Additional beach behaviour analysis for Saltdean: longshore transport investigation

This report provides additional analysis to complement preceding analysis for Saltdean found in the Phase 1 report on 'Changes in beach topography', the Phase 2 background report 'Case study for longshore transport calculations using modelled wave data and beach surveys' and the manuscript: Dornbusch, U., D. Robinson, C. Moses and R. Williams (submitted). Variation in beach behaviour in relation to groyne spacing and groyne type for mixed sand and gravel beaches, Saltdean, UK. *Zeitschrift für Geomorphologie, Supplement Band*

Introduction

Beach behaviour is driven by the wave environment and the action of the waves is modified by the tide level. Waves arriving at and oblique angle to the beach generate longshore transport that is related to the longshore wave power (LSWP) of the waves. One aim of the BAR project is it to related LSWP to the amount of material transported along mixed beaches with the ultimate aim of being able to better predict longshore transport for these types of beaches.

To this end beach topography on a range of beaches has been surveyed at regular intervals from which sediment movement over these time intervals can be calculated and ultimately linked to wave conditions. The curtailing of the length of the project has seriously affected this aim by a) reducing the number of surveys and wave environments to be studied and b) reducing the time available to analyse the available survey and wave data, to understand the link between them better and to formulate and test predictive formula for longshore transport on mixed beaches.

Following the results of the case study at Telscombe an analysis covering the whole 1.5 years for which surveys are available for Saltdean was carried out because longshore transport at Saltdean is simple in that each groyne compartment is divided into a western and an eastern half and because volume changes between these two halves have been calculated very accurately.

Aims

Explore the link between longshore wave energy and beach volume changes.

Method

The method is based on data from topographic surveys as described in Phase 1 reports and the wave modelling described in the Phase 2 background report. Inshore wave data was modelled for points in the centre of each groyne compartment at a depth of -1m OD.

Calculation of longshore wave energy was carried out using equation (1)

$$P_l = ECn \sin\alpha \cos\alpha \qquad (1)$$

with *E* being the energy flux $E = (\rho g H^2)/8$ where ρ = density of water, *g* = acceleration due to gravity and *H* the wave height,

C being the wave phase velocity $C = ((gT)/2\pi)\tanh((2\pi d)/L)$ where *T* = wave period, *L*= wave period and *d* = water depth,

n being the ratio of wave group celerity to wave phase celerity which in the nearshore is 1,

and α being the angle between the wave crest and the beach. Beach angle was taken from the average angle of the mean water line based on the preceding survey.

LSWP has been calculated for wave conditions every 0.5 hours. These half hourly values have been summed over a period of 4.5 hours around high water, that is the time waves had and impact on the upper mixed beach. The LSWP per tide calculated in this was analysed and compared with the beach volume change information.

Results

The analysis starts with results for Beach 4 because this beach has been surveyed the longest and has not been influenced by management activity like Beach 3.

Beach 4

The aim of this section is to explore the links between longshore transport and LSWP, especially whether it is the sum, average or extreme component of LSWP during each period between surveys that can be best linked to the observed changes in longshore beach distribution.

Beach 4 (Figure 1) is the beach compartment that has been surveyed for the longest period of time (July 2003 to January 2005) did not show any long-term change in the volume of beach material present between the concrete groynes and did not suffer any management intervention as beach 3.

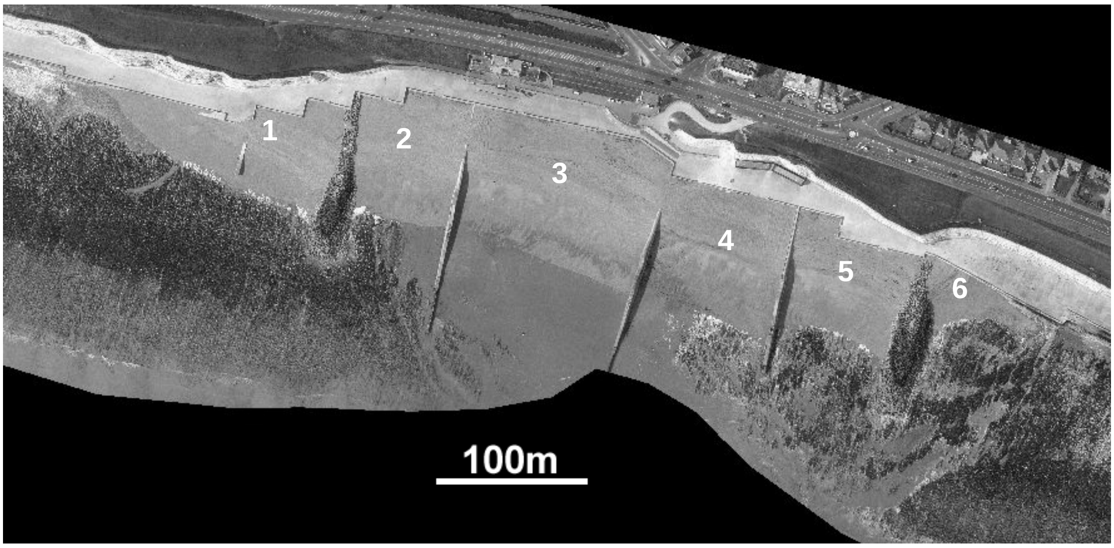

Figure 1: Location of beach 4

Figure 2 shows the distribution of the beach volume in the longshore direction together with LSWP and high tide water levels. From the beach volume distribution it appears as if there is preferred distribution with a surplus of 500-600m³ on the eastern half which almost appear to be an ‘equilibrium’ distribution that was maintained between July to October 2003 and from February to June 2004. There is only one survey that shows an increase of the imbalance to 1000m³ in July 2004 and two significant reversals of the distribution to levels of -800m³ in November 2003 and 2004.

The graph suggests that variations in LSWP (both magnitude and direction) for the first 4 surveys have been insufficient to move material along the beach, while LSWP during the period February to July 2004 might have moved material (higher magnitude than for the first 4 surveys) but that the net movement between two surveys roughly equalled out. This observation would suggest that there is an LSWP threshold of ~10,000 that needs to be exceeded per tide to initiate any measurable movement of material. The influence of the tide level, influencing the potential amount of beach volume to be moved, can be seen in the changes from June to July 2007 when the beach reached its highest volumes on the eastern half following a period of easterly directed LSWP during spring tide; the westward transport event that followed, apart from be shorter in duration also coincided with a neaptide so that material that had been moved onto the higher part of the eastern part could not be moved westward again because it was out of reach for the waves due to the ~1.5m lower water levels.

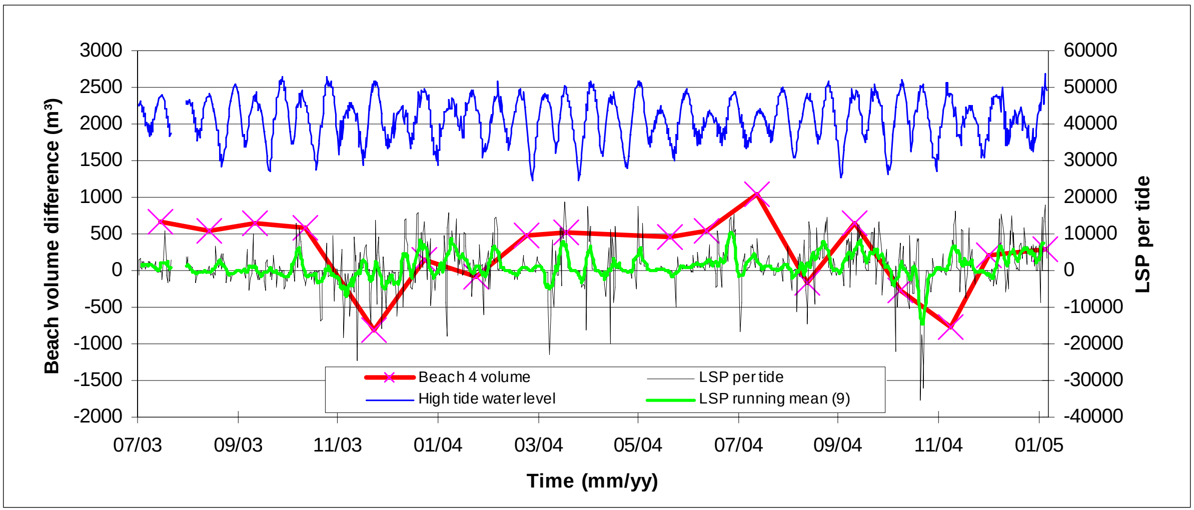

Figure 2: Difference in beach volume on beach 4 (positive values indicate more material in the eastern than in the western half, each cross indicates the volume distribution at each survey) plotted against LSWP for each tide (LSP per Tide) and a running mean over 9 tides. The upper blue curve indicates the water level at high tide (unit is m * 10,000)

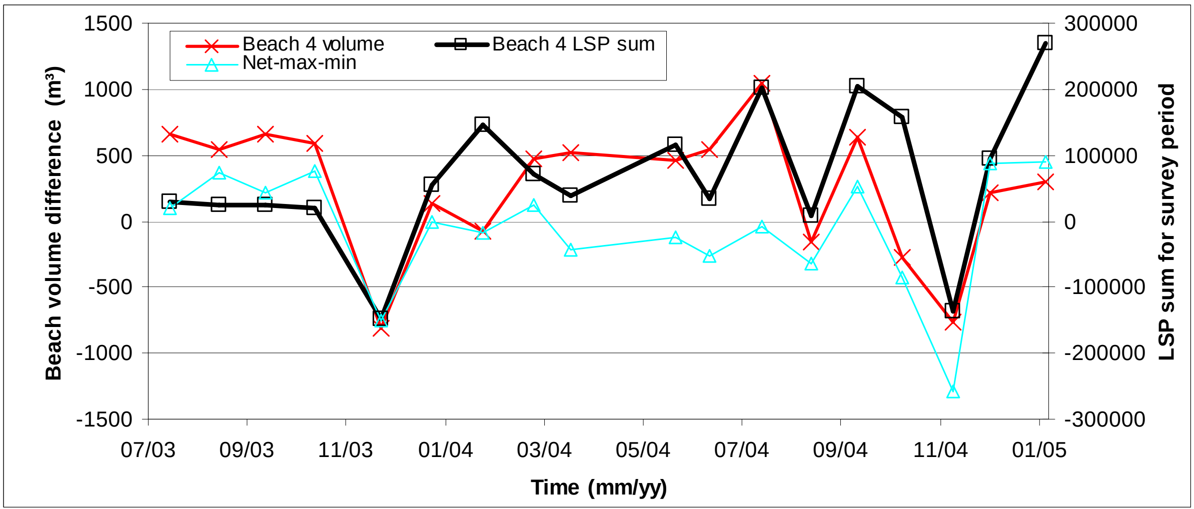

Figure 3: Difference in beach volume on Beach 4 plotted against the sum of all tidal LSWP between each survey and the sum of the maximum and minimum LSWP * 10 (Figure 4) for each survey period.

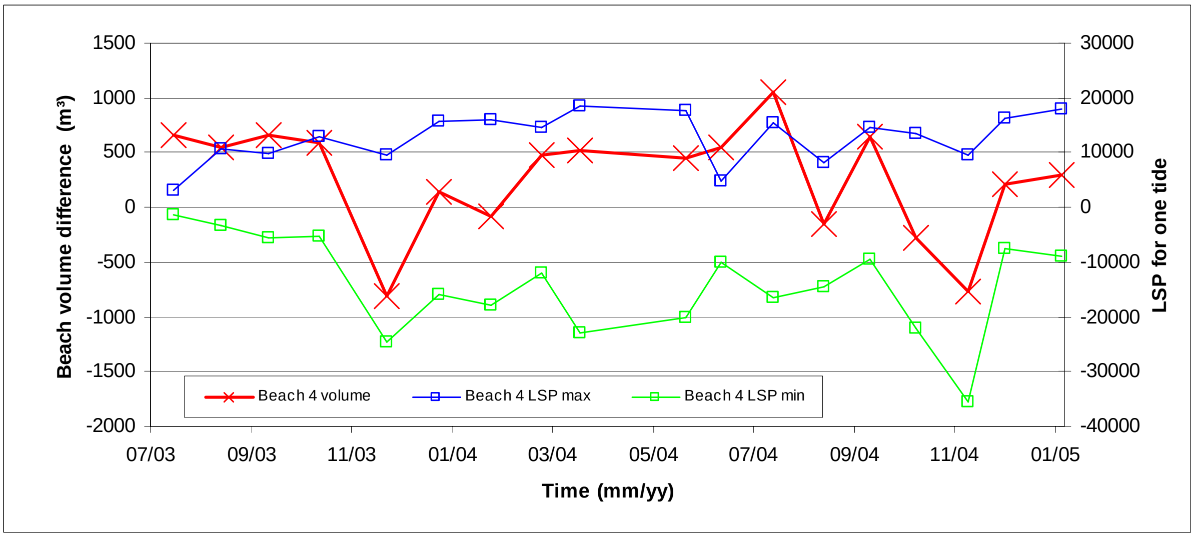

Figure 4: Difference in beach volume on beach 4 plotted against the maximum and minimum tidal LSWP

Figure 3 shows the same volume distribution curve as in Figure 2, however, this time plotted against the sum of all tidal LSWP values between two surveys (the sum and average have a very high correlation and it would appear as if the sum is a more useful measure). The graph supports some of the analysis above in that the stable beach volume distribution during the first 4 surveys coincides with low net LSWP. That the net LSWP is not 0 is likely to be due to variation around the mean wave direction produced from the model and errors associated with determining the angle of the beach plan shape. The larger variations in the magnitude of tidal LSWP values (Figure 2) for the period February to June 2004 results in larger variation of the net LSWP during this period of beach volume stability, again indicating the influence of errors associated with the terms entering equation (1). The correlation between volume distribution and the LSWP sum is .533.

The negative deviations of beach volume distribution coincide with nearly the same magnitude of net LSWP despite the beach volume distribution during the preceding survey being very different. This would suggest that for a given LSWP there is a given beach volume distribution independent of the antecedent distribution, or rather that the beach volume distributions adjusts over a very short period of time of a few tides.

However, there are three surveys were the generally good agreement between volume distribution and LSWP does not hold: February 2003, September 2004 and January 2005. The likely reasons – and the general problem with the summing up of the tidal LSWP – is that low values of tidal LSWP, that actually are below the threshold of producing any change on the beach, are summed up and may become dominant over a small number of significant events.

Figure 3 also shows the net LSWP between the tidal maximum and minimum during each survey period (see Figure 4). While generally copying the pattern of the LSWP sum it matches the beach volume distribution much better on the three surveys mentioned above and in consequence the correlation between beach volume distribution and the net LSWP min-max is increasing to 0.736 (Table 1).

This appears to support the notion that the ‘background’ LSWP of small magnitude has only little effect on the actual beach volume distribution and that instead the role of individual larger scale events is more important. This is supported by sensitivity tests where the sum of LSWP for each period was restricted to events with either 10,000, 12,000 or 15,000 watts. Though these produced similar curves to those shown in Figure 3 the correlation never exceeded 0.629 (the 15,000 case) and thus remained substantially lower than for the min-max case.

From Figure 6 it is evident, that maximum values for LSWP increase with water depth. This is to be expected as water depth enters the LSWP calculation (Equation (1)), however, it also means that the min-max scenario may use minimum and maximum values for each survey period that relate to different tide levels and therefore should have different impact on the amount of material that can be moved alongshore, so that the difference between the extremes should be moderated by the water level.

In addition to the influence water level might have, the combination of wave angle and wave height producing a certain LSWP might be important. If the LSWP is achieved by a high wave that has only a small angle to the beach, errors associated with the wave angle can have a much higher influence than if the same LSWP is composed of a moderate wave height and a large angle. Figure 5 shows this in an example for Beach 4. It also shows that highest and lowest LSWP values are achieved at angles >10° and wave heights between ~1m and ~1.8m.

	Sum LSWP	Net LSWP
Beach 2	.374	.393
Beach 3	.657	.727
Beach 4	.553	.736
Beach 5	.383	.315

Table 1: Correlation between the beach volume change and the LSWP.

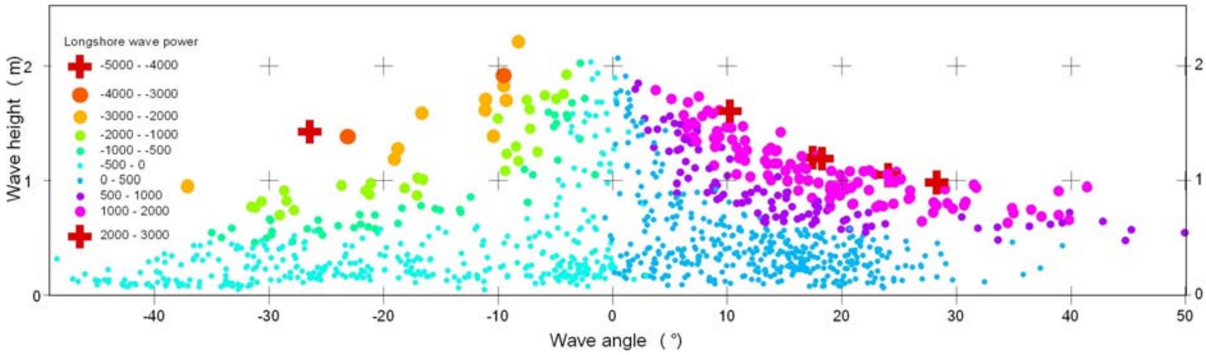

Figure 5: Scatter plot for Beach 4 showing for each tide the average wave angle, wave height and LSWP over the 2.5 hours of high tide.

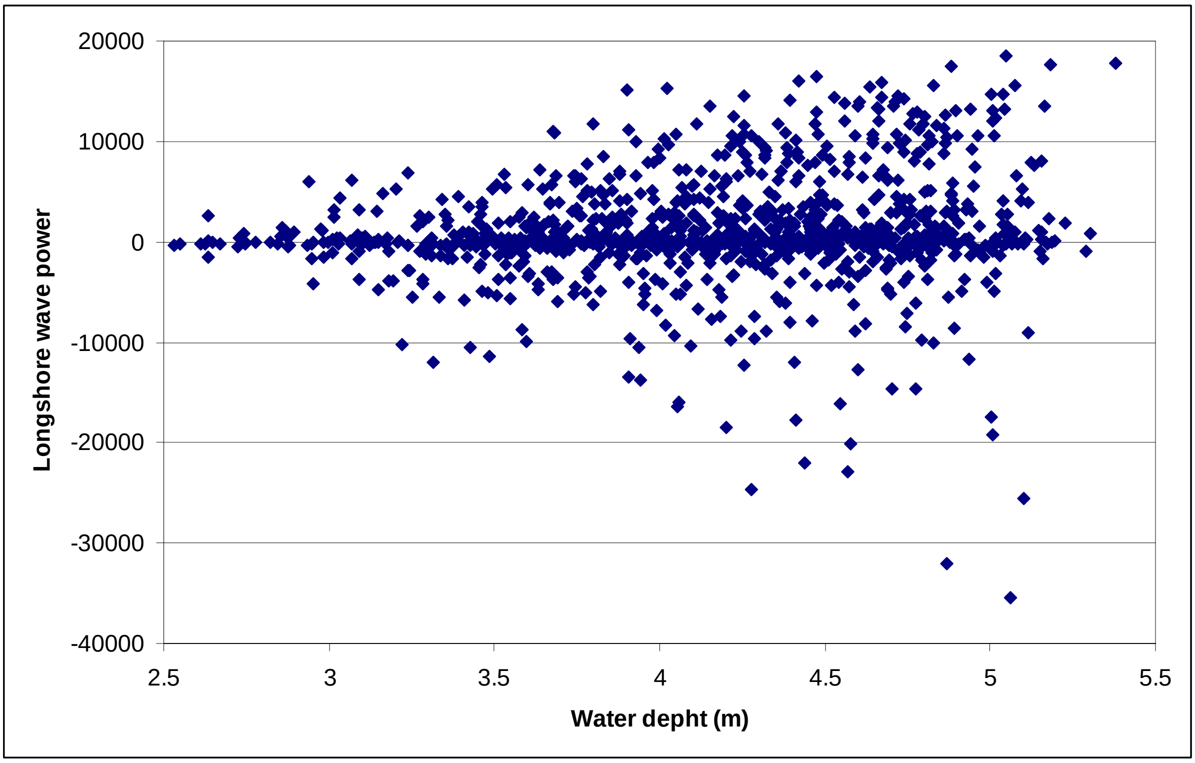

Figure 6: Scatter plot showing for each tide the maximum water depth plotted against the tidal LSWP.

Beach 3

As has been demonstrate in previous work (see also Figure 7), the beaches at Saltdean behave very similar with the only significant difference being the magnitude of change, ie the amount of beach material moved from one side to the other.

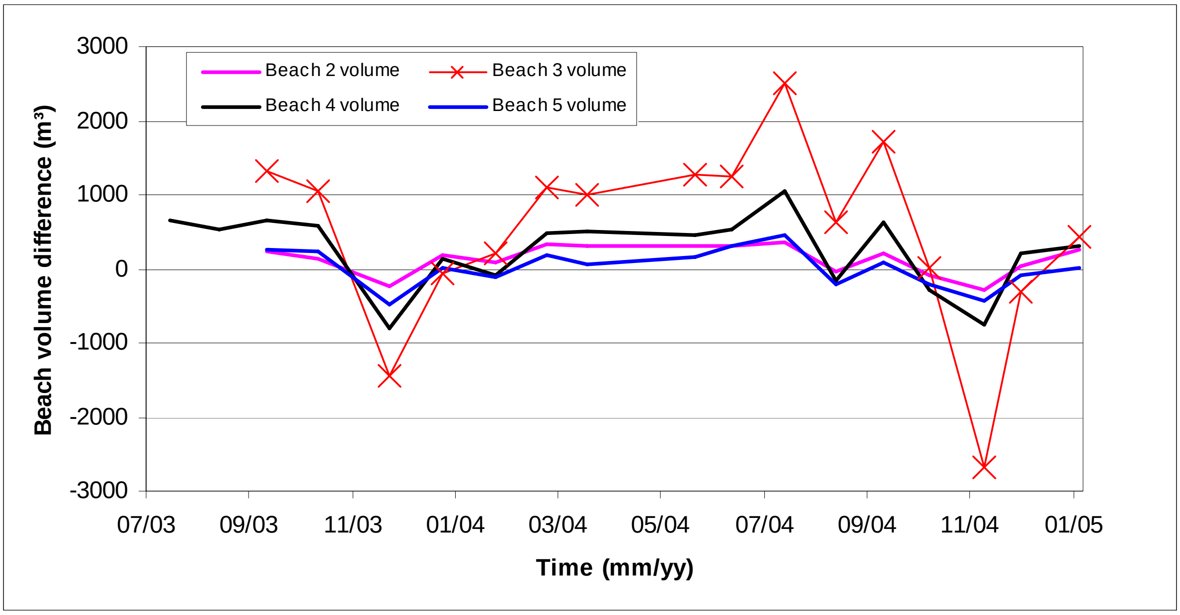

Figure 7: Difference in beach volume on Beaches 2 to 5.

Given the proximity of the beaches to each other the wave environment is also very similar. Therefore, Figure 8 shows a pattern very similar to that shown in Figure 3 for Beach 4, however, the x-axis ranges are bigger.

Comparing the correlation between the volume change and the LSWP sum and the net LSWP the correlations are respectively 0.657 and 0.727, again showing that the net LSWP appears to be a better predictor for the beach volume change.

However, if the net LSWP and beach volume change are shown in a scatter plot together with best fit linear regressions (Figure 9), the scatter in the data is very large and the linear regression equation is a poor predictor of beach behaviour. It is interesting to note that the most negative values in the net LSWP for each data set coincide with comparatively low amounts of beach volume change and could be classed as outliers, however, while for Beach 2 and 5 these occur on the 13-09-2003, for Beaches 3 and 4 they occur on the 16-11-2004.

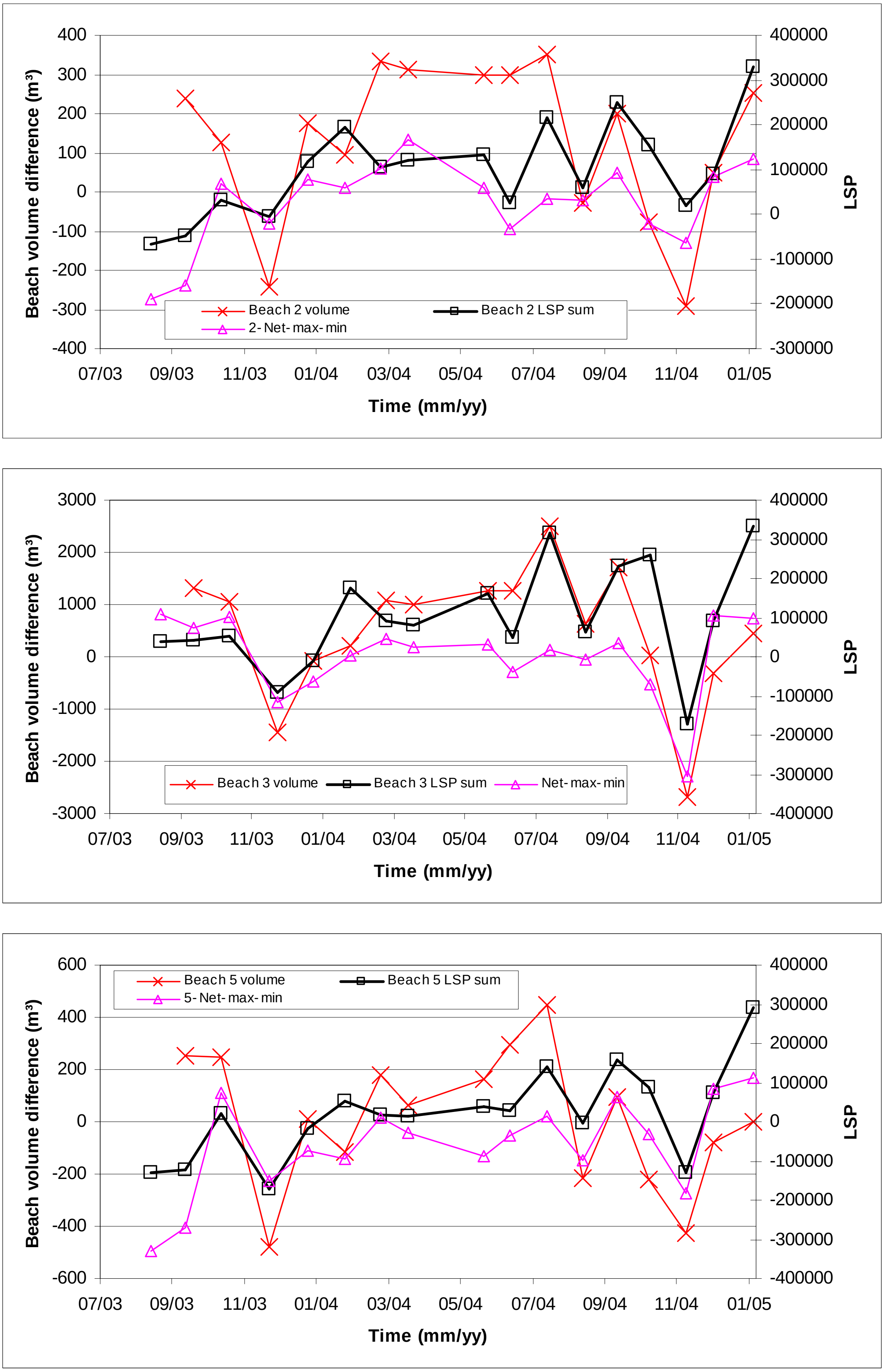

Figure 8: Difference in beach volume on Beaches 2, 3 and 5 (a, b, c) plotted against the sum of all tidal LSWP between each survey and the sum of the maximum and minimum LSWP * 10 for each survey period.

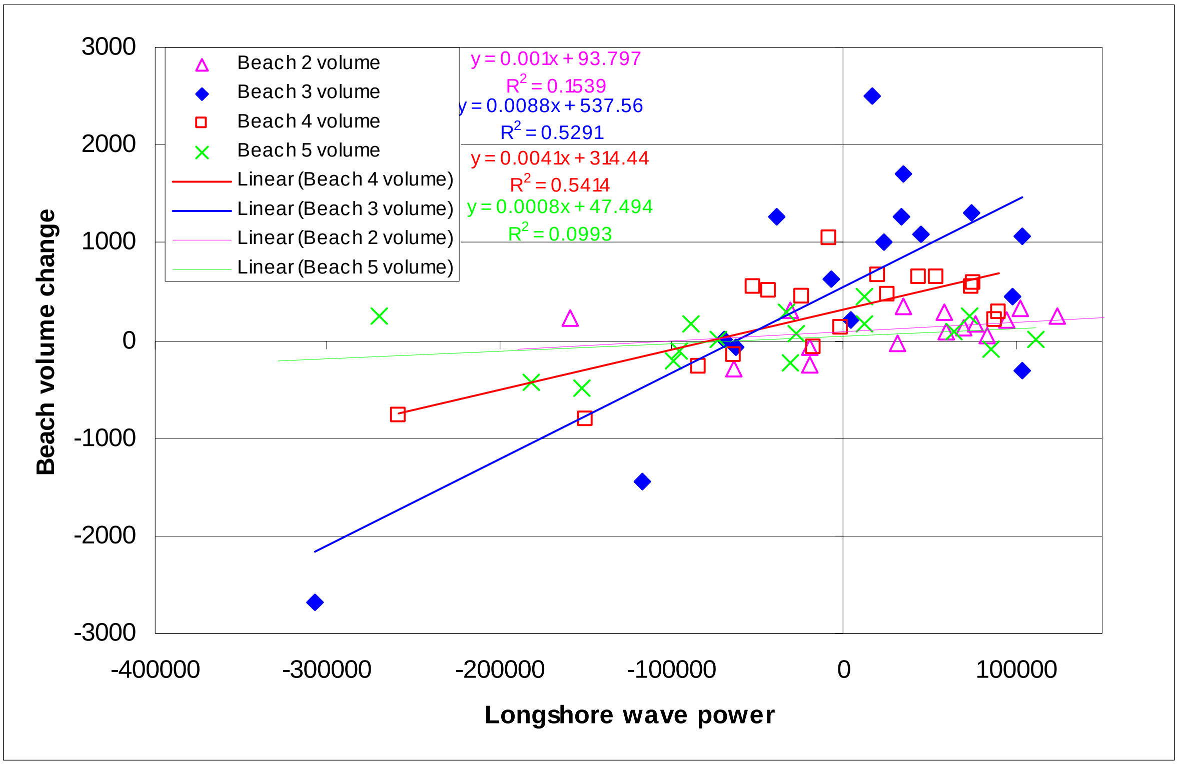

Figure 9: Scatter plots between the net longshore wave power and the beach volume changes on Beaches 2 to 5. Linear regression lines, equations and R^2 values as determined by Excel are shown in the respective colours.

Beaches 2 and 5

The patterns of volume change and LSWP are broadly similar between Beaches 2 to 5 (Figure 8). However, the correlation between volume change and LSWP are much poorer on beaches 2 and 5 (Table 1) than on beaches 3 and 4. This is also seen in Figure 9 for the R^2 value.

Discussion

Beach behaviour on all beaches at Saltdean is similar with regard to the distribution of beach material on the western and eastern halves. The pattern of beach volume change over time shows similarities with the amount of LSWP experienced over the period between two surveys with both the sum of all tidal LSWP and the net LSWP using the maximum and minimum LSWP producing reasonable correlations for beaches 3 and 4 but much poorer for beaches 2 and 5. From the analysis above it would appear as if there is good ‘qualitative’ relationship between beach behaviour and LSWP, however, the quantitative link is too weak to provide a satisfactory predictive relationship.

Using a different approach in the data analysis the predictive relationship might be improved or it may help to explain its limitations.

Figure 10 shows in a scatter plot the change in volume for the eastern half of the Beaches 3 and 4 from one survey to the other against the change in the net LSWP from one survey to another. The assumption here is that when the beach volume on one side of the beach is not changing (small values on the y-axis) there should not be a change in the LSWP over the same period. What the graph suggests is that there could be a hyperbolic relationship between beach volume change and LSWP though the amount and distribution of the data points makes this somewhat speculative. This means that beach volume change will not increase linearly with LSWP but that the beach volume can only be moved up to a certain level, that is there will never be the case that all the beach material is in on half only.

Consequently, and increase in LSWP will not necessarily change the beach further because the geometry of sediment in the groyne bay does not allow this to happen through some form of feedback.

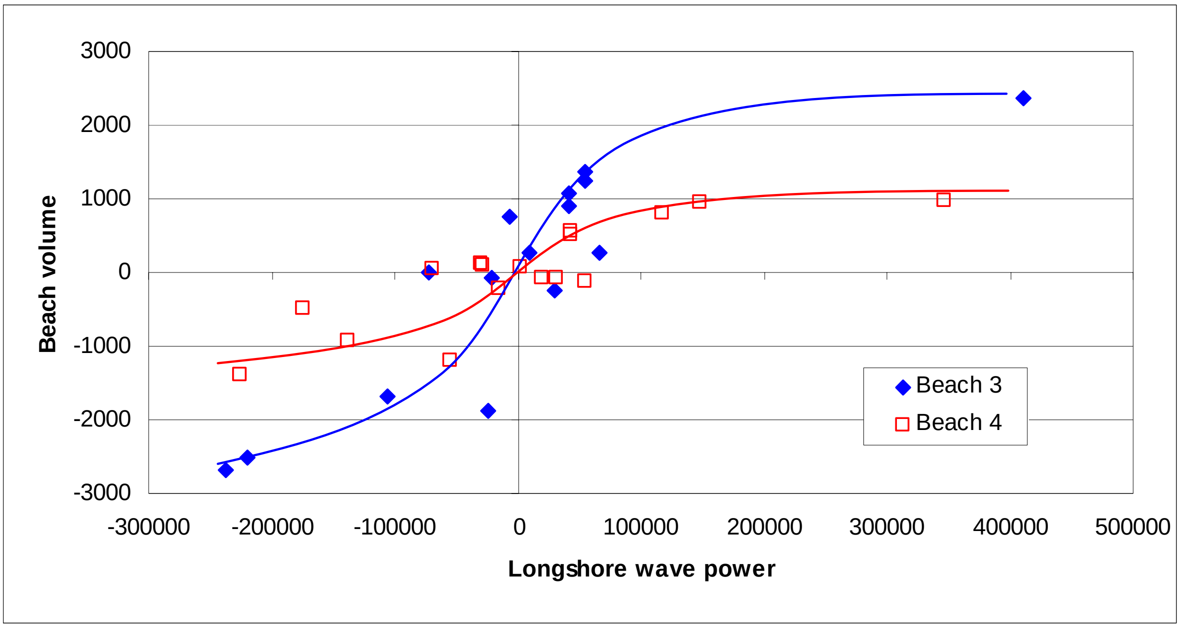

Figure 10: Scatter plot for Beaches 3 and 4 between the change in volume on the eastern half of the beach from one survey to the other and the change in the net LSWP from one survey to another. Lines showing possible regression were drawn by eye.

10-01-2007 Uwe Dornbusch