to 45% reduction in erosion effect respectively).

Taking assumptions that a 20% trippage reduction is preserved for the duration of the 30-year lifespan of the project and the ferry speed reduction to 5 knots is maintained through 2015, then the updated conceptual impact is reduced to 1.33ha (rather than 1.43ha). Therefore, there has been a reduction in the predicted conceptual impact and this reduction is mainly attributable to the greater than expected ferry speed reduction.

In response to this new information on trippage and ferry speeds updated versions of the original impact tables and figures that were provided for Natural England by ABPmer (2011) are shown in Table B1[9] and Images and Figures B1 and B2.

Also, a prediction has also been made of the effect arising if the ferry speed continues to be maintained at 5 knots. If these slower speeds were maintained for the lifetime of the ferries then the conceptual impact would be 0.87ha (of combined loss and change of low shore mudflat). This is shown at the bottom of Table B1 and in Figure B3 and B4.

These calculations are, as described above, theoretical only. As described in the main report the combined weight of evidence from the monitoring work (both that undertaken by Wightlink Ltd, LHC and

[9] In 2013 as adjustment to this model was made in response to comments received by HR Wallingford (2012). It is agreed that the ‘accommodation period’ after the restoration of baseline ferry speeds post 2015 has been removed (Column 4, Table A1) and the erosion rates just assumed to return to pre-2011 levels.

CCO) and other observations within the estuary, indicate that any physical or ecological effects from the ferry are undetectable in reality.

Table B1. Predicted worst-case loss/change to mudflat habitat due to the W-Class ferry operations (expressed in hectares and hectare-years)

Year	Natural England Worst-Case Prediction and Updates (Annual Hectares)			Natural England Updated Worst-Case Prediction (Cumulative Hectares)	Natural England Updated Worst-Case Prediction (Hectare-years)
	Original worst-case habitat loss/change annual rate in hectares*	17-46% Loss rate reduction due to reduced trippage from 2009 to 2014. A 20% reduction then assumed from 2015 to 2038 (hectares) *	Further 52% Loss rate reduction due to reduced ferry speed which has been, and is predicted to be, 5 knots below wave screen from 2011 to 2014 (hectares)●	Updated worst-case habitat change and loss after trippage and slower ferry speed mitigation has been accounted for (cumulative effect in hectares – see Figure D1)	Cumulative updated worst-case habitat change and loss after trippage and slower ferry speed mitigation has been accounted for (hectares-years – see Figure D2)
2009	0.155	0.122	0.122	0.122	0.1
2010	0.146	0.121	0.121	0.244	0.4
2011	0.138	0.110	0.053	0.297	0.7
2012	0.129	0.101	0.048	0.345	1.0
2013	0.121	0.081	0.039	0.384	1.4
2014	0.112	0.062	0.034	0.418	1.8
2015	0.103	0.054	0.026	0.443	2.3
2016	0.095	0.076	0.076	0.519	2.8
2017	0.086	0.069	0.069	0.588	3.4
2018	0.078	0.062	0.062	0.651	4.0
2019	0.074	0.059	0.059	0.710	4.7
2020	0.070	0.056	0.056	0.766	5.5
2021	0.066	0.053	0.053	0.819	6.3
2022	0.062	0.050	0.050	0.868	7.2
2023	0.058	0.046	0.046	0.915	8.1
2024	0.054	0.043	0.043	0.958	9.0
2025	0.050	0.040	0.040	0.998	10.0
2026	0.047	0.038	0.038	1.035	11.1
2027	0.043	0.034	0.034	1.070	12.1
2028	0.039	0.031	0.031	1.101	13.2
2029	0.037	0.030	0.030	1.131	14.4
2030	0.035	0.028	0.028	1.159	15.5
2031	0.033	0.026	0.026	1.185	16.7
2032	0.031	0.025	0.025	1.210	17.9
2033	0.029	0.023	0.023	1.233	19.2
2034	0.027	0.022	0.022	1.255	20.4
2035	0.025	0.020	0.020	1.275	21.7
2036	0.023	0.018	0.018	1.293	23.0
2037	0.021	0.017	0.017	1.310	24.3
2038	0.019	0.015	0.015	1.325	25.6◆
Total	2.01	1.53	1.33	25.6 (ha-yr)◆	N/A

Notes:

* The 'Natural England Worst-Case Prediction' based on an average of 1.55ha/decade loss reducing over 30 year life of the ferry service. With that rate halving at 10yrs, again at 20yrs and then again at 30yrs (and using a 5% per year reduction over each 10yr period to reflect the progressive nature of the change).

* The trippage reduction was originally predicted to be 24% (with equivalent 24% impact reduction accruing) but based on actual observations from 2009 to 2012 it has, for now, been assumed to be 20% throughout the operational life of the ferries. However, from 2013 to 2015 trippage rates are, and will be, very much reduced to match capacity with demand and this may persist for several years leading to modest reductions in the modelled impacts overall (e.g. a 48% reduction over the full remaining lifetime of the ferries from 2015 to 2038 would reduce column total from 1.53ha to 1.22ha).

● If the 5 knot speed persisted over the full remaining lifetime of the ferries from 2016 to 2038 would reduce column total from 1.33ha to 0.87ha (see Figure B3) or 0.72ha in tandem with the trippage-based reduction cited in previous bullet point.

◆ This value reduces to 16.6ha-yr if there is a 48% reduction in trippage and ferry speeds are maintained at 5 knots the full remaining lifetime of the service from 2016 to 2038 (see Figure B4).

Appendix B. Figures

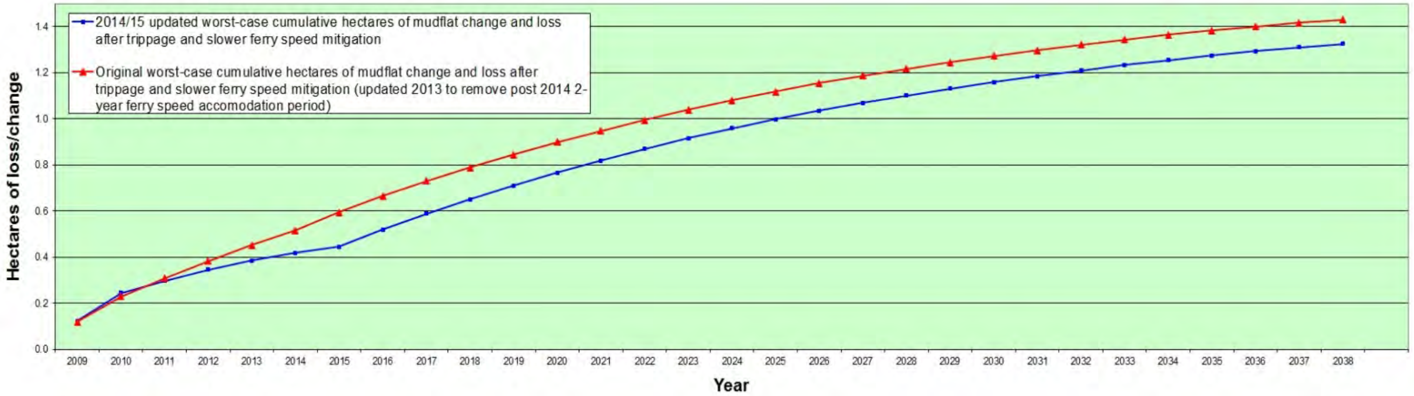

Figure B1. The worst-case cumulative hectares of mudflat change and loss after trippage and slower ferry speed mitigation

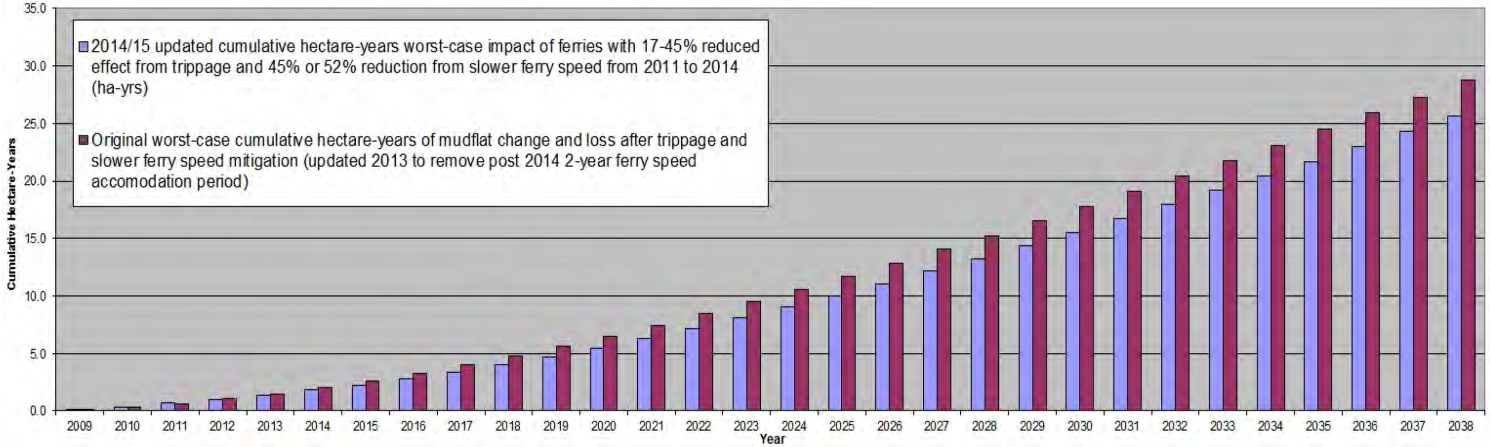

Figure B2. The worst-case cumulative hectare-years of mudflat change and loss after trippage and slower ferry speed mitigation

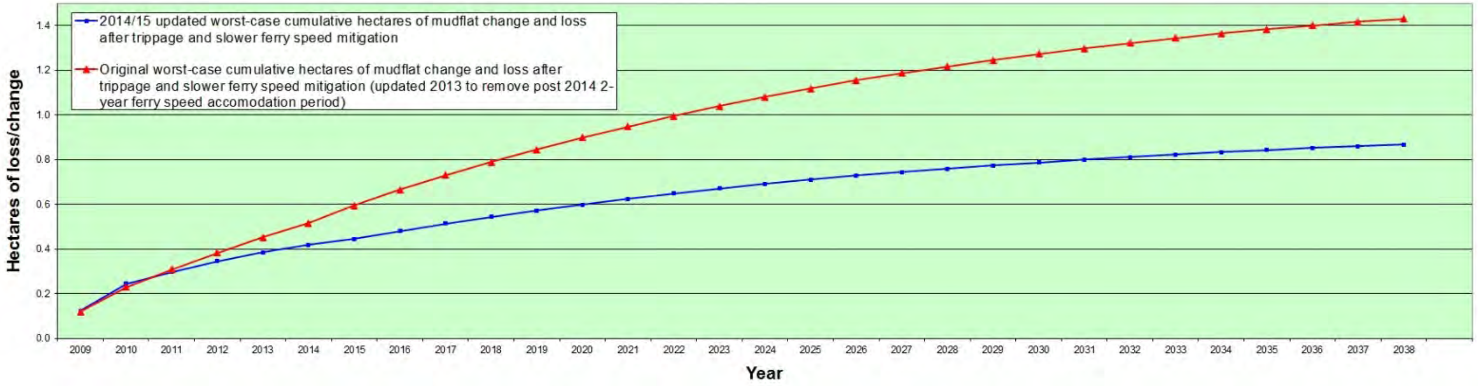

Figure B3. The worst-case cumulative hectares of mudflat change and loss after trippage and slower ferry speed mitigation (assumes 5 knot speed throughout full remaining lifetime of the service)

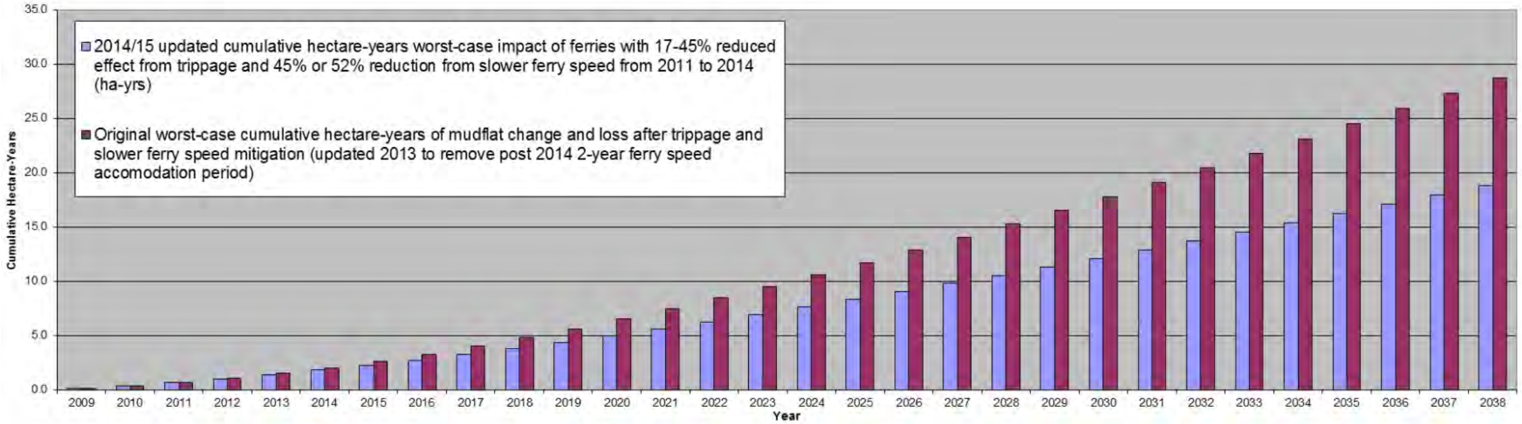

Figure B4. The worst-case cumulative hectare-years of mudflat change and loss after trippage and slower ferry speed mitigation has been accounted for (assumes 5 knot speed throughout full remaining lifetime of the service).

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