# Planning and modelling of a beach improvement scheme, Poole, UK

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## Abstract

The sandy beaches of Poole Bay, in Dorset, are eroding, in part due to sea level rise. Allowing this shoreline to retreat is impractical, therefore the beach between Sandbanks and Branksome Dene Chine was improved by a recharge scheme during winter 2005/06. The coastal defence strategy envisages further recharge schemes at approximately 10 year intervals to protect the sea walls, so preventing recession of sandy cliffs behind them. This will also maintain and enhance the important tourism and recreational values of those beaches.

A preliminary study assessed numerous options, both novel and traditional, on the basis of their direct and intangible benefits to the frontage. These included breakwaters, reefs and various types of groyne. Four preferred schemes were recommended and used for public consultation. These options were then were refined using numerical modelling, making different assumptions about how climate change might affect future wave conditions. This modelling showed that no control structures were necessary along the western part of the study frontage.

The study finally recommended five new groynes at the eastern end of Poole Borough's coastline. This scheme, completed in May 2009, was more modest than originally envisaged, so reducing its costs and its effects on the amenity value and aesthetics of the beaches.

Through appropriate application of a numerical model the final scheme selected provided significant cost savings and additional amenity and aesthetic benefits.

**Keywords**

coastal defences, beach management, climate change, numerical modelling

# 1. Introduction

Most sandy beaches around the world are eroding, partly because of gradually increasing sea levels; global warming can be expected to increase these problems (Leatherman, 1989). In most UK coastal resorts the seafront infrastructure e.g. roads and hotels, often makes it impractical to achieve a gradual landward recession of beaches and promenades. So there is considerable pressure to improve and preserve existing beaches, not only as coastal defences but also because they attract visitors and hence contribute to the local economy. This is now often best achieved by periodic recharge (ASBPA, 2012), mainly using sediments dredged from the offshore seabed, and building structures such as groynes that reduce beach sediment losses. To achieve the most economic scheme for beach management, a balance has to be struck between capital expenditure on structures and the recurring costs of adding or recycling sediment. A thorough assessment of all possible options, considering both traditional and novel types of beach control structures is a difficult task, even if only engineering and economic issues are considered. However in coastal resorts, the impacts of management options on both the natural and the human environment also have to be considered, the latter including the amenity and aesthetic aspects of the beaches.

This paper examines how a range of possible beach management schemes can be assessed and refined, in part through numerical modelling of beach plan-shape evolution, using as an example a recent study of a beach in Poole Bay, Dorset. The beach between Shore Road and the boundary between Poole and Bournemouth (Figure 1) is one of the focal points of the tourist industry within Poole, with up to 700,000 visitors per year (Poole Tourism, 2007); three sections of it have Blue Flag status. The frontage is backed by a sea wall, sections of which are more than 70 years old, and a promenade. To the rear of the promenade the cliffs are approximately 25–30 m high and mainly of Eocene sandstone. Prior to the construction of the promenade and sea wall, these cliffs were receding at up to 1 m/year, and supplying a substantial quantity of sand to the beaches of Poole Bay.

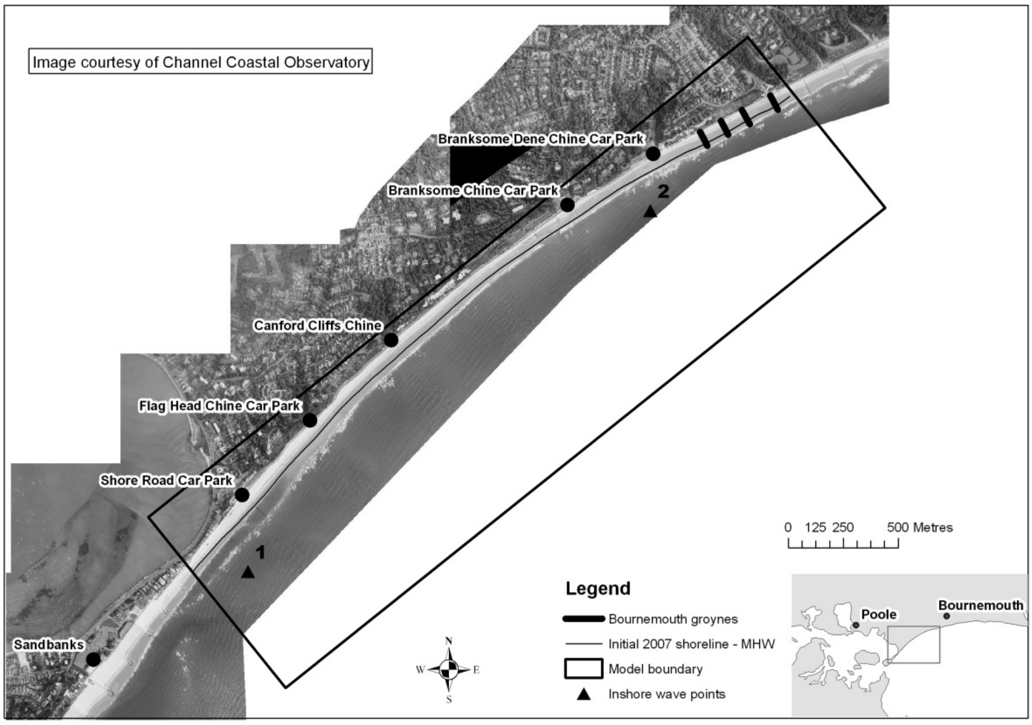


Figure 1 Location map + location of nearshore wave points + model boundary

In 2004, beach widths were narrow, particularly near Branksome Dene Chine (Photograph 1) and Flag Head Chine (Photograph 2) where the sea wall has a convex (seawards) plan shape. This led to occasional, localised flooding of the promenade by wave overtopping. However, the main concern was that if beach levels became too low, the sea wall might be undermined. The cliffs behind the promenade would then be at risk of sliding, threatening valuable houses and infrastructure on the cliff top.

The Poole and Christchurch Bay Shoreline Management Plan (SMP) (Halcrow, 1999) resulted in an agreed policy to hold the existing line of coast defence between the entrance to Poole Harbour to beyond the

Poole/Bournemouth Borough boundary; this policy was reviewed and confirmed by the Poole Bay Coastal Strategy Study (Halcrow, 2004) and the second generation SMP (Royal Haskoning, 2011).

Late in 2004, following the completion of the Coastal Strategy Study (Halcrow, 2004), Borough of Poole Council started to investigate how to improve the standard of coastal defence through a combination of periodic beach recharge, at approximately 10 year intervals, and installing structures designed to maintain adequate beach widths. This strategy aims both to reduce the risks of damage to the sea wall and to maintain and enhance the amenity, tourism and recreational values of Poole's beaches. For the most cost-effective beach management scheme, a balance has to be struck between expenditure on beach control structures and the recurring costs of adding or recycling sediment.

During the winter of 2005/06, an opportunity arose to recharge beaches in Poole Bay using sand excavated during a deepening of the entrance channel to Poole Harbour. By working in partnership with Poole Harbour Commission, this beneficial use of dredged material meant that the local Councils of Poole, Bournemouth and Purbeck saved the tax payer between £8 million and £15 million (http://www.poolebay.net) when compared with conventional beach recharge schemes.

This beach recharge had buried the existing short timber groynes (about 45 m long at 120 m spacing) which had almost come to the end of their operational life (Photograph 3).

Given this 'blank canvas', to obtain best value from the recharge and maintain adequate beach widths along their frontage, Borough of Poole Council decided to investigate alternative beach control schemes. Defra, who funded this study, requested that it considered novel structures such as reefs and permeable groynes as well as conventional schemes such as timber groynes.

Photograph 1 Low beach levels and damaged sea wall near Branksome Dene Chine (at approximately low water)

Photograph 2  Narrow beach width near Flag Head Chine (at approximately low water)

Photograph 3 Original short (45 m) groyne at the end of operational life (at approximately low water)

## 2. Identifying possible schemes

The shallowly sloping sand beaches along this frontage have a sand bar 100-150 metres offshore. While the net longshore drift is eastwards, south-easterly storms occasionally cause a reverse drift. Waves vary in both intensity and mean direction along the frontage (HR Wallingford, 1995), with both the range of wave directions and wave heights being larger at its eastern end, which is less sheltered by the Isle of Purbeck. The tidal range is modest (1.6 m on a Mean Spring) and nearshore tidal currents are very weak east of Flag Head Chine. Overall this frontage resembles those found in parts of the world, e.g. Italy, the USA and Japan, where beach control structures can be very different to those commonly used in the UK.

Therefore, as a first step, an extensive review was undertaken of past experience of a wide range of coastal defence structures around the world. Two other consultants contributed to this review. Professor Gianfranco Liberatore reviewed beach control structures on sandy beaches in Italy, where the tidal range is small. The other (ASR Ltd), based in New Zealand, concentrated on multi-purpose reefs. These reviews indicated the potential suitability of novel types of structure for this specific frontage and their likely effects on longshore drift and the beach plan-shape.

The reviews identified a wide range of structures that have been used to control longshore sediment transport and hence affect the beach widths. However, choosing a reasonable number of suitable options was difficult. It is important not to eliminate candidates at too early a stage (ICE, 2002), but carrying out an initial design, estimating the whole-life costs and numerically modelling the effects on beach widths of every possible scheme was impracticable.

Additionally, the possible effects of any scheme on the amenity and aesthetic values of this coastline were important. For example, local consultation had indicated a desire to minimise the number of structures installed, and a need to consider public safety.

Following discussions with both officers and elected representatives of the Council, ten alternative schemes were short-listed (Table 1). Possible structures included impermeable groynes (of rock or timber), permeable groynes (which are popular along many Italian beaches), nearshore surface-piercing breakwaters and multi-purpose reefs. Further information on these types of structures can be found in the Beach Management Manual (CIRIA, 2010) and other engineering textbooks. For each scheme, an initial layout, i.e. the number, dimensions and spacing of the structures, was produced using the conclusions of the reviews, together with results obtained during previous modelling of wave climates and modelling to indicate how far offshore longshore drift takes place (HR Wallingford, 2006), which is particularly relevant when considering the possible structures and the lengths of groynes. It was emphasised, however, that any of these schemes would need further refinement before recommending a preferred scheme for detailed design.

Table 1 Short list of beach control options

| | | | |
|---|---|---|---|
| **1.** | Impermeable groynes | Length: 75 m | Spacing: 150 m |
| 2. | Impermeable groynes | Length: 75 m | Spacing: 225 m |
| 3. | Impermeable groynes | Length: 75 m | Spacing: 300 m |
| 4. | Impermeable groynes | Length: 110 m | Spacing: 220 m |
| 5. | Impermeable groynes | Length: 110 m | Spacing: 3000 m |
| 6. | Impermeable groynes | Length: 110 m | Spacing: 440 m |
| 7. | Permeable groyne | Length: 75 m | Spacing: 150 m |
| 8. | Permeable groyne | Length: 110 m | Spacing: 220 m |
| 9. | Multi-purpose reefs | (4 No) | |
| 10. | Nearshore breakwaters | Length: 100m | (4 No) |

The number of schemes suggested to the Council was then reduced by a two-stage comparative assessment of these ten schemes. First, the costs and effects on the beach widths of schemes were compared using a simple multi criteria analysis, in which various criteria were ascribed different weight.

Following discussion with Borough of Poole Council, the largest weightings were given to maintaining adequate beach widths, slowing the longshore drift and the initial cost of each scheme. Consideration was also given to maintenance costs and the past performance of the types of structure (see Table 2). This exercise was transparent, because it could be repeated to assess the sensitivity of the comparisons using different weightings reflecting the importance of the various criteria. However, it was found that the highest-scoring four schemes still retained the same rankings if changes in weightings of only ± 1 were applied.

Table 2 Assessment criteria

| Assessment criterion | Importance | Weighting |
|---|---|---|
| Maintaining adequate minimum beach width | H | 8 |
| Slowing longshore drift/sand losses | M | 6 |
| Comparative construction costs | M | 6 |
| Ease/costs of maintenance/adjustment | M | 4 |
| Impact on downdrift beaches (Bournemouth) | M | 5 |
| Tried and tested scheme | L | 2 |

The primary purpose for the beach control structures along the frontage is to help retain a satisfactory beach and the costs of their construction are justified primarily on that basis. Therefore, the criteria set out in Table 2 were the primary factors for deciding which schemes to take forward to the modelling stage. However, where alternative schemes are proposed that provide a similar benefit-cost ratio, then it is appropriate to consider the options further, taking into account other benefits that they might, or might not, provide. In coastal resorts, the financial benefits to the local economy of a pleasant, uncluttered and safe beach with easy access are important, and this will often influence the choice of a coastal management scheme. Accordingly, a separate exercise was undertaken to assess the effect of schemes on the human and the natural environment of the frontage. This considered the aesthetics, amenity value of the beaches and nearshore waters of Poole Bay and the safety of those using them. This ensured that schemes put forward for more detailed design and modelling had also been considered from the viewpoint of their likely acceptability to both local residents and visitors. This part of the study, in particular, involved consultations and discussions with the public, elected councillors, and officers in various departments of the Council.

Following this two part comparison, and public consultation, four schemes were recommended to the Council in May 2008 for further consideration and refinement through numerical modelling namely:

- Nine impermeable groynes each 75 m long at 300 m spacing (4:1);
- Twelve impermeable groynes each 75 m long at 225 m spacing (3:1);
- Seventeen impermeable groynes each 75 m long at 150 m spacing (2:1);and
- Four multi purpose reefs, as recommended by ASR Ltd.

It was intended that the groynes schemes would extend along the whole frontage between Shore Road and the borough boundary. At this time, no recommendation was made on the groyne construction materials.

The last of these schemes involved installing four multi purpose reefs, each about 30–60 m long. These were to be about 750 m apart and about 50¬¬¬–100 m offshore from the coastline. As well as helping to maintain adequate beach widths, these reefs were also expected to improve the seabed ecology and some aspects of surfing (ASR report in HR Wallingford, 2006).

These four preferred schemes were then further examined and refined through detailed numerical modelling of their effects on beach widths.

# 3. Numerical modelling of beach changes

Initial designs for conventional beach control structures, for example the length and spacing of groynes, can be produced on the basis of field experience and other rules of thumb. For example, observation of the successful timber groynes along the Bournemouth frontage indicated that groynes perform less well where the spacing to length ratio is greater than 2. From the literature review undertaken as part of this study (HR Wallingford, 2006) it was found that the main guidelines for installing groynes on sand beaches were:

1. The crest of the groyne should not be greater than about 1 m above that of the beach profile (Aminiti et al, 2004, Gomez-Pina, 2004, and Van Rijn, 2004)
2. The groyne should not extend beyond the landward side of the beach profile bar, if it exists, to prevent sand from being diverted offshore (Fleming, 1990 and Van Rijn, 2004).
3. The ratio of the spacing between groynes to their length should not be greater than 4:1 (Van Rijn, 2004).
4. Groynes are not effective on beaches with very low or no net longshore drift.

When comparing conventional with novel structures or unconventional scheme layouts, however, numerical modelling provides a valuable way of quantifying their effects on beach changes and can lead to added value of the scheme selected. The main effects of control structures can be predicted using a 'one-line' numerical model of beach plan evolution. There are several similar mature models of this type that can do this, including GENESIS (Hanson & Kraus, 2011), LITPACK (DHI, 1998) and Beachplan (Ozasa and Brampton, 1983, Kemp *et al*, 2011) the last of which was used in this study. Information on the plan-shape of the MHW contour (June 2007), the sediment grain size ($D_{50}$ of 0.40 mm), the mean beach profile (slope of 1:30 and crest height of around 2.5 m ODN), on the sea wall and on the 75 m long timber groynes along the western end of Bournemouth Borough's frontage were provided by the Channel Coastal Observatory and the two Councils. The existing short (45 m) timber groynes were not represented in the model as they had been completely buried by the 450,000 $m^3$ beach recharge. Since it is not possible to predict future wave conditions or their sequence of occurrence precisely, a standard modelling technique is to use a long sequence of wave conditions that have occurred previously. Provided all the options are studied using the same set of wave conditions, this produces a reasonable basis for comparing their likely performance.

Because there were insufficient directional wave measurements at the location of interest, an existing 18-year time-series of nearshore wave conditions at two locations (Points 1 and 2 in Figure 1) were used in the model. These were obtained from a previous modelling exercise (HR Wallingford, 1995) based on offshore waves forecast by the UK Met Office.

As a first step, the potential drift rates were calculated using these wave conditions. Over 18 years the net potential drift rates close to the ends of the study frontage, see Figure 1, were:

- Point 1 - Mean 5,000 $m^3$/year eastwards with a Standard Deviation of 73,000 $m^3$/year
- Point 2 - Mean 46,000 $m^3$/year eastwards with a Standard Deviation of 104,000 $m^3$/year

The net eastward drift in Poole Bay increases to the east of Sandbanks, causing a long-term reduction in beach widths. The large standard deviations indicate that there is a substantial variation in annual net drift rates, to the extent that at Point 2 the drift rate varied between 200,000 $m^3$/year eastwards and 160,000 $m^3$/year westwards (i.e. a drift reversal), and imply that year-to-year changes in beach plan-shape could be large.

This preliminary analysis also allowed the selection of five years of wave conditions which, overall, produced a net eastward drift rate equal to the mean drift rate over the whole 18 year period. Using this representative five-year wave sequence, subsequently allowed more efficient and rapid modelling of beach plan-shape evolution.

There was insufficient survey data following the recharge for a detailed site-specific validation of this model. However, it was still necessary to demonstrate that the model represented the main features of the beach and its evolution. This required matching observed beach alignments along the whole frontage and reproducing the accumulation of sand on the western, i.e. updrift side, of the long (75 m) groynes in Bournemouth; following numerous model runs this was achieved. The five end-of-year positions of the mean high water contour replicated the observed gradual beach erosion, as a result of the net eastwards drift. The model was then used to predict the effects of alternative schemes on beach widths, starting with the shoreline position in June 2007.

The wave conditions input to the model were specified at three-hourly intervals throughout the selected five-year period, and included severe storms approaching from both the south-west and south-east sectors. Because of the variations in drift rates both in the short-term, for example during storms and annually, the beach widths varied throughout the model run. The model can present the predicted position of the Mean High Water (MHW) contour at any time specified, for example at the end of each year. However, such ‘snapshots’ may reflect the effects of a recent storm event rather than clearly showing long-term trends in beach widths. Because of this, the main results presented were the predicted minimum and maximum positions of the shoreline during the five year run, and its mean position during the fifth year. The minimum predicted beach widths indicate where undermining and overtopping of the sea wall is most likely to occur. The mean position in the final year shows the overall ability of each scheme to retain sediment and maintain beach widths, thus allowing an assessment of the economic, amenity, and aesthetic benefits of a scheme.

The first, ‘baseline’ model run assumed no structures would be installed west of the existing groynes in Bournemouth. Figure 2 presents these results from the baseline run. The points showing the mean, minimum and maximum beach widths are not joined to form a continuous line in this, or in similar subsequent figures, to emphasise the fact that these positions do not occur concurrently. Unexpectedly, the results indicated the minimum beach width occurred just **west** of groynes, i.e. adjacent to what is usually their updrift flanks. This was found to be the outcome of a single severe, long-lasting storm approaching from the south-east during the last of the five years simulated.

When the model predicts the shoreline retreats to the sea wall, it continues calculating how low the beach level will drop, using the beach gradient to show an “equivalent” position of the MHW contour had no sea wall existed (Ozasa and Brampton, 1983). As the beach level falls, the shoreline retreats further landward of the sea wall. Figure 2 shows this might occur along a substantial stretch of the eastern part of the frontage. This baseline run also predicted a substantial reduction in the mean beach width over the five year period. The aim of installing beach control structures is to reduce these problems.

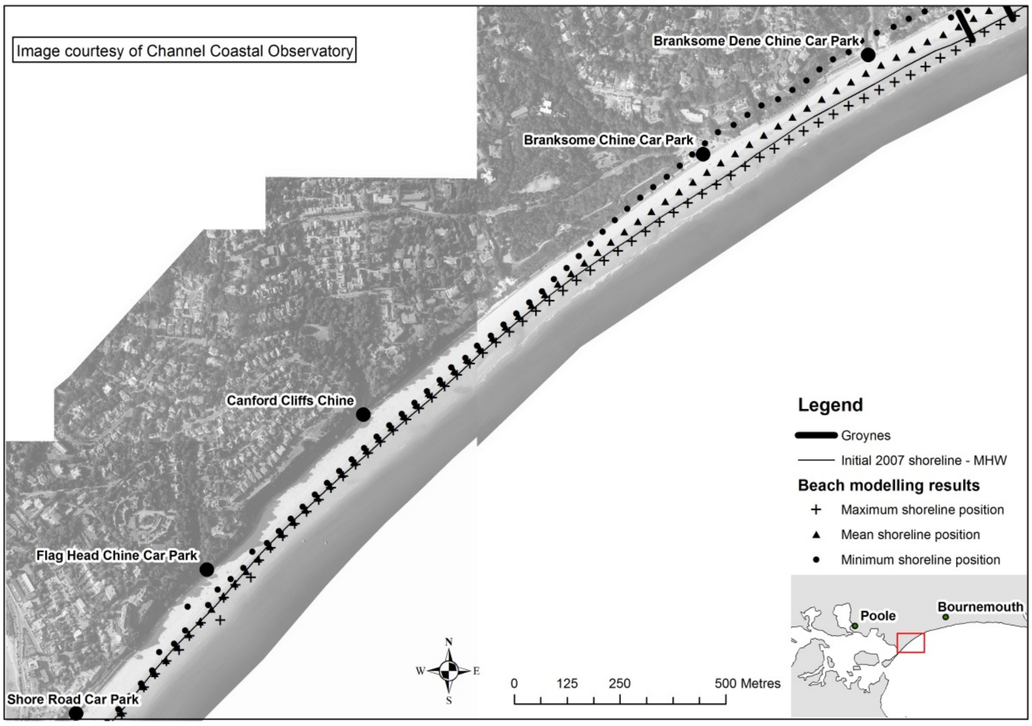


Figure 2 Predicted mean, minimum and maximum beach positions during the baseline run

# 4. Testing the preferred schemes

## 4.1. Method for assessing modelling results

It is important to identify which results from numerical modelling are most appropriate for assessing different coastal defence schemes. Along this study frontage, as in many other coastal resorts, a particular challenge is to maintain adequate beach widths in front of sections of a sea wall that protect small promontories, such as at Branksome Dene and Flag Head Chines (see Photograph 1 and Photograph 2), without beaches elsewhere becoming wider than needed. If control structures can achieve this and reduce how quickly beach sediment is lost, future recharge schemes should be less frequent and /or smaller. The model results that can best be used to assess how well schemes achieve these two objectives (maintain adequate beach widths and retain beach sediment) are the minimum beach widths, at known vulnerable locations and the total beach area above MHW. As always when using a numerical model, the assessment and comparison of these results had to be supplemented by engineering judgement.

## 4.2. Assessing the schemes

The three short-listed groyne schemes were modelled first. Based on a separate prediction of the distribution of the longshore drift down the beach profile, the groyne lengths in all these schemes was chosen to be 75 m (so finishing landward of the sand bar), and matching previous groynes both at Sandbanks and along the adjacent Bournemouth frontage further east.

As expected, these schemes produced a 'saw-toothed' beach plan-shape with the minimum beach widths predicted adjacent to the groynes themselves. An example result is presented in Figure 3. As a result of a severe storm from the south-east the minimum beach widths occur just west of the groynes.

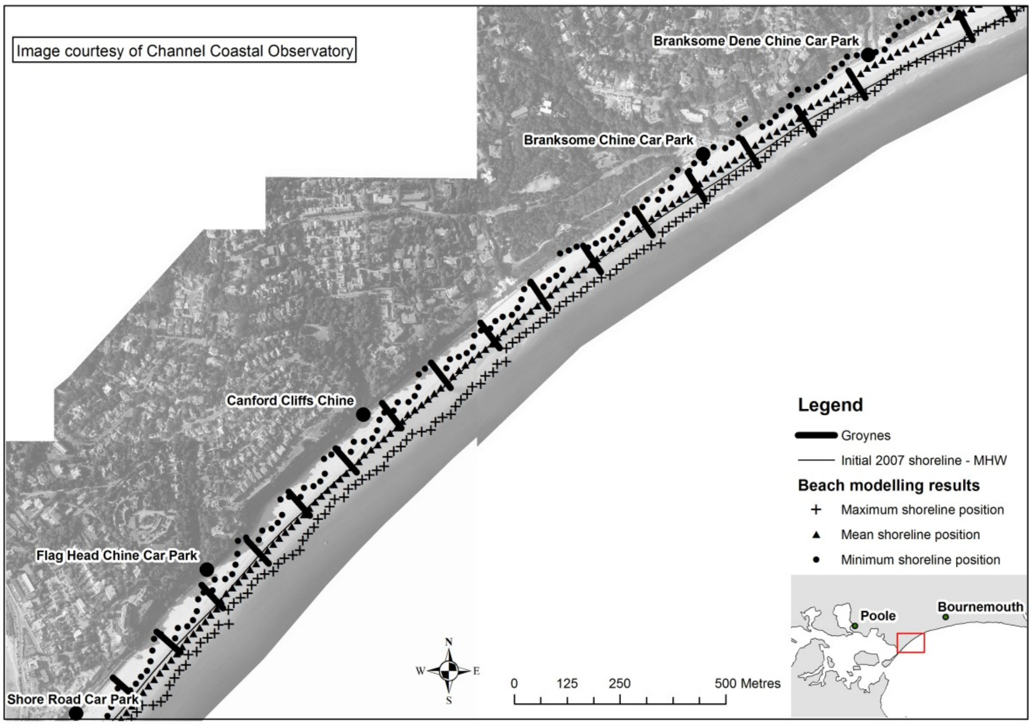


Figure 3 Plan shape model results for groyne scheme at 2:1 spacing

For ease of comparison of model results, Table 3 summarises the predicted minimum beach widths (between the MHW contour and the sea wall) in three crucial areas, namely immediately east of the bulge in the sea wall at Branksome Dene Chine, in front of Flag Head Chine and halfway between. Negative numbers indicate that this contour was extrapolated landward of the sea wall, indicating low beach levels at its toe.

Table 3 Minimum beach position along shoreline (relative to sea wall in m)

| Beach frontage | Model runs | | | |
|---|---|---|---|---|
| | Baseline run | 4:1 groynes 9 @ 300 m | 3:1 groynes 12 @ 225 m | 2:1 groynes 17 @ 150 m |
| Branksome Dene | -49.2 | -64.4 | -32.8 | -32.8 |
| Central frontage | 27.1 | -39.8 | -19.1 | -15.6 |
| Flag Head Chine | 42.9 | -28.8 | -16 | 16.6 |

As may have been expected, the minimum beach widths were greater between the most closely spaced groynes. However, the modelling also predicted that, except at Branksome Dene, the minimum beach widths were less than in the baseline run, i.e. with no beach control structures. This reflected often short-lived beach local erosion on the downdrift side of the proposed groynes.

As well as aiming to avoid narrowing the beach; the other objective of the proposed schemes is to retain beach sediment for longer, thus reducing the frequency/ volume and expense of future beach recharges To assess the effectiveness of the proposed groyne schemes in retaining sand placed during the 2005/06 recharge, the model also calculated the mean area between the sea wall and the MHW contour from just west of the Bournemouth Borough Council groynes to just west of Shore Road, a distance of about 2700 m. For this comparison, it was assumed that there was no restriction on sand arriving from the west. While this may be optimistic, results from modelling the proposed groyne schemes can still be reliably compared to one another, and to the baseline run. Table 4 presents these areas at the end of each year. Although all groyne schemes show a loss in beach area in years 1 and 2 in relation to the initial beach, by year 3 the beach had recovered and by the end of the modelling period the scheme with the most closely spaced groynes is the most effective. No clear advantage of the groyne scheme with 3:1 spacing was identified compared to that with 4:1 spacing.

Table 4 Predicted changes in beach area (m2) above the mean MHW contour

| | Beach area above MHW ($m^2$) | | | |
|---|---|---|---|---|
| Year | Baseline run | 4:1 groynes 9 @ 300 m | 3:1 groynes 12 @ 225 m | 2:1 groynes 17 @ 150 m |
| 1 | -12,800 | -3,500 | -5,700 | -2,100 |
| 2 | -17,000 | -12,800 | -19,200 | -21,100 |
| 3 | -13,500 | 5,400 | 700 | 4,100 |
| 4 | 100 | 27,400 | 22,300 | 27,900 |
| 5 | -6,800 | 6,400 | 6,300 | 8,500 |

On sand beaches, a groyne spacing of 2:1 is conventional and has been used successfully along the Bournemouth frontage, further east. This option performed better than the other two in the model testing, and while it would be much more expensive initially, it might still be the most cost-effective if it reduced the costs of future beach recharges over the lifetime of the scheme.

Further examination of the modelling results suggested that there might be no advantage gained by installing groynes (or other beach control structures) along the western part of the frontage. While all the groyne schemes improved beach widths along the western part of the frontage compared to the baseline run, this was at the expense of the beaches further east, at Branksome and Branksome Dene Chines, becoming narrower. The minimum beach widths along this western frontage occurred close to each groyne. It was therefore reasoned that groynes were unlikely to improve the overall standards of defence along this part of the frontage. This conclusion was supported by surveys showing the beach along this western part of the frontage had changed very little in the two years after the recharge operation in early 2006, despite no groynes being present. Further, reducing the number of groynes would be beneficial to the aesthetic and amenity value of this part of the frontage, as well as reducing the initial costs of a scheme.

The final short-listed scheme comprised of four multi-purpose reefs distributed evenly along the study frontage. However, because the initial modelling of the three groyne schemes indicated no need for beach control structures along the western part of the study frontage, it was decided to model a modified scheme involving the construction of only two reefs, i.e. one west of Branksome Dene Chine, and the second west of Branksome Chine (Figure 4). The reefs proposed were each 100 m long and positioned approximately parallel to the shoreline about 180–200 m offshore, in a depth of approximately 3–4 m water at high tide. In the modelling, the reefs were treated as low-crested breakwaters that would reduce wave heights passing over them by 20 per cent, based on calculation of an average wave transmission coefficient using the Rock Manual (CIRIA, 2007). Other aspects of the reef design, such as their cross-sectional shape were not specified, as it is their position, length and effect on wave heights that dominates their influence on the beach morphology.

Beach plan-shape modelling, using the same five-year wave sequence, showed that both reefs would retain wider beaches in front of the sea wall promontories near Branksome and Branksome Dene Chines. However, the model results indicated that minimum beach widths along the remainder of the frontage would become worryingly narrow, with the MHW contour shown typically 30–40 m behind the sea wall, indicating very low beach levels just in front of it (see Figure 4). Further, the reefs performed less well than any of the groyne schemes in retaining beach areas above MHW.

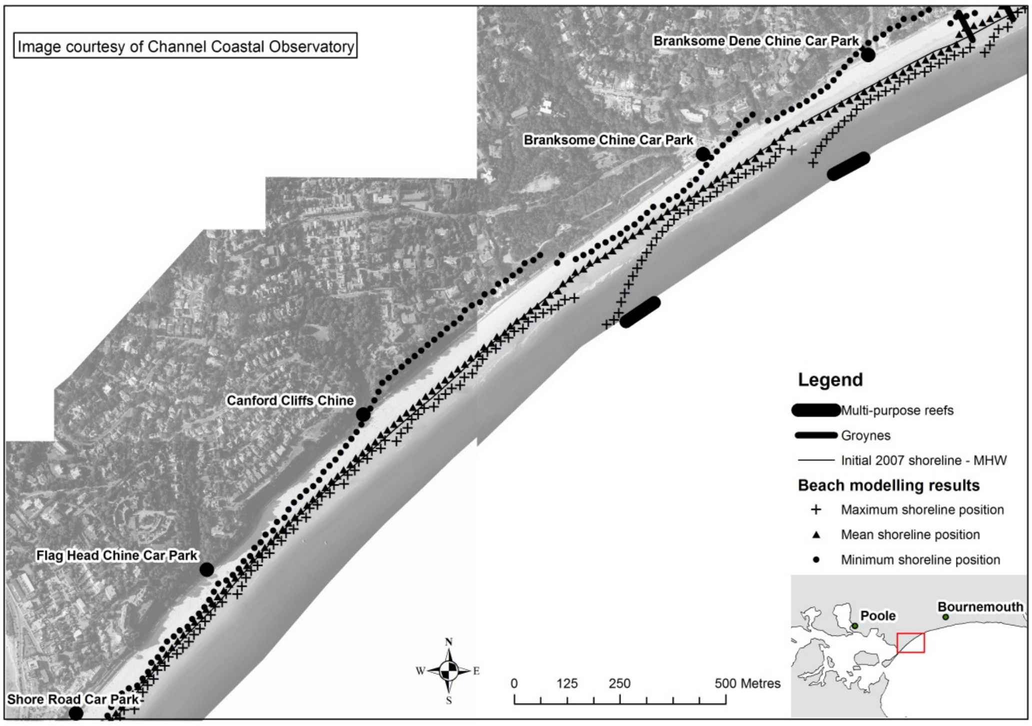


Figure 4 BEACHPLAN results for a two reef scheme

## 4.3. Sensitivity testing for climate change

The initial modelling of beach changes in Poole Bay assumed wave conditions would continue unchanged. We believe that it is good practice to make allowances for potential future changes in wave conditions when designing a coastal defence scheme, so that if these occur, then proposed defences will function in a satisfactory manner.

While guidance is provided on testing schemes assuming a possible increase in storm wave heights and periods(UKCP09), there has been little attention drawn to possible future potential changes in wave directions caused by global warming.

Re-running the model assuming 10 per cent increases in all wave heights and wave periods resulted in little change to the predicted future beach widths or the expected performance of the proposed schemes. However along most of the coastline of the UK, the net longshore drift rate is sensitive to changes in the mean wave direction, and this can result in substantial changes in beach widths.

Long-term narrowing of beaches in the western part of Poole Bay has been caused by the modest net eastward drift. However, the present drift regime may change, for example if waves approached from west of south more frequently. It was therefore decided to re-run the plan-shape model, for both the groyne and reef schemes, using a five-year sequence of waves that produced a mean net drift rate 60 per cent higher than at present. This was achieved very simply by applying a 2° increase to all the nearshore wave directions.

The results from re-modelling the three groyne layouts, and the two reefs, assuming this increased drift rate did not alter the conclusions drawn regarding the relative performance of these schemes. However, there would need to be more frequent (or larger) beach recharges to counter the faster losses in beach width. We believe that this type of sensitivity testing, while slightly extending the duration and costs of the modelling, is a sensible precaution when modelling beach plan-shape changes.

## 4.4. Final scheme selection and optimisation

The main conclusions from the numerical modelling of the four short-listed schemes were that that it appeared unnecessary to install any beach control structures along the western part of the study frontage and that groynes spaced at twice their length would perform better in retaining adequate beach widths than the other schemes. These results, and the other advantages and disadvantages of the four schemes, were discussed with Poole Borough Council. While the reefs showed some promise in maintaining adequate beach widths in their lee, it was felt that the recreational and aesthetic advantages of these would not outweigh their disadvantages, in particular predicted lower beach levels elsewhere. The Council had also carried out a more detailed costing and comparison of timber and rock groynes, and concluded that the latter option was preferable. It was therefore decided that a scheme with rock groynes at 2:1 spacing was the preferred option. Further modelling of this scheme was then started, aiming to reduce both its costs and any adverse environmental effects.

A problem common with many groyne schemes is that of beach narrowing just downdrift of the most downdrift groyne. In this study, the main problems of beach narrowing occurred during a period of intense westerly drift, i.e. reverse drift. At this time, the beach immediately adjacent to the most westerly of the new groynes was predicted to become very narrow, implying the risk of overtopping and even of undermining of the sea wall there.

This common problem has been mitigated elsewhere by tapering the groyne lengths at the end of a scheme. This spreads the erosion over a longer beach frontage, so reducing recession at any single location, particularly adjacent to the groynes. Even so, it is sometimes necessary to strengthen a sea wall locally to reduce the risks of it being undermined or damaged by increased wave overtopping.

The plan-shape model was used to refine the originally short-listed scheme of 17 groynes spaced 150 m apart, successively reducing the number and subsequently the lengths of the groynes while trying to maintain their performance in retaining the recharged beach area and avoid the risks of localised beach lowering at the sea wall.

Figure 3 shows that the minimum beach widths are predicted just to the west of each of the groynes along the whole frontage being modelled. In contrast, Figure 5 and Figure 6 show results obtained towards the end of this study. By this stage, the scheme had been reduced to just six groynes. Three of these remained 75 m long, but the lengths of the western three were 60 m, 45 m and 30 m respectively. This reduced beach erosion adjacent to them when the drift was westerly. The minimum beach widths along the western part of the study frontage in these figures are much greater than shown in Figure 3, even in front of the seaward protrusion in the sea wall at Flag Head Chine.

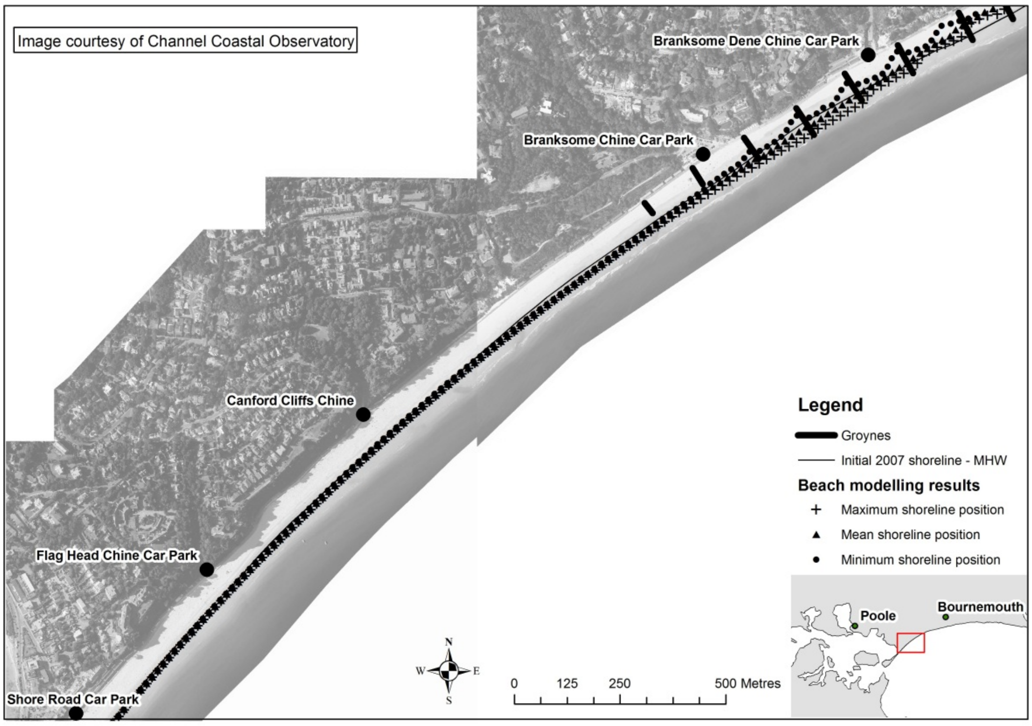


Figure 5 BEACHPLAN results for optimised groyne scheme at 2:1 spacing (Year 4)

Figure 5 shows the minimum, maximum and mean positions of the MHW contour during year four of the model run, during which the net drift was eastward and higher than the long-term average net drift. The minimum beach widths shown give no cause for concern and indeed are little different from the mean and maximum positions during that year. This smaller number of groynes both substantially reduces the cost of the original short-listed scheme shown in Figure 3, and the impacts of a scheme on the visual and amenity value of the beaches. Also the mean position of the MHW contour in year five indicates that this reduced scheme achieves better retention of the beach area than any of the originally short-listed schemes.

However, potential concerns still remain. Figure 6 shows the results during the fifth year of the model run, during which there was a period of strong westward drift (i.e. a drift reversal). The minimum beach widths shown indicate the potential for short-term beach lowering to the west of the groynes, with the MHW contour shown about 36–40 m behind the sea wall to the west of the westernmost of the new groynes. This is equivalent to the beach level falling to just below that of Mean Low Tide at this time. It can also be anticipated that the beach width in front of Flag Head Chine will decrease over time. However, it was concluded that a more cost effective and appropriate way to manage these potential and localised problems would be to strengthen the sea walls so that they can resist undermining during periods of lower beach levels rather than installing groynes along the entire frontage.

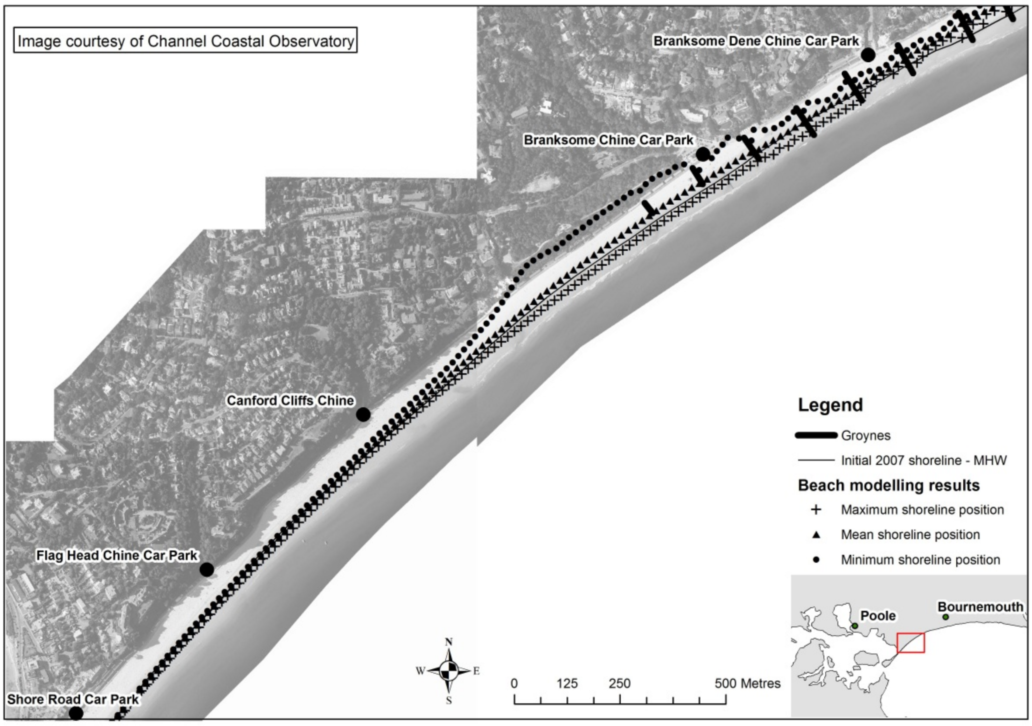


Figure 6  BEACHPLAN results for optimised groyne scheme at 2:1 spacing (Year 5)

Finally, at the end of the numerical modelling study, a small alteration to the proposed spacing of the groynes was tested.  This showed that moving one of the proposed groynes to combine it with an existing storm water outfall did not affect the general outcome of the scheme but would improve the visual and amenity qualities of this frontage.

Following this modelling study, Poole Borough Council approved the proposed scheme in May 2008, completed its detailed design, obtained Grant Aid and installed the groynes by the end of May 2009.  As part of the post project assessment regular beach surveys are being undertaken and analysed to monitor changes in beach plan-shape along the study frontage.  So far, the scheme has performed rather better than expected.

# 5. Conclusions

1. Designing beach management schemes in coastal resorts needs consideration of a wide range of issues, including costs, performance, sustainability and effects on the environment, including those on the amenity and aesthetics of the frontage.
2. Following a recharge, the western part of Poole Bay had no existing beach control structures, for example groynes.  This provided an unusual ‘blank-canvas’ opportunity to consider a large number of both novel and traditional beach management schemes. A preliminary view had to be taken not only on the likely long-term performance, benefits and costs of each scheme, but also of their environmental

acceptability. In particular, the Borough of Poole Council had concerns about possible adverse effects on the amenity value of the Blue Flag beaches which are vitally important to the local economy. This is an issue common to many UK coastal resorts.

3. The many possible management options made it difficult to justify and recommend a modest number of schemes to be taken forward for a more thorough assessment, including public consultation, numerical modelling and then detailed design. Comparing schemes by assessing their technical and less tangible merits separately, using simple multi-criteria analyses, allowed the involvement of the public and councillors in choosing four short-listed schemes.
4. Numerical modelling of beach changes was only practicable once this modest number of options had been agreed. A plan-shape model was used to assess how the beaches would develop without intervention and then to predict the effects of different schemes. In either role, the model results were regarded as aids to decision making rather than deterministic forecasts of future beach widths.
5. In such modelling, it is important to define, in advance, the criteria that will be used to interpret results when deciding which, if any, of the proposed schemes performs best. Simple comparisons of 'end-of-year' beach positions can be misleading. In the present study it was decided that predictions of minimum and mean beach widths would provide better measures of the performance of each scheme.
6. Little attention is given in existing guidance on examining the effects of climate change of proposed coastal defences regarding potential changes in wave directions. However, longshore drift rates, and hence beach evolution, are more sensitive to small changes in wave direction than in wave heights or periods. Extra sensitivity tests were carried out conjecturing possible future changes in wave conditions, in particular in mean wave direction, and the relative performance of the short-listed schemes re-examined. These tests and the initial modelling results contributed to the choice of a preferred scheme.
7. Through the later optimisation phase of the modelling, the number of beach control structures required along the frontage was reduced to just five new groynes (and one refurbished groyne) at the eastern end of Poole Borough's coastline, thus significantly reducing costs and improving the amenity value and aesthetics of the beaches compared to the original plans.
8. Overall this paper demonstrates how numerical modelling can assist in making beach management decisions, which led to significant cost savings and improvements to the amenity value and aesthetics of the beaches.

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