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EX 5937

Wightlink Ferries, Lymington

Shoreline Management & Geomorphological Advice to Natural England

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Prepared ....

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Summary

Wightlink Ferries, Lymington

Shoreline Management & Geomorphological Advice to Natural England

Report EX 5937
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Wightlink are proposing to introduce a larger ferry ('W Class') into their Lymington-Yarmouth service. The proposals include shore-side works which require an Appropriate Assessment to be undertaken before they can be carried out because Lymington Harbour is designated as a Special Protection Area (SPA), a Ramsar site and a Special Area of Conservation (SAC). This designated status is awarded because of its intertidal areas (mudflat and saltmarsh) which are considered to be nationally and internationally important habitats.

Natural England is acting as advisor to the Competent Authorities (New Forest District Council and the Marine and Fisheries Agency) who will oversee the Appropriate Assessment process. In December 2008 Natural England commissioned HR Wallingford to provide advice to them regarding the potential for physical impacts on the designated habitat arising from past and future ferry activity. This report presents the outcome of the study and addresses questions asked by Natural England.

This version of the report supersedes Release 2.0 of the same and has been written following:

- discussions between Natural England, Lymington Harbour Commissioners, Wightlink, Black and Veatch, ABPmer and HR Wallingford;
- further analysis of bathymetric data by ABPmer;
- further input regarding the measured drawdown and return current measurements from Ryan Willegers (Lymington Harbour Commissioners) and Ian Dand (BMT SeaTech);
- discussions with Lymington River Association.

The key points arising from the analysis in this report can be summarised as follows:

- The evidence is that the rate of erosion of the mudflat in Lymington Harbour (at Chart Datum and Mean Low Water) has increased from around the time that the C Class ferries were introduced. Since this time erosion of the Low Water channel itself has also occurred.
- Recent measurements and observations undertaken by Lymington Harbour Commissioners and BMT SeaTech, in combination with evidence of the speeds at which ferries travelled within the Harbour prior to 2007, suggest that the combination of drawdown and return currents from ferry movement would have led to significant[1] erosion of the mudflat. This concurs with the analysis undertaken by HR Wallingford in 1991.
- There is therefore both circumstantial evidence for the observed erosion in the inner parts of the Harbour having been caused by the C Class ferry and a measured mechanism by which this ferry can have caused the erosion. It is therefore most likely that the erosion of the mudflats observed since the 1970's, at least upstream (landward) of Pylewell, is predominantly a function of the C Class ferry activity.

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[1] See Section 1.4 for definition of significant

Summary continued

- It is suggested in ABPmer studies that there has been no change to the Chart Datum and Mean Low Water contours since 1994. However this result is not supported by the 1993 survey which indicates progressive changes in contours. In our view the contours resulting from the 1993 survey appear more plausible than those of the 1994 survey. In addition the precautionary principle would dictate that, of the two, the 1993 survey should be considered as being the result upon which management decisions should be made.

- Downstream (seaward) of Pylewell the increasing effect of natural wind waves have probably dominated the erosion process. However, since the ferry has contributed to erosion upstream it is also likely to have contributed to erosion in this part of the Harbour to some extent.

- The recent reduction in speed of the C Class ferries means that the erosion which has been observed probably as a result of the drawdown/return flow effect, is greatly diminished from the historic trend. That is not to say it has disappeared altogether. The passing of ferries near Bag of Halfpence and Pylewell will produce large shear stresses which will continue to erode the lower intertidal. In addition the thrust jet interacts with the foreshore in the vicinity of Cage Boom during turning.

- The evidence of the drawdown measurements indicates that the W Class ferry has the ability to generate drawdown-induced current speeds across the mudflat, near low water and during ferry passage, of the order of those which, it is argued here, have led to significant[4] erosion of the mudflat in the inner Harbour. This will result in an enhanced rate of loss of mudflat compared to the present scenario (C class vessels adhering to the speed restrictions in the Harbour), and a similar rate of loss compared to the historic rates which have occurred prior to 2007.

- An estimate of the recession rate of Chart Datum resulting from the use of W Class vessels is in the region of 0.4ha per decade.

- An estimate of the recession rate of Mean Low Water resulting from the use of W class vessels is in the region of 1.3ha per decade. However, as the mudflats erode further, the role of wind waves will become increasingly more important and thus it is likely that the observed rate of erosion will be higher than these rates calculated on the basis of the ferry alone.

- It seems to be agreed by all parties that the W Class ferry will produce greater underkeel turbulence, backflow, return currents and thrust jet speeds. It is therefore to be expected that further deepening will occur in the channel.

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1. Introduction

1.1 BACKGROUND

Wightlink are proposing to introduce a larger ferry ('W class') into their Lymington-Yarmouth service. The proposals include shore-side works which require an Appropriate Assessment to be undertaken before they can be carried out because Lymington Harbour is designated as a Special Protection Area (SPA), a Ramsar site and a Special Area of Conservation (SAC). This designated status is awarded because of its intertidal areas (mudflat and saltmarsh) which are considered to be nationally and internationally important habitats.

Natural England is acting as advisor to the Competent Authorities (New Forest District Council and the Marine and Fisheries Agency) who will oversee the Appropriate Assessment process. In December 2008 Natural England commissioned HR Wallingford to provide advice to them regarding the potential for physical impacts on the designated habitat arising from past and future ferry activity. Specifically, Natural England requested answers to the following questions:

Q1 Have Wightlink provided convincing evidence that the inter-tidal (above CD) is resilient to changes in the navigation channel?

Q2 In light of answer to Q1 and given the nature of the estuary (profiles, geology, substrate) how would we expect the inter-tidal to react to further deepening and widening that is predicted from the 'W class'?

Q3 Now that the first 'W' class has arrived and sea trials for safety are underway, Natural England is being criticised for not advising that Wightlink (LHC) obtains further field information from sea trials. Natural England seeks advice on the degree to which further field data would help to improve decision-making in the light of Q1 and Q2 above specifically:
a) probe sampling of water flows under and around the boat, from propulsion and backflow, to estimate erosive force compared to 'C class'.
b) sampling of sediment disturbed by 'C class' and 'W class' as indication of relative differences in erosive potential.
c)how do the benefits to be gained above relate to the cost and time implications?

Q4 If further quantification of deepening and widening, and further field evidence are not appropriate, is there a basis for asking Wightlink to better quantify it using other means, i.e. could they do this using VSP [*Voith Schneider Propeller*] flow modelling?

Q5 Is there any way of approximately quantifying losses of inter-tidal from estimated further deepening of the navigation channel.

Q6 Modelling suggests that drawdown of the 'W class' could be reduced by small reductions in speed so that drawdown was similar to the 'C class'. Natural England has now received field information from the sea trials comparing 'W class' drawdown (vertical) at different states of tide in different locations. Drawdown currents are lower than expected, what are the implications for potential erosion? If drawdown is still a problem help is needed to assess at what speed and at what state of tides ‘W class’ drawdown is similar to ‘C class’.

Q7 In light of sea trials data, Lymington Harbour Commissioners have indicated that they will ask Natural England advice on the speed, navigation, tide and wind parameters that the ‘W class’ should operate under to avoid adverse effect/detrimental effect (clarification sought on legal remit) on Natura 2000 features.

Q8 Please assess the analysis of morphological evolution that has informed Natural England thinking and advise on any incorrect interpretations. (With a view to advising on the likely effects of the ferries on local sediment recycling)

Q9 A sub-tidal bank of sediment is deposited across the mouth of the estuary. The ferries carve two tracks through this. Lymington River Association says that the cuts in the bank allow greater wave penetration that would significantly increase wind wave penetration to the mouth of the navigation channel causing erosion. Is this likely?

1.2 SOURCES USED IN THIS REPORT

The sources used in this report include the following:

- ABPmer (2008a) Wightlink – Replacement Lymington to Yarmouth Ferries: Information for Appropriate Assessment, ABPmer Report R.1427, May 2008.
- ABPmer (2009) Wightlink – Replacement Lymington to Yarmouth Ferries: Information for Appropriate Assessment, Extra Analysis, January 2009.
- BMT SeaTech (2008a) Ferry Operations at Lymington, Phase 1: The Present Situation and Future Prediction, Report C13537.R01.V2, March 2008.
- BMT SeaTech (2008b) New Ferries for Lymington/Yarmouth: Drawdown, Wash and Flow Measurements, Report C13537.01.R01, 24 November 2008.
- Eagle Lyon Pope (2006) Wightlink Ferries Lymington Harbour Navigational Review, Report number ELP-55272-1206-57219-Rev 1, December 2006.
- HR Wallingford (1991) Proposed New Tonnage Lymington Yarmouth Ferry, Mud erosion in Lymington River, HR Wallingford Report EX 2390, July 1991.
- Black and Veatch (2008) Lymington Harbour Protection, Environmental Statement, Final Draft, April 2008.

Additional input from Lymington Harbour Commissioners, BMT Seatech and Lymington River Association (2008) is also drawn upon.

In the preparation of this report HR Wallingford has relied on third party data and has not conducted analysis of bathymetric data or field measurements in the present study.

1.3 STRUCTURE OF REPORT

The remainder of this report comprises five further chapters. Chapters 2, 3 and 4 present the evidence for potential impact arising from past, present and future ferry activity. The loss of intertidal area resulting from the W class ferry being put into operation is estimated in Chapter 5. Chapter 6 presents answers to the specific questions raised by Natural England. The conclusions of the report are presented in Chapter 7.

1.4 REPORT DEFINITIONS

Backflow – when a ship moves in water it induces flow velocities over its hull, some of which are greater than its speed through the water. This effect is enhanced in shallow water and may be seen as an additional current in the water close to the ship. This is called *backflow* (BMT SeaTech, 2008a). In practice it is difficult to separate the effect of *backflow* and turbulence from the *Voith Schneider propeller*.

Return Current – when a ship moves in a confined channel its motion through the channel causes a current to flow throughout the remaining cross-section in the opposite direction.

Drawdown – As the vessel moves along the displaced water flows rapidly back along the vessel (*backflow*). The increase in speed reduces the water pressure and as a result the water level is lowered locally. This causes squat of the vessel but also drawdown of the water levels around the vessel. The drawdown can be thought of as a long period wave with a height of tens of centimetres and a period of 20-60 seconds. As the wave meets an intertidal slope a current is induced down the slope and then back up the slope. Depending on the period of the drawdown wave, the slope of the intertidal and the amplitude of the drawdown the current speed induced can be significant.

Ship Wash – The term *ship wash* refers to the creation of waves on the surface of the water by the passage of vessels.

Voith Schneider propeller (VSP) – The Voith Schneider propeller (VSP), also known as a cycloidal drive is a specialized marine propulsion system. It is widely used on tugs and ferries. Arranged on a circular plate, rotating around a vertical axis, there is a circular array of vertical blades. Each blade can rotate itself around a vertical axis. The internal gear changes the angle of attack of the blades in sync with the rotation of the plate, so that each blade can provide thrust in any direction, very similar to the collective pitch control and cyclic in a helicopter.
(*http://en.wikipedia.org/wiki/Voith_Schneider_Propeller*).

Thrust jet – The action of the Voith Schneider Propeller results in a jet of water which flows in the opposite direction to the direction of motion. This will be referred to henceforth as the *thrust jet*.

Significant – this word has a specific meaning in Appropriate Assessment or Environmental Statements. The word as used in this report is used in the sense of ordinary English and not the formal meaning used in the assessment procedure.

1.5 LOCATIONS REFERRED TO IN THIS REPORT

The locations referred to in this report are shown in Figure 1.

Figure 1 Location map of Lymington Harbour showing approximate location of navigation posts

2. *Evidence for potential impact arising from past ferry activity*

2.1 INTRODUCTION

Lymington Harbour, like many locations within the Solent region, is experiencing significant erosion of mudflat and saltmarsh along the seaward edge of the estuary system. The historical evidence is that this effect has been continuing for some time (possibly centuries, ABPmer, 2008a). However, this report is not concerned with the ongoing erosion at the seaward boundary but on the potential for erosion to have occurred within the Harbour, adjacent to the navigation channel. In particular, the possibility that erosion could have occurred historically in response to ferry activity, and may occur in response to the introduction of the proposed new ferries, is considered.

The 'C Class' vessels which are currently in action in the Lymington Harbour have been in operation since 1973. They have the same Voith-Schneider propulsive system as the proposed 'W Class' vessels but the size and power of the C class vessels are less than those of the W class vessels. The introduction of the C Class vessels coincided with a significant recession in both mudflat and saltmarsh adjacent to the navigation channel throughout the Harbour (see Sections 2.3 and 2.4). However, while the juxtaposition of these two events is reason to reflect on the potential for the C class to contribute to erosion, it must remembered that there are natural erosion effects at work within the Harbour also which *may* dominate, *or not*, the effects of ferry passage. In particular there is the significant loss of mudflat and saltmarsh at the shoreward edge of the Harbour which is considered to be a function of wind wave activity, and which is increasingly impinging further into the Harbour itself (ABPmer, 2008a, and Ryan Willegers, Lymington Harbour Commissioners, *pers.comm*, 2008).

The purpose of this chapter is to review the available evidence for ferry-induced impact from the C Class vessels. In particular the bathymetric data presented in ABPmer (2008a), measurements of drawdown and return currents conducted by BMT SeaTech and Lymington Harbour Commissioners, and the studies conducted by HR Wallingford in 1991.

2.2 THE IMPORTANCE OF CHART DATUM AND MEAN LOW WATER TO HABITAT DESIGNATION

The changes in CD and MLW may (subject to confirmation by Natural England) both have formal meaning with regard to the integrity of the designated habitat. Both the SAC and the SPA/Ramsar sites are bounded on their seaward edge by MLW. The SAC is bounded along the navigation channel by the navigation posts which are more or less located at CD (Claire Lambert, Natural England, *pers.comm.,* 2008). The whole of the navigation channel is located within the SPA/Ramsar site although the designated features are associated with intertidal habitat.

2.3 OBSERVED BATHYMETRIC CHANGES TO CHART DATUM

2.3.1 Observed Bathymetric changes

ABPmer (2009) presents historical bathymetric cross-section data based on survey data from New Forest District Council. The data presented in the (2009) note is revised from the May 2008 Report (ABPmer, 2008a). ABPmer now consider the cross-section data to contain sufficient uncertainty that it may not be the most reliable means of discerning changes in the channel at Chart Datum (Peter Whitehead, ABPmer, *pers.comm*., 2009). The argument is that because the cross-section data was based not on the measured data itself but on the interpolation of the New Forest District Council digital terrain model, itself an interpolation of the measured data, there is much potential for error in the resulting cross-sections. Moreover (as the author of this report can confirm) the bathymetric measurements were not always measured perpendicular to the channel, especially around the turn at Cocked Hat/Cage Boom leading to errors when cross-sectional data is derived. Instead ABPmer (2009) presents contours of CD derived from interpolation of the original chart data (rather than from the NFDC digital terrain model) at Harpers Post South, Cocked Hat, Bag of Halfpence Post and Seymours Post.

The new contours of CD (Figure 2 presented in ABPmer, 2009) indicate that changes to CD have been limited since 1994. This is a very different result from the cross-sections provided in the May 2008 report (and which were discussed in the previous version of this HR Wallingford report). In order to provide more confidence in the new data it was agreed at a meeting on January 13 2009, as a check of the data presented in Figure 2 of ABPmer (2009), that the difference in channel width at CD be derived from the original charts by measuring using a ruler between data points of 0mCD (thus minimising, if not removing, error due to digitising and interpolation). This analysis of the original charts was undertaken by ABPmer and the results illustrated in Figure 3 of ABPmer (2009) are summarised in Table 1.

Table 1 Historical changes in width of channel at Chart Datum, based on ruled distances between 0mCD data points from original charts (ABPmer, 2009, Figure 3)

Year		Harpers Post South	Cocked Hat	Bag of Halfpence	Seymour's Post
1981	width at CD (m)	60	86	97	98
	cumulative change (m)	0	0	0	0
1988	width at CD (m)	65	83	107	101
	cumulative change (m)	5	-3	10	3
1991	width at CD (m)	67	89	108	109
	cumulative change (m)	7	3	11	11
1993	width at CD (m)	66	84.8	101	101
	cumulative change (m)	6	-1.2	4	3
1994	width at CD (m)	80	90	104	107
	cumulative change (m)	20	4	7	9
2005	width at CD (m)	89	94	110	109
	cumulative change (m)	29	8	13	11
2006	width at CD (m)	84	96	110	112
	cumulative change (m)	24	10	13	14
2008	width at CD (m)	84	93	116	112
	cumulative change (m)	24	7	19	14

Table 1 indicates that there has been some widening (7-24m with a mean value of 16m) of the width of the channel at Chart Datum at all of the sections presented between 1981 and 2008. The proportional change in width is greatest for Harpers Post South.

The widening represents a loss of intertidal area of around 1.3ha between Harpers Post South and Seymours Post over the 27 year period of data or around 0.05ha/yr. The 1993/1994 surveys imply that the change since 1993/1994 is in the region of 0.035-0.07ha/yr. Using the rate from 1981-2008 and extrapolating the change back to 1973, (wich was the year of introduction of the C Class ferries) one could reasonably assume a total loss since 1973 of 1.7ha.

For completeness the corresponding data based on the NFDC cross-sections is presented in Table 2.

Table 2 Observed changes in width of channel at chart datum (taken from ABPmer, 2008a, Figures 7, 8 & 9)

Cross-section	Year 1988	1993	1999	2006	increase 1988-2006
Harpers post south	65	72	73	72	7
Cocked Hat post	82	75	90	96[2]	14[2]
Bag of Halfpence post	105	104	112	109	4
Seymour post	105	99	106	111	6
Post 7	121	111	125	125	4
Posts 5 to 6	-	172	280	322	150

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[2] ABPmer revised the 2006 cross-section at Cocked Hat in ABPmer (2009).

The cross-section data indicates that there has been some widening (7-14m between Harpers Post South and Seymours Post, with a mean value of 8m) of the width of the channel at Chart Datum at all of the sections presented between 1988 and 2006. This is of the same order, but less than, the corresponding mean change for the period 1988-2006 from the Table 1 data (11.5m). Thus although the details of the changes differ between Tables 1 and 2 in broad terms they are similar enough and it is clear that changes to Chart datum have taken place over the last 20-30 years. For the purposes of this report, however, the changes to CD will be taken from Table 1, which is considered to be more reliable data for the purposes of the present analysis.

2.3.2 Discussion

The changes in CD presented above could in theory arise from a number of different sources:

- Tidal currents;
- Wind-generated waves;
- Ferry activities.

It is considered that the evidence presented in the BMT SeaTech reports is sufficient to lead to the conclusion that ship wash generated by the ferries is not an important effect compared to the others in the list above. It is probable that the large number of movements of smaller craft in Lymington Harbour has some detrimental effect on intertidal areas but it is considered that these effects are not as major as those listed above and there is little data as a whole to evaluate this effect more fully.

Tidal currents
Peak tidal currents occur on the late ebb on spring tides (around tidal levels of +1.4mCD) and have been measured up to 0.57m/s at Pylewell on a larger than mean spring tide of 2.8m range (BMT SeaTech, 2008a) and up to 0.2m/s in Horn Reach. On the edge of the channel between Cocked Hat and Pylewell the peak ebb tidal currents have been measured as 0.46-0.5m/s on spring tides (BMT SeaTech, 2008a, Ian Dand, BMT SeaTech, *pers.comm.*, 2008, Ryan Willegers, Lymington Harbour Commissioners, *pers.comm.*, 2008). The shear stress imposed by the measured currents between Cocked Hat and Pylewell at peak ebb at Chart Datum (i.e. 1.4m water depth) over a muddy bed is, using Equation 1 (see below), 0.48N/m^2. This indicates that mean spring tides do not result in erosion of the (consolidated) bed at Chart Datum and only the very largest tides (with tidal ranges in excess of a mean spring tide) could erode the bed at this level. Moreover, since the period over which these peak speeds are experienced is only in the region of 15 minutes, on less than 10% of tides and the shear stress applied is only just larger than the erosion threshold of consolidated material, this suggests that tidal currents are not responsible for any significant recession of the Low Water contour.

It is possible that historically tidal currents were larger in the river than they are now. The Lymington Yacht Haven and Berthon marinas were built in the late 1960's/early 1970's just before the introduction of the ferries in 1973. These marinas will have increased the tidal volume of the estuary at this time, particularly just seaward of Lymington Yacht Haven. An argument can be made that the increase in speeds from marina construction led to widening (and deepening) of the channel and which then in turn reduced the currents to the levels observed at present. This argument has some potential purchase with respect to the changes at Harpers Post South which are large relative to the original width of the channel and have appeared to have slowed in later years. However the strength of this argument more generally is diminished by the following facts:

- The channel width (at Chart Datum) has progressively widened over the whole period 1981-2008 meaning that the forcing process causing this change is still continuing and the change is less likely to be a result of an episodic change nearly 40 years before.
- The measured changes in width are largest at Harpers Post South, reduce at Cocked Hat and then increase again at Bag of Halfpence and Seymours Post. If the effect of marina construction was large it would be expected that there would be a steady decline in its effect with distance seawards along the estuary.
- The increase in tidal volume would not necessarily lead to an increase in peak ebb current of the same order. This is because the late peak ebb current speeds are a direct result of the combination of large expanses of mudflat and saltmarsh combined with a relatively deeper channel. Effectively it takes longer for water to make its way off the saltmarshes owing to friction. Increasing the tidal volume by marina construction creates tidal volume but also increases subtidal volume. As water flows much more quickly in subtidal areas the water flowing out of the marinas does so much more quickly and the increase in discharge resulting from flow out of the marinas occurs earlier in the ebb tide. A first order estimation of this effect can be achieved using the analysis by Dronkers (1998) which suggests that the peak ebb would not increase substantially, although there would be a correspondingly larger (proportional) change in flood tide currents.
- The actual increase in tidal volume associated with the marina construction is not as large as one might initially think. The increases of 230,000m^3 and 15% used in ABPmer (2008a) have been identified as incorrect. A more realistic assessment for the increase in volume is 140,000m^3 (which takes into consideration Lymington Yacht Haven and Berthon Marinas (Peter Whitehead, ABPmer, *pers.comm.,*2009). The figure used by ABPmer for the tidal volume (1.85Mm^3) seems to relate to a much smaller area of the inner harbour (Peter Whitehead, ABPMer, *pers.comm,* 2008) and simple back of the envelope calculations suggest that it relates to the tidal volume landward of Cocked Hat. The tidal volume quoted by ABPmer is from studies by Townend (2005). Since this time the tidal volume for Lymington Harbour as a whole as been corrected as part of the Defra FD2107 project studies and is in the region of 3.6Mm^3 (Richard Whitehouse, HR Wallingford, *pers.comm*, 2009). The change in tidal volume caused by marina construction can therefore be estimated as 4% of the total tidal volume of Lymington Harbour and 7.5% of the volume upstream of Cocked Hat. Tidal currents are therefore unlikely to have been very much higher than just before the marinas were constructed

It is concluded that the effect of the construction of the marinas may have caused some of the changes observed at Harpers Post but the main underlying cause of the widening of the Inner Harbour cannot be directly attributed to tidal currents.

Waves

At Harpers Post South, waves are less than 0.3m (HR Wallingford, 1991, Black and Veatch, 2008). Further seaward at Cage Boom waves can increase up to 0.5m under Force 9 and Force 10 Winds from the South (Ryan Willegers, Lymington Harbour Commissioners, *pers.comm.*, 2008). Further seaward still than Pylewell the intertidal areas become more exposed and wave heights increase.

Waves are not considered to be a cause of changes in width of the channel at CD upstream of Seymours Post. This is because:

- Near Low Water there is still “no line of sight” (i.e. no direct fetch) for waves from the South into the estuary;
- Waves occurring in the Inner Harbour near Low Water are therefore relatively small because the fetch that generates them is small. The shear stress that these waves generate on the bed at CD is too small to erode the bed.
- When the largest waves occur, the depth of water above CD will be 2-3m. For muddy conditions (where the erosive action of waves is best represented by assuming smooth turbulent conditions, Whitehouse et al, 2000) in the Inner Harbour even the largest waves would not be sufficient to erode the bed at CD (although they would be expected to erode the upper part of the mudflat and saltmarsh).

South of Pylewell it is likely that waves play an increasingly important part in recession of intertidal areas.

C Class Ferries
As discussed in Section 2.9 it is generally agreed that the C class ferry erodes the bed underneath and in the vicinity of the ferry. However, this effect does not itself cause erosion of the intertidal areas. The very shallow currents induced by the drawdown over the intertidal areas (see Section 2.8) occur higher in the tidal frame than Chart Datum and so, unless they are very large (such as when ferries travel at high speeds or when ferries pass), are not likely to be responsible for changes to Chart Datum. The return current effect discussed in Section 2.7 is more likely to be responsible for erosion near Chart Datum on the basis that ferries in general used to go much faster near Low Water than they do now. On the basis of return currents that can be inferred from ferries travelling at 6 knots at Cocked Hat, 6 knots at Bag of Halfpence and 7 knots at Seymours Post at tidal levels of +0.8mCD to +1mCD a return current of 0.6-0.7m/s can reasonably be inferred (see Section 2.7) which would result in shear stresses of 0.7-1.0N/m^2, a higher force than is required to erode the bed and significantly more than the stresses induced by tidal currents or waves.

The erosion caused by this mechanism can be estimated using Equation 1:

$$\frac{\partial m}{\partial t} = M_e(\tau - \tau_e) \qquad (1)$$

Where $\frac{\partial m}{\partial t}$ is the rate of mass of sediment eroded; M_e is the erosion constant (assumed to be 0.001 kg N^{-1}s^{-1}), τ is the applied shear stress (N/m^2), and τ_e is the erosion threshold shear stress (N/m^2).

If the shear stresses identified above are assumed to occur for a period of 30 seconds at any point on each ferry trip (of which there are 20,000/yr), and if only those journeys when the tidal level is less than +1mCD (assumed to be an hour per tide) are considered, and if the erosion threshold at CD is assumed to be 0.5N/m^2, and if the density of the seabed at Chart Datum is assumed to be 500kg/m^3 then the depth of vertical erosion occurring over 27 years is calculated to be around half a metre. The resulting recession rate, assuming a slope of 1:20, is of the order of 10m (on either side of the channel), similar to the mean observed recession rate.

In addition to the return current effect, there is evidence that the thrust jets of the ferry can interfere with the banks of the estuary in shallow water on the east bank opposite Bag of Halfpence (see Section 2.10). Whilst this effect is not easily quantifiable owing to the complexity of the processes involved, it is unlikely that this effect is insignificant.

It is concluded that the most likely cause of the recession of the CD contour is ferry activity.

2.4 OBSERVED BATHYMETRIC CHANGES TO MEAN LOW WATER

2.4.1 Observed Bathymetric changes

In the ABPmer report (2008a, Figure 5) contours of MLW data over the period 1807-2006 are shown superimposed on a recent aerial photograph of the estuary. The MLW data presented by ABPmer (2008a) in broad terms shows that there has been ongoing erosion of the MLW line since 1870 but also suggests that the rate of erosion increased significantly after 1975[3]. The rates of mudflat recession are highest at the mouth of Lymington Harbour (consistent with the effect of natural wind waves) and the channel between Harpers Post and Bag of Halfpence. This seems to be accepted by all parties. What seems not to be accepted by all parties is how the MLW level has changed from 1994 onwards.

The evidence presented in Figure 5 of ABPmer (2008a) was used by ABPmer to make the case that while there had been a recession of the MLW contour between 1975 and 1994 there had not been any recession over the period 1994-2006. This point, if substantiated, is important because ***if*** the MLW contour has not moved over the period 1994-2006 ***then*** it could be argued that the C Class Ferry has had no measurable effect on intertidal erosion over the same period. However, as noted below, other organisations have also investigated the data and come to different conclusions:

- NFDC (ABPmer, 2008a) based on surveys undertaken in 1993, 1995, 1999 and 2001 found erosion of between 38m and 78m between Harpers Post and Enticott.
- NFDC (ABPmer, 2008a, citing A Colenutt *pers.comm.*) suggest that the position of MLW has not varied significantly between 2001 and 2007.
- Black and Veatch (2008) reviewed the available evidence for studies concerning the proposed wave protection structure and present evidence (Figure 6.20 and 6.21 of the report) that MLW continued to recess between 1992 and 2002 and that the saltmarsh toe has continued to be eroded to the present day.

The 13 January 2009 meeting allowed discussion between Black and Veatch, ABPmer and Lymington Harbour Commissioners and identified that Black and Veatch had mainly relied on the analysis of New Forest District Council (Norman Cox, Black and Veatch, *pers.comm.*, 2009), which used data from their digital terrain model. The extent to which this NFDC data could be relied upon was unclear but the NFDC finding that erosion of between 38-78m since 1993 between Harpers Post and Enticott was of concern. To test confidence in the 1994 survey (which it was considered was a key result) another survey, the 1993 survey, was analysed. The results are shown in Figure 1 of ABPmer (2009).

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[3] There is some discussion as to whether the 1975 survey actually dates from 1975 or from the 1960's. Whilst this uncertainty needs to be resolved, it does not change the conclusion resulting from the use of this data – although potentially one might need to reduce the inferred rate of change of area above MLW since 1975.

The 1994 contour is shown with the commentary that this result corroborates the idea that there has been no recession of MLW after 1994. However, this conclusion is not substantiated by the 1993 survey contour which is sufficiently different from the 1994, 2006/2008 contours to indicate that erosion has taken place since 1993. An analysis of the change in areas above MLW (based on Figure 1 of ABPmer, 2009) is summarised in Table 3 below. The table shows that there has been a **recession** of 2ha of intertidal area above MLW since 1993, half this occurring north of Pylewell. However if one interprets a change based on the 1994 contour the change between 1994 and 2008 is 0.5ha **of accretion**. This result of accretion is possible but considered less likely especially given the change between 2006 and 2008 is for further erosion.

Table 3 Change in area between charted Mean Low Water contours (based on Figure 1 of ABPmer, 2009) – positive values indicate loss and negative values gain

Date	Zone	loss (ha)[4]
1907-75	Harpers Post South to Pylewell	1.9
	Pylewell to No.7 Post	0.5
1975-93	Harpers Post South to Pylewell	4.0
	Pylewell to No.7 Post	2.3
1975-94	Harpers Post South to Pylewell	5.2
	Pylewell to No.7 Post	3.6
1993-2008	Harpers Post South to Pylewell	0.9
	Pylewell to No.7 Post	1.1
1994-2008	Harpers Post South to Pylewell	-0.3
	Pylewell to No.7 Post	-0.2
2006-2008	Harpers Post South to Pylewell	0.6
	Pylewell to No.7 Post	0.5
1975-2008	Harpers Post South to Pylewell	4.9
	Pylewell to No.7 Post	3.4

Table 3 shows the changes in area above MLW between 1907 and 1975 (assumed to represent the data available before the C class ferry was introduced in 1973) and between 1975 and 2008 (assumed to represent the period after the ferry was introduced). The table shows that there is a much larger loss of area above MLW after 1975. When the rate of change in total area is considered the summary data in Table 4 shows that the rate of loss of area above MLW after 1975 (between Harpers Post South and Post 7) is six times greater than that prior to 1975.

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[4] The figures shown in Table 3 differ from those shown in Table 2 of the previous version of this report because here the data only refers to the area from Harpers Post South to No.7 post. The change in area analysed is due to the more limited data coverage of the 1993 survey. However, there is a further loss of designated intertidal area (since 1975) on the east side of the channel upstream of Harpers Post South of around 1.2ha.

Table 4 Change in area between charted Mean Low Water contours (based on Figure 1 of ABPmer, 2009)

Date	Zone	Loss (ha/yr)
1907-75	Harpers Post South to Pylewell	0.03
	Pylewell to No.7 Post	0.01
1975-93	Harpers Post South to Pylewell	0.22
	Pylewell to No.7 Post	0.13
1993-2008	Harpers Post South to Pylewell	0.06
	Pylewell to No.7 Post	0.07
1975-2008	Harpers Post South to Pylewell	0.15
	Pylewell to No.7 Post	0.10

The loss of intertidal area above MLW presented in Table 2 suggests an increase in erosion rate after 1975. However, in our view the loss south of Pylewell can be attributed predominantly (but not exclusively) to wind waves. Similarly not all the loss north of Pylewell can be attributed to ferry activity – wind waves and yachting activity may also have contributed. An estimate of the loss directly resulting from ferry activity is presented in Chapter 5.

2.4.2 *Error analysis*

ABPmer (2009) state that the spatial error in identifying the MLW contour after 1965 is +/- 3.5m. They further state that the spatial error in identifying the MLW contour from bathymetric charts is +/- 10m. These errors in part correspond to the random error of measurement - the error resulting from underestimating or overestimating individual depth measurements - and the slope of the sea bed over which they were measured. For a large number of measurements (as is represented by a contour or an area) the average error becomes less significant and on this basis, over periods of more than 5 years one can effectively disregard this random error when using the data. However, one of the main sources of error in surveys is not random but constant and occurs when the survey measurements are tied into Chart Datum by accounting for the tidal level at which they were measured. This source of error applies to the whole of a survey. It can result in individual surveys undertaken at similar times being very different to each other, such as is observed for the MLW contours derived from the 1993 and 1994 datasets. When this occurs it is prudent to apply less certainty to survey results which are "outliers" when compared with other surveys. On the assumption that the progression in time of contours is most likely to show consistency, in our view the 1994 contour should be associated with more uncertainty than the 1993 contour.

2.4.3 *Discussion*

The loss of intertidal area since 1975 outlined in Table 3 could in theory arise from a number of different sources:

- Tidal currents;
- Wind-generated waves;
- Ferry activities.

As for the discussion on changes to CD it is considered that ship wash generated by the ferries is not an important effect compared to the others in the list above and the potential effects of smaller craft are smaller and less well described than those listed above.

Tidal currents

Peak tidal currents occur on the late ebb on spring tides (around tidal levels of +1.4mCD) and have been measured as 0.5m/s between Cocked Hat and Pylewell and 0.2m/s in Horn Reach (BMT SeaTech, 2008a, Ian Dand, BMT SeaTech, *pers.comm.*, 2008, Ryan Willegers, Lymington Harbour Commissioners, *pers.comm.*, 2008). The shear stress imposed by the measured currents between Cocked Hat and Pylewell at peak ebb at around MLW (i.e. 0.4m water depth at a tidal level of +1.4mCD) over a muddy bed is, using Equation 1 (see Section 2.3.2), is $0.52N/m^2$. This result indicates that mean spring tides can “just” result in erosion of the (consolidated) bed at MLW. These shear stresses are considerably less than can occur from drawdown (see Section 2.8). The period over which these peak speeds are experienced is only in the region of 15 minutes, on 10% of tides and the shear stress applied is only just larger than the erosion threshold of consolidated material.

Considering this result and the fact that the scale of changes in the MLW contour greatly exceed the changes that have occurred at CD (which would be unexpected if tidal currents were the cause of erosion), and the fact that the highest rates of recession occur opposite Bag of Halfpence, which cannot be explained by considering tidal currents, it is concluded that tidal currents are not the main driver for recession of the Mean Low Water contour.

As discussed in Section 2.3.2 it is possible that, historically, tidal currents were larger in the river than they are now. The discussion of the importance of the effects of the marina construction made in that section are equally applicable here.

Waves

The discussion regarding waves in Section 2.3.2 is equally applicable when considering change at MLW. As a result waves are not and have not been the largest driving force occurring on the lower part of the intertidal areas. It is acknowledged, however, that waves are an ever-increasing factor in intertidal erosion and that waves may be the dominant factor in erosion of the upper part of the intertidal profile inside the estuary.

C Class Ferries

As discussed in Section 2.8 the very shallow currents induced by the drawdown over the intertidal areas can generate high shear stresses at tidal levels around Mean Low Water. On the basis of return currents that can be inferred from ferries travelling at 5 knots at Cocked Hat, 6 knots at Bag of Halfpence and 7 knots at Seymours Post at a tidal level of +1mCD a drawdown current in excess of 0.5m/s can reasonably be inferred (see Section 2.8) which would result in shear stresses of $0.7\text{-}1N/m^2$ – significantly more than is required to erode the bed and significantly more than the stresses induced by tidal currents and/or waves.

The erosion caused by this mechanism can be estimated using Equation 1. If the shear stresses identified above are assumed to occur for a period of 30 seconds on each ferry trip (of which there are 20,000/yr), and if only those journeys when the tidal level is around Mean Low Water (assumed to be an hour per tide) are considered, and if the erosion threshold at MLW is assumed to be $0.5N/m^2$, and if the density of the seabed of the lower intertidal profile is assumed to be $700kg/m^3$, and the imposed shear stress is $0.7\text{-}1N/m^2$, then the depth of vertical erosion occurring over 33 years (1975-2008) is calculated to be around 1m. The resulting recession rate, assuming a slope of 1:50, is of the order of 20-55m (on either side of the channel), and double this for a slope of 1:100, which is of a similar order to the observed recession rates. The recession at the location where ferries pass is larger than this distance (on the east bank) but is easily accounted for by the effects of ferries passing.

It is probable that at times and in certain locations the ferry can have generated an impact further up the intertidal profile. Records of the C Class vessel travelling at 6 knots between Harpers Post and Cage Boom at a tidal level of +1.6mCD are presented in Eagle Lyon Pope (2006) and at over 8 knots at Tar Barrel. At these speeds Schijfs diagram (PIANC, 1987) would suggest drawdown of 20cm (which equates to high shear stress values from the associated drawdown-induced currents) even with tidal levels close to Mean Water Level.

Ferries pass in the Harbour at between Pylewell and Bag of Halfpence (Ryan Willegers, Lymington Harbour Commissioners, *pers.comm*., 2009). This reach of the estuary is associated with the highest rates of recession of MLW on the east bank. When the ferries pass the blockage of the channel is double that of normal operations and therefore the currents induced by drawdown will typically be around double that of the corresponding drawdown from a single ferry passage. As a result the shear stress on the intertidal resulting from ferry passage is very high and will be potentially significant at levels above MLW, possibly even large enough to affect the toe of saltmarsh. This is considered to be the most likely reason for the large rates of recession of mudflat that have historically been seen along this stretch of the Harbour.

It is concluded that the most likely cause of the recession of the MLW contour north of Pylewell is ferry activity.

2.5 LYMINGTON RIVER ASSOCIATION (2008)

Lymington River Association (LRA) presented evidence based on aerial photography to show that the saltmarsh cliff between Harpers Post and Bag of Halfpence has receded at a much higher rate over the period 1973-1999 (2.8m/yr) compared to the rate over the period 1942-1973 (0.8m/yr). Whilst this increase in saltmarsh recession has occurred at the same time as the introduction of ferries there has also been an increase in wave activity within the Harbour, which would also lead to an increase in saltmarsh recession. Disentangling the effects from waves and ferry drawdown would require further wave modelling and measurements of drawdown during ferry passage (and potentially measurements of the turbulence and current flow induced by thrust jets at higher tidal levels) which are beyond the scope of the present study. However, it is has been demonstrated (in Section 2.4.3) that there is a least one mechanism by which ferries could have historically have led to erosion of the saltmarsh, albeit in a local area, and that is from the drawdown effect when ferries pass.

2.6 HR WALLINGFORD (1991)

In 1991, as input to discussions regarding the introduction of a larger ferry at that time, HR Wallingford undertook a study on behalf of Lymington Harbour Commissioners (LHC) of the relative magnitude of the factors affecting erosion of the mudflats and channel in the Lymington Harbour (HR Wallingford, 1991). This study focussed on potential effects of the C Class ferry in the stretch of the Harbour known as Horn Reach and made an assessment of which erosive processes – ferry-induced or natural - were dominant. The study considered the potential for wind waves, tidal currents, ship wash, drawdown and return currents to have an erosive effect on the intertidal area. The study concluded that, in Horn Reach at least, tidal currents and wind waves were insufficient to erode the intertidal mud flat but that speeds of up to 1m/s were generated over the mud flat by ferry-induced drawdown and return currents which would cause erosion. A quantification of this effect came to 20m of horizontal recession over a ten year period, or 2m/yr, which agrees with the rates of observed erosion that have been observed in this part of the Harbour after 1973 (See Figure 1, ABPmer, 2009).

The important aspect regarding the HR Wallingford measurements is that, because the field measurements were conducted in Horn Reach where tidal currents and wave activity are low, any natural erosion effects contributing to erosion could be effectively ruled out as being minor effects compared to those of the ferry. In general, as you go further seaward the relative impacts of the ferry will reduce as compared with natural wind wave action but this does not mean there has been no effect from the ferry – just that other processes have additionally contributed to the erosion process.

The HR Wallingford study tested samples of the sediment from the mudflat in Horn Reach in the laboratory to derive their erosion threshold. The laboratory measurements found that mud on the lower part of the flat had an erosion threshold of around $0.5N/m^2$ while mud from higher up on the mudflat had higher erosion thresholds (0.8-$3.8N/m^2$). In the present study it is assumed that the value of $0.5N/m^2$ is generally representative (of the lower mudflat) throughout the estuary.

It is possible that since these measurements were taken in 1991 the erosion of the mudflat has uncovered sediment which is harder to erode. Alternatively as the sediment is uncovered the action of biology, waves and currents may generate a mudflat surface with similar properties. It is not known which of these scenarios is true for Lymington Harbour.

2.7 MEASUREMENTS OF CURRENTS GENERATED BY RETURN CURRENTS IN SHALLOW WATER

This section is revised from the previous version of this report following further discussion with Ryan Willegers of Lymington Harbour Commissioners and Ian Dand of BMT SeaTech.

In recent months (the date is not specified in BMT SeaTech, 2008b) LHC measured the currents induced over the mudflats by deploying a current meter from a small dinghy located in shallow water on the lower part of the mudflat near the Cocked Hat buoy. A number of measurements were taken of natural currents and ferry passage (see Table 5).

The measurements were made in around 40cm of water (Ryan Willegers, LHC, *pers.comm.*, 2008). Because of this the measurements are made close to, but in greater water depth than, the very shallow water where the sheet of water passing over the mudflat as a result of the drawdown effect. However, the deeper water means that the effect of return currents induced by the ferry motion are also occurring. To some extent therefore these measurements represent a combination of drawdown and return currents but will henceforth be referred to (for brevity) as return currents.

One of the most notable measurements was of a ferry moving at 5 knots north of Pylewell (BMT SeaTech, 2008b) with a tide level very near to Low Water Springs. This speed is not typical of ferries in this location near Low Water but was requested by LHC to try to replicate the nature of ferry movement that regularly occurred prior to 2007. Actually a 6 knot vessel speed was requested but this proved impossible to achieve at this stage of the tide. The return current measurements for this ferry passage had to be aborted because the drawdown effect was so high that the dinghy was nearly run aground. However the effects observed during this time, of large turbulence and suspended sediment plumes were sufficient to indicate that mass erosion events will have occurred prior to 2007. Owing to the hydrodynamics of navigation at Low Water the largest effects experienced from return currents would probably occur when the ferry is travelling at water levels above Low Water Springs when the ferry is able to sail at speeds in the region of 5-6 knots (Ryan Willegers, LHC, *pers.comm.*, 2008).

Table 5 Return currents measured by LHC as a result of passage by C class vessels (from BMT SeaTech, 2008b)

Class	Tide height (m CD)	Ferry direction	Actual speed of ferry (knots)	Measured current speed (m/s)	Induced shear stress at 40cm depth (N/m^2)	Induced shear stress at 0mCD contour (N/m^2)
C	1.8	Outbound	5.8	0.18	0.08	0.06
C	1.1	Outbound	6.5	0.47	0.57	0.45
C	0.6	Inbound	5.1	Effects too high to measure	-	-
C	0.3	Outbound	4.0	0.51	0.67	0.72
C	0.3	Inbound	4.5	0.21	0.11	0.12

The shear stresses in Table 5 are calculated using the following equation (Soulsby, 1997):

$$\tau = \rho \left\{ \frac{0.4}{ln\left(\frac{H}{z_0}\right)} \right\}^2 u^2 \qquad (1)$$

Where ρ is the density of seawater, 1025kg/m^3;
H is the water depth;
U is the depth-averaged current speed; and,
z_0 is the physical roughness length associated with a silty sea bed, which takes a value in the region of 0.05mm (Soulsby, 1997) based on measurements of natural sea beds.

Some aspects of the results in Table 5 require additional explanation and setting in a historical context. Firstly it should be noted that the return current measurements were made at Cocked Hat Post on the inside of the bend. It would be intuitive that outgoing vessels being closer to the measurement location would register higher effects that vessels which are incoming and further away. Although the overall assumption in the BMT report is that at Cocked Hat the effects of vessel disturbance are similar on each bank, it was recognised that there was tendency for outbound vessels to “hug the inside of the bend” (BMT SeaTech, 2008b). By implication one would imagine a tendency for inbound vessels to drift slightly to the outside of the bend. The effect of this small but important difference in vessel line is shown by the vessel measurements at 0.3mCD. Both vessels are travelling at similar speeds in almost no current flow, yet the return current measured on the inside of the bed is 2½ times larger for the outbound vessel. It is concluded that there is a strong likelihood that the measurements for inbound vessels significantly underestimate the return current effect felt on the eastern bank. The effect of the return current on the eastern bank induced by the incoming ferry travelling at 5.1 knots may have therefore been even larger than that induced on the west bank.

Secondly, the measurements of return current at tidal levels of +1.1mCD (at 6.5 knots) and +0.6mCD (at 5.1 knots) represent a ferry travelling fast at a relatively high water level, but not causing a current speed greater than 0.5m/s, and a ferry travelling at a speed which would not normally be adopted by a ferry so near to Low Water (Ryan Willegers, Lymington Harbour Commissioners, *pers.comm*, 2009) but which causes return currents too high to be measured. These measurements do not quite capture what may be the most relevant scenarios - vessels travel at more than 6 knots at water levels between +0.6mCD and 1.1mCD. Previous to 2007 it was reportedly common for ferries to sail at speeds of up to 6 knots north of the wave screen and up to 8 knots south of the wave screen (Ryan Willegers, Lymington Harbour Commisioners, *pers.comm*., 2008). Eagle Lyon Pope (2006) records such a ferry passing at 6.4 knots at a tidal level of +0.8mCD on the ebb tide past Cocked Hat. On the basis of the recorded measurements and methods for estimating return currents, such as Schijfs diagram (PIANC, 1987), it is reasonable to assume the induced return currents would be of the order of 0.7m/s which would generate shear stresses in 40cm of water and at 0mCD of over 1N/m^2. Moreover, it should be remembered that in the 1970's the cross-section of the channel was smaller and return currents would have been higher. It is assumed on the basis of the anecdotal and reported evidence that this scenario would be a relatively common event for ferries travelling at tidal levels of around +0.8mCD.

In addition to the comments above it should be noted that the measurements do not reflect the return currents that occur when ferries pass in the river. This effect will be localised around the area between Pylewell and Bag of Halfpence but the return currents would be expected to be at least twice those experienced in other parts of the river because there is twice the blockage.

2.8 ESTIMATION OF DRAWDOWN CURRENTS OVER THE MUDFLAT

This section is revised from the previous version of this report following further discussion with Ryan Willegers of Lymington Harbour Commissioners and Ian Dand of BMT SeaTech.

Table 6 shows the calculated drawdown speeds (BMT SeaTech, 2008b) over the mudflat resulting from C class ferry passage at Harpers Post South (Harpers S), Cocked Hat and at Pylewell. The current speeds across the mudflat are inferred from the measured speed of vertical change and the slope of the intertidal. The resulting shear stress is estimated on the basis that the depth of water when the drawdown currents are experienced is in the region of 10cm. The measurements of drawdown occurred on the south bank at Harpers Post South, the west bank at Cocked Hat and on the East Bank at Pylewell.

Table 6 Estimated drawdown-induced current speed over the mudflat and bed shear stress near Cocked Hat resulting from C class ferry passage (BMT SeaTech, 2008b)

Area	Tide height (m CD)	relative speed of ferry (knots)	Estimated current speed induced by drawdown (m/s)	Drawdown height (mm)	Induced shear stress (N/m^2)
Harpers Post South	0.53	3.1‡	0.09	33	0.03
	0.53	3.1‡	0.11	47	0.05
	0.59	4.0‡	0.30	81	0.34
Cocked Hat	1.35	4.3‡	0.15†	38†	0.08†
	0.72	4.5‡	0.15†	55†	0.08†
	0.72	5.1‡	0.40*	154*	0.60*
Pylewell	0.71	4.9	0.20*	95*	0.15*
	0.82	4.9	0.34	92	0.44
	1.13	6.3	0.31	100	0.36
	1.07	6.4	0.39	98	0.57

** Underestimated due to location of monitor on inside of bend and largest effect of ferry occurring on outside of bend*

† Direction of ferry (incoming/outgoing) unknown, vessel speeds shown are speed over ground. In addition these drawdown values and speeds appear anomalously low and less emphasis should be placed upon them (Ian Dand, BMT SeaTech, pers.comm., 2009)

‡ *Vessel speeds shown are speed over ground*

As discussed in BMT SeaTech (2008b) the measurements of drawdown at Pylewell are significantly affected by whether vessels are inbound or outbound because the outbound vessel adopts a line on the west side of the navigation channel and the inbound vessel adopts a line on the east side of the navigation channel. This in no way detracts from the data for its primary use in evaluating the safety issues corresponding to passage of C class and W class vessels. However, when using the data to infer potential impact on *adjacent* intertidal areas the effects of outbound vessels are underestimated. Measurements of W class vessels indicate that drawdown from outbound vessels at Pylewell could be under-estimated in these measurements by up to a factor of 3.

In addition there is evidence that the drawdown effect of inbound vessels (which will have their largest effect on the east bank) may also be underestimated in the measurements at Cocked Hat. The Lymington Harbour Commissioners website and Tide Tables show an aerial photograph with an inbound ferry moving between Bag of Halfpence Post and Cocked Hat Post. The drawdown effect can be seen on the east bank due to the presence of the breaking wave as the water flows back up the bank after the initial lowering of the water level. However, there is not a corresponding disturbance on the west bank. This observation suggests that the result of the incoming ferry travelling at 5.1 knots is significantly underestimated (as well as any other results of incoming ferries measured at Cocked Hat).

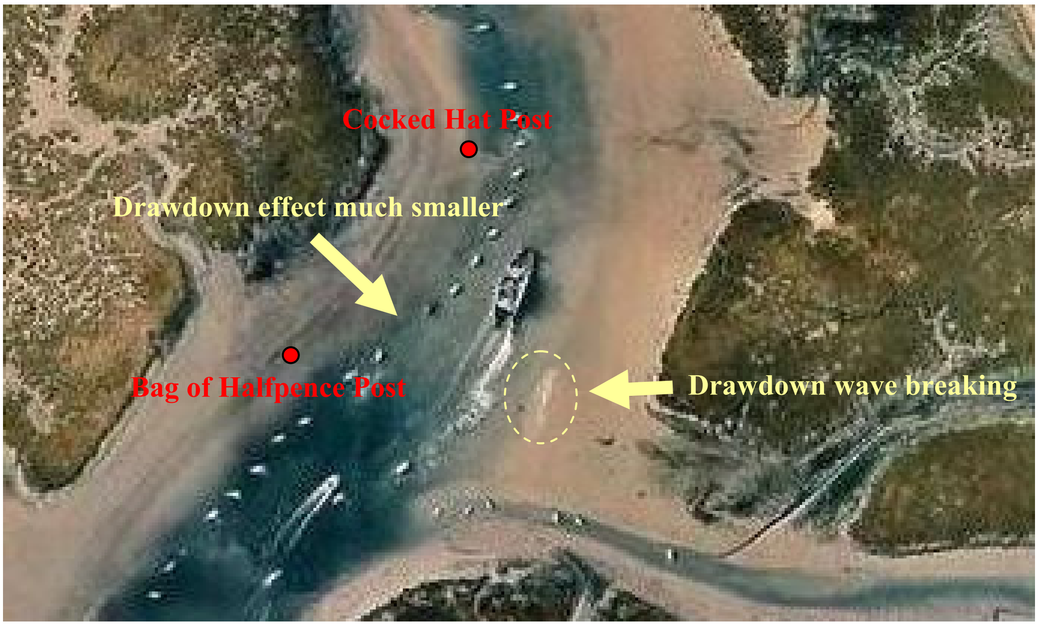

Figure 2 **Aerial photograph showing effects of drawdown from inbound ferry (Photograph shown by kind permission of Lymington Harbour Commissioners)**

The results show that the drawdown-induced currents are less than 0.5N/m^2 indicating that at the speeds measured the drawdown-induced currents are insufficient to erode the bed (assuming an erosion threshold of 0.5N/m^2, see Section 2.6). However, as noted above, previous to 2007 it was reportedly common for ferries to sail at greater speeds. Eagle Lyon Pope (2006) present speeds measured aboard the *Caedmon* which indicate that, at water levels of 0.75-0.8mCD, C class vessels routinely travelled at 5 knots past Harpers Post South, 6 knots past Cocked Hat and routinely travelled at 7 knots past Pylewell/Tar Barrel. The drawdown effect varies with the square of the vessel speed relative to the tidal flow. Therefore the current speeds induced over the mudflat by the drawdown effect would be considered to vary with the square of the vessel speed relative to the tidal flow. Thus there is every expectation that the drawdown effect, as experienced now in response to C Class ferry passage, is significantly reduced from the levels seen over the period 1973-2007.

Using standard drawdown calculations (Schijf's diagram, PIANC, 1987) and the knowledge that drawdown is proportional the square of the relative vessel speed, it can be estimated that previous to 2007 (at these tidal levels) the induced drawdown would be more than 0.5m/s at all these locations corresponding to induced shear stresses of at least 0.7N/m^2 and probably as much as 1N/m^2.

In addition it is necessary to consider the effects of ferries passing between Pylewell and Bag of Halfpence. Ferries passing would double the blockage in the channel and so at least double the drawdown and resulting current speed over the intertidal areas. This would produce shear stresses of at least four times the Pylewell values shown in Table 6.

The effect of ferries moving at high speeds south of Pylewell can be also inferred by use of Schijf's diagram. If a blockage ratio of 5% is used, a channel water depth of 5m and a vessel speed of 7 knots the drawdown resulting would be of the order of 20cm.

Using the shear stresses derived from the measured drawdown as a guide 20cm would be equivalent to a shear stress of around 1N/m^2.

2.9 VOITH SCHNEIDER PROPELLER

The rotation of the blades of the Voith Schneider Propeller (VSP) causes considerable turbulence and this turbulence, potentially, scours the bed immediately below the propeller units. This fact appears to be agreed by all parties and is considered to be the predominant reason why there has been erosion of the channel bed. Lymington River Association (2008) cites an excerpt from Jean Chitty's "The River is within us" published in 1983, pp 66-8, quoting Mr. P. W. Penny, Manager of Sealink ferries:

> *"The Cenwulf and the Cenred are sister ships and are absolutely identical and there is also the smaller Freshwater. They all have this Swiss Voith Schneider propulsion, with a unique type of propeller which can be feathered as in an aircraft. There is one propeller at each end and you can literally run the ship round on the spot and also crab her sideways. So these are ideal for this type of work in the river which is very restricted and where there are many yachts. Another advantage is that in the river, where there is a lot of silting, the propellers skim and scour the bottom. Whereas before 1965 we had to have a regular dredging programme every four or five years, we have not needed to dredge since then."*

The scouring effect of the VSP is caused by a combination of the turbulence from the rotation of the propeller, the backflow around the hull of the ferry caused by drawdown at the ship and the thrust jet, especially as it is directly underneath the hull of the vessel.

ABPmer (2008a) report that the scouring effect of the ferries has led to the deepening of the low water channel of around 0.5m (although the amount of deepening varies in different locations). This does not seem to be disputed by the various parties. The locations of deepening appear to be associated with the path that the ferries normally take (Ian Dand, BMT SeaTech, *pers.comm.*, 2009), however the scouring effect associated with the propellers would be unlikely to impact on intertidal areas unless the ferry was forced to come into very shallow water, which is assumed to be rare. However, on occasion the thrust jet can be directed towards intertidal areas and this is discussed in Section 2.10 below.

2.10 EFFECT OF THE THRUST JET ON INTERTIDAL AREAS

The Voith Schneider Propeller results in a jet of water being discharged from the rear of the vessel. Measurements in conditions which attempt to replicate those of ferry operations under normal sailing in the river indicate that the speed of this jet (relative to the speed of the vessel) varies from 0.5m/s to 1.5m/s (BMT SeaTech, 2008b).

When the ferry is underway the vessel is moving in the opposite direction to the jet the effect of the jet in terms of current speed over the bed tends to be reduced within a relatively short distance, although the turbulence of the jet may eminate further from the vessel. The exception to this might occur at the bend between Bag of Halfpence and Cocked Hat. As the ferry turns it needs to adopt an angle to the flow to counteract the affects of drift. This angle is more likely to turn the thrust jet onto the foreshore. This affect can be seen in the aerial photograph presented on the Lymington Harbour Commissioners website and Tide Table booklet (see Figure 3).

Figure 3 **Aerial photograph showing C Class ferry thrust jet interacting with foreshore (Photograph shown by kind permission of Lymington Harbour Commissioners)**

The effect of jet-induced currents on erosion of the sea bed is more than an order of magnitude higher than an equivalent depth-averaged tidal current: the shear stress produced by the jet is approximated by of $50u_j^2$ (where u_j is the jet-induced current velocity at the bed, Blaauw and van de Kaa, 1978) while the shear stress over mud in (for instance) 1m of water is around $1.6u_w^2$ (based on equations presented in Soulsby, 1997, where u_w is the depth-averaged current speed). As a result even a relatively small jet-induced current could cause erosion of the mudflat. It must be said that attenuation of the jet current speed would be expected between the ferry and the mudflat but once the jet has touched the surface or bed the attenuation can be relatively slow, reducing inversely with distance to the power of 0.6, or if there is also interaction with the bank, 0.25 (Fuehrer et al, 1987). Indeed the measurements of field and laboratory modelling of the thrust jet presented in ABPmer (2008a) and BMT SeaTech (2008b) show that whilst the surface layer of the jet is attenuated there is little or slow attenuation of the jet speed at a depth of 1m from the surface, at least at the distance where the measurements end.

Historically incoming ferries have waited adjacent to Pylewell to enable ferries to pass at the agreed location. When waiting the ferries hold station against the tide and wind. For stronger westerly and south westerly winds the thrust jet is directed towards the bank. There is no direct evidence (to the author's knowledge) of the magnitude of the thrust jet impacting on the shallow intertidal. However, it must be noted that it remains a significant possibility and the effects, if such an impact does routinely occur, could be considerable.

2.11 INDIRECT EFFECTS OF DEEPENING

The deepening of the channel which has historically occurred since the 1970's, and which (it is argued) can be predominantly attributed to ferries, may have had a wider effect on Lymington Harbour because of potential changes in tidal currents and tidal asymmetry. It would normally be expected that deepening would tend to lengthen the flood tide, and shorten the ebb tide, accentuating ebb tide currents and reducing flood tide currents (Dronkers, 1998) and perhaps reduce tidal currents slightly as a whole. However to be sure of this effect at Lymington it would be necessary to undertake computational flow modelling of the Harbour system.

The effect of larger ebb tide currents would tend to be to export sediment from the Harbour system as a whole. Again the significance of this effect cannot be known without computational modelling.

2.12 RECESSION OF BANKS ALLOWING GREATER WIND-WAVE ENERGY INTO THE HARBOUR

Considering all the evidence presented above it is concluded that the dominant influence contributing to mudflat erosion landward (north) of Pylewell can be attributed historically to the C Class ferry. With distance seaward of this position it is increasingly likely that wind waves have dominated the erosion process and the effect of the ferry becomes less significant in a relative sense. However, the erosive effect of the C class Ferry prior to 2007 (which can be identified in the inner harbour due to the relatively small natural contributions) would also be expected to be causing erosion of a similar order closer to the Harbour mouth although this may be masked to some degree by the effect of wind wave erosion. The channel is wider and deeper nearer the harbour mouth but the speed of the C class vessel has historically been greater here, even exceeding 9 knots at times past Posts 5 and 6 (Eagle Lyon Pope, 2006). Therefore it seems likely that, in particular, the recession of the eastern bank at Pylewell, and, potentially, of the western bank between Posts 6 and 7, can be attributed to some degree (but by no means primarily) to the contribution of the C class Ferry. The configuration of the shoreline at the mouth has historically limited the wave fetch from the south so the recession of the shoreline over time has led to greater wave penetration within the estuary.

2.13 SIMILARITY OF LYMINGTON TO OTHER HARBOURS WITH EROSION OF SALTMARSH

There is a current debate as to how appropriate it is to compare the erosion of mudflat and saltmarsh within Lymington Harbour with erosion of similar systems in other parts of the Solent. In particular the comparison is often made with the Bealieu Estuary, immediately to the east of Lymington Harbour. This comparison is particularly relevant because Beaulieu is closely situated to Lymington (and therefore has some real similarities in the general nature of the site), and is experiencing high rates of erosion of saltmarsh but does not have a ferry service. If the nature of saltmarsh and mudflat erosion were to be similar in both estuaries then this might lead to the conclusion that the effect of the ferry is of a lesser significance than the effect of other factors, such as natural wind waves.

When the changes in morphology of the most exposed parts of the estuaries are compared Lymington Harbour and Beaulieu Estuary are very similar. They are both experiencing similar rates of saltmarsh die-off and disintegration by wind waves. However, further inland where the effects of wind waves are reduced, the morphological changes at Lymington are not the same as Beaulieu. At Beaulieu the intertidal erosion does not result in smooth flats like Lymington but in exposed remnants of the saltmarsh cliff. This difference implies other factors are influencing the erosion in Lymington Harbour besides wind waves.

2.14 CONCLUSION

- The evidence is that the rate of erosion of the mudflat alongside the navigation channel within Lymington Harbour has increased from around the time that the C class ferry was introduced. Since this time erosion of the Low Water channel itself has occurred.
- It is stated in ABPmer (2009) that there has been virtually no recession of the Chart Datum contours on either side of the Low Water channel – but this is not backed up by the evidence available from charts.
- It is further stated in ABPmer (2008a, 2009) that there has been no movement of the MLW contour since 1994. This conclusion is suggested by the 1994 survey MLW contour but not supported by the 1993 survey MLW contour. Of the two the 1993 survey result seems most plausible in our view and in any case the precautionary principle suggests that the 1993 survey result (which suggests a greater historical impact from ferries) should be the basis for decisions on impact on designated habitat until further information indicates otherwise.
- Recent measurements and observations undertaken by Lymington Harbour Commissioners, in combination with evidence of the speeds at which ferries travelled within the Harbour previous to 2007, suggest that the combination of drawdown and return currents from ferry movement would have led to significant erosion of the lower part of the mudflat. This concurs with the analysis undertaken by HR Wallingford in 1991. Evidence of interaction of the thrust jet with the foreshore on the outside of the Cocked Hat/Cage Boom bend suggests an additional mechanism for erosion to have occurred as a result of ferry passage.
- The effects of tidal currents and wind waves generate levels of bed shear stress which are significantly less than those generated by ferries and which are less (except on extreme tides) than the estimated threshold for erosion on the lower mud flat.
- There is therefore both circumstantial evidence for the observed erosion in the inner parts of the Harbour having been caused by the C class ferry and a measured mechanism by which this ferry can have caused the erosion. It is therefore most likely that the erosion of the mudflats observed since the 1970's, at least upstream (landward) of Pylewell, is primarily a function of the C Class ferry activity.
- Downstream (seaward) of Pylewell the increasing effect of natural wind waves have probably dominated the erosion process. However, since the ferry has contributed to upstream erosion it is also likely to have contributed to erosion in this part of the Harbour.

3. *Evidence for potential impact arising from current ferry activity*

3.1 INTRODUCTION

Since April 2007 the C Class ferry speeds have been monitored by Lymington Harbour Commissioners using a Global Positioning System (GPS) and this has led to strict adherence of the Harbour restrictions on vessel speed of 6 knots south of the wave screens and 4 knots north of this point in Horn Reach. As a result it would be expected that some of the erosive effects of ferry passage observed since 1973, in particular drawdown, backflow and return currents, which are strongly related to vessel speed, would diminish. This section explores how the C Class ferry may (or may not) be contributing to erosion of the mudflat following these speed reductions.

3.2 RETURN CURRENT EFFECT

The highest return current speed measured close to the bank for a C Class vessel in the recent trials was measured to be 0.51m/s by LHC at Cocked Hat at very Low Water (+0.3mCD) for a vessel speed of 4 knots passing Cocked Hat (BMT SeaTech, 2008b). This speed was similar to naturally-induced current speeds at the same location of 0.5m/s at peak ebb (Data provided by Ian Dand, BMT Seatech, and Ryan Willegers, LHC, 2008). Although return current speeds of this magnitude are still sufficiently high to erode the bed at CD, the resulting rate of erosion would be much reduced compared to the historical context. As a result the rate of erosion of Chart Datum resulting from return currents is expected to many times smaller than the historical rate.

The exception to this general conclusion is the effect of return currents that occur when ferries pass around the area between Pylewell and Bag of Halfpence. The return currents would be expected to be at least twice those experienced in other parts of the Harbour and it would be less likely that ferries would pass significantly quicker prior to 2007 than they do today. In this section of the estuary the rate of erosion of Chart Datum would be expected to continue at something like the historic rate.

3.3 DRAWDOWN

The largest drawdown-induced speed measured while the C Class ferry was sailing at appropriate speeds is 0.4m/s (BMT SeaTech, 2008b and Table 6) which induces a shear stress of around $0.6N/m^2$. This is much reduced from the erosion events that are likely to have occurred prior to 2007. However, ferries passing between Bag of Halfpence and Pylewell will induce much larger current speeds and shear stresses over the local mudflats. Thus there will still be erosion of the mudflat at Mean Low Water (MLW) as a result of C Class Ferry activity but it is to be expected that erosion of the lower mudflat will still occur but at a much slower rate.

The exception to this general conclusion is the effect of drawdown-induced currents that occur when ferries pass around the area between Pylewell and Bag of Halfpence. The drawdown currents would be expected to be at least twice those experienced in other parts of the Harbour and it would be less likely that ferries would pass significantly quicker prior to 2007 than they do today. In this section of the estuary the rate of erosion of MLW would be expected to continue at something like the historic rate.

3.4 SHIP WASH

The ship wash created by the ferries is of the order of several centimetres in height (BMT SeaTech, 2008b) and therefore does not represent, in our view, a process that will cause erosion of the same significance as other processes considered in this study.

3.5 UNDERKEEL TURBULENCE AND BACKFLOW INDUCED BY THE VOITH SCHNEIDER PROPULSION SYSTEM

As stated in Sections 2.9 and 2.10, the Voith Schneider system creates considerable turbulence around the propeller units and this turbulence is combined with the effect of backflow induced by the drawdown process and the thrust jet. The turbulence from this system has effectively kept the channel bed free from deposits of fine sediment and led to the deepening of the channel by around 0.5m over the last 20 years. Although the bed is now very gravelly it would be expected that deepening would continue to occur as the turbulence/backflow/thrust jet from the ferry is still able to disturb the gravelly bed and erode the bed underneath.

3.6 THRUST JET

As discussed in Section 2.10 the thrust jet interacts with the foreshore around the turn at Cocked Hat/Cage Boom. The significance of this erosive affect is not known but it is likely that it contributed to the erosion of the bank at this point. However, we are advised by Lymington Harbour Commissioners that the practice of waiting in the channel is likely to be ended and as a result any effects of the thrust jet being directly directed at the bank at Pylewell would be removed.

3.7 CONCLUSIONS

The recent reduction in speed of the C class ferries means that the erosion of the lower part of intertidal areas (Chart Datum and Mean Low Water) which has been historically observed will have been greatly reduced. That is not to say it has disappeared altogether. In addition there is still the possibility that the thrust jet is contributing to erosion of the intertidal in the vicinity of Cage Boom during turning. More information is required to verify this statement.

4. *Evidence for potential impact arising from W class ferry activity*

4.1 INTRODUCTION

The new W Class ferry is larger and more powerful than the C class (BMT SeaTech, 2008a). Because of this the new ferry will cause more drawdown (Eagle Lyon Pope, 2006, BMT SeaTech, 2008a), higher return currents (BMT SeaTech, 2008a), more near bed turbulence and backflow and produce a greater thrust jet (BMT SeaTech, 2008a). The potential consequences of operation of the W class ferry are explored below.

4.2 CHANGES IN RETURN CURRENTS

LHC measured the drawdown-induced current speed over the mudflat using a current meter (BMT SeaTech, 2008b). The measurements were made on the west bank roughly mid way between Cocked Hat and Harpers Post South. The measurements are presented below in Table 7. The LHC measurements indicate drawdown currents of up to 0.5m/s. When the W class vessel results are normalised to compare directly with the C Class it can be seen that increases in measured return currents speed vary up to 100% (see Table 7).

In reality the variation in the measured return current speeds for W and C Class vessels may reflect the difficulty in measuring the complex hydrodynamics occurring near the shoreline. Theoretically the return currents induced by the W class vessel will be 30% higher because the beam of the W Class ferry is 30% greater than the beam of the C Class ferry and the blockage of the flow will therefore be 30% greater (BMT SeaTech, 2008). For a given speed of vessel passage, return currents would therefore be expected to be 30% larger for the W class ferry than the C class ferry.

Table 7 shows a comparison of return currents for C Class and W Class ferries measured by LHC. Only those measurements where both the tide height and the speed of the ferry were similar are shown. The results presented in the Table show a large variation in the relative strengths of the return currents from the two ferry vessels. However, at the tide height between Low Water and Mean Low Water, which are of key interest in the context of this study, the return currents induced by W Class ferries appear to be at least 45% larger than those induced by C Class ferries.

Table 7 A comparison of return currents measured from passage by C class and by W class vessels (from BMT SeaTech, 2008b)

Class	Tide height (m CD)	Actual speed of ferry (knots)	Measured return current speed (m/s)	Normalised return current speed to enable comparison with C class Ferry (m/s)	% increase of normalised W class result compared to C class
C	1.8	5.8	0.18	0.18	-
W	1.8	5.5	0.20	0.21	16%
C	1.1	6.5	0.47	0.47	-
W	1.2	4.1	0.43	0.68	45%
C	0.3	4.5	0.21	0.21	-
W	0.5	2.7	0.28	0.45	110%

This simple conclusion may not always hold for conditions at Low Water itself as the W class vessel, because of its greater beam will at times (e.g. near to Low Water), have to travel more slowly than 4 knots. However, the most significant scenarios for erosion of the mudflats occur above Low Water and therefore this conclusion is considered appropriate.

The effect from the increase in the blockage is at least as large as the reduction in vessel speeds (potentially 6 to 4 knots and 8 to 6 knots) that has occurred since 2007, but probably greater (on average) because the speeds of 6 and 8 knots were not sustained in the Harbour all the time prior to 2007. It is therefore to be expected that the W class vessel will produce (on the whole) greater return currents than to the C Class vessel prior to 2007 and that the historic rate of recession of the Chart Datum contour would continue.

4.3 CHANGES IN DRAWDOWN CURRENTS

BMT Seatech (BMT) calculated drawdown-induced currents resulting from the passage of W Class and C Class vessels (BMT SeaTech, 2008b, Table 1). The horizontal drawdown speed was derived by computing the vertical drawdown speed and translating this vertical speed into a horizontal speed over the intertidal by taking into account the intertidal slope.

Table 8 shows a comparison of the calculated (by BMT SeaTech) drawdown speeds over the mudflat resulting from C Class and W Class ferry passage at Harpers Post South (Harpers S) and at Pylewell. As drawdown is a function both of vessel speed and the cross-section/draught of the vessel compared to channel cross-section area/depth only the drawdown speeds which are compatible in terms of water level are compared. Moreover, as drawdown is a function of vessel speed (relative to the water speed) squared, and the speeds differ between the C Class and W Class measurements, the W class measurements have been "normalised" to make the measurements directly comparable to the C class measurements.

The figures show that the effect of the W Class on drawdown (for a given current speed) is between 11% and 200% higher than the C Class but for the larger drawdown speeds (at Pylewell) the limited data here suggests a figure more like 50-60%. This increase is in line with the increases predicted by Eagle Lyon Pope (2006) but smaller than the increase initially predicted by BMT SeaTech (2008b) of 70-90% although the BMT prediction corresponded to ferry passages specifically at Low Water.

Table 8 Drawdown-induced current speed over the mudflat resulting from C and W class ferries calculated by BMT SeaTech (2008b)

Position	Class	Tide height (m CD)	Relative spd of vessel (knots)	Calculated Drawdown speed (m/s)	Normalised drawdown (m/s)	% increase of W class result compared to C class
Harpers S	C	0.53	3.1‡	0.086 to 0.114	0.086 to 0.114	-
	W	0.53	3.1‡	0.284	0.323	183% to 276%
Harpers S	C	0.59	4.0‡	0.302	0.302	-
	W	0.59	4.3‡	0.319	0.335	11%
Pylewell	C	0.82	6.2	0.343	0.343	-
	W	0.82	4.9	0.430	0.544	59%
Pylewell	C	1.13	6.3	0.305	0.305	-
	W	1.33	5.9	0.424	0.453	48%

‡ Vessel speeds shown are speed over ground

Table 8 shows that the drawdown from the new ferry, if it travels at the same speeds as the C Class vessel currently adopts, will cause current speeds over the mudflats around 50-60% higher than occur at present, and potentially higher near low water or for speeds of 6 knots around Cocked Hat. This means that the shear stress experienced over an adjacent mudflat when the ferry passes will be around 2½ times higher than that experienced at present.

As for the return current effect it is useful to try and compare the increase in drawdown resulting from the W Class ferry's greater beam and to compare this with the reduction in drawdown that results from the difference in the speed historically attributed to the C Class vessels (i.e. before 2007) and the proposed operating speeds of the W Class ferry.

The analysis above, and that of Eagle Pope Lyon (2006) and BMT indicates that the drawdown of the W class ferries (and hence the induced speeds across the lower intertidal profile) will in general be around 50-60% more than the C Class vessel *for a given speed*. We are advised that ferry speeds have reduced in the channel in general since 2007. The maximum speeds have reduced by as much as 30% (from 6 knots to 4 knots north of the wavescreen and from 8 knots to 6 knots south of the wavescreen) and the speeds at certain locations (e.g. Cocked Hat) at Low Water appear to have reduced by a similar amount (e.g. 4 knots to 2.7 knots) due to navigational requirements. However, for the conditions that appear to generate the most drawdown (e.g. tidal levels of +0.75mCD to +1mCD) the reductions in speed are more likely to be from 5 knots to 4 knots above the wave screen or from 6 knots to 5 knots around Cocked Hat/Cage Boom or from 7 knots to 6 knots around Pylewell. On this basis the W Class Ferry would be expected to induce drawdown speeds at least of the magnitude of those that have been historically experienced within the estuary.

Table 9 Drawdown-induced current speed over the mudflat resulting from W class ferries calculated by BMT SeaTech (2008b)

Position	Tide height (m CD)	Relative spd of vessel (knots)	Calculated Drawdown speed (m/s)	Drawdown (mm)	Induced shear stress (N/m²)
Harpers Post South	0.53	3.1‡	0.28	93	0.30
	0.59	4.3‡	0.32	111	0.39
Cocked Hat	0.52*	3.8*‡	0.17*	71*	0.11*
Pylewell	0.52	4.0	0.18†	43†	0.12†
	0.83	4.6	0.15†	78†	0.08†
	0.82	4.9	0.43	190	0.7
	1.43**	4.4**	0.84**	215**	2.7**
	1.33	5.9	0.42	121	0.66

** Data underestimates drawdown effect on adjacent intertidal because monitor is on the other side of the channel*
*** Data is measuring the effect of a ferry passing on the other side of the channel with a ferry waiting and stemming the tide near to the monitoring location*
† These drawdown values and speeds appear anomalously low and less emphasis should be placed upon them (Ian Dand, BMT SeaTech, pers.comm.)
‡ Vessel speeds shown are speed over ground

The data in Table 9 indicates that the shear stress imposed on the intertidal by the W class ferry at Pylewell are in the region of 0.7N/m^2 except for when ferries pass when the shear stress rise to 2.7N/m^2 (and probably more as the measurements will underestimate the effect of ferries passing). However because the measurement at a tidal level of +0.83mCD corresponds to a vessel speed over the ground of only 4 knots and because the measurement at a tidal level of +1.33mCD is an underestimate of the effect at say +1.0mCD, it is considered that 0.7N/m^2 is a lower limit for the effect of single W class vessels passing Pylewell. It is considered that a reasonable range for the shear stress from drawdown induced by single ferries would be 0.7-1.0N/m^2 which is similar to the assessment of the historic effects of the C Class ferry. Note that the effect of ferries passing is likely to cause considerable erosion.

The data at Cocked Hat is insufficient to make an assessment of the effects of W class ferry drawdown because the one measurement available took place on the other side of the channel to the ferry. The data at Harpers Post South is also inconclusive.

4.4 CHANGES IN UNDERKEEL TURBULENCE/BACKFLOW

All parties appear to agree that the new W Class ferry will result in more underkeel turbulence and backflow and enhanced thrust jet currents and that this will cause further erosion of the bed of the navigation channel. The concern for this report is whether these processes could affect intertidal areas.

It is established that the thrust jet can interact with the shoreline on the east bank around Cage Boom and thus it would be expected that this interaction would be enhanced (see Section 4.5 below). It is also established that ferries will no longer, as a rule, wait in the Harbour before passing which will (virtually) eliminate any effects of the thrust jet being directed towards the adjacent bank and eliminate any larger eddy currents that are generated as the ferry holds station. The effect of the backflow which occurs close to the vessel would, if large enough to affect the intertidal areas, manifest itself as a return current. If the backflow effect was routinely experienced at the shoreline then the measured return currents and the subsequent analysis presented above would account for the backflow effect.

It would seem that the only other way for the high turbulence underneath the vessel to be exported to intertidal areas is if the ferry moves very close to the bank, such as may be required from time to time when avoiding other vessels. The extent to which this could and does occur is not known at the time of writing of this report. However this scenario is likely to be limited to some degree because of the risk of grounding. It is clear however that if the ferry strays near to the bank the turbulence, backflow and thrust jet has the capacity to cause more erosion of the foreshore than the return current and drawdown mechanisms.

There is a concern that has been expressed that the deepening of the channel as a result of the enhanced turbulence that will result from the W Class ferries, could in itself lead to widening of the channel, much as increases in tidal currents within a channel often lead to both deepening and widening. However, the enhanced turbulence from the W class vessel is much more localised than the extra turbulence related to tidal currents across a channel and it is much more likely as a rule that return currents, drawdown currents and in certain locations, thrust jet currents, will dominate the erosion of the shoreline.

As discussed in Section 2.11 the further deepening of the channel may have a wider effect on Lymington Harbour because of potential changes in tidal currents and tidal asymmetry. It would normally be expected that deepening would tend to lengthen the flood tide, and shorten the ebb tide, accentuating ebb tide currents and reducing flood tide currents and perhaps reduce tidal currents slightly as a whole. However to be sure of this effect it would be necessary to undertake flow modelling of the system.

4.5 CHANGES IN THRUST JET

As discussed in Section 2.10 the thrust jet does interact with the bank around the turn at Cocked Hat. BMT SeaTech report (2008a) that the velocities in the W-class slipstream (thrust jet) for a given power setting are greater than those for the C-class. How much greater they will be in practice depends on the operational mode that the W class vessel will use and trials for this are still underway. Measurements to date (Ian Dand, BMT Sea Tech, *pers.comm.*) indicate that the speeds in the slipstream are at least as large as those measured for the C class vessel under its present usage.

If the final configuration for operations results in thrust jet currents which are larger than those for the C Class vessel then it would be assumed that the erosion of the foreshore at the turn around Cocked Hat/Cage Boom which, it is argued, partly arises from the thrust jet, would increase.

4.6 CONCLUSIONS

The evidence of the drawdown measurements indicates that the W class ferry has the ability to generate drawdown-induced current speeds across the mudflat, near low water and during ferry passage, of the order of those which, it is argued here, have led to significant erosion of the mudflat in the inner Harbour. This will result in an enhanced rate of loss of mudflat at MLW compared to the present scenario (C class vessels adhering to the speed restrictions in the Harbour), and a similar rate of loss compared to the situation prior to 2007 (C class vessels not adhering to the speed restrictions).

The widening of the Low Water channel is predicted to continue, especially around Cocked Hat/Cage Boom caused by a combination of the thrust jet and return currents. In general the recession of the CD contour is expected to be the same as has historically been observed for the C class vessel. However, depending on the operational mode that will be used by the W class vessel it is possible that the interaction of the thrust jet around the bend at Cocked Hat/Cage Boom will increase, and thereby enhance the local rate of erosion at this point.

Note that the future erosion of intertidal areas will occur in the context of an ever increasing effect of wave erosion. Thus the erosion rate of intertidal areas may occur in the future at a greater rate than has been observed historically because of the additional effect of wave erosion.

5. Estimation of the loss of intertidal area resulting from the W Class ferry being put into operation

5.1 INTRODUCTION

For the purposes of formally identifying impact and potential mitigation the estimation of loss of intertidal area resulting from the W class ferry being put into operation is identified from the date of designation in 1998. The results of bathymetric analysis shown in Chapter 2 are used to estimate the area of intertidal at Chart Datum and Mean Low Water at this date and to establish the loss of area between 1998 and 2008 (Section 5.2).

Once the loss of habitat from 1998-2008 is established it is necessary, on the basis on the work described above, to estimate how much of the historical loss is due to ferry activity and how much to other potential causes (such as tidal currents, waves and other vessels). This loss is calculated in Section 5.3.

The future loss that is estimated to arise from the operation of W Class vessels is estimated based on the analysis presented in this report and is considered in Section 5.4.

5.2 LOSS OF DESIGNATED HABITAT TO DATE

5.2.1 Changes to Chart Datum since 1998

Table 10 shows the increase in channel width at Chart Datum between Harpers Post South and Seymours Post based on the ABPmer (2009) data based on the analysis of original charts. In the absence of any other data the New Forest District Council (NFDC) cross-section data has been used at Post 7. No positions further seaward than Post 7 have been considered because the changes at CD become much larger and are much more likely to be occurring as a result of wave activity. The rates of change from the various surveys close to 1998 have been used and averaged to produce a “best estimate” of changes in width.

To estimate the change in area at the Chart Datum (CD) contour the various calculated changes in width along the channel at CD have been averaged and multiplied by the length of the reach between Harpers Post South and Post 7 which is about 800m.

Table 10 Estimation of changes to width of channel at Chart Datum between 1998 and 2008

Year	Harpers Post South	Cocked Hat	Bag of Halfpence	Seymour's Post	Post 7*
1991-2008	17	4	8	3	-
1993-2008	18	8	15	11	14
1999-2008	-	-	-	-	0
Average rate of loss (m/yr)	1.10	0.38	0.74	0.45	0.47
Estimated loss 1998-2008 (m)	11.0	3.8	7.4	4.5	4.7

** This figure is based on the NFDC cross-section data in lieu of any other source*

Using these figures for change in the width of the channel at Chart Datum, the loss of designated intertidal area (above Chart Datum) that has occurred since 1998 is in the region of 0.6ha.

This does not include any loss of intertidal area on the eastern shore between Harpers Post South and the ferry terminal.

5.2.2 Changes to Mean Low Water since 1998

Table 9 shows the changes in area above Mean Low Water on designated intertidal area between Harpers Post South and Posts 5 and 6 based on the ABPmer (2009, Figure 2) data. The rate of change of area from the 1993 and 2008 surveys have been used to produce "best estimate" of changes in area between Harpers Post South and No.7 Post while the difference between the 1975 and 2008 surveys has been used to derive a suitable figure for loss between the Ferry Terminal and Harpers Post South.

Table 11 Estimation of changes to designated intertidal area above MLW between 1998 and 2008

Date	Zone	loss (ha)
1993-2008	Harpers Post South to Pylewell	0.9
	Pylewell to No.7 Post	1.1
1975-2008	Ferry terminal to Harpers Post South	1.2
1975-2008	No.7 Post to Posts 5 and 6	5
1998-2008	Ferry terminal to Harpers Post South	0.6
	Harpers Post South to Pylewell	0.6
	Pylewell to No.7 Post	0.8
	No.7 Post to Posts 5 and 6	1.5

Using these figures the loss of intertidal area (above MLW) that has occurred since 1998 is in the region of 3.5ha.

5.3 LOSS OF DESIGNATED HABITAT ATTRIBUTABLE TO C CLASS FERRIES

The total loss of intertidal area alongside the navigation channel at CD and at MLW since designation is derived in Tables 10 and 11 and equate to 0.6ha and 3.5ha respectively. However, not all of this loss is directly attributable to the ferry activities. The analysis above suggests that the ferry activity is predominant north of Pylewell but that south of Pylewell wind waves are more important. In addition the effects of tidal currents, dredging and other vessels will have contributed.

For the present we have made what we consider are reasonable estimates for the proportion of loss attributable to different causes. It is assumed here that within Horn Reach ½ of the loss of intertidal is from dredging and half from the affect of ferries. Between Harpers Post South and Pylewell it is assumed that ¾ of the loss of intertidal is due to ferry activity. South of Pylewell it is assumed that ¼ of the loss of intertidal is due to ferry activity. These assumptions result in the estimates of area loss presented in Table 12.

Table 12 Estimation of changes to designated intertidal area between 1998 and 2008 due to ferries

Level	Zone	loss (ha)
CD	Ferry terminal to Harpers Post South	Not known
	Harpers Post South to Pylewell	0.39
	Pylewell to No.7 Post	0.02
	No.7 Post to Posts 5 and 6	0.02
	TOTAL	**0.4**
MLW	Ferry terminal to Harpers Post South	0.3
	Harpers Post South to Pylewell	0.45
	Pylewell to No.7 Post	0.2
	No.7 Post to Posts 5 and 6	0.4
	TOTAL	**1.3**

5.4 LOSS OF DESIGNATED HABITAT THAT WILL ARISE FROM W CLASS FERRIES

The analysis undertaken in this report has come to the conclusion that the introduction of the W class ferries will have more or less the same effect as the C class ferries had prior to 2007 when the Harbour Byelaws regarding speed of vessels were (reportedly) not adhered to. On this basis the loss of intertidal area resulting from operations of W class ferries will be 0.4ha/decade of area at Chart Datum and 1.3ha/decade of area at Mean Low Water.

Since there is likely to be continued erosion of intertidal area following the introduction of the W Class ferry, there is a question as to whether there is a limit or upper bound to this erosion that will form a useful input to the discussion about loss of designated habitat. In broad terms (i.e. with the exception of the area where ferry passing occurs) the erosion that is considered to be occurring at present as a result of C Class vessel activity is much reduced. The W Class vessel is predicted to increase the blockage of the channel by an extra 30% and hence to cause a significant increase in erosion rate generally within the Inner Harbour. It is reasonable to assume that this erosion will continue (albeit at a slower and slower rate) until the channel cross-section is 30% larger, whereupon the blockage will have reduced to the present blockage value of the C Class ferries. As a result of the effects of the turbulence under the W Class vessel the channel is likely to deepen by something like 0.5m (ABPmer, 2008a) or roughly 10% of the depth. As a result it is likely that the channel will widen by 20%. This corresponds to a maximum loss of intertidal at Chart Datum of 2ha and a maximum loss of intertidal at MLW of around 3.7ha and would occur over a period of 30-50 years

Note that this erosion will take place in the context of continual loss of saltmarsh within the Harbour. Some sources (New Forest District Council, cited by Black and Veatch, 2008) estimate that the saltmarsh within the Harbour will have disappeared within the next 30 years or so which would significantly change the estuary system before the upper bound for erosion is attained.

6. Answers to Natural England Questions

This chapter presents questions raised by Natural England (in italics) and answers based on the evaluation in this report.

Q1 *Have Wightlink provided convincing evidence that the inter-tidal (above Chart Datum) is resilient to changes in the navigation channel?*

A1 No the channel width at Chart Datum has widened since 1998 leading to a loss of 0.4ha in the Harbour since designation in 1998. The channel width at Mean Low Water (MLW) has widened significantly leading to a loss of intertidal above this level of around 1.3ha since 1998.

Q2 *In light of answer to Q1 and given the nature of the estuary (profiles, geology, substrate) how would we expect the inter-tidal to react to further deepening and widening that is predicted from the 'W class'?*

A2 The intertidal would be expected to further deepen and widen roughly at the rate seen prior to 2007. This will cause a recession of 0.4ha per decade at CD and a recession of 1.3ha per decade at MLW. It is also possible to estimate the upper bound of losses that will occur as a result of this erosion. The estimated total loss is 2ha at CD and 3.7ha at MLW but it is likely that before these upper limits have been reached there will have been major changes in the harbour as a result of the continued loss of saltmarsh and mudflats from windwaves.

Q3 *Now that the first 'W' class has arrived and sea trials for safety are underway, Natural England is being criticised for not advising that Wightlink (LHC) obtains further field information from sea trials. Natural England seeks advice on the degree to which further field data would help to improve decision-making in the light of Q1 and Q2 above specifically:*

a) probe sampling of water flows under and around the boat, from propulsion and backflow, to estimate erosive force compared to 'C class'.

b) sampling of sediment disturbed by 'C class' and 'W class' as indication of relative differences in erosive potential.

c)how do the benefits to be gained above relate to the cost and time implications

A3 (a) Sampling of flows underneath or near to the ferry would be possible but costly and impractical in the present circumstances. It seems to be agreed by all parties that there is substantial scouring potential underneath the vessel and that there will be more for the W Class ferry. However, this effect is relatively localised around the ferry and does not in itself directly affect intertidal areas. If there is a concern that the turbulence close to the vessel could be exported to the foreshore then it would be possible to monitor the potential effects at the shoreline in locations most likely to experience this effect.

(b) There is little point sampling sediment suspended behind the ferry as there may not be much sediment left on the bed that can be resuspended after vessel passage and in any case all parties expect the bed to erode further. If sampling is to be done it would be better to sample drawdown and or return current effects in combination with sampling of the sediment that is eroded from the shallow intertidal areas.

(c) A large range of different measurements could be undertaken but measurements are really only required if there is disagreement about the magnitude/significance of a particular effect. It is difficult at present to predict the matters that will arise after Natural England present their advice, although the extent and importance of drawdown from the W class could be one of the most likely candidates. Undertaking well thought out monitoring of the mudflats with various types of equipment will have a time implication of weeks to months. Measurements of drawdown/return current speeds alone from a few ferry passages appear to be able to be undertaken relatively quickly by LHC/BMT SeaTech.

Q4 *If further quantification of deepening and widening, and further field evidence are not appropriate, is there a basis for asking Wightlink to better quantify it using other means- could they do this using VS* [Voith Schneider Propeller] *flow modelling?*

A4 In our view there is a case for field measurements but not laboratory or computational fluid dynamic (CFD) modelling.

Q5 *Is there any way of approximately quantifying losses of inter-tidal from estimated further deepening of navigation channel.*

A5 This analysis is presented in Chapter 5.

Q6 *Modelling suggests that drawdown of the 'W class' could be reduced by small reductions in speed so that drawdown was similar to the 'C class'. Natural England has now received field information from the sea trials comparing 'W class' drawdown (vertical) at different states of tide in different locations. Drawdown currents are lower than expected, what are the implications for* *potential erosion? If drawdown is still a problem help is needed to assess at what speed and at what state of tides 'W class' drawdown is similar to 'C class'.*

A6 As described above, in general drawdown speeds are lower than they have been historically because of the recent (since 2007) adherence to speed restrictions. The drawdown of W Class vessels appears to be 50-60% higher (in general) for the W Class vessel compared to the C class. The result of this will be that erosion can occur from use of the W class vessel but in all likelihood not at the rate that has been observed prior to 2007. To reduce the effect of the W class vessel drawdown to the present effect of the C Class vessel drawdown would require a reduction in speed of 25-30%. Reducing the speed of the W class ferry, however, may have implications for navigation in the river but such matters are outside the scope of this report.

In addition to the considerations of the speed of the W Class ferry, passing of two W Class ferries (at the expected transit speeds) has been shown to produce drawdown speeds which produce high shear stresses over intertidal areas. Reducing speeds to eliminate this effect is not likely to be possible.

Q7 *In light of sea trials data, Lymington Harbour Commissioners have indicated that they will ask NE advice on the speed, navigation, tide and wind parameters that the 'W Class' should operate under to avoid adverse effect/detrimental effect (clarification sought on legal remit) on N2K features.*

A7 As discussed in the proposal for providing the advice contained in the present report – a full answer to this question (i.e. what speeds would be required under different tidal and wind conditions) is outside the remit of the study. The evidence available states that to reduce the effect of the W class vessel drawdown to the present effect of the C class vessel drawdown would require a reduction in speed of 25-30% from those speeds currently adopted by the C Class ferries. Reducing the speed of the W class ferry, however, may have implications for navigation but such matters are outside the scope of this report. Passage of W Class ferries has been shown to produce drawdown speeds which produce high shear stresses over intertidal areas. Reducing speeds to eliminate this effect is not likely to be possible so, from an environmental point of view this practice should be stopped where possible. In addition there could be additional restrictions around the bend at Cocked Hat under strong winds (to reduce the likelihood of the thrust jet washing over the mudflats).

Q8 Please assess the analysis of morphological evolution that has informed Natural England thinking and advise on any incorrect interpretations. (With a view to advising on the likely effects of the ferries on local sediment recycling)

A8 Natural England has a concern as to the importance of local sediment recycling during storms and whether the ferries (in addition to the effects discussed above) have the effect of interfering with this process. The advice of HR Wallingford is that the hydraulic impact of the ferries presently affect the edge of the channel and sediment eroded from the edge of the channel, both by ferries or natural processes is likely to end up in the dredged areas within the harbour (if eroded on the flood tide) or outside the estuary (if eroded on the ebb tide). The impact of the ferries does not really interfere with the deposition of sediment on the saltmarsh (which manifestly comes from marine sources) and so does not interfere with the vertical accretion of the marshes, but does lead to enhanced lateral erosion of the marshes.

Natural England requested confirmation as to the importance of sediment supplied from fluvial sources. This is currently thought to be in the range 1,600-16,000m^3/yr (Blain, 1974) and Black and Veatch (2008) considered a best estimate might be in the region of 5,000m^3/yr. This is significantly less than the current maintenance dredging requirement (generally quoted as 30,000m^3/yr) or the marine supply.

Natural England requested advice on whether it was worthwhile requesting Wightlink to undertake a full sediment transport study. It is pointed out that the effect of the ferries is to contribute to erosion of the mudflats (and potentially saltmarsh) along the edges of the channel and that these effects are best quantified by field measurement. In this respect the discussion of the potential impacts of past and future ferries will not be particularly aided by a full sediment transport modelling study. However, such a study would be beneficial in the general context of the need to understand the processes in Lymington Harbour better and the need to tie in the end-users and regulators associated with Lymington with investigating better ways of managing the estuary, then Wightlink should be involved. Depending on the most relevant questions which require answering, the involvement of Wightlink and other parties might include contributing to flow, wave and sediment transport modelling, investigation of methods to preserve (or hinder erosion of) the saltmarsh, beneficial use options, a review of dredging practice, and field monitoring.

Q9 *A sub-tidal bank of sediment is deposited across the mouth of the estuary. The ferries carve two tracks through this. LRA say that the cuts in the bank allow greater wave penetration that would significantly increase wind wave penetration to mouth of navigation channel causing erosion.*
Is this likely?

A9 Any increase in wave energy arising from erosion of the deepest part of the channel is small compared to the increase in wave energy resulting from the ongoing recession of the mudflats.

7. Conclusions

Based on the analysis in the present report the following conclusions are drawn:

- The evidence is that the rate of erosion of the mudflat in Lymington Harbour (at Chart Datum and Mean Low Water) has increased from around the time that the C Class ferries were introduced. Since this time erosion of the Low Water channel itself has also occurred.
- Recent measurements and observations undertaken by Lymington Harbour Commissioners and BMT SeaTech, in combination with evidence of the speeds at which ferries travelled within the Harbour prior to 2007, suggest that the combination of drawdown and return currents from ferry movement would have

led to significant[5] erosion of the mudflat. This concurs with the analysis undertaken by HR Wallingford in 1991.

- There is therefore both circumstantial evidence for the observed erosion in the inner parts of the Harbour having been caused by the C Class ferry and a measured mechanism by which this ferry can have caused the erosion. It is therefore most likely that the erosion of the mudflats observed since the 1970's, at least upstream (landward) of Pylewell, is predominantly a function of the C Class ferry activity.
- It is suggested in ABPmer studies that there has been no change to the Chart Datum and Mean Low Water contours since 1994. However this result is not supported by the 1993 survey which indicates progressive changes in contours. In our view the contours resulting from the 1993 survey appear more plausible than those of the 1994 survey. In addition the precautionary principle would dictate that, of the two, the 1993 survey should be considered as being the result upon which management decisions should be made.
- Downstream (seaward) of Pylewell the increasing effect of natural wind waves have probably dominated the erosion process. However, since the ferry has contributed to erosion upstream it is also likely to have contributed to erosion in this part of the Harbour to some extent.
- The recent reduction in speed of the C Class ferries means that the erosion which has been observed probably as a result of the drawdown/return flow effect, is greatly diminished from the historic trend. That is not to say it has disappeared altogether. The passing of ferries near Bag of Halfpence and Pylewell will produce large shear stresses which will continue to erode the lower intertidal. In addition the thrust jet interacts with the foreshore in the vicinity of Cage Boom during turning.
- The evidence of the drawdown measurements indicates that the W Class ferry has the ability to generate drawdown-induced current speeds across the mudflat, near low water and during ferry passage, of the order of those which, it is argued here, have led to significant[4] erosion of the mudflat in the inner Harbour. This will result in an enhanced rate of loss of mudflat compared to the present scenario (C class vessels adhering to the speed restrictions in the Harbour), and a similar rate of loss compared to the historic rates which have occurred prior to 2007.
- An estimate of the recession rate of Chart Datum resulting from the use of W Class vessels is in the region of 0.4ha per decade.
- An estimate of the recession rate of Mean Low Water resulting from the use of W class vessels is in the region of 1.3ha per decade. However, as the mudflats erode further, the role of wind waves will become increasingly more important and thus it is likely that the observed rate of erosion will be higher than these rates calculated on the basis of the ferry alone.
- It seems to be agreed by all parties that the W Class ferry will produce greater underkeel turbulence, backflow, return currents and thrust jet speeds. It is therefore to be expected that further deepening will occur in the channel.

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[5] See Section 1.4 for definition of significant

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