Introduction

- Concerns have been expressed that the beach and foreshore has undergone significant recent change at Southend-on-Sea. The purpose of this report is to determine whether the perceived changes have actually occurred and if so to determine whether they might relate to any management activities, such as dredging or beach management. Data from a number of sources have been collated, checked and analysed. The analysis presented below is based on data provide by the EA and DP World, to quantify changes since 1994. No additional data has been collected.

Data

- Two independent sources of lidar have been examined, provided by EA Geomatics and DP World. The coverage details and other supporting assessments of data are detailed in Appendix A.

- EA lidar data sets do not cover the area of interest over the relevant period (2008-present). Much of the earlier data contains a significant survey area of data that includes reflected elevations of water surface, making it unsuitable for analysis of change of the mudflats. This is because the tidal elevation was above low water in at least one of the surveys, or because residual water has remained in channels at low water. The lidar cannot penetrate the water to provide true sea bed elevations.

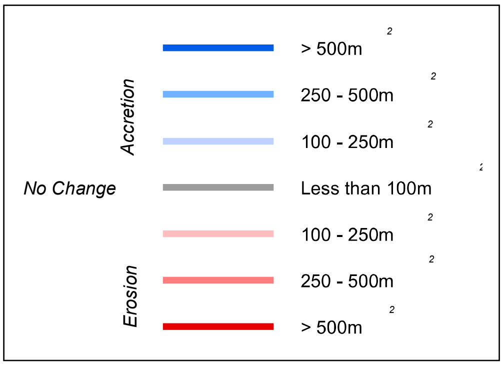
- DPW lidar data sets are of variable quality and are inconsistent, some being filtered (with buildings removed) and others being unfiltered. This is possibly because the surveys have been completed by different contractors. The more recent surveys appear to have been more rigorously controlled. Significant manipulation has been required in earlier assessments of the data by HR Wallingford to make the data usable, due to control issues with the raw data. This analysis has been carried out appropriately and the change analysis presented appears a true reflection of the data. Much of the data however contains a significant quantity of reflected elevations of water surface, making it unsuitable for analysis of change of the mudflats. Much of the change shown in the HR Wallingford analysis suggests changes of surface elevations, but simply shows water in channels and does not reflect real changes to the mudflat surface. These images are somewhat misleading in this context. The analysis presented by HR Wallingford identifies changes that are greater than +-0.2m, which is entirely reasonable for such data, especially where the data has been manipulated before analysis. Well controlled lidar data might reasonably be expected to resolve data to a vertical accuracy of about +-0.1m but this poorly controlled data can clearly not be resolved to such accuracy.

- A long term data set of intertidal topographic survey profiles, spaced at an interval of 1km, has provided the basis of the data analysed for this investigation; this data has been provided from the EA strategic coastal monitoring programme and dates back to 1992. Two more detailed surveys of a short section of beach have also been provided. The quality and consistency of this data seems to be good.
- Data has been supported by digital orthophoto aerial surveys which provide morphological context to the profile analysis and is also well controlled.

Methods of analysis

Topographic data

- Profile surveys spaced at a longshore interval of about 1km have been repeated since 1992. These are strategically located profiles that have no particular relationship to structures, but when considered together should present a regional pattern of change.
- The majority of the analysis was carried out on the topographic profile lines at 1km spacing, which were analysed in SANDS software. This data comprised an extensive time series, and encompassed the whole of the area of interest.
- Profiles spanned different lengths from the seawall to low water, so a master profile (MP) of MLWS (-2.4m OD) was used to provide the basis of change comparisons, to derive cross-sectional area above MP.
- Recent changes in cross-sectional area were calculated for the period covering the two years pre-dredging (2008-2010) and for the two years post-dredging (2010-2012). Cross-sectional areas were also derived for 1999-2010, in order to look at longer-term trends
- Profiles were split into the "shingle" upper beach area and "mudflat" lower inter-tidal area and the difference in cross-sectional area of each component was calculated separately.
- The distribution of changes in cross-sectional area for each profile, for each of two two-year epochs, were highlighted by plotting against the 2011 aerial photography (Figure 1)
- The following scale (see diagram below) was applied to describe the change in profile cross-sectional area of each profile. A change of 100m^2 over the whole profile typically corresponds to a vertical change of only 5cm over the entire profile length. This may generally be considered to be within the noise of acceptable survey accuracy and this is considered in this analysis to represent no change.



- Similar analysis was carried out on a 2.5km stretch of Jubilee Beach in the Southend-on-Sea area which was replenished in 2002 with 190,000m^3 of sediment

<u>Lidar</u>

Environment Agency Lidar:

- Difference models were constructed for all of the supplied data which spanned the beach (1999-2006). The addition of the 2002 beach replenishment scheme was clearly noticeable, but both data sets had extensive amounts of water left in them; these data both predate the dredging programme. No conclusions could be drawn from this data, relating to recent (post 2006) changes.

- It is understood that a 2013 lidar survey is to be conducted that covers the whole area of interest to MLWS. It may be possible to detect changes between that data set and 2006, although the challenges of water surface within the data are likely to restrict the value of any analysis.

Results

<u>Profile analysis</u>

- Figure 1 shows the changes in cross-sectional area of each of the 1km profiles for each of the epochs (2008-2010 and 2012- 2012) and for cumulative change. The length of the profile lines on the diagrams corresponds to the true extent of the profiles. The change in cross-sectional area of the shingle and mudflat components is shown separately in the table attached to the figure. The majority of change in cross-sectional area has occurred on the mudflats, not on the sand and shingle beach. The general pattern observed over each of the two year time frames indicates change which is generally within the expected noise of survey accuracy, although the net changes suggest gradual deposition on the intertidal flats on all profiles (2008-2010) and gradual deposition on 9 out of 11 profiles (2010-2012).

- Figure 2 illustrates the short-term changes (August 2011 to January 2012) of the recent surveys where the spatial density of profiles has been increased to

50m, which cover a small portion of the area of interest. The time series is too short to be able to distinguish any trend from seasonal changes. The change shown is within expected survey error on all but three profiles which show slight short term seasonal erosion.

Cross-sectional area trend analysis

- Figure 3 shows the trends and actual cross-sectional area over time for all available data, from 1994 – 2012, for the 1km spaced topographic profiles, together with the linear trend. The beach replenishment (2002) and dredging start date (March 2010) are represented on the graphs by a vertical line
- A similar pattern of gradual increase in cross section is shown on all profiles.
- There is no evidence of any change in trend of the cross-sectional area since dredging took place. Inter-annual variability has continued to demonstrate a pattern of gradual accretion.
- Since 2002, the inter-survey variability in cross-sectional area is much more consistent than prior to that. This may be the result of a change in survey technique, but it has not been possible to confirm this

Conclusions

- Although profiles spaced at 1km intervals could be considered to be too widely spaced to provide other than strategic level information, at this location there is limited variability of the longshore beach morphology. The widely spaced profiles appear representative of the shoreline as a whole and the regional pattern of change is entirely consistent for the whole of the monitoring period. There is evidence of localised patterns within the overall trend which might be affected by large structures, but more detailed local measurements are needed to clearly link any patterns with structures.
- A walkover survey and local photographs confirmed the profile evidence of longshore consistency and there were no obvious changes in gradient of longshore transport, evidenced by consistent patterns of build up against groynes.
- Given the unsuitability of most of the supplied lidar data, the long-term 1km profile data set has proven to be the only useful data set for analysis.
- No observable difference in the pattern of beach evolution has been observed outside of the normal inter-annual variability, since dredging commenced.

- Neither topographic beach surveys nor lidar are suitable for determining small-scale changes over mudflats and some of the reported changes can simply not be detected with the available data.
- The analysis of long term trends suggests that a consistent pattern of very gradual deposition is evident across the lower intertidal zone, across the whole of the frontage analysed. This pattern has been evident since the initial surveys commenced in 1992; this has not changed in the past few years. Some interannual variability is evident but the overall trend is clearly of gradual accretion. Localised changes in analysis cannot be detected from this data, since the profiles are too widely spaced to pick up small scale features eg outfalls, groynes etc. There is evidence of a veneer of sandy material on mudflats at some locations (from photographs).
- In order to provide more detailed assessments of changes more-dense and well controlled data is required.
- The lidar collected to date has proven to be unsuitable for detection of detailed intertidal changes for the following reasons.
- A variety of filtered and unfiltered lidar data has been provided that includes an inconsistent combination of surfaces with and without structures
- Surveys contain significant areas that indicate water rather than mud flat surface.
- Careful planning of lidar surveys may provide an opportunity to conduct surveys that are less affected by surface water. This will generally mean conducting surveys towards the end of the suitable tidal window, to allow as much water to drain from the surface as possible. It is likely that water will always be evident in some of the channels. Lidar is however likely to provide the best method of measuring changes over a large area. A 1m grid resolution should provide a suitable density for measurement of change. It should be noted that where there are sharp steep drops eg. Adjacent to structures that the lidar will not describe these accurately, due to the averaging footprint of $1m^2$.
- The logistics problem of survey planning presents a significant challenge. Issues such as weather, cloud cover, tidal limits and air traffic control must all be considered together to achieve suitable surveys.
- Data is only fit for purpose if it is surveyed at the appropriate time within the tidal window. This site is particularly challenging as water must drain from channels as well as the general tidal changes. This is not an uncommon problem at many sites. Post processing of data to remove water out of every creek system is a manual and very time consuming procedure which cannot be achieved with automated algorithms. The data need to be fit for purpose,

and the water needs to be removed or accounted for in difference models to achieve this.

- Careful control of lidar is needed by using control surfaces that are unlikely to have moved *e.g.* concrete slabs, car parks *etc*. Such surfaces can be used to improve the vertical accuracy of the lidar, by registering the lidar data against these control surfaces and adjusting data to fit this known surface elevation. This approach has been adopted for some of the more recent DPW surveys. Experiences at other sites suggest that it might be reasonable to achieve a vertical accuracy of +-0.05-0.07m with good local ground control.

- Further support can be provided by continuing with the strategic profiles, and the higher density profiling. When suitable lidar is available the topographic profiles can be used to provide further quality checks on the lidar.

- Detailed analysis of beach structure interaction can be determined based on detailed topographic surveys typically using dense spot height surveys or using techniques such as terrestrial laser scanning. Such techniques might be considered somewhat extreme for such an application and a pragmatic solution would be to continue with annual, but better controlled lidar surveys supported by sampled topographic profiles.

- Further surveys are planned in conjunction with the Anglian Coastal Monitoring programme and it is suggested that this data is integrated with the DPW data when available, to provide independent comparisons.