10 Literature Review and Historical Change

Introduction

10.1 This Chapter covers a review of existing literature on Slapton Sands, and an analysis of data on historical changes in beach position. Figure numbers in this section start at 10.9.

Literature reviews

Literature review of barrier beach processes

10.2 A barrier beach is a narrow, elongated ridge of sand or gravel sitting slightly above high tide level. The ridge extends generally parallel to the shore, but is separated from it by a wetland, lagoon or a tidal flat. Barrier beaches act as natural means of coast protection. In addition, wetlands and lagoons formed behind barrier beaches provide shelter for many coastal habitat and are therefore of considerable environmental significance.
10.3 Barrier beaches are constantly changed and modified by coastal processes in short and longer terms. Short term changes in barrier beaches are related to local wave and current climate, tidal variations, frequency and magnitude of storm events, barrier geometry including foreshore slope, pre-storm crest height and alignment, type of beach sediment and permeability. Over longer terms, sea level rise, longshore sediment transport and sediment sources and/or sinks are the primary factors for change and modification of barrier beaches (Orford et al., 1995).

10.4 A barrier beach can respond to these factors by landward or seaward migration, reshaping and re-alignment, crest breakdown or build-up and no change subject to certain critical but as yet ill defined thresholds (Carter et al, 2003). Over-washing and associated breaching and over-topping are the primary phenomena behind long term and short term barrier evolution.

10.5 Long term barrier evolution associated with coastal processes such as sea level rise is well documented, mainly based on field investigations. It has been found that the landward migration of the seaward shoreline of a barrier beach is linearly proportional to annual sea level change whereas the rate of back barrier migration is not related significantly to the rate of change in sea level (Orford et al., 1991). The difference between front and back barrier migration response to sea level rise is found to reflect the role of short-term processes such as storm events (frequency and magnitude), waves and currents. It has also been found that short-term sea level rise (<10 years) may be influential in the rate of barrier break down, (Orford et al., 1996). Reshaping of barrier beaches due to sediment sources/sinks and sand bypassing associated with longshore sediment transport are discussed in Duncan et al. (2003).

10.6 Previous studies, of any nature, aiming at short term barrier evolutionary processes associated with storm events, local wave climate and tidal variations are extremely scarce. Bradbury (2000) carried out a series of 3-D mobile bed laboratory tests on barrier crest response to hydrodynamic conditions and initial barrier geometry. Based on the model investigations, several categories of barrier response to hydrodynamic conditions were identified and underlying characteristics were qualitatively defined; crest raised by overtopping, crest lowered due to undermining of crest but with no overtopping, crest raised by over-washing with roll-back, crest lowered by over-washing with roll-back and finally, no change to the crest elevation with profile contained to seaward of the barrier crest. An expression for an over-washing threshold of barrier crests was also proposed based on regression analysis, which is a function of wave steepness, barrier free board and cross-sectional area. The expression was validated against field data gathered at Hurst Spit, UK and found to be consistent with the field data. In addition, a conceptual model for barrier over-washing was formulated. According to his model, the beach will initially attempt to reach a dynamic equilibrium; if the critical barrier inertia is exceeded then over-washing will lower the crest. It was also found that hydraulic conditions such as wave climate and storm intensity are more significant to barrier beach evolution than barrier geography.
10.7 The balance between building-up or breaking-down of a barrier beach, which controls barrier migration and reshaping/realignment depends on both short term and long term barrier response to coastal processes. However, it has been identified that barrier beaches recover after storms to positions consistent with their long term trends given that the frequency of occurrence of storms permit beach rebuilding in-between them. They will not experience long term beach erosion in response to storm impact if sea level rise is not significant and sediment supply does not change (Zhang et al., 2002).

10.8 Coarse grained barrier beaches with steep seaward slopes possess distinct morphodynamic and hydrodynamic characteristics which differ from those on sandy barrier beaches. The reflective nature of the seaward barrier favours development of low-frequency waves that dominate the local on-off shore and longshore sediment transport and barrier over-washing. Also, high seepage potential in coarse grained barrier beaches and lack of distinct tidal passes associated with that generates very little offshore sediment transport, thus creating barrier migration only in the onshore direction (Carter and Orford, 1984).

10.9 However, barrier beaches with a steep seaward slope are found to be relatively stable under wave attack. Sediment particles in a coarse grained barrier are entrained only under high-energy wave attack and produce hydrodynamically rough surfaces capable of affecting inshore wave spectra. They have low landward migration compared to sandy counterparts unless they have a low or breach in the fore dune, which speeds up the migration process.

Some conclusions of the review

10.10 Other than the model based on regression analysis (Bradbury, 2000), no process-based models or probabilistic models are available to predict over-washing/overtopping thresholds.

10.11 The steepness of the seaward slope of the barrier beach is a significant parameter for overtopping.

10.12 Over-washing and the breaching threshold of coarse grained barriers depend on

- low-frequency waves generated by swell, which extend swash run-up up to, over and beyond the barrier crest.
- Morpho-sedimentary structure which leads to form seepage hollows to maintain seaward discharge in the absence of tidal inlets; gradual excavation of seepage hollows acts to undermine the barrier crest and create incipient breach points (Carter and Orford, 1984).

Review of existing literature on Slapton barrier beach
10.13 The coastline of Start Bay includes a series of minor headlands separating Hallsands, Beesands, Slapton Sands and Blackpool Sands. Both Beesands and Slapton Sands are barrier beaches, between 100m and 140m wide at high tide. The shingle barrier beach impounds the lagoons of Slapton Ley and Higher Ley. The crest of the barrier at Slapton Sands falls within 6.0m O.D. ±0.5m. The tidal range in Start Bay is of the order of 2m at neap tides and 5m at spring tides.

10.14 Skerries Bank, which lies on the southern end of Start Bay, extends from Start Point and runs 6.4km in the northeast direction. The bank consists of coarse sand and shell. Maximum height of the bank is -4.8m while the height over most of its length is -7.5m to -9.0m.

10.15 The orientation of Start Bay makes it subject to rapid changes in wave regime. Skerries bank adds further contributions to the changes in wave regime, especially at low water. Previous wave refraction analysis undertaken at Start Bay has clearly shown the significance of Skerries Bank on the wave climate where north-easterly waves with periods between 7 and 14 seconds entering the bay are refracted by Skerries bank directly on to the south of Slapton Sands, Beesands and Hallsands (Hails, 1974 and Holmes, 1975).

10.16 Tidal current data collected at five stations within Start Bay suggest that the submarine topography of the bay is formed by tidal streams and that waves are less effective than currents in transporting bottom sediment. It is also suggested that little sediment from offshore reaches the beaches of Start Bay (Hails, 1974).

10.17 Gleason et al. (1975) collected sediment samples at Start Bay around high water and low water marks during a series of spring tides over a period of six months. They also conducted monthly measurements of bottom profiles at 300m intervals along Start Bay. In addition, some tracer experiments were carried out to relate longshore sediment movement to incident wave energy. Analysis of the sediment samples has shown that the beach material at Slapton Sands is predominantly granules (-1 to -2Φ) and small pebbles (-2 to -4Φ). Gleason et al found from their analysis that Slapton Sands has a pronounced longshore grading of sediment and that there is a considerable variation in mean sediment diameter at different times of the year. They also noticed frequent short term and short distance reversal of longshore sediment grading due to rapid variation in incident wave direction.

10.18 According to the field investigations of Gleason et al., there is a tendency for Slapton beach to be narrower and beach material to become coarser towards the south. It was also noted that greatest accretion and depletion of sediment occurred at Torcross Point and Strete Head where coarse materials accumulated against the headlands. Materials pass these headlands only at severe weather conditions. Slapton beach was found to be the most stable beach segment within the Start Bay.
10.19 Analysis of 50 vibro-core and 200 bottom sediment samples all over Start Bay showed that three discrete sediment units could be identified within the Bay (Hails, 1975). These have been described as bay, bank and barrier deposits. The bay deposits were composed of medium to fine grained sand with varying concentration of silt and whole and broken shell. The bank deposits were mainly coarse, shelly sand and approximately occupy the area of Skerries Bank. The barrier deposits consisted of shingle or beach gravel and occupy a relatively narrow zone extending from the backshore of the beach to about 200m beyond low water mark.

10.20 Field measurements have been undertaken at Slapton Sands to measure bed load sediment transport, surface profiles and currents. During these measurements, the incident wave periods were around 5-6 seconds; wave approach was oblique, breakers forming an angle of about 15º to the shoreline. Breaking wave heights were 0.5-0.6m and the breakers were of surging type. It was found from these measurements that there was a long period wave component at about twice the incident wave period in the surface profile and flow spectra. The bed load transport appeared to be dominated by this long period wave energy.

10.21 Robinson (1961) found that Skerries Bank has been relatively stable for over a century and there has been a very little change in plan form of the bank from 1825 to 1951. He also found that apart from the shingle found on the barrier and the immediate foreshore very little shingle was found elsewhere. The materials on Skerries Bank mobilised by moderate to high seas is redistributed by tidal currents running parallel to the coast rather than being carried shoreward.

10.22 Carr, Blackley and King (1982) carried out site investigations and field surveys to determine spatial and seasonal aspects of beach stability at Slapton beach over a period of one year from September 1971 to September 1972. Site investigations included collection of original wave data from wave-rider buoys and frequency-modulated pressure recorders. Based on these measurements they concluded that a direct relationship could not be found between incident wave energy and change in beach height. This was due to several reasons; oblique wave incidence from two widely different directions (NE and SE), rock headlands intervening between various bays and the influence of offshore bathymetry on wave energy arriving at the shoreline. Also, it was noted that the beach alignment at Slapton does not indicate any relationship with the wave approach angle.

10.23 The investigations of Carr et al. (1982) identified that even though Start Bay appears to have significant on-offshore sediment interchange from time to time, it does not extend beyond the near-shore zone. Therefore, sediment is not irrevocably lost to the system. The mobility of sediment in the longshore direction is relatively high due to oblique wave incidence and the steep beach gradient. Brief tracer experiments carried out on the beach showed that sediment can be transported in both northerly and southerly directions, depending on the direction of wave approach. The headlands appeared to act as groins, causing piling up of sediment against them. It was also identified that the seasonal change in beach volume is very complicated and
there was actually a net increase in beach volume during the winter months of that particular year.

10.24 The Shoreline Management Plan (SMP) for Lyme Bay and South Devon (Posford Duvivier, 1998) identified Start Bay as a closed sediment cell and Skerries Bank as a wave and sediment barrier. Skerries Bank focuses wave energy onto the southern sector of Start Bay, modifying wave approach direction by diffraction and refraction. A limited net northward drift was identified within the bay. According to their calculations, the net northward alongshore transport in the southern part of Start Bay (Hallsands and Beesands) was 10,000m³/yr - 14,000m³/yr and that of the northern part (Slapton Sands) was 60,000m³/yr - 75,000m³/yr. The report states that Slapton Sands is likely to benefit from this northward drift. They also found that Slapton Sands has suffered very little erosion in recent years except the rapid erosion recorded in the winter 1995. It should be noted that the sediment transport calculations for Start Bay in the SMP for Lyme Bay and South Devon (1998) were based on a theoretical wave analysis and were not validated against reliable estimates of beach volume changes.

10.25 The SCOPAC sediment transport study (2002) on the littoral system of Start Bay suggests that the net northward alongshore drift may not be typical in the long term and switches between decadal intervals of weak northward and southward net drift might be anticipated in future. This is based on the fact that if a unidirectional drift system is to be maintained, shoreline erosion should be observed in the southern part of Start Bay, which is opposed to its current stable condition.

10.26 Two studies have been undertaken, subsequent to the road collapse in January 2001. In his report to English Nature, Pethick (2001) states that:

- Slapton barrier has been rolling landward over the past 5000 years to keep pace with sea level rise.
- The rolling over process is effected by wash-over, transferring sediment from shore face to back barrier
- The beach face has retreated by an average of 0.8m/yr between 1972 and 1995
- The wash-over process is unsustainable since sediment must be transferred from width to height. Thus, the barrier is decreasing in width by 15m per century. Since there is no sediment source to maintain barrier width, it must eventually become so narrow as to allow breaching.
- The generally agreed hypothesis for Slapton Sands is that it is a closed sediment system.
- The Slapton system is entering the breakdown stage of the Carter-Orford barrier model (Orford, 1995).
10.27 Orford (2001) in his report to English Nature states that the landward retreat of the barrier is a function of:

- Rising sea levels. Barrier retreat elsewhere suggests 0.9m/yr for a sea level rise of 1mm/yr.
- Variation in on-shore wave climate associated with east and southeast storm waves. Such a wave climate shows variation in storminess over a decadal scale.
- Variation in relative overtopping to over-washing as a function of variation in breaking wave height. Relative balance of these two processes governs the average barrier retreat.
- Variation in long-shore spatial position of over-washing as a function of near-shore wave focusing.

10.28 Orford (2001) suggested that the 2001 beach stabilisation by rock armouring would reduce the local rollover rate of the barrier at the potential breach point, but will not inhibit rollover rate at the terminal points. It will also alter the anticipated geomorphological change of the barrier in response to sea level rise and storminess in the longer term.

10.29 FUTURECOAST (2002) was commissioned by DEFRA and carried out over a period of approximately 21 months. The study provides predictions of coastal evolutionary tendencies over the next century, which are to be considered in the updating of SMPs and other Strategic Plans targeted at determining broad scale future coastal defence policy throughout the open coast shorelines of England and Wales. The analysis of future shoreline evolution potential for each section of coast, which is the main component of the study, provides an improved understanding of the coastal systems and their behavioural characteristics. A framework to enable consistent reporting, assimilation and presentation of the study results was developed. A detailed analysis of the coastal processes and characteristics of the Slapton Line as set out in FUTURECOAST are outlined in Appendix A.

FUTURECOAST identifies Slapton Sands as a self-contained beach, which does not have significant sediment sources or sinks. The river Dart is not recognised as a major influence on coastal evolution as it is separated from the rest of Start bay by hard rock headlands. Sediment exchange between Slapton beach and Skerries bank is not observed. Although beach materials move alongshore in both NE and SE directions depending on the incident wave direction, widening of the beach to the north implies a net northward drift. It also identified that frequent storms from the East and Southeast can have a significant impact on longshore transport.

10.30 According to the shoreline behaviour statement in FUTURECOAST, the recent storm damage to the central part of Slapton barrier appears inconsistent with the general long-term behaviour of the barrier. Evidence from historic mapping suggests that the general alignment and integrity of the barrier has changed very little until recently. It is found that a part of the barrier beach does
not appear to have been retreating in response to sea level rise while the remaining part is shown to have a slow retreat.

10.31 The FUTURECOAST assessment of future evolution of the beach states that the barrier beach would undergo retreat through landward rollover. This process is unlikely to result in the loss of beach material, although the barrier would become narrower as it develops a slightly longer, more curved plan form. Periods of storm damage seen recently would continue in the future and breaching of the barrier would be expected within the next century.

### Sediment sampling and analysis

#### Locations of samples

10.32 Twelve sediment samples were taken at various representative positions along Slapton Sands. The gravel was analysed using British Standards sieve analysis techniques to determine the distribution of grain sizes over the beach.

![Figure 10.9 Positions of sampling](image)

10.33 Samples were taken at each of the three sites illustrated in Figure 10.9 at High, Mid and Low tide positions. Sediment at the Strete Gate end of the beach was taken from the surface and from about 300mm below ground level to ensure that there was no critical change with depth. It was observed that there was no significant difference and therefore further sampling was limited to surface material. During this initial field trip it was observed that Beesands, a neighbouring beach, joins the Slapton Sands sediment system at low tide. Therefore a sediment sample from Beesands was taken and analysed at a later date. This sample site is not shown on the map.
Results

10.34 From the sieve analysis, a grain size distribution curve was plotted for each of the sediment samples. These graphs allowed the $D_{50}$ and the $D_{80}$ to be calculated, as shown in Table 10.1.

Distribution with depth

10.35 From the analysis of the Strete Gate samples it was clear that there was no major difference in grain size to a depth of about 300mm at the high water and mid-tide locations. However, at the low-tide level there was more of a difference between the surface and 300mm depth sample.

Table 10.1 Sediment size results

<table>
<thead>
<tr>
<th>Site</th>
<th>Surface</th>
<th>300mm</th>
<th>Description</th>
<th>$D_{50}$</th>
<th>$D_{80}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Strete Gate</td>
<td>H.W</td>
<td></td>
<td></td>
<td>1.88</td>
<td>2.33</td>
</tr>
<tr>
<td>Strete Gate</td>
<td>H.W</td>
<td></td>
<td></td>
<td>1.8</td>
<td>2.2</td>
</tr>
<tr>
<td>Strete Gate</td>
<td>Mid. Tide</td>
<td></td>
<td></td>
<td>3.04</td>
<td>4.23</td>
</tr>
<tr>
<td>Strete Gate</td>
<td>Mid. Tide</td>
<td></td>
<td></td>
<td>2.62</td>
<td>4.33</td>
</tr>
<tr>
<td>Strete Gate</td>
<td>L.W</td>
<td></td>
<td></td>
<td>3.9</td>
<td>4.78</td>
</tr>
<tr>
<td>Strete Gate</td>
<td>L.W</td>
<td></td>
<td></td>
<td>1.8</td>
<td>3.09</td>
</tr>
<tr>
<td>Road erosion event</td>
<td>Breach</td>
<td></td>
<td></td>
<td>2.55</td>
<td>4.38</td>
</tr>
<tr>
<td>Road erosion event</td>
<td>H.W</td>
<td></td>
<td></td>
<td>3.55</td>
<td>4.55</td>
</tr>
<tr>
<td>Road erosion event</td>
<td>L.W</td>
<td></td>
<td></td>
<td>4.9</td>
<td>8.13</td>
</tr>
<tr>
<td>Torcross</td>
<td>Near Wall</td>
<td></td>
<td></td>
<td>9.5</td>
<td>18</td>
</tr>
<tr>
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<td>H.W</td>
<td></td>
<td></td>
<td>7</td>
<td>8.83</td>
</tr>
<tr>
<td>Torcross</td>
<td>L.W</td>
<td></td>
<td></td>
<td>8</td>
<td>12.58</td>
</tr>
<tr>
<td>Bee Sands</td>
<td></td>
<td></td>
<td></td>
<td>5.14</td>
<td>8.73</td>
</tr>
</tbody>
</table>

Distribution on profiles

10.36 Strete Gate and the Breach Position (Figure 10.10 and 10.11) showed similarity in the grain size distribution along the beach profile. At these two sites the grain size increased from the high water mark to the low water mark. Torcross sediment (Figure 10.12) proved to be of much larger size than any of the other sites and did not show the same distribution with profile.
Sediment Distribution along profile at Strete Gate

Figure 10.10  Sediment Grain Size at Strete Gate

Sediment Distribution along profile at Breach Position

Figure 10.11  Sediment Grain Size at road erosion location.

Sediment Distribution along profile at Torcross

Figure 10.12  Sediment Grain Size at Torcross
10.37 Torcross, Breach Position and Strete Gate: The longshore distribution of grain size shows that sediment size increases from Strete Gate to Torcross (Figure 10.13 and 10.14). Torcross has a much larger sediment size than both Strete Gate and the breach position.

10.38 Beesands: The sample taken at Beesands showed a sediment size, which was smaller than Torcross but larger than the other two sample sites.

![Change in Sediment Size at H.W Between Sites](image1)

**Figure 10.13** Sediment sizes at high water between sites.

![Change in Sediment Size at L.W Between Sites](image2)

**Figure 10.14** Sediment sizes at low water between sites.
Other Coastline Areas within Start Bay

Hallsands

10.39 In 1896, Sir John Jackson was awarded a contract to extend the Keyham dock, Devonport. A license was awarded by the government of the time for Sir John Jackson to start dredging between Hallsands and Beesands. Dredging commenced in April 1897.

10.40 The majority of the shingle was taken from between the low and high water mark. In 1900 the villages began to notice the problems caused by the dredging. The road and the sea wall were beginning to become dangerous.

10.41 On September 11th 1901, Captain G C Frederick visited the bay to measure how much the beach level had decreased. He found that the level had decreased along the whole coast but had fallen by up to 12 feet in places where the dredgers had operated. He found that continued dredging should be stopped because if allowed to continue, the road and the houses would be at risk during a storm.

10.42 On the 26th of February 1903 at high tide, a storm started to bring water over the walls, which led to houses closest to the beach being undermined. Two nights later, the quay at the southern end of the village collapsed, as did the road and more houses.

10.43 The villages were awarded compensation by Sir John Jackson and the Board of Trade. The money was given on the condition that the villages accepted it on the condition that it was the final settlement and that they could not claim for any damage that may occur in the future. The villages were able to repair the defences and provide new homes to the people who were worst affected.

10.44 On the 26th January 1917, there was a south westerly storm that breached the walls and destroyed many homes. 24 families were homeless however no one was killed. Only homes that were on the top of the cliff survived.

Blackpool Sands

10.45 The SMP identifies that the coast is eroding, and hence that to do nothing along this stretch of coastline would eventually lead to undermining of the current coastal defences, which would result in loss of recreational land and eventually the A379. An area of Car Parking and property would become susceptible to flooding.

10.46 The SMP identifies that the embankment and wave return wall are currently not performing satisfactorily. Additional defences are required. Future works should incorporate beach recharge.
Beesands

10.47 The SMP reports that beach level at Beesands vary seasonally, with an annual range of approximately 5m at the south end. In recent storms, beach material has been taken from around the high water line to around the low water line. This has resulted in exposure if the east cliff material along the front of the village.

10.48 The SMP identifies that works are required to hold the defence line.

Historical data analysis

Beach profile analysis

10.49 Beach profiles along Slapton Sands at 10 locations from Strete Gate to Torcross, (sections SS1 to SS10) have been surveyed by the Field Studies Centre since 1972. Figure 10.15 shows beach profiles at SS3 from March 2000 up to May 2003, which is the location of the road collapse in 2001. The figure clearly shows crest cut back and steepening and lowering of the beach profile during the storm that occurred from the 10 to 15 January 2001. The subsequent profile accretion is partly due to the renourishment after the road collapse.

![Figure 10.15](image_url)  
**Figure 10.15** Beach profiles at location SS3.

10.50 Figure 10.16 shows beach profiles at Strete Gate, covering the period 1972 to 2003. It is seen that the crest height of the beach had been varying by about 1 m while the beach front at mean high water level moved about 25m. The beach width had varied widely over the years. However, it can be noted that the beach width had one of the smallest values just before the storm event in January 2001.
Figure 10.16  Beach profiles at location SS1 (Strete Gate).

10.51 Figure 10.17 shows beach profiles at SS10 (Torcross) from 1972 to 2003. It can be seen from this figure that the crest height and the beach width had been varying very widely each year. The total change in crest height is about 2.0m while change in beach width at mean high water level is about 25m. The highest and the widest beach profile at Torcross had occurred soon after the road collapse in January 2001.
Figure 10.17  Beach profiles at location SS10 (Torcross).

10.52 The profiles available at Strete Gate (SS1), Torcross (SS10) and at the breach (SS3) were analysed further and beach areas above mean high water level (MHWL) and at mid tide (MWL) were derived. The beach areas were then drawn against time. Figures 10.18 (a), (b) and (c) show beach areas above MHWL and MWL at SS1, SS3 and SS10 respectively.
Figure 10.18 Beach areas against time. (a) SS1 – Strete Gate, (b) SS3 – Location of breach, (c) – SS10 – Torcross.

10.53 Linear regression lines were drawn for each set of data except for SS3 where beach nourishment has taken place in 2002.
10.54 According these figures, the long term trend of beach areas above both mean high water and mid tide levels have increased at Strete Gate, which indicates sediment accretion and hence shoreline advance. The percentage increase of beach area over the 31 years from 1972 to 2003 at MHWL and MWL are 10% and 12% respectively. However, it should be noted that there is considerable variation about the trend line and the trend may not be statistically significant, due to the irregularity of the survey data and inherent surveying inaccuracies. Beach areas at Torcross show a downward trend indicating shoreline retreat. The percentage reduction in beach area at MHWL and MWL at Torcross during the same period was 10% and 9% respectively. At SS3 a downward trend was found within the period from 1981 up to when beach nourishment took place in 2002. Reduction in beach areas at MHWL and MWL were 57% and 42% respectively.
Analysis of Erosion Rates

10.55 Erosion rates have been analysed by comparison of the following maps and photographs:

- OS Maps for epochs 1880/90, 1904/05, 1950’s, 1980’s and 2003
- Aerial photographs for 1999 and 2003
- Various historical photographs

10.56 The historical photographs below were analysed for erosion rates at the ‘Tank Car Park’. It is clear from the photographs taken in 1890 and 1900 that the shingle bank was more stable and vegetated compared to the photographs from the 1920’s. Where sheet metal piles have been constructed to prevent undermining of the road in this location, whilst allowing waves to overtop. This structure still exists on the beach today.

10.57 Using the front of the Torcross Hotel as a baseline (visible in all images with an unchanged face), the distance of the road from the crest of the shingle beach was measured. Although only approximate due to date variation and details of scale, the order of erosion is approximately 0.6m per year over a period of nearly 40 years at this location.

1890 North Torcross. Vegetated shingle.
1900’s Lower Ley/Torcross. Wider shingle crest and narrower vegetated shingle area.

1920’s. Sheet piling with concrete top constructed 1917. Vegetated shingle not visible.
1900’s Royal Sands Hotel, located at Slapton Bridge. Area of vegetated shingle in front of the hotel.

10.58 The Royal Sands Hotel, located at the middle of the Ley near Slapton was built in the 1800’s on the coast road between Slapton and Torcross. It was mined as a defence against German invasion but was destroyed during the Second World War and is now the middle sands car park. The land seaward of the hotel in the above photograph has since been eroded, and the middle sands car park is now protected by concrete revetment blocks.
10.59 Using the seafront of the Hotel as a baseline (now the car park edge), the distance of the road from the shingle bank was measured. The seaward edge of the middle sands car park is currently 35m from the new road position. The above photograph and historical OS maps from 1880-90 were used to calculate that the road was 35.6m from the shingle bank. Therefore although there have probably been seasonal and annual variations, the approximate distance of the shingle crest from the road remains the same.

10.60 The position of the high and low water marks for three epochs (1880/90, 1904/05 and 2003) clearly show that the 1880/90 and 1904/5 shoreline positions are virtually coincident. The 2003 lidar survey, however, shows some differences, At Strete Gate the shoreline has advanced seaward by about 45m, whilst at Torcross it has retreated by about 30m and the beach has apparently steepened. In the central portion of the beach the shoreline remains very similar to the previous epochs.

10.61 Historical maps from 1890 were compared with maps from 1904 with the existing OS map 2002. Cross sections were measured every 500m from Strete Gate to Torcross. The average difference between 1904 and 2002 at Strete Gate showed approximately 0.2m advancement seaward of the shingle crest per year.

10.62 The central area of shingle crest around Slapton Bridge showed differences from 1890 to 2002 ranged from –1.1m per year retreat to 0.05m per year advancement. The area of Torcross had a difference of –0.01m per year between 1904-2002, this area included the shingle crest defended by the rock revetment.

10.63 The erosion measurement exercise was repeated for OS Maps from the 1950's and 1980's. None of these showed any significant changes in crest position. Comparison of aerial photographs for 1999 and 2003 showed 4m difference (erosion) in crest position in the central area near to the car park.

10.64 Taking all available long-term data into account, it has been calculated that the average long-term erosion rate for the crest of the shingle barrier is in the order of 0.1m per year. These calculated erosion rates must be treated with caution as they include the effects of any structures or inhibiting features, such as the road, and are therefore not entirely ‘natural’ rates.

10.65 The main findings from the historical analysis are therefore:

- The history of construction of defences along the face of the shingle barrier suggests a generally continuing problem of erosion
- However, the long-term erosion rate of the crest of the shingle bank is quite small – about 0.1m per year over the last 100 years. At Strete Gate the beach has actually increased in width. This suggests that the problem is more one of episodic erosion events than continuous erosion.
Over shorter periods of time there have been large fluctuations in beach profile. For example between 1890 and 1904 the beach width at Torcross reduced by about 16m, and between 1995 and 2001 the beach width (at a level below the crest) at the central car park reduced by about 25m.

**Natural Crest Line**

10.66 Aerial photographs of Slapton Sands show that at any time there are shingle ridges on the face of the beach. They occur when a wave event modifies the beach profile, and their level up the beach is dictated by the water level at the time. The ridges adopt a consistent plan shape, which is indicative of a near-equilibrium condition.

10.67 By plotting this plan shape line on a map, and projecting landwards, it is possible to identify areas where the upper beach is ‘out of step’ with the general shape of the beach. Such an exercise has been carried for the 1999 aerial photographs, and is presented as Figure 2.4 and 10.26 in Volume II. The broken red line (the ‘Natural Crest Line’) shows a near equilibrium crest line, which the beach would take up if it wasn’t constrained by human interference, or affected by localised steepening. Where the red line is landward of the vegetation line or the road or car park it indicates that in these locations the beach was steeper than normal and therefore more likely to erode.

10.68 The figure matches well with locations where erosion occurred in 2001.

**Historic Chart Analysis**

10.69 The most recent admiralty chart was based on survey data from 1951. For the basis of further modelling and historical comparisons, a bathymetric survey was conducted for this Study by EMU Ltd in January 2004. The details of this survey have been supplied in hard copy to the Slapton Line Partnership Group.

10.70 The 1951 Admiralty chart (E9601) of Start Bay was compared to the 2004 Bathymetric survey of Start Bay conducted by EMU Ltd. The purpose of the comparison was to establish if Skerries Bank and the near shore bathymetric depths had changed in the last 50 years. A reduced depth on Skerries Bank (deeper measurements metres CD) could indicate increased erosion and removal of sediment, and conversely a shallower depth could suggest increased sediment transport accumulation. Cross sections were compared for the area of Skerries Bank and in the near shore area of Slapton Sands. Depths are measured at metres below Chart Datum.

10.71 Local opinion suggests that there has been no change to Skerries Bank over the years, based on the location of pits used to fish crabs.

‘The Skerries is made up of very fine shingle and shell and rises up very steeply from outside the bay, from 150ft to about 70 or 80ft. Along the bank are various pits which drop away almost vertically to depths, in some cases to 160ft. The bottom of these pits is think black clay. In
human terms these pits and banks have never changed and their landmarks have been passed on from generation of fishermen to generation.’ C.Venmore, 2002.

10.72 The profiles intersecting Skerries Bank and along the bank showed a slight variation in depth over the last 50 years. This ranged from −10m- +12m in places, with a general trend of decreasing depths over time; see Figures 10.19-10.23. The greatest difference can be seen in the southern Skerries Bank cross section, this is on the edge of the bank near the channel that separates Skerries from the shore, and is subject to strong currents. Over the last 50 years the depth in this area has deepened by 11m in some places, indicating a loss of sediment at approximately 0.2m per year.

This cross section is located between the Skerries Bank and Start Point Headland. Because of its geographical positioning, very strong currents occur in this area, giving rise to higher sediment transport rates.

![Comparison of depth over skerries bank, South to North.](image)

**Figure 10.19** Graph of the longitudinal section of Skerries Bank.
10.73 The profiles from the nearshore area (see Figure 10.22) show little variation over the last 50 years. The average depth increase is between 0.03-0.02m per year. The depth gradient increases from 12m-15m according to the 2004 survey, whilst the 1951 survey showed a slope of 12-14m. Indicating that sediment paths in this area remain relatively unchanged after 50 years.

10.74 The comparison of profiles parallel to the shingle beach shows a slight variation in depth at the southern end of the cross section. This area runs parallel to Hallsands and Beesands where erosion and sea defences could have impacted on the existing sediment transport paths (see Figure 10.23).
Nearshore profile, (Slapton Sands to Skerries)

Figure 10.22  Graph of profile at nearshore location, from Slapton Sands to Skerries Bank.

Comparison of depth along Slapton Sands, from South to North.

Figure 10.23  Profile comparisons over time depth changes at Slapton Sands below low water.

10.75 A Side Scan Sonar Survey was conducted simultaneously with the Bathymetric Survey, and covers the same survey lines. A plot of the survey lines can be seen on Figure 10.24. On the left of the figure, side scan sonar photographs have been used to scale the sediment sizes found within Start Bay and identified on the right in the main plot.

10.76 The sidescan sonar records appear to indicate that throughout the survey area the seabed composition is primarily fine sediment, with several areas of outcropping bedrock or coarse sediment, such as gravel and cobble. However, no grab samples were obtained in order to confirm this.

10.77 The steeply dipping beach profile is clearly seen at the inshore extent of the survey Area A. The nearshore area is dominated by megaripples, with wavelengths of 1-5m, extending
approximately 400m from the beach. Rock outcrops are present at the northern and southern extents of the survey area. There is a ridge of sand approximately 1km in length along the seaward edge of Area A.

10.78 Area B covers Skerries Bank. The southern extent of Area B consists of rock showing through the seabed. There is a large area of sandwaves wavelength 100-300m over the bank. The sandwaves are superimposed with ripples. There are areas of megaripples across the bank ranging between 1-10m wavelength.

10.79 Area C is characterised largely by a featureless seabed. There are however areas of rock emerging through the sediment to the south of this area. There is also a discrete area of patchy coarse sediment adjacent to the rock outcrops to the west of the area. It has been noted that there were no large targets seen on the digital records. A number of ‘pot buoy’ lines were detected throughout the survey area with the majority located on the inshore side of Skerries Bank and along the inshore rock outcrops. The areas are defined from the following location plan of the survey lines:
Figure 10.24  Bathymetric and Sidescan sonar survey lines.
11 Conceptual Beach Process Model

Introduction

11.1 This Chapter presents information on water levels, wave climate, sediment transport and beach processes. Together this information is combined to build a conceptual model of what drives the evolution of the beach and shingle barrier at Slapton, and how and why the beach responds in the way it does. At the end of the Chapter there is a summary of key points related to beach processes. It attempts to pull together all the work undertaken on geomorphology in Chapter 5, on historic change in Chapter 10 and in the first part of this Chapter to provide an overview.

Water Levels

Normal water levels

11.2 Levels given in the Admiralty Tide Tables for astronomical tides at Plymouth (Devonport) are summarised in Table 11.1. Chart Datum is 3.22m below Ordnance Datum and water level ranges during spring and neap tidal conditions are 4.7m and 2.2m respectively.

<table>
<thead>
<tr>
<th>Level, metres above Chart Datum (CD)</th>
<th>Level, metres above Ordnance Datum Local (OD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>HAT</td>
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<tr>
<td>MHWS</td>
<td>5.5</td>
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<td>MHWN</td>
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<td>Mean Sea Level</td>
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<td>-3.22</td>
</tr>
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Table 11.1: Astronomical Tide Levels (Admiralty Tables, 2003)

Extreme water levels

11.3 For the purpose of future predictions it is important to view the water levels at the time of the January 2001 event in the context of their estimated return periods. The nearest tide-gauge record is from a University of Plymouth station at Teignmouth Pier, with observations taken every 10 minutes dating back to June 2000. The available Devonport tide-gauge record dates back to 1991, although measurements began as early as 1962. In 1991 and 1992 observations at Devonport were hourly; they increased to 15 minute observations starting in 1993.
11.4 A plot of days when water levels reached heights above 2.5 m OD at Teignmouth (Figure 10.29) shows that the road collapse occurred during relative modest water levels, but following an autumn during which water levels reached as high as 3.12 m OD. The highest water level in the autumn of 2000 at Devonport was reached on the 28th of September (6.17 m above CD, 2.95 m above OD). On the 12th of December 2000 the tide gauge at Devonport registered 2.94 m above OD. The return period for these water levels is 7-8 years as calculated from the 1991-2003 Devonport tide-gauge record (Figure 10.30C).

11.5 At the time of the road collapse (January 9-12), water levels reached as high as 2.54 m above OD at Teignmouth (January 9) and 2.72 m above OD at Devonport (January 12). At both stations much higher water levels were reached in the weeks following the breach.

11.6 The 2000-2001 autumn/winter water levels have not been reached again in the following years, although at Devonport several tide levels were close. At Teignmouth, however, the height of the water levels reached in the autumn and winter of 2000/2001 clearly stand out in the 3.5 year record (Figure 10.29). The graph of return periods of extreme water levels at Teignmouth (Figure 10.30D) must be treated with caution due to the short duration of the observations.
Figure 11.1  High water levels at Teignmouth and Devonport 2000-2003.

Data for Devonport are only available up to 30 September 2003. The red dots indicate water levels on 10 January 2001 at Teignmouth and on 12 January 2001 at Devonport.
**Figure 11.2**  
A. Gumbel reduced variate plotted versus height for Devonport. B. Gumbel reduced variate plotted versus height for Teignmouth. C. Return periods of extreme water levels for Devonport. D. Return periods of extreme water levels for Teignmouth.

Return periods were calculated based on linear fits to Gumbel distributed data (A and B), following methods described in Chadwick and Morfett (1998). Record lengths are March 1991 to September 2003 for A and C and June 2000 to December 2003 for B and D.
Flood risk area and water levels

11.7 Water is discharged into the Ley from 3 rivers, the Gara River, Start River and Stokeley River. The weir at the south of the Ley keeps the water height constant at 3.1mOD, this can become blocked with overwashed shingle and during high flows in winter the level of the Ley can rise by up to 1m. Therefore for the purpose of this calculation it is assumed that the level of the Ley at its highest is 4m when the breach occurs.

11.8 The 200year water level used for a breach calculation is 3.2m OD (taken from the Shoreline Management Plan). The extents of the flood risk area into which this water flowed, would therefore be dependent on the level of the Ley at the time. If at its lower level of 3.1m the maximum height the water in the Ley could rise to, would therefore be 3.2m OD, to equal the level of the sea. However if the Ley was at its higher level of 4mOD, the water in the Ley would be higher than the sea level and flow out over the breached bank. Therefore in a breach situation the outline of the associated flood risk envelope would be no higher than the winter limit of the Ley at 4mOD.
Offshore wave climate

11.9 Measured wave data were not available for a sufficiently long period to undertake a reliable wave climate study. The best available data set was the UK Met. Office (UKMO) European wave model output. A correlation of UKMO waves were therefore made using a time series of recorded data on a wave rider buoy. The results indicated that UKMO model predictions are consistent with the field observations. The measured data were obtained from a wave rider buoy installed in an offshore location at the South Devon Coast under the Lyme Bay and South Devon Shoreline Management Plan. The results of the correlations are shown in Figures 11.3 and 11.4.

Figure 11.3: Comparison of UKMO and Buoy data
Simultaneous water levels and waves were transferred to the coastline using a numerical wave model. In order to set up the models, 3 digital elevation models of the seabed were created. Figure 11.5 shows a simplified plot of the model bathymetry.

The model runs were carried out for two cases:

- Offshore wave statistics for the duration July 1988-October 2003 obtained from the UKMO.
- Offshore time series of waves and simultaneous water levels from January 1999-December 2002

The wave statistics were transformed using two models and the water level was chosen as 3.3mCD (MSL). This involved running the model for a specific wave height/period/direction combinations for all bands of the statistics. Each model run represents the complete data set consisting of 3 hr occurrences covering a duration of 16-years.

Figures 11.6 to 11.11 illustrate results from the modelling. The plots show wave heights and directions as arrows, overlain on a contour plot of resulting wave height. The plots represent only six out of over 100 model runs undertaken.
Figure 4.1: Model bathymetry
Figure 11.5: Wave model bathymetry
Figure 11.6: Wave refraction diagram for East model (offshore Hs=2.6m, Tm=6.1sec, dir=60 deg/N)
Figure 11.7: Wave refraction diagram for East model (offshore Hs=1.8m, Tm=5.2 sec, dir =89 deg/N)
Figure 11.8: Wave refraction diagram for East model (offshore Hs=2.2m, Tm=5.7 sec, dir =114 deg/N)
Figure 11.9: Wave refraction diagram for South model (offshore Hs=3.4m, Tm=7 sec, dir =166 deg/N)

Figure 11.10: Wave refraction diagram for South model (offshore Hs=2.6m, Tm=6.1 sec, dir =185 deg/N)
Figure 11.11: Wave refraction diagram for South model (offshore Hs=4.6m, Tm=8.1 sec, dir =207 deg/N)
11.14 Figures 11.12 to 11.14 show inshore wave roses from the modelling.

**Figure 11.12:** Inshore wave rose for Torcross (at –12.5mCD)
Figure 11.13: Inshore wave rose for Slapton Ley (at -14.3mCD)
Wave data analysis

The inshore wave data points at eleven locations along the coastline of Start Bay are shown in Table 11.2 and Figure 11.15. Five data points (5, 6, 7, 8 and 9) out of these eleven points fall within the Slapton Sands frontage. In the present analysis, inshore wave data at these five points were transformed to the break point using a shoaling/refraction model, assuming shore-parallel bottom contours. The effect of tides and storm surge on waves were included in the analysis process by considering the actual water depth at each wave record. Breaking wave heights was determined by the Goda (1985) wave breaking criterion and the incident wave angle at wave breaking was determined by linear shoaling/refraction analysis. The beach slope corresponding to each wave point was derived from the cross sections mapped in January 2004.

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<td>48000</td>
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<td></td>
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Table 11.2 Inshore wave points.
Figure 11.15 Inshore wave extraction points

11.16 The derived wave data for point 7 is presented graphically in Figures 11.16 to 11.18

Wave height/period scatter plot point 7

Figure 11.16 Wave height compared to wave period.
11.17 These figures show that the largest waves come from an Easterly direction, but that the waves with the longest period come from a Southerly direction.

### Storm Conditions in 2001

11.18 Figure 11.19 shows wind speeds during the time of the 2001 storm sequence. Wind speeds increased during the storm.

11.19 Figure 11.20 shows the wave heights water levels and wave direction at the time of the road collapse. The maximum wave height, during this period is the 3rd largest in the 4 year record. The storm was from the East and the water levels were not extreme, though this was a period of Spring tides and therefore water levels were consistently moderately high.
11.20 Figure 11.21 shows the wave heights from October 2000 to Jan 2001. It can be seen from this figure that a succession of large waves occurred throughout November and December 2000, culminating in the largest prolonged storm in January 2001.

11.21 Figure 11.23 is a Gumbel plot of the 31 highest independent storm events in the 4 year record. This has been used to estimate the wave heights of various return periods (shown in Figure 11.24 and Table 11.3) and the return period of the Jan 2001 event, which is estimated as 1.2 years if wave height alone is considered.

11.22 When wave height, storm duration, wave direction and water level are all taken into account it is found that the storm was very unusual. The combination of a long-duration storm (4 days), with a 1-year wave height, from the east, coincident with Spring tides is estimated to occur on average only once every 25 years or so.

![Wind Speed (m/s)](image)

**Figure 11.19:** Wind speed (maximum gust)

**Probability of the 2001 Storm Event**

11.23 These calculations determine the probability of a storm event occurring that may result in overtopping, or erosion of Slapton Sands. The type of storm event that may result in these has been determined by analysing wind data for storm events that have resulted in actual overtopping.

11.24 Overtopping and damage to Slapton Sands occurred in January 2001, coinciding with spring tide levels measured at Salcombe as 5.3m OD at 19.18 on 11th Jan and 5.6m OD at 07.37 on 12th Jan. The maximum wind speed during this event was often greater than 33 knots. The wind
direction mostly varied between 60 and 90 degrees (with 0 degrees as north). The wind speeds 34 – 40 knots equates to force 8.

11.25 Overtopping occurred along the Slapton Line in December 1995 between the 14\textsuperscript{th} and the 16\textsuperscript{th}. The maximum wind speed was greater than 33 knots for a sustained period. The wind direction varied between 50 and 110 degrees.

11.26 Based upon these two storm events, the limits for deciding a breach causing storm were set as follows:

1. Average wind speed > 33 knots for a continuous period of 48 hours.
2. This must occur between 50 and 130 degrees.

Wind data was analysed between 1980 and summer 2004, a period of 24.5 years. During this period 5 storms relating to the two conditions occurred. However, a breach is only likely to occur if the storm event coincides with Spring Tides.

Probability of a storm event occurring in any given year = 0.204. Spring tide taken as occurring for 6 days out of 28, probability = 0.214. This gives a combined probability of 0.044, or a potential breach causing storm event will occur once every 22.9 years. The probability of a similar storm event similar to the 2001 storm, is therefore approximately 1 in 25 years.

![Storm Conditions Jan 2001](image)

**Figure 11.21** Storm conditions in January 2001
Figure 11.22  Wave heights

Figure 11.23  Gumbel plot of 31 highest independent storm events within a 4-year period.

Figure 11.24  Wave height return periods over a range of years.
Table 11.3 Wave heights against return periods.

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Breach prediction model

11.27 The breach prediction model of Bradbury (2002) given in equation (1) was used to predict whether the 2001 road collapse was due to breaching. \[ \frac{R_c B_a}{H_s^3} = 0.0006 \left( \frac{H_s}{L_m} \right)^{-2.54} \]

(1) where \( B_a \) = barrier cross section, \( R_c \) = barrier free board, \( H_s \) = significant wave height and \( L_m \) = wave length corresponding to mean wave period.

11.28 A beach section within the breach location was selected (section 29, Slapton Ley Coastal Survey, 2004) and the dimensionless barrier inertia parameter \( \left( \frac{R_c B_a}{H_s^3} \right) \) was calculated for all wave data available from January 1999 to December 2002. The actual water depths were considered in deriving free board corresponding to each wave event. The values of dimensionless barrier inertia parameter were drawn against wave steepness \( (H_s/L_m) \). The breach prediction model was also drawn on the same plot as shown in Figure 11.25. It is seen from the results that the model did not predict a breach event during this period.
11.29 It should be noted that the cross section used in this analysis is a section measured in January 2004, after the beach nourishment took place at Slapton Sands following the breach event in January 2001. Therefore, computed beach areas and hence the barrier inertia parameter does not represent the actual conditions prior to and at the breach event.

11.30 A sensitivity analysis of this result was undertaken to ascertain if increasing water levels, due to sea level rise, or decreasing cross-sectional area, due to beach recession, would produce a breach event.

11.31 Figure 11.26 (a) shows the effect of increasing the sea level by 250mm. It is clear that such a rise makes very little difference, with breaching still not predicted. Figure 11.26 (b) shows the effect of reducing the cross-sectional areas by 30%. This value was chosen by comparing the cross-sectional area at section SS3, at the time of the breach, with that of section 29 in 2004. Again, this change does not significantly alter the result.
11.32 It is therefore concluded that the available freeboard at the time of the breach was sufficiently large to prevent breaching. The event in January 2001 was more likely to have been a crest cut back rather than a classic breach. It can be further concluded that a future sea level rise of 250mm and a reduction in cross-sectional area to that at the time of the road collapse will not produce a breach event.

**Figure 11.26** Sensitivity tests of the breach prediction model. (a) for sea level rise (b) for 30% reduction in area.
Analysis of longshore sediment transport

11.33 Once the wave height and the incident wave angle at the break point were determined for each individual wave record, longshore sediment transport rates were computed using three different longshore transport formulae:

1. The CERC formula (using a coastal constant $K$ applicable to coarse grained beaches).

11.34 These formulae were found to give best performance on coarse-grained beaches (Van Wellen et al., 2000). Net annual sediment transport was found by summing up all transport rates within each year. It was found from the results that the Kamphuis (1991) and Chadwick and Van Wellen (2000) formulae gave similar results for all cases considered and that the CERC formula gave much lower estimates. This latter result was expected as the $K$ value was that derived for a grain size of 20mm. Therefore, further analysis was restricted to the transport rates derived from the Chadwick and Van Wellen (2000) formula.

11.35 The sediment size ($D_{50}$) for computation of longshore transport was selected based on the results of sieve analysis of the 12 sediment samples taken along Slapton Sands. $D_{50}$ values varied from 1.8mm to 9.0mm from Strete Gate to Torcross and therefore, a mean value of 5 mm was selected for the present analysis.

11.36 Beach bearings corresponding to each wave measuring point were obtained from a map of historic shoreline position at Slapton Sands (Scott Wilson) where the mean high water (spring) shoreline in 2003 was selected for the present analysis. It should be noted that these beach bearings remained constant throughout the calculation procedure.

11.37 The volume of net annual longshore sediment transport corresponding to each wave point within each year (1999-2002) was obtained by the summation of sediment transport rates computed for three-hour periods. Figure 11.27 shows net annual sediment transport volume along Slapton Sands from Torcross to Strete Gate.
Figure 11.27  Net annual sediment transport volume along Slapton Sands.

11.38 Positive transport volumes in the figures show northward bound sediment transport (towards Strete Gate) whereas negative values indicate southward bound sediment transport (towards Torcross). It is seen in this figure that direction of net annual sediment transport varies each year where northward bound transport occurred in years 2000 and 2002 while southward bound transport occurred in years 1999 and 2001. It can also be seen that a significant volume of sediment moves along the Slapton barrier beach each year.

11.39 Figure 11.28 shows average annual volumes of sediment transport. The figures were obtained by averaging the net annual transport volumes from 1999 to 2002. These values are much smaller than those for individual years, because net yearly transport fluctuates between Northerly and Southerly directions.
11.40 A more refined estimate of the longshore transport rates has been made using the one-line model described in section 10. The results are shown in Figure 11.29 and 11.30.

Figure 11.28 Average annual alongshore transport volume along Slapton Sands.

Figure 11.29 Net annual sediment transport volumes, using the one line model.
11.41 Over the four years from 1999 to 2002, a northward bound transport is predicted to have occurred over most of Slapton beach. These results are clearly different to the simpler calculations. They indicate that net transport rates are highly sensitive to the changing beach line position.

11.42 Figures 11.31-11.35 show the net annual sediment transport rates, in volumes, for the Slapton shingle barrier. These are shown for years 1999, 2000, 2001 and 2002. Figure 11.35 shows an average of these volumes over the four years.
Figure 11.31  Net Annual Sediment Transport, 1999 Slapton.
Figure 11.32  Net Annual Sediment Transport, 2000 Slapton.
Figure 11.33  Net Annual Sediment Transport, 2001 Slapton.
Figure 11.34  Net Annual Sediment Transport, 2002 Slapton.
Figure 11.35  Net Annual Sediment Transport, 1999-2002 Average, Slapton.
One-line shoreline evolution modelling

11.43 The shoreline movement at Slapton barrier beach between 1999 and 2003 was modelled using a one-line-shoreline evolution model (as described, for example in Chadwick and Morfett 1998). The model uses the Chadwick and Van Wallen (2000) longshore sediment transport formula and operates on an explicit forward difference numerical scheme on a staggered grid.

11.44 The original shoreline of Slapton beach from Torcross to Strete Gate was modelled using thirteen nodal points, resulting in 12 beach cells. Each cell was 461 m long. The initial shoreline was obtained from a map of historic shoreline change. The mean high water (spring) shoreline in 2003 was selected. It should be noted that this initial shoreline did not correspond to that which existed at the start date for the wave record. However, this shoreline was not on record. The results of the shoreline modelling analysis, therefore, indicate the trends of shoreline changes for the period January 1999 to December 2002 rather than actual historical change. Table 11.4 shows the details of the initial shoreline model.

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Table 11.4 Initial shoreline and beach slope.

11.45 At Torcross, the assumed boundary condition is a terminal groyne for water level conditions above mid tide and an open beach for lower tide levels. At Strete gate a terminal groyne condition has been assumed over all water levels. Whilst these boundary conditions are not precise, they are a good approximation to reality.

11.46 The depth of closure \((D_c)\) was taken as 9.2 m based on the formula

\[
D_c = \text{Tidal range} + 1.6 \times H_{s12} \tag{2}
\]

where \(H_{s12}\) is the 12-hour significant wave height. An approximate value for \(H_{s12}\) was selected as 3.0 m. The tidal range was taken as 4.4 m. This assumed value for \(D_c\) is not exact, but should
be of the right order. The resulting rate of change of shoreline movements are inversely related to $D_c$.

The position of the shoreline from 01 January 1999 to 31 December 2002 was computed at 3-hour intervals. Figure 11.36 shows the shoreline position computed by the one-line model at the end of each year.

**Figure 11.36** – Shoreline change between 1999 and 2002.

11.47 This illustrates that quite large variations in shoreline position do occur from one year to the next (10m to 15m), particularly at Torcross and Street Gate.

11.48 Figure 11.37 shows the mean shoreline position and the envelope of the expected 95% variations in shoreline position. This figure illustrates that larger variations in shoreline position occur at the ends of the beach than occur in the middle of the beach.

**Figure 11.37** Mean shoreline position and the envelope of the expected 95% variations in shoreline position.
11.49 The change in shoreline position at and around the breach point was looked at in more detail from October 2000 up to breach event. Figure 11.38 shows the shoreline position around the breach point. It can be seen that the shoreline had receded approximately 5 m from 1st October 2000 to 14th December 2000. At node 7 in the model, the lowest beach width occurred on the 14th Dec 2000, but on 10th Jan 2001 the recession since the 1st October 2000 was still about 4m.

![Shoreline change around the breach point from October 2000 to January 2001.](image)

**Figure 11.38** Shoreline change around the breach point from October 2000 to January 2001.

11.50 To show the changes in shoreline position more clearly for the whole beach, Figures 11.39 to 11.49 show the time histories of beach line changes at each node in the model.

![Shoreline change node 1 (Torcross).](image)

**Figure 11.39** Shoreline change node 1 (Torcross)
Figure 11.40  Shoreline change node 2

Figure 11.41  Shoreline change node 3

Figure 11.42  Shoreline change node 4

Figure 11.43  Shoreline change node 5
Figure 11.44  Shoreline change node 6

Figure 11.45  Shoreline change node 7 (breach location)

Figure 11.46  Shoreline change node 8

Figure 11.47  Shoreline change node 9 (Strete Gate)
Shingle profile modelling

11.51 To predict the cross-shore profile during the January 2001 storm, Powell's shingle profile model has been applied (Powell 1990). This model has been found to give reasonable agreement with our full scale experimental studies (Blanco and Holmes (2003)). However, when applied to the Slapton situation, the combination of wave and grain size parameters is outside the range of applicability of the Powell model. Nevertheless, Figure 11.50 has been prepared. This shows the predicted profile and its calculated location with respect to the pre-existing profile before the breach at the nearest location for cross-sectional data.

11.52 This suggests that the crest will form seaward of the intersection of the still water line with the pre-existing profile, with a crest height about 3.4m above the still water line. The location of this profile is not considered realistic, but the crest height is probably reasonably accurate, thus demonstrating that for the January 2001 event the beach crest probably reached road level.

11.53 This shows that such an event had the potential to affect the crest of the shingle ridge, thus causing erosion to the crest. The profile shows significant beach steepening.
Figure 11.50. Predicted profile for the January 2001 storm event
Summary and Conclusions

11.54 Sea level at Slapton has risen by 18 metres during the past 9000 years. In the recent century the rate of relative sea-level rise has been 1.7 mm/year.

11.55 The rate of long-term land subsidence at Slapton is 1.1 m per 1000 years (equivalent to 1.1 mm/yr). The subsidence rate is faster than the value used by UKCIP02 (0.6 mm/yr).

11.56 Sea level is predicted to be at least 20 cm higher by 2080 (low emission scenario) and may be as high as 80 cm above present level (high emission scenario). The most conservative estimate indicates that water levels that today occur once every 7-8 years are expected to occur, by 2080, about 3 times per year.

11.57 Slapton Ley has been non-tidal for 3000 years. Prior to 3000 years ago, the barrier at Slapton was interrupted by one or more tidal inlets and a tidal lagoon existed landward of the barrier.

11.58 The key beach processes affecting Slapton Sands are:

- Short-term storm impacts
- Medium term longshore transport gradients
- Long-term sea level rise and trend of the ridge to rollback.

11.59 Each of these processes has been studied. Short- and medium-term impacts are coastal process issues, whereas long-term changes are best considered within a geomorphological framework.

11.60 The cross-shore profile predicted by Powell's model, for the time and location of the road collapse in January 2001, shows that the storm event was of a sufficient severity (wave height) and occurred in conjunction with a sufficiently high still water level, to impact on the crest of the shingle ridge.

11.61 The breach prediction model of Bradbury suggests that at the time of the road collapse in January 2001, the loss of road was due to beach cut back not due to the mechanism of over washing and roll back. The sensitivity tests showed that neither a sea level rise of 250mm, nor a reduction in cross-sectional area of 30% would significantly increase the chances of the overwashing mechanism becoming dominant.

11.62 The erosion event can therefore clearly be categorised as one of cut-back of the edge of the shingle barrier as indicated on Figure 10.25 in Volume 2, and not as a breach of the barrier.

11.63 Examination of aerial photographs from 1999 shows that, compared to adjacent areas, the face of the shingle ridge was further seawards at the central car park and at the location where the...
road was undermined. Therefore these areas had steeper beaches and were therefore at higher risk of greater erosion than other areas.

11.64 It is possible that other factors such as differential permeability (for example due to presence of made ground), presence of buried channels or rock outcrops also contributed to the differential rates of erosion observed, but there is insufficient information on these aspects on which to base a hypothesis.

11.65 The overall assessment of the contemporary coastal morphology is that Start Bay comprises a closed coastal sediment cell. There is some exchange of sediment between locations within Start Bay, but changes to beach volume at Slapton are dominated by sediment movements within the area of Slapton Sands itself.

11.66 Large changes in beach areas and shoreline position occur over medium term time scales (weeks, months). The trends in the amount of beach volume above the mid and high water lines have been increasing gradually to the north of Strete Gate, decreasing more rapidly at the road collapse location and decreasing gradually at Torcross. However, these trends are based on a data set which is probably statistically unreliable.

11.67 Longshore transport rates have been calculated based on a new and comprehensive analysis of 4 year’s data, which includes the effect of varying water levels and thus the influence of the Skerries Bank on the waves and sediment movements. The results show that high rates of net annual sediment transport do occur (of the order of 150,000 m$^3$ per annum), but that the rate and direction varies from year to year and with location along the frontage. Averaged over the 4-year period, the net transport rates are lower (about 75,000 m$^3$), indicating landward retreat at Torcross and accretion at Strete Gate over this period. Given that a 4-year record is short compared to the expected natural variability of climate over decadal time scales, these results should not be extrapolated to decadal time scales.

11.68 Results from a numerical model demonstrate that quite large changes in the shoreline position (of the order of 5 to 10m) can occur in medium term periods (weeks, months). Model results show that at the time of the road collapse in January 2001, the shoreline position around the location of the collapsed road had receded by about 4m from 1st October 2000 to 10th January 2001.

11.69 At the time of the road collapse event in January 2001, the beach volumes above mid and high water levels at the breach location were at the historically lowest recorded value in the 31-year record.

11.70 The storm was an unusual combination of moderately high water levels at Spring tide and a sustained period of high waves from the east. Based on analysis of wind speeds, wind direction,
and storm duration from a data set from 1980 to 2004, it is estimated that the storm had a return period of 25 years.

11.71 The storm of 1995, which was notable but did not cause such extensive damage, was identified by the same analysis of wind data as being less severe, but also a severe, infrequent event (return period about 10 years).

11.72 The overall assessment of the January 2001 event is that it was caused by a combination of beach line recession due to differential longshore transport rates in the preceding autumn and the occurrence of a severe storm, which further cut back the profile, with the beach crest reaching road level.

11.73 Because the storm coincided with a period when the beach was at a historically narrow state, its observed effect on infrastructure (road, car park) was greater than it would have otherwise have been.

11.74 Figure 11.51 (Volume II) shows areas at risk at any time from a single storm event. Using the 2001 storm event, when 5m of shingle ridge was eroded, it is assumed that a similar event of 1 in 25 year probability would have a similar erosion impact. Therefore a 5m setback from the vegetated crest line has generally been drawn. However, the extent of erosion expected to occur at a point along the beach is a function of two other main variables: beach steepness (the steeper the beach, the more likely is erosion of the crest); and presence of defences (these inhibit erosion of the crest). The steepest beaches occur in the central area near the car park and previous road realignment.

11.75 The figure shows that the main areas at risk are (south to north):

- The length of road immediately north of the rock revetment, including the length where the rock revetment is badly degraded
- The central car park
- The two road sections north of the car park where the new road alignment joins the original road alignment

11.76 Long-term barrier retreat rates have been estimated, based on a conceptual model of the long-term evolution of the Slapton Sands coastline, and a numerical formulation relating sea level rise to barrier retreat rate. The retreat rates calculated are not precise, and for the present day are somewhat higher than observed sustained retreat rates.

11.77 The historical data analysis suggests that in overall terms the Slapton Sands shingle ridge has been stable over the last century, but with some net beach accretion at Strete gate and recession at Torcross. Long-term net erosion rates for the crest of the barrier are low, with a
best estimate over 100 years of 0.1m/year for the centre of the Bay. Analysis of a number of maps and photographs for different periods of time between 1890 and the present day all indicate little overall movement of the crest. However, over shorter time periods rates of 0.4-0.6m have been found.

11.78 The geomorphologically based estimates for long-term barrier retreat give values of 0.3m/year at the present day, increasing to at least 0.4m/year due to sea level rise.

11.79 The maps shown as Figures 11.52(a-g) (Volume 2), show areas at risk within different time epochs along the shingle bank. In accordance with guidance for Shoreline Management Plans, three epochs have been used: 0-20 years, 20-50 years and 50-100 years. The retreat rates used in preparing these maps are those of a ‘Low Emission Scenario’ and are applicable to the next 100 years.

11.80 The rates used in the Low Emission Scenario are derived from the geomorphology-based retreat rates from the low emission scenario for climate change and sea level rise up to year 100. The geomorphology-based projection suggests more rapid rate in years 50-100, of the order of a further 30m.

11.81 In the geomorphology-based projections for the high emission scenario both sea level rise and retreat rates over years 50-100 are predicted to accelerate rapidly and are higher still. These are displayed on Figures 11.53 (a-g) (Volume 2).

11.82 In using the maps the following should be noted:

- The projections are indicative, with a considerable degree of uncertainty, despite any appearance of precision. The uncertainty increases over time.

- The retreat rates used (even for the lower emission scenario) are higher than the long-term historical change which has actually occurred.

- Erosion may occur landward of the ‘At Risk’ areas in particularly severe events.

- If the high emission scenario becomes reality, or indeed if any scenario occurs other than the low emission scenario, then the ‘At Risk’ areas will rapidly project landwards after year 100.

- The projections are long-term averages, and will only occur if a given period of time has the expected number of severe storm events. It is the severe storm events which drive retreat of the barrier.

11.83 It has been postulated by various authors that the shingle bank is likely to break down irreversibly and breach, forming tidal inlets, within the next 30 to 50 years. This is considered to
be highly unlikely. Neither of the storm events which have occurred in the last 10 years have had a major impact on the shingle barrier height or width, and neither has come close to causing a breach of the barrier. The current return period for a breach is considered to be much less than 100 years.

11.84 Sea level rise and increased storminess will increase the rate of erosion and the risk of major recession event, but the risk of a breach of the shingle bank will remain low over the next 20 or 50 years.

11.85 Possibly after 50 years, and definitely beyond 100 years, a No Intervention scenario will result in breakdown of the shingle barrier, with breaching and forming of intermittent tidal inlets.

11.86 Retreat of the shingle barrier will eventually result in lowered beaches in front of Torcross, and leave the northern part of Torcross exposed to wave attack. Protection of Torcross will require an extension of the sea wall to link up with the retreated barrier location.
12 Option Development

Introduction

12.1 The option development carried out as part of this study will lead to a strategic appraisal rather than scheme specific appraisal, to fit in with the strategic framework for the area. The appraisal considers broader shoreline management options rather than more specific ‘scheme scale’ options.

12.2 The broad scale options considered for this study are in accordance with guidance for shoreline management:

- Do nothing (also described as ‘No Active Intervention’)
- Keep the Coast Road -Do minimum (short-term options)
- Keep the Coast Road (long-term options)
- Advance the line
- Managed realignment (of the road)

12.3 Within the context of these broad scale options, some more detailed options are considered in order to fully understand the viability of the above management options. These more detailed considerations include proactive and reactive do minimum options, forms of defence for the purpose of holding the line and potential options for relocating the line of defence for the managed realignment option.

12.4 The options development only considers the technical viability of options at this stage. Environmental and economic issues are considered in later sections of this report.

12.5 Options development has been carried out in accordance with DEFRA’s PAG series of documents, taking into account the latest changes following publication of the Treasury’s Green Book. Options are defined and developed in this section and compared in Chapter 14. Since the objective of this part of the study is to evaluate the viability of the hold the line option, the selection of a preferred option is not carried out in detail. Instead, Chapter 17 provides recommendations on how to proceed in Phases 2 and 3 of this study in order to determine the final preferred management strategy.

Objectives

12.6 English Nature have indicated that although a breach of the barrier would cause them concern since SSSI features could be affected; such a breach would be possible in future and considered as part of the natural geomorphological evolution of the shingle barrier.
12.7 Analysis carried out as part of this study has shown that following a breach the number of properties at risk from flooding would be less than 10. Furthermore, a breach would be unlikely to remain open in the short to medium term.

12.8 The risk to human life and property is limited and the Slapton barrier beach is therefore unusual in coast defence terms, in that a breach of the barrier would not necessarily have a significant negative impact.

12.9 However, the road that runs along the barrier is of significant importance to the local community, and the socio economic impact of losing this transport link is a critical factor in determining the long-term strategy for this area. The main issue in determining the options for long-term management of the Slapton Line is whether or not the road can be maintained in its current position or whether alternative options should be considered. The shoreline management standard concept of holding the line has therefore been recast as Keeping the Coast Road.

12.10 It is therefore important to distinguish between a breach in the barrier beach, leading to saline intrusion into the freshwater Ley, and an erosion event or ‘breach’ to the road, leading to a loss of the transport link but no physical breakdown of the barrier separating the Ley from the sea. In order to make this distinction clear during the development of options the term road damage event will be used to describe any event leading to the loss of the road as a functioning transport link. The term breach will only be used to refer to events leading to a physical breach in the barrier beach leading to saline intrusion into the Ley.

12.11 Based on the above issues, one key objective is maintaining the local infrastructure for socio-economic reasons. The other is minimising adverse environmental impact.

No Active Intervention (Do Nothing)

Introduction

12.12 The Do Nothing scenario forms the baseline case against which all other options are compared. Under this scenario no action would be taken to protect the shingle ridge from erosion or to mitigate the effects of erosion.

12.13 The development of a realistic Do Nothing scenario is essential for a rigorous appraisal of options so that the most appropriate strategy is proposed.

12.14 As discussed in the previous section, the critical event in terms of the management of the Slapton Line is an event leading to the destruction of the road, termed a road damage event.
Probability and timing of a road damage event

12.15 An analysis of shoreline evolution and the probability of destructive storm events has shown that the most vulnerable section of the road is just either side of the recently relocated section between Slapton and Strete. In this area the road would be damaged under an event similar to that in January 2001, which has an estimated return period of 1 in 25 years. The annual probability of a road damage event in a single storm or short sequence of storms is therefore 4%.

12.16 Given this probability a further road damage event can be expected to occur within the next ten to twenty years. Since such an event is not primarily dependent on long-term erosion rates, but rather the probabilistic occurrence of a storm with the required intensity and duration, estimations of the timing of the event can only be given in probabilistic terms.

Breach mechanism

12.17 As the road construction is less easily eroded than the shingle beach, the presence of the road will slow down the gradual erosion of the shingle barrier to some extent, although eventual breaching of the barrier would inevitably take place in the long term. It is unlikely that a breach will occur within the next 50 years, but possible that a breach could take place during the period of concern for this study (100 years). This assumption is based on adoption of projections consistent with the low emission climate change scenario.

Consequences of a breach

12.18 A complete breach of the shingle ridge would allow saline intrusion into Slapton Ley and would alter the ecological make up of the area. However, it is likely that this would at first be temporary and that the first breach would repair itself temporarily by natural means. Breaches would then occur on a more frequent basis until eventually a permanent breach would be formed. Following this the ecological makeup of Slapton Ley would be permanently changed into a saline environment.

12.19 Roll back of the shingle barrier, and formation of tidal inlets due to breaching, would expose areas of the Slapton coast to flooding and wave action. One such area is likely to be in Torcross, where properties currently lie very close to the shores of Slapton Ley. If the barrier was to roll back as shown by the geomorphological projections, then it would be necessary to protect Torcross by extension of the existing sea wall along the coast and linking in with the barrier location.

12.20 Other impacts expected within the 100-year study period are likely to be limited to loss of the monument, car park and road with the associated socio economic, and historic environmental impacts.
Do Minimum

12.21 For the purpose of this study the Do Minimum option has been divided into reactive and proactive approaches. Both would maintain the coast road for a limited period of time.

12.22 If a road damage event were to occur then emergency repairs would be carried out to reinstate the road or at least make it passable in one direction. The advantage of such an approach would be that the residual strength of the existing natural defences would be used to the full and financial input would not be required until a road damage event occurred. However, the disruption caused by such an event and by the emergency repairs required afterwards would be likely to be significant, and no planning with regard to the timing of expenditure would be possible.

12.23 The proactive Do Minimum option would involve close monitoring of the beaches and road in order to be able to carry out works to protect the road from undermining just before any actual damage occurs. Clearly it would not always be possible to accurately predict when such works would be necessary and the risk of unexpected damage to the road would have to be accepted, although an agreed management plan, including action and emergency trigger levels, could be used to reduce this risk. Planning with regard to expenditure might be limited under such an option. The advantage of this scenario would be similar to the reactive option in that the existing defences would be used until the last moment.

12.24 This option would need to include provision for protection of the 20 or so buildings at Torcross at some point in the future.

12.25 Both these options are technically viable, and since these options do not result in an unacceptably high risk to human life or property they will be included in the options appraisal in Chapter 14.

Keep the Coast Road

12.26 This option would involve a commitment to maintain the current position of the road for the duration of the study period – 100 years. Since the analysis of beach processes has shown that some sections of the road will be at risk of undermining, the construction of some form of defence would be required in order to guarantee the structural stability of the road.

12.27 A number of options for holding the road have been considered as follows:

- Beach nourishment
- Beach recycling
- Revetment
- Sheet piled retaining wall
12.28 Shore perpendicular structures such as timber or rock groynes have not been included in this appraisal since the problem experienced at the site is caused mainly by extreme storm events against which groynes would afford little protection. Offshore structures such as breakwaters are very expensive to construct and given the limited value of property at risk are unlikely to yield and acceptable benefit cost ratio. They would also have a number of negative environmental impacts, which are unlikely to make such structures acceptable.

Beach nourishment

12.29 Beach nourishment would involve importing a suitable material from an offshore source and depositing it on the foreshore to provide additional material for the natural defences. Such an option may not be acceptable from an environmental point of view due to the importance of the beach material to the environmental value of the area. However, it would potentially be less intrusive than the construction of hard defences and is a technically viable solution. Beach recharge will therefore be included in the option appraisal in Chapter 14.

Beach recycling

12.30 Beach recycling has been carried out in the past with material moved in trucks from the foreshore at Strete to the area affected by the erosion in January 2001. Such an operation could be carried out on a regular basis in order to protect the most vulnerable areas of the Slapton Line in combination with a regular monitoring programme.

12.31 There would be disturbance due to the movement of trucks, but it should be possible to mitigate this. The use of material that already originates from the Slapton Line area would resolve the potential problems associated with introducing a new material through beach recharge.

Revetment

12.32 The construction of a rock revetment would provide a hard defence against erosion that could be designed to withstand the most severe events for the strategy period. However, the introduction of hard defences into such an environmentally sensitive area poses problems.

Steel sheetpile retaining wall

12.33 A sheetpiling retaining wall, similar to that already built at Torcross, would act as a final line of defence during extreme storm events. The wall would be constructed at the seaward side of the road and would remain buried under the sand. If the beach were to be eroded during an extreme event then such erosion could only progress as far as the sheetpile wall and the structural stability of the road would be maintained. However, such vertical structures are highly reflective and once exposed would lead to accelerated erosion in front of the wall.
Advance the Line

12.34 Advancing the line of the defences would involve either the construction of a large broad crested revetment or substantial renourishment volumes beyond what would be required for coastal defence purposes. Since such an option would require considerable expenditure without providing a justifiably higher defence standard this option has not been considered further.

Managed Realignment

12.35 Managed realignment usually refers to the repositioning of defences further inland. However, in this case it is more appropriate to refer to the realignment of the road that currently runs along the crest of the barrier beach.

12.36 There are a number of options for realignment. One option would be to keep the road on the Slapton Line but relocate it further back, thereby increasing the distance between the beach and the road. This could be done in stages to spread out the cost and to deal with the most vulnerable sections first. In the long term the beach is likely to eventually erode entirely, leading to a breach of the barrier beach and hence the road. This option is essentially the same as the Do Minimum Proactive option and so has not been considered separately.

12.37 The second option would be to relocate the road inland of the Ley, constructing a new link along the west side of the Ley. While such an option would be technically viable it may be prohibitively expensive.

12.38 The third option is to use the existing road network, with minor upgrades at junctions to make the route acceptably safe.
Summary

12.39 Only the advance the line option has been discounted at this stage since it would be considerably more expensive and environmentally intrusive than the other options, but offers no advantages over the hold the line option.

12.40 All options considered include a certain degree of environmental impact, which is considered further in Chapter 13.

12.41 The financial viability of the options is considered in Chapter 14.

12.42 The final list of options is:

- **Option 1**: No Active Intervention i.e. no further investment in coastal defences or road maintenance;

- **Option 2**: Beach Nourishment; increase beach width/height to prevent road closure/damage;

- **Option 3**: Beach Recycling; extract beach material from the northern end, transport south and widen beach in front of the existing road at the southern end of the beach;

- **Option 4**: Rock Revetment; construct a rock revetment along the seaward side of the existing road on the upper beach;

- **Option 5**: Sheet Pile; construct sheet pile wall along the seaward edge of the existing road, the top of the piling level with road;

- **Option 6**: Realign the existing road along the shingle ridge; retreat road to evade erosion;

- **Option 7**: Upgraded Route along existing road network landward of Slapton Ley;

- **Option 8**: New Road landward of Slapton Ley
12 Option Development

Introduction

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12.7 Analysis carried out as part of this study has shown that following a breach the number of properties at risk from flooding would be less than 10. Furthermore, a breach would be unlikely to remain open in the short to medium term.

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**No Active Intervention (Do Nothing)**

**Introduction**

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12.16 Given this probability a further road damage event can be expected to occur within the next ten to twenty years. Since such an event is not primarily dependent on long-term erosion rates, but rather the probabilistic occurrence of a storm with the required intensity and duration, estimations of the timing of the event can only be given in probabilistic terms.

Breach mechanism

12.17 As the road construction is less easily eroded than the shingle beach, the presence of the road will slow down the gradual erosion of the shingle barrier to some extent, although eventual breaching of the barrier would inevitably take place in the long term. It is unlikely that a breach will occur within the next 50 years, but possible that a breach could take place during the period of concern for this study (100 years). This assumption is based on adoption of projections consistent with the low emission climate change scenario.

Consequences of a breach

12.18 A complete breach of the shingle ridge would allow saline intrusion into Slapton Ley and would alter the ecological make up of the area. However, it is likely that this would at first be temporary and that the first breach would repair itself temporarily by natural means. Breaches would then occur on a more frequent basis until eventually a permanent breach would be formed. Following this the ecological makeup of Slapton Ley would be permanently changed into a saline environment.

12.19 Roll back of the shingle barrier, and formation of tidal inlets due to breaching, would expose areas of the Slapton coast to flooding and wave action. One such area is likely to be in Torcross, where properties currently lie very close to the shores of Slapton Ley. If the barrier was to roll back as shown by the geomorphological projections, then it would be necessary to protect Torcross by extension of the existing sea wall along the coast and linking in with the barrier location.

12.20 Other impacts expected within the 100-year study period are likely to be limited to loss of the monument, car park and road with the associated socio economic, and historic environmental impacts.
Do Minimum

12.21 For the purpose of this study the Do Minimum option has been divided into reactive and proactive approaches. Both would maintain the coast road for a limited period of time.

12.22 If a road damage event were to occur then emergency repairs would be carried out to reinstate the road or at least make it passable in one direction. The advantage of such an approach would be that the residual strength of the existing natural defences would be used to the full and financial input would not be required until a road damage event occurred. However, the disruption caused by such an event and by the emergency repairs required afterwards would be likely to be significant, and no planning with regard to the timing of expenditure would be possible.

12.23 The proactive Do Minimum option would involve close monitoring of the beaches and road in order to be able to carry out works to protect the road from undermining just before any actual damage occurs. Clearly it would not always be possible to accurately predict when such works would be necessary and the risk of unexpected damage to the road would have to be accepted, although an agreed management plan, including action and emergency trigger levels, could be used to reduce this risk. Planning with regard to expenditure might be limited under such an option. The advantage of this scenario would be similar to the reactive option in that the existing defences would be used until the last moment.

12.24 This option would need to include provision for protection of the 20 or so buildings at Torcross at some point in the future.

12.25 Both these options are technically viable, and since these options do not result in an unacceptably high risk to human life or property they will be included in the options appraisal in Chapter 14.

Keep the Coast Road

12.26 This option would involve a commitment to maintain the current position of the road for the duration of the study period – 100 years. Since the analysis of beach processes has shown that some sections of the road will be at risk of undermining, the construction of some form of defence would be required in order to guarantee the structural stability of the road.

12.27 A number of options for holding the road have been considered as follows:

- Beach nourishment
- Beach recycling
- Revetment
- Sheet piled retaining wall
12.28 Shore perpendicular structures such as timber or rock groynes have not been included in this appraisal since the problem experienced at the site is caused mainly by extreme storm events against which groynes would afford little protection. Offshore structures such as breakwaters are very expensive to construct and given the limited value of property at risk are unlikely to yield and acceptable benefit cost ratio. They would also have a number of negative environmental impacts, which are unlikely to make such structures acceptable.

Beach nourishment

12.29 Beach nourishment would involve importing a suitable material from an offshore source and depositing it on the foreshore to provide additional material for the natural defences. Such an option may not be acceptable from an environmental point of view due to the importance of the beach material to the environmental value of the area. However, it would potentially be less intrusive than the construction of hard defences and is a technically viable solution. Beach recharge will therefore be included in the option appraisal in Chapter 14.

Beach recycling

12.30 Beach recycling has been carried out in the past with material moved in trucks from the foreshore at Strete to the area affected by the erosion in January 2001. Such an operation could be carried out on a regular basis in order to protect the most vulnerable areas of the Slapton Line in combination with a regular monitoring programme.

12.31 There would be disturbance due to the movement of trucks, but it should be possible to mitigate this. The use of material that already originates from the Slapton Line area would resolve the potential problems associated with introducing a new material through beach recharge.

Revetment

12.32 The construction of a rock revetment would provide a hard defence against erosion that could be designed to withstand the most severe events for the strategy period. However, the introduction of hard defences into such an environmentally sensitive area poses problems.

Steel sheetpiling retaining wall

12.33 A sheetpiling retaining wall, similar to that already built at Torcross, would act as a final line of defence during extreme storm events. The wall would be constructed at the seaward side of the road and would remain buried under the sand. If the beach were to be eroded during an extreme event then such erosion could only progress as far as the sheetpile wall and the structural stability of the road would be maintained. However, such vertical structures are highly reflective and once exposed would lead to accelerated erosion in front of the wall.
Advance the Line

12.34 Advancing the line of the defences would involve either the construction of a large broad crested revetment or substantial renourishment volumes beyond what would be required for coastal defence purposes. Since such an option would require considerable expenditure without providing a justifiably higher defence standard this option has not been considered further.

Managed Realignment

12.35 Managed realignment usually refers to the repositioning of defences further inland. However, in this case it is more appropriate to refer to the realignment of the road that currently runs along the crest of the barrier beach.

12.36 There are a number of options for realignment. One option would be to keep the road on the Slapton Line but relocate it further back, thereby increasing the distance between the beach and the road. This could be done in stages to spread out the cost and to deal with the most vulnerable sections first. In the long term the beach is likely to eventually erode entirely, leading to a breach of the barrier beach and hence the road. This option is essentially the same as the Do Minimum Proactive option and so has not been considered separately.

12.37 The second option would be to relocate the road inland of the Ley, constructing a new link along the west side of the Ley. While such an option would be technically viable it may be prohibitively expensive.

12.38 The third option is to use the existing road network, with minor upgrades at junctions to make the route acceptably safe.
Summary

12.39 Only the advance the line option has been discounted at this stage since it would be considerably more expensive and environmentally intrusive than the other options, but offers no advantages over the hold the line option.

12.40 All options considered include a certain degree of environmental impact, which is considered further in Chapter 13.

12.41 The financial viability of the options is considered in Chapter 14.

12.42 The final list of options is:

- **Option 1**: No Active Intervention i.e. no further investment in coastal defences or road maintenance;
- **Option 2**: Beach Nourishment; increase beach width/height to prevent road closure/damage;
- **Option 3**: Beach Recycling; extract beach material from the northern end, transport south and widen beach in front of the existing road at the southern end of the beach;
- **Option 4**: Rock Revetment; construct a rock revetment along the seaward side of the existing road on the upper beach;
- **Option 5**: Sheet Pile; construct sheet pile wall along the seaward edge of the existing road, the top of the piling level with road;
- **Option 6**: Realign the existing road along the shingle ridge; retreat road to evade erosion;
- **Option 7**: Upgraded Route along existing road network landward of Slapton Ley;
- **Option 8**: New Road landward of Slapton Ley.
13 Environmental & Socio-economic Appraisal

13.1 This chapter reviews the implications of the possible options (Chapter 12) on the environment, using the baseline information in accordance with TAG methodology. The TAG methodology has developed from and incorporates many of the features of GOMMS. Specific guidance is provided in the TAG Unit 3.3.1 on the approach taken to appraising options against environmental objectives.

13.2 The appraisal tables within Chapter 15 provide an overview on the environmental and socio-economic implications of each option. In accordance with the TAG guidance the assessment and appraisal of the options is at a level of detail sufficient to compare them in order to allow for the decision making process to be taken forward. Within this assessment, an abbreviated form of the TAG methodology has been used and a weighted scoring system introduced to enable some rudimentary quantitative comparison between options.

13.3 The options have been assessed in terms of their impact on ecology, geomorphology, heritage/archaeology, landscape and socio-economic criteria. At the time of writing this report (October 2004) the socio-economic appraisals were awaiting the results of the business survey. However, tentative qualitative appraisals have been made by Atlantic Consultants having considered the likely changes arising from retention or loss of the existing road and its possible replacement with an alternative route. Although transportation issues are reviewed within this chapter, they are not included within the scoring system adopted as it is felt that this would lead to substantial double counting as the transportation issues and solutions underpin many of the other assessments, most notably for socio-economic criteria.

13.4 The future routing of the South-West Coast Path National Trail is not considered within the options reviewed below. The issue might variously sit (at least in part) within the landscape, the socio-economic or the transportation appraisals. The current route of the trail follows the Slapton Line and retaining its alignment will depend on the physical presence of the shingle ridge, but not the retention of the road. Retention of the existing route in the long term is thus dependant upon options (or a combinations of options) that maintain the Slapton Line. In the event of abandonment of the Line, it likely that the existing route could be retained for substantially longer that the road alignment. By the time when actual physical fragmentation of the shingle bar occurs, an inland route would need to have been identified. Potential routes for this exist in part although substantial elements of new footpath would need to be designated and potentially two crossings of reed bed areas and streams by boardwalks would be required. The latter may however prove unacceptable from an ecological perspective, requiring major rerouting of the Trail further inland.
Options Considered

13.5 Environmental and Socio-economic appraisals were undertaken for the following options:

- **Option 1**: No Active Intervention i.e. no further investment in coastal defences or road maintenance;
- **Option 2**: Beach Nourishment; increase beach width/height to prevent road closure/damage;
- **Option 3**: Beach Recycling; extract beach material from the northern end, transport south and widen beach in front of the existing road at the southern end of the beach;
- **Option 4**: Rock Revetment; construct a rock revetment along the seaward side of the existing road on the upper beach;
- **Option 5**: Sheet Pile; construct sheet pile wall along the seaward edge of the existing road, the top of the piling level with road;
- **Option 6**: Realign the existing road along the shingle beach; retreat road to evade erosion;
- **Option 7**: Upgraded Route along existing road network landward of Slapton Ley; and
- **Option 8**: New Road landward of Slapton Ley

13.6 Full details of the options are elsewhere within this report.

Appraisal Score

13.7 As stated above and given that option development is fairly elemental, within this optioneering study an abbreviated form of the approach described with the TAG methodology has been used. Within the abbreviated methodology of TAG applied here, the specialists determined the overall appraisal category by joint consideration of the resource value / receptor sensitivity and the magnitude of the potential impact.

![Appraisal Category Table]

13.8 Further details of the appraisal methodology are available in the TAG Unit 3.3.1 to 3.3.11. This can be accessed from [www.webtag.org.uk](http://www.webtag.org.uk).
13.9 In order to compare the various options against each other, the methodology has been extended using an amended version of a weighted scoring system used successfully for a coastal scheme in Yorkshire. The conversion factors and weighting are defined in detail within Chapter 15, which also includes the integrated assessment tables for technical, socio-economic and environmental sub-objectives.

Ecology

Existing Situation

13.10 The Ecology baseline for Slapton Ley and its immediate environs has been well documented through the activities of the Slapton Ley Field Centre and other organisations and individuals who have studied the various floral and faunal groups at this important wildlife site. The site is designated as a Site of Special Scientific Interest (SSSI) and a National Nature Reserve (NNR), with the detail documented in Chapter 4 ‘The Ecological Baseline’.

13.11 In summary, the reasons for designation as a SSSI are:

- Coastal Geomorphology;
- Vegetated shingle;
- Open water;
- Reed-bed, tall-herb fen and fen woodland;
- Breeding bird assemblage of ‘Lowland open waters and their margins’
  Breeding Cetti’s warbler (nationally important breeding bird);
- Non-breeding passage birds;
- Wintering bittern (nationally important wintering bird);
- Vascular plant assemblage (including strapwort); and
- Lichen assemblage.

13.12 The NNR was designated for the following reasons:

- Slapton Ley is the largest natural freshwater lake in South West England;
- The shingle barrier is a nationally important example of a bay barrier;
- Slapton Ley demonstrates better than any other site in the British coast, the links between seabed features and shoreline landforms;
- The reedbeds and rich fen and willow carr vegetation of the Leys support a very diverse flora and fauna with one national rarity;
There are over 2000 species of macro and micro fungi, 29 of which are described are new to science; and

Slapton Ley is an important staging post for wintering and passage birds.

A number of locally designated County Wildlife Sites and Local Wildlife Sites are also present within the study area.

The nature conservation value of the SSSI/NNR is considered to be High. Locally designated sites within the wider study area are considered to be of Medium importance, whilst other undesignated habitats are likely to be of Negligible to Medium importance.

Potential Impacts

13.13 Impacts of the options on the geomorphology are addressed in the Geomorphological Section.

Option 1: No Active Intervention

13.14 If no shoreline management works or works to the existing A379 are undertaken, the shingle barrier will migrate inland in response to rising sea levels. At the same time there will be increased potential for breaching or over washing. Although in the short-medium term, breaches are not expected to be permanent, tidal flows or over-washing will result in the seawater inputs into the Ley causing a change in habitats and species. This would be a major negative impact on the existing features of the SSSI/NNR that are dependent on a freshwater influence. However, the saline influence would probably create habitats of at least equal importance to those that are already present, such that there could be an overall neutral impact on the SSSI/NNR, dependant on the magnitude of changes that occur and the relative value of the habitats. Over the longer term, it is likely that there will be net loss of wetland habitat (of any type) as it is squeezed against the hinterland. However given that the magnitude of change is difficult to predict, for the purposes of this appraisal a neutral effect is given to this option (Overall Appraisal Category = 0).

Option 2: Beach Nourishment

13.15 This option would provide protection for the inland features of the SSSI/NNR assuming that nourishment raises the crest of the shingle bank relative to sea level. The placement of imported material on to the beach, presumably at the southern end close to Torcross, would also provide some element of protection to the existing shingle vegetation further north. It is anticipated that, with appropriate mitigation during the import of material, this option would result in a neutral effect (no observable impact in either direction) on ecology resources within the project area (Overall Appraisal Category = 0).
Option 3: Beach Recycling

13.16 As for Option 2, this option would provide protection for inland features of the SSSI/NNR assuming that nourishment raises the crest of the shingle bank relative to sea level. It would also protect the existing shingle vegetation, described in Chapter 4. It is anticipated that this option would result in a neutral impact on ecological resources, giving rise to a neutral effect score for this option (Overall Appraisal Category = 0).

Option 4: Rock Revetment

13.17 The construction of a rock revetment along the road on the upper beach would provide protection for the inland features of the SSSI/NNR. In the long-term the revetment would prevent the landward movement of the shingle barrier and could also result in the possible erosion of the existing beach. This erosion would, in turn, result in a loss of the shingle vegetation that represents several stages of landward zonation in the colonisation of the shingle. In the longer term fixing the crest height will result in an increased overwashing ratio and hence salt water inputs to the Ley. It is also possible that there will be impacts on overall barrier permeability (reduced) and resultant changes in water level with the Ley. Overall, the impact is anticipated to be of intermediate negative magnitude in the long-term, giving rise to a large adverse effect (Overall Appraisal Category = -3).

Option 5: Sheet Pile

13.18 As for Option 4 Rock Revetment, Option 5 Sheet Pile would prevent the landward movement of the shingle barrier resulting in a long-term loss of shingle vegetation. In the longer term fixing the crest height will result in an increased overwashing ratio and hence salt water inputs to the Ley. It is also possible that there will be impacts on overall barrier permeability (reduced) and resultant changes in water level with the Ley. The reduction is permeability would be greater than for rock revetment protection (Option 4). This is considered to be a long-term intermediate negative impact, giving rise to a large adverse effect (Overall Appraisal Category = -3).

Option 6: Realign the existing Coast Road on Slapton Line

13.19 This option would allow the landward movement of the shingle barrier and probably the establishment of new vegetated shingle areas. Associated protection, that will be necessary for the medium to long-term retention of the realigned road, would provide protection for the inland features of the SSSI/NNR. However, the realignment of the existing road along the shingle barrier would probably result in the loss of some scrub habitats from the SSSI/NNR. In the longer term fixing the crest height (the new road alignment) will probably result in an increased over-washing ratio and hence salt water inputs to the Ley. With appropriate advance mitigation for the loss of habitat during construction, it is likely that an adverse habitat effect can be...
avoided and for the purposes of this assessment, a neutral effect is predicted (Overall Appraisal Category = 0). It is however possible that it may not be possible to re-create vegetated shingle habitats on the seaward side of the new alignment and there could be a net loss of this habitat (M Lees *in litt.*)

Option 7: Upgraded Existing Roads Landward of Slapton Ley

13.20 The abandonment of the existing road in favour of a newly upgraded route corridor landward of Slapton Ley, involving upgrading of existing roads, would allow natural processes along the shingle beach to occur unhindered, including barrier migration, increased saltwater inflows and net loss of existing wetland habitats over time. There would be some local habitat related impacts inland where upgrading was required although this should be outside sites designated for their nature conservation importance. It is accepted that this option would result in the breach in the long term of the shingle barrier, with the existing freshwater lake becoming a saline lagoon. This would probably be a major negative impact on the fresh water features of the SSSI/NNR although it is possible that, over time, freshwater habitats could migrate up the low-lying river valleys. However, the saline influence would probably create habitats of at least equal importance to those that are already present, such that there could be an overall neutral impact on the SSSI/NNR, dependant on the magnitude of changes that occur and the relative value of the habitats. Over the longer term, it is likely that there will be net loss of wetland habitat (of any type) as it is squeezed against the hinterland. However given that the magnitude of change is difficult to predict, for the purposes of this appraisal, and to account for habitat losses along the upgraded inland route, a slight adverse effect is given to this option (Overall Appraisal Category = -1).

Option 8: New Road Landward of Slapton Ley

13.21 As for Option 7, the abandonment of the existing road in favour of a new road just landward of Slapton Ley, would also allow natural processes along the shingle beach to occur unhindered, including barrier migration, increased saltwater inflows and net loss of existing wetland habitats over time. As for option 7, it is accepted that this would result in the breach in the long term of the shingle barrier, with the existing freshwater lake becoming a saline lagoon. This would result in a change in those habitats and species present within and around Slapton Ley at that point in time. However, the saline influence would probably create habitats of at least equal importance to those that are already present, such that there could be an overall neutral impact on the SSSI/NNR, dependant on the magnitude of changes that occur and the relative value of the habitats. Over the longer term, it is likely that there will be net loss of wetland habitat (of any type) as it is squeezed against the hinterland.
13.22 *For the purposes of this assessment* and given that there are no obvious unprotected possible route corridors just inland of the Ley, it is assumed that a new ‘theoretical’ road, along a preferred *engineering* alignment, would follow the western boundary of the Ley. This would result in the loss of wetland habitats from the SSSI/NNR and would be likely to result in the loss of hedgerows and farmland. This would be a major negative impact, giving rise to a large adverse effect. Any new bridge, or road works could result in a substantial loss of habitats and impacts on sensitive species.

13.23 Although it is possible that impacts to the Ley as a result of the increased salinity are difficult to predict (and are judged here to be neutral for this assessment), the likely substantial losses to habitats within protected areas for a new road corridor will give rise to a large adverse effect (Overall Appraisal Category = -3)

**Geomorphology**

**Existing Situation**

13.24 Slapton Sands is one of a series of shingle barrier beaches along the east-facing shoreline of Start Bay. These beaches are composed predominantly of fine gravels and small pebbles with flint the dominant sediment type. There is a gradual decrease in beach crest height and coarsening of the beach material towards the south. These beaches can also be regarded as swash aligned i.e. the beach planform is adjusted to an orientation that minimises the angle between shoreline and approaching wave crest so limiting net longshore sediment transport. Full details of the geomorphologic interests are described in Chapter 5 ‘Geomorphology Baseline’.

13.25 The potential impacts of scheme options on the geomorphology of the Slapton barrier beach have been considered in terms of:

1. Impact on the GCR interest of the site:
   - Distinctive beach materials i.e. flints and chert shingle, with little local material;
   - Longshore sediment grading i.e. sediment size increases towards the south;
   - The easterly aspect of the beach i.e. a unique barrier orientation for the south coast of England.

2. Impact on the dynamic behaviour of the barrier beach:
   - Longshore sediment transport;
   - Beach profile changes i.e. overtopping (barrier crest height increases) and overwashing (reduction in barrier crest height and transfer of material to the back beach).
13.26 Note that this assessment does not consider impacts on the hydrological connectivity between the barrier and the lagoons/wetlands.

13.27 Note that it is assumed that the “hold the line” options would provide protection for the entire barrier section of the beach. Partial protection schemes would have additional impacts over and above those described here.

Barrier Beach Behaviour

13.28 Two components of beach behaviour are important considerations for the purposes of this assessment:

1. Longshore sediment transport; the longshore component of wave power (i.e. sediment transport potential) is related to the wave approach angle relative to the shoreline. Longshore wave power ($P_L$) is defined by:

   $$ P_L = 0.5 \times (EC) \sin 2\beta $$

   ($\beta$ is the angle between the wave crest and the shoreline; $E$ (wave energy density) = $1/8 \rho g H^2$ and $C_b$ (wave phase velocity) = $(2gH_b)^{0.8}$)

2. Profile response to surging waves; surge flows up the beach face include:
   - Overtopping surge that transports material up the beach face and leads to increase in crest height;
   - Overwashing surge that carries gravel over the crest and towards the back-beach. This involves a greater magnitude of surge than overtopping events.

The overwashing ratio is the proportion of waves of sufficient magnitude to generate overwash events.

Beach behaviour involves, therefore, brief episodes of overwashing and crest lowering, followed by longer periods of recovery during which the “damage” to the beach crest caused by storm events is "healed" during overtopping surge events.
The overwashing ratio (OWR) is a function of the wave climate and the barrier crest height relative to sea level (Orford et al 1995). It is a measure of the potential for breaching. A number of conditions can be defined:

<table>
<thead>
<tr>
<th>Sea-level fall</th>
<th>Barrier Crest Constant</th>
<th>Barrier Crest Increase</th>
<th>Barrier Crest Decrease</th>
</tr>
</thead>
<tbody>
<tr>
<td>OWR decrease</td>
<td>OWR decrease</td>
<td>OWR constant*</td>
<td></td>
</tr>
<tr>
<td>Sea-level constant</td>
<td>OWR constant</td>
<td>OWR decrease</td>
<td>OWR increase</td>
</tr>
<tr>
<td>Sea-level rise</td>
<td>OWR increase</td>
<td>OWR constant*</td>
<td>OWR increase</td>
</tr>
</tbody>
</table>

Note: * assumes that crest height change is equivalent to sea-level change.

Increased storminess is likely to be accompanied by an increase in overwashing ratio.

Potential Impacts

Option 1: No Active Intervention

13.29 The barrier beach will migrate inland, becoming progressively anchored onto hinterland slopes. Eventually this will lead to the formation of a fringing beach. In addition there is likely to be a loss of the barrier beach and back barrier wetlands. In geomorphologic terms the potential impact of this option is considered to be neutral (Overall Appraisal Category = 0).

This option could potentially affect the wetland areas of the Higher and Lower Leys, as any option that is likely to increase the overwashing ratio will increase the threat to these habitats. These issues are addressed in the ecology appraisal.

Option 2: Beach Nourishment

13.30 This option will involve the potential altering of the beach composition by placing ‘alien’ material onto the beach. Furthermore, the composition of the imported material could have an effect on the shingle barberries permeability with allied effects on the water levels in the Lower Ley.

It is also likely that the associated beach widening will result in the extension of the beach profile into deeper water impacting on the dynamic behaviour of the barrier beach. This will result in a higher wave energy setting than the current beach profile, leading to an increase in longshore wave power and sediment transport rates and is likely to result in an acceleration of beach face erosion.

The effect on the geomorphology of this option would indicate an intermediate negative impact that is therefore likely to be large adverse effect (Overall Appraisal Category -3).
Option 3: Beach Recycling

13.31 As with Option 2, Beach Recycling will result in the extension of the beach profile into deeper water impacting on the dynamic behaviour of the barrier beach. This will result in a higher wave energy setting than the current beach profile, leading to an increase in longshore wave power and sediment transport rates and an acceleration of beach face erosion. However beach grading is likely to become re-established over time.

Furthermore, removal of beach material from the north (i.e. in front of the Strete Gate to Pilchard Cove cliff line) will cause beach lowering/narrowing in this area. This could lead to increased cliff recession along this section, although increased northwards sediment transport from the barrier section may offset these beach changes. The effect on the geomorphology of this option would indicate an intermediate negative impact that is therefore likely to be slight to moderate adverse effect (Overall Appraisal Category -1 to -2).

Option 4: Rock Revetment

13.32 Barrier crest protection (i.e. rock revetments) will cause a reduction in the up-beach transport of sediment by surging waves. Although this will reduce the tendency for barrier retreat (i.e. roll-over), it will also prevent crest height increase during overtopping events. As sea level rises, the net effect will be a reduction in the relative crest height and, hence, an increase in the overwashing ratio and increased likelihood of overwashing of the road, beach face and crest erosion and breaching (Figure 13.2). The revetment may affect the water levels in the lower Ley due to changes in the barberries permeability.

The effect on the geomorphology of this option would indicate an intermediate negative impact that is therefore likely to be large adverse effect (Overall Appraisal Category -3).

Option 5: Sheet Pile

13.33 Barrier crest protection (i.e. piling) will cause a reduction in the up-beach transport of sediment by surging waves. Although this will reduce the tendency for barrier retreat (i.e. roll-over), it will also prevent crest height increase during overtopping events. As sea level rises, the net effect will be a reduction in the relative crest height and, hence, an increase in the overwashing ratio and increased likelihood of overwashing of the road, beach face and crest erosion and breaching (Figure 13.2).

This option would have no effect on the composition of the beach materials or the easterly orientation of the beach, nor would it result in the disruption of the longshore beach grading. However, the sheet pile may affect the water levels in the lower Ley due to changes in the barberries permeability. The effect on the geomorphology of this option would indicate an
intermediate negative impact that is therefore likely to be a large adverse effect (Overall Appraisal Category -3)

Option 6: Realign the existing Coast Road

13.34 This option would have no direct effect on the barrier beach. However, the dynamic behaviour of the barrier beach would be affected if overwash material is removed from road surface and returned to beach face, rather than allowed to migrate inland, preventing barrier beach migration. As sea level rises, this will lead to a reduction in the relative crest height, an increase in the overwashing ratio (OWR) and increased likelihood of overwashing of the road, crest/beach face erosion and breaching.

There would not be any effect on the composition, grading or orientation of the beach as a result of this option. As there would be no observable impact in either direction this option will score neutral (Overall Appraisal Category = 0).

This option would potentially affect the wetland areas of the Higher and Lower Leys, as any option that is likely to increase the overwashing ratio will increase the threat to these habitats. These are addressed in the ecology appraisal.

Option 7 and Option 8: Upgraded Existing Roads Landward of Slapton Ley & New Road Landward of Slapton Ley

13.35 The abandonment of the existing road in favour of a new road or an upgraded route landward of Slapton Ley would allow the barrier beach to migrate inland, becoming progressively anchored onto the hinterland slopes, and forming a fringing beach. Over time, this would result in the loss of the barrier beach and back-barrier wetlands. It would not however affect the composition of the beach materials, there would be neither disruption of longshore beach grading nor any change to the Easterly beach orientation.

13.36 A new road I or an upgraded route landward of Slapton Ley would also have a likely effect on the hill slopes by impacting on the soils, slopes, surface and groundwater – the exact impacts dependant on the final alignment and design. These two options are considered as having a neutral impact on the geomorphology of the barrier beach, whilst the effect of these options on the hill slopes is considered to have a slightly adverse impact on the geomorphology (depending on the alignment and design of the road) and therefore both are given a slight adverse score (Overall Appraisal Category = -1).

13.37 It is difficult to provide reliable estimates about the timing, rate and significance of the impacts, especially the change in overwashing ratio. However, current views of shingle barrier behaviour suggest that although protection works will reduce the likelihood of breaching in the short term
(e.g. 5 – 10 years), over time (>10 years) the chances of a “catastrophic change” will increase (e.g. Orford 2001). In reality, the potential for overwashing-induced breach will be controlled by the crest height of any defence line. Further details are provided in Chapter 5 ‘Geomorphology Baseline – Conceptual Framework’.
Figure 13.2  A summary of the impacts of beach stabilisation
Archaeology

Existing Situation

13.38 The baseline assessment for the Slapton Line identified a number of archaeological sites within a 3km radius of the road. The sites represented date from the prehistoric to modern period and include prehistoric earthworks, artefact scatters and post-medieval features/structures. The majority of the sites recorded are not located within close proximity of the proposed options therefore the impact on these is regarded as negligible. However, sites, which may be impacted upon, include prehistoric earthworks, medieval features, post-medieval buildings and World War II defensive sites.

13.39 Situated within the northwestern, southwestern and northeastern extent of the study area are clusters of prehistoric, medieval, post-medieval and modern sites, which are outlined in the baseline study. This would suggest extensive activity within these areas. It is likely that similar sites may occur which may be affected by the proposed options.

13.40 Located within the immediate vicinity of Slapton Line are a number of World War II defensive structures, which were either built in 1940, or between 1943 and 1944. Those built in 1940 were constructed to deter a German invasion. In 1943 the area surrounding the Slapton Line was designated as the Slapton Battle Training Area. A number of structures including pillboxes and gun emplacements were constructed to allow for the invasion of Europe to be rehearsed. It is reported that during one exercise code named Tiger, German E-boats successfully infiltrated the defences. There are a number of structures including pillboxes and gun emplacements, which still survive in the area. These bear testament to the part that Slapton played in the Defence of Britain thus are of importance to the heritage of the area.

13.41 To reference the full list of sites affected please refer to table in Chapter 6.

Potential Impacts

Option 1: No Active Intervention

13.42 If no active intervention is undertaken it is likely that a number of archaeological/historical sites will be destroyed or impacted upon by natural erosion processes. These sites include prehistoric defensive sites and artefact scatters, post-medieval buildings, a shipwreck and World War II defensive sites. Similarly the unknown archaeological resource along the barrier beach will be affected. The impact of this option is considered to be moderate adverse (Overall Appraisal Category = -2).

Option 2: Beach Nourishment

13.43 It is possible that dredging associated with works undertaken for Option 2 may impact on unknown archaeological remains associated with the marine environment and/or wreck sites. It is also likely that nourishment would bury/conceal artefacts that are emerging from the beach face. This option is therefore considered to have a moderate adverse effect (Overall Appraisal Category = -2).

Option 3: Beach Recycling

13.44 It is likely in the short-term that operations associated with beach recycling will lead to increased erosion within close proximity to the northern extent of the Slapton Line. This will indirectly impact upon World War II Defensive sites and may directly impact upon possible remains associated with the prehistoric scatter (102) discovered within the northern extent of Slapton Ley. It is also likely that re-cycling would bury/conceal artefacts that are emerging from the beach face and its also possible that unknown archaeological sites may be affected. This option is considered as having a slight adverse effect (Overall Appraisal Category = -1).

Known Sites possibly affected (102, 77, 171-173).

Option 4 and Option 5: Rock Revetment and Sheet Pile

13.45 It is likely that groundworks and/or main construction works associated with options 4 and 5 will directly or indirectly impact on prehistoric sites and World War II defensive sites (including pill boxes and gun emplacements) located within close proximity to the Slapton Line. Similarly operations associated with these options may impact on the unknown archaeological resource, however, such remains may have been destroyed by the construction of the existing road. It is therefore considered that either of these options would have a slight/moderate effect (Overall Appraisal Category = -1 to -2)

Known Sites possibly affected (30, 31, 77, 102, 143, 163-166 and 171-173)

Option 6: Realign the existing Coast Road

13.46 Ground works and or main construction works are likely to directly impact on the known and unknown archaeological sites within close proximity to the proposed road option. Those sites recorded date from the prehistoric to modern period and include prehistoric standing stones and artefact scatters, medieval and post-medieval features and World War II defensive sites including pillboxes and gun emplacements.

There are a number of historic buildings and structures within the study area that date from the medieval to modern period. These either carry a statutory or local listing and include churches, priories, crosses, public houses and bridges. The majority of these will not be impacted upon,
however, those located within close proximity to the line including the coast guard station (23), a public house (56) and kennels (59) will be either directly or indirectly affected upon by this option. It is therefore considered that this option will have a moderate to large adverse effect (Overall Appraisal Category -2 to -3)

Known Sites possibly affected (12, 23, 30, 31, 51, 52, 56, 59, 69, 70, 77, 78, 79, 80, 93, 102, 132-135, 162-167, 169-173)

Option 7 and Option 8: Upgraded Existing Roads Landward of Slapton Ley & New Road Landward of Slapton Ley

13.47 Both of these options could potentially have a significant impact on the known and unknown archaeological resource in the area, as demonstrated by the number of archaeological sites recorded within in close proximity to the road option. The sites recorded within near vicinity to the line date from the prehistoric to modern period and include prehistoric standing stones, prehistoric artefact scatters, medieval and post-medieval features and World War II pillboxes and gun emplacements. These may be impacted upon during groundworks associated with the construction of the road and associated bridge. Similarly the setting of surviving structures including pillboxes may be affected. A new road (Option 8) would passes through a rural landscape which has not been impacted upon by modern development, therefore there is potential for archaeological sites to be discovered during groundworks. The potential would be reduced for the upgrade of existing roads.

13.48 A number of historic buildings and structures are recorded within the study area (encompassing a new alignment inland of the Ley but not all of likely route of upgraded roads) date from the medieval to modern period. These either carry a statutory or local listing and include churches, priories, crosses, public houses and bridges. Most of these will not be impacted upon, however, those within close proximity to Option 8 including a public house (56) and a mansion (67) will be directly or indirectly affected.

It is therefore considered that Option 8 will potentially have a large adverse effect (Overall Appraisal Category = -3) whilst Option 7, with less landtake, will potentially have a moderate adverse effect (Overall Appraisal Category = -2).

Known Sites possibly affected for Option 8 only (16, 42, 52, 70, 69, 92, 93, 102, 114, 115, 132-135 142, 143, 157, 159, 160 and 168-170)

Qualitative Comments

13.49 Although the options appraisal has given an outline of the potential for the known and unknown cultural heritage resource in the area the sites identified will need to be assessed in greater detail to determine the level of impact that the options will have on individual sites. Analysis of
aerial photographs, documentary and historic sources will need to be assessed to determine the potential for the unknown archaeological resource, however these further assessments are outside the remit of this study and should be conducted during a later detailed design stage. Following this a mitigation strategy will need to be devised to reduce/alleviate the impacts of the preferred option.

Landscape
Existing situation

13.50 The study site lies within the much dissected plateau landscape of the South Hams within South Devon. The study zone covers a 3km radius area centred on the memorial car park at Slapton sands. The shingle barrier of Slapton Sands divides the study area from the South Devon coast to the east, and retains the fresh water body of Slapton Ley to the west. Behind the Ley the landscape quickly rises up to form a rolling agricultural plateau landscape, regularly dissected by wooded steep river valleys, which gradually widen as they approach and terminate within the Ley. The study site is located within the South Devon Area of Outstanding Natural Beauty (AONB). The primary importance of the AONB is to conserve and enhance the natural beauty of the landscape. In addition to its AONB status the study area contains the following designations.

- Coastal Preservation area
- Slapton Ley and the shingle has also been designated as Site of Special Scientific Interest

13.51 In order for qualification as an AONB the landscape must fulfil the following criteria:

- The landscape should be a resource of national importance, for reasons of rarity or representativeness;
- It should be of high scenic quality, with important aesthetic factors;
- The landscape within the area should be unspoilt by large scale, intrusive industrial or other inharmonious development;
- It should have a distinctive and common character, including topography and visual unity and a clear sense of place;
- In addition to scenic qualities, it should include other notable conservation interests, such as features of historical, wildlife or architectural interest;
- There should be a consensus of both professional and public opinion as to its importance.
13.52 The study site and its immediate environs consist of the following landscape elements.

- Shingle Beach.
- Fresh Open Water.
- Reed Beds/Marginal aquatics/Carr woodland.
- Deciduous woodland areas.
- Sea Cliffs.
- Arable Plateau.
- Pastoral Plateau.
- Settlements of Slapton, Torcross and Stokenham.

**Potential Impacts**

**Option 1: No Active Intervention**

13.53 This option would initially present no landscape or visual changes, however, modelling of potential sea level rise suggest that in time the beachcrest will retreat and eventually the A379 will be cut off. The shingle barrier will continue to retreat and will either breach or be overwashed. Once breached the Ley will presumably over time become a brackish or saline lagoon. Although these changes would occur as the result of natural events the impact in terms of landscape and visual change may be significant if substantial areas of the shingle ridge height are lost or if the ridge becomes fragmented.

13.54 With reference to landscape change a number of landscape character areas would potentially be affected. Over time the man-made elements contained within ‘LCA1’ including the road, car park and associated buildings would also be lost. There would also be changes to the landscape character of the shingle ridge, dependant upon the exact nature of the shingle ridge morphological changes. Currently the shingle barrier forms a rare landscape feature, which due to it's shear scale and juxtaposition next to the open water body of Slapton Ley creates a visually impressive landscape element within the South Devon AONB. The predicted overwashing and modification of the existing shingle barrier will result in significant visual change.

13.55 The second landscape character area to be affected would be ‘LCA2’, the fresh open water body. The breaching and overwashing of the shingle barrier by the sea would change the ecology of the Ley from a freshwater body to a brackish or salt-water lagoon. The changes above could result in the loss of the freshwater marginal and aquatic vegetation along the margins of the Ley although vegetation suited to the newly saline environment would colonise.
13.56 The loss of the road and associated infrastructure elements would, however, be beneficial reducing the impact of these features within the AONB, however this is of lesser importance if the shingle barrier itself became reduced in scale or fragmented.

13.57 Although the landscape that will evolve, if and when the shingle barrier is breached, is to some extent uncertain, it is likely to include the modification over time of the morphology of the shingle barrier and the fresh water habitats of the Ley. This is classed as a large adverse (negative) visual effect due to the loss of existing aesthetically outstanding landscape elements, which are highly visible and of great landscape value within the existing context of the AONB, and their likely replacement with more ubiquitous landscape elements. The changes to the landscape character and the associated visual impact are classed as having a moderate adverse impact (Overall Appraisal Category = -2).

Option 2: Beach Nourishment

13.58 This option would require the incorporation of approximately 20,000m³ a year of shingle, imported from other areas to replenish lost material. This scheme would have neutral effect following site operations, as the scheme will blend in well with surrounding landscape features and existing elements. Selection of aggregate for beach nourishment will be the critical issue to ensure that colour, size, shape and texture is the same of the current beach material.

13.59 During the construction period the option will have a slight adverse impact on the landscape due to the high visibility and prominence of the constructions operations (Overall Appraisal Category = -1).

Option 3: Beach Recycling

13.60 This option will have a neutral effect on the landscape. Following completion of the operations, it is anticipated that the beach profile will become slightly modified although wave action will re-establish an equilibrium in beach profile naturally. During the construction period highly frequent vehicle movements are expected along the A379 transporting aggregates from the northern end of Slapton sands to the areas requiring additional shingle. These identified vehicle movements and the operation of heavy plant on the beach will visually have a slight adverse effect during the construction phase of this option (Overall Appraisal Category = -1).

Option 4: Rock Revetment

13.61 This option will have a moderate adverse (negative) effect upon the landscape due to the incorporation of this unnatural linear element along the length of the shingle barrier. This will not only affect the landscape character of the barrier but will also reduce access to the beach and waterfront. The revetment will be visible to a number of sensitive receptors including users of
the ‘South West Coast Path National Trail’ and residents of properties at Strete Gate and Torcross and in addition be visible to inshore boat users. During construction to revetment works will be highly visible due to the machinery required to carry out this operation and this will visually have a slight adverse effect (Overall Appraisal Category = -1).

Option 5: Sheet Pile

13.62 This option will potentially have a neutral landscape impact following construction due to the buried nature of the sheet plies. However, if the piles become exposed due to the coastal erosion then this feature will have a major adverse effect on the landscape. This will be due to the linear engineered appearance of the piling within the naturalistic setting of the study zone. If the piles become exposed and the beach levels were reduced then access to the beach could also be compromised. The piling would be visible to a number of sensitive visual receptors including residential properties located at Torcross and Strete Gate users of the South West Coast Path National Trail and inshore boat users. During construction of sheet piling, works will be highly visible due to the machinery required to carry out this operation. Overall the landscape and visual effects are judged to be moderate adverse (Overall Appraisal Category = -2).

Option 6: Realign the existing Coast Road

13.63 Realigning the coast road, without any additional measures, would not maintain the shingle bar although it would likely extend the life of the route corridor. This option would therefore be similar to that for no active intervention and have a large adverse landscape effect, as the existing landscape will be lost over time. Both areas ‘LCA1’ and ‘LCA2’ would probably reduce in extent over time at an unknown rate.

13.64 Currently the shingle barrier forms a rare landscape feature, which due to it’s shear scale and juxtaposition next to the open water body of Slapton Ley creates a visually impressive landscape element within the South Devon AONB. Option 6 in isolation would not maintain these features and therefore have a potentially large adverse effect following construction. During the construction period the option will also have a slight adverse (negative) effect on the landscape due to the high visibility and prominence of the constructions operations (Overall Appraisal Category = -3).

Option 7: Upgraded Existing Roads Landward of Slapton Ley

13.65 The option to upgrade the existing road network well to the west of the Ley will have some implications to the landscape of the wider study zone. The upgrading of the route would require
loss of some boundary features (loss of Devon hedgerows) and probably some cuttings and bridge building works across valleys.

13.66 The upgraded road and in particular those elements that require major works would be visible from a relatively small number of sensitive receptors. The implication of this scale of development will be a moderate adverse effect (Overall Appraisal Category = -2)

Option 8: New Road Landward of Slapton Ley

13.67 An option to realign the road immediately west of the Ley would have major implications to the landscape of the study zone, all of which would lie within the AONB. The construction of the road would result in a major cutting operation along the western edge of the Ley and in addition three new bridges would probably require construction one from Strete Gate across the higher key, one below Slapton village and the third south of the Lower Ley between Torcross and Stokenham.

13.68 The road construction would also require two new junction upgrades. The new road will be visible from a greater number of sensitive visual receptors including residences at Strete Gate, Slapton and Torcross, users of the South Devon Coastal Path and inshore boat users. The implication of this scale of development within the study zone would be a large adverse effect (Overall Appraisal Category = -3).

Transportation

Existing Situation

13.69 The road along the shingle bank at Slapton Ley is approximately midway along the A379, which links Kingsbridge to Dartmouth. This road is classified as a Secondary County Route in the Devon Road Network. It is a relatively low speed / low capacity route which contains numerous narrow single lane sections, particularly within the villages through which it passes. An alternative route exists between Kingsbridge and Dartmouth via the A381 and A3122, which are classified as Primary County Routes in the Devon Road Network. This route is of a generally better standard than the A379 and passes through far fewer settlements of any size.

13.70 The A379 is however no doubt chosen, particularly by visitors, as it follows the coast in part and provides interesting and spectacular views. Visitors typically also stop at the car parks at Slapton Sands and Torcross in the middle of their journey. The area contained within the A379, A381 and A3122 is criss-crossed by a network of narrow country lanes, typically bordered by high 'Devon Hedges'. The lanes are for the most part single track and the provision of passing places varies greatly; some are properly formed and surfaced, others are informal in gateways.
13.71 During the period of the last closure of the A379 in January-March 2001 it is understood from DCC that no alternative routes through the local lanes were signed. It is further understood that the immediately local population ‘chose’ the better of the substandard country lanes and generally followed informal one-way routes in order to minimise conflict.

Impact of the closure of the A379 at Slapton Ley

13.72 The impact of the closure of the A379 obviously becomes greater the closer one gets to the point of closure. This is demonstrated in the table 13.2 where column 3 shows travel distances via the A379, column 4 shows travel distances via the A3122/A381 and column 5 the difference between the two. For non-commercial vehicles the route into/out of Kingsbridge via Belle Hill would be available and this reduces the distances shown via the A381/A3122 by approximately 2km.

Table 13.2 Impact of the Closure of the A379 on travel distances

<table>
<thead>
<tr>
<th>To</th>
<th>From</th>
<th>via A379 km</th>
<th>via A3122/A381 km</th>
<th>difference km</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dartmouth</td>
<td>Kingsbridge</td>
<td>24.1</td>
<td>22.4</td>
<td>-1.7</td>
</tr>
<tr>
<td></td>
<td>Stoke Fleming</td>
<td>21.0</td>
<td>25.5</td>
<td>4.5</td>
</tr>
<tr>
<td></td>
<td>Strete</td>
<td>17.6</td>
<td>28.9</td>
<td>11.3</td>
</tr>
<tr>
<td></td>
<td>Strete Gate</td>
<td>14.8</td>
<td>31.7</td>
<td>16.9</td>
</tr>
<tr>
<td>Kingsbridge</td>
<td>Dartmouth</td>
<td>24.1</td>
<td>22.4</td>
<td>-1.7</td>
</tr>
<tr>
<td></td>
<td>West Charleton</td>
<td>22.0</td>
<td>24.5</td>
<td>2.5</td>
</tr>
<tr>
<td></td>
<td>Frogmore</td>
<td>20.0</td>
<td>28.2</td>
<td>8.2</td>
</tr>
<tr>
<td></td>
<td>Chillington</td>
<td>18.2</td>
<td>30.0</td>
<td>11.8</td>
</tr>
<tr>
<td></td>
<td>Stokemham</td>
<td>15.4</td>
<td>32.8</td>
<td>17.4</td>
</tr>
<tr>
<td></td>
<td>Torcross</td>
<td>13.1</td>
<td>35.1</td>
<td>22.0</td>
</tr>
<tr>
<td>Torcross</td>
<td>Strete Gate</td>
<td>3.8</td>
<td>42.7</td>
<td>38.9</td>
</tr>
</tbody>
</table>

13.73 First Western National uses the A379 to link Kingsbridge to Dartmouth by its route number 93 with over 10 services daily, Monday to Saturday, and 4 on Sundays. Given the number of settlements along this route it clearly would not be replicated by transferring the service onto the A381/A3122. This service also links to Plymouth and Derriford Hospital and its importance should not be understated. Were the A379 to be closed it would seem that this service would have to be replaced by small feeder services from Torcross to Kingsbridge and Strete to Dartmouth with interchanges at the larger towns to continue the journeys. This is essentially what happened during the last temporary closure.

13.74 The secondary school catchment areas divide at Strete Gate and hence there should be limited disruption were the road to be closed. The situation with regard to school transport is however
complex due to parental choice. The situation at present is that the number of pupils from the Dartmouth area electing to be educated at Kingsbridge has reduced the capacity at the Kingsbridge Community College for pupils within its own catchment area and hence some of the latter are ‘forced’ to travel to Dartmouth. The County Council provides funding for the latter to travel on public service buses to Dartmouth but does not provide funding for the former who have ‘chosen’ to travel to Kingsbridge. A secondary effect is that the scholars from Dartmouth fill the service bus towards Kingsbridge such that as the bus passes Torcross there is standing room only for Kingsbridge catchment area scholars from Stokenham etc. The County Council therefore provides a funded bus service for the latter pupils. The County Council is not finding it easy to obtain school bus providers and this particular service utilises the same bus, which also does a run to Stoke Fleming School and uses Slapton Line to travel between the two. School transport is not provided for primary school children and parental choice will again blur nominal catchment areas and result in criss-crossing parental journeys.

13.75 The area is covered by two fire stations, at Kingsbridge and Dartmouth. The Home Office standard for the area is Class D whereby one appliance is expected to attend within 20 minutes of the alarm being raised. The division between their territories occurs at Strete Gate however where an incident involves property fire or trapped persons it is normal for one appliance to attend from each station. A closure of the A379 in the vicinity of Torcross could prevent the attendance time to Slapton village from Kingsbridge being maintained and a closure anywhere could give problems during the busier summer months. A closure would have a similar effect upon the emergency ambulance, patient transport and police services in being able to carry out their duties to the standard expected.

13.76 Those options under consideration, which retain the route between Strete and Stokenham at or close to its current alignment, would have little if any impact on journey time or distance. The options requiring works or intervention to the shingle bank are likely to involve an increase in heavy goods vehicle movements through the villages along the A379, which is likely to be unwelcome and cause congestion and increased hazard. Similarly works requiring road construction will involve construction traffic using this road. The inland route option would have an impact on journey time and distance and require a positive effort on the part of drivers to visit Torcross or the other car parks along the Ley. It would make the shore less accessible to those reliant on public transport.

13.77 During the period of the previous closure, the Doctors Surgery at Chillington reported severe difficulty in maintaining a normal service for its patients, whilst the surgeries at Kingsbridge and Dartmouth, being further from the closure, appear not to have been affected.

13.78 There will be several ‘end-to-end’ trips on the A379 that would also be affected by a closure of the road, including postal delivery/collection, refuse collection, deliveries of milk, fuel, goods, newspapers etc. A closure would reduce the ‘passing trade’ to the local shops, hostelries, cafes, tourist facilities, etc. To maintain their trading position they would have to market
themselves in a similar fashion to the many other areas around the coast of Devon that were at the end of cul-de-sac.

13.79 It is clear that whilst the route between Kingsbridge and Dartmouth via Slapton Ley is not required for through traffic (other than for maintaining the livelihood of businesses reliant on passing trade) it does perform an important local movement function. The events during the last temporary closure demonstrated that not maintaining a route of some description is not an option.

13.80 Were the road on the shingle bank ceases to exist, allowing vehicles to find their own way through the existing network of country lanes is not considered to be an acceptable alternative. The lanes are, in particular, not suitable for commercial vehicles and it is unrealistic to expect that the police would have the resources to adequately enforce a wide-ranging weight or width restriction. Physical measures to enforce such restrictions are likely to be impractical since access will have to be retained for servicing and the passage of local farm vehicles.

Potential Impacts

Option 1. No active intervention

13.81 The closure, either temporary or permanent, of the A379 will increase traffic flow in unsuitable country lanes. It is likely that highway accidents will increase. Costs will rise to virtually all road users. It is doubtful whether replacement public transport services could be provided. Non-car owners would be unlikely to have access to the Slapton area apart from by cycle. It is therefore considered that this option will have a large adverse effect (Not scored).

Option 2. Beach nourishment and Option 3. Beach recycling

13.82 There would be no change to existing access arrangements associated with these two options. There would however be issues with congestion, environmental and safety implications of additional HGV movements through the villages on the A379 during shingle transportation activities. It is therefore considered that this option will have a moderate adverse effect (Not scored).

Option 4. Rock Revetment

13.83 If sea transport is used there would be a minimal increase in HGV movements through the villages along the A379. If land transport is used, congestion, environmental and safety implications of additional HGV movements through the villages on the A379 may apply. It is therefore considered that this option will have a slight adverse effect (Not scored).
Option 5. Sheet piling

13.84 During the construction stage there will be an increase in HGV movements through the villages on the A379. When the piles are finally exposed there would need to be beach replenishment that would have the effect as for Option 2. It is therefore considered that this option will have a moderate adverse effect (Not scored).

Option 6. Realign the existing Coast Road

13.85 If the realignment is reactive then there will be periods when the road is closed in advance and during construction. This temporary closure of the A379 will increase traffic flow in unsuitable country lanes and as for Option 1 would probably lead to an increase in highway accidents. Costs will rise to virtually all road users. It is doubtful whether replacement public transport services could be provided. Non-car owners would be unlikely to have access to the Slapton area apart from by cycle. If the realignment is proactive then it should be possible to keep the road open. Construction traffic will impact on communities along the A379 to a greater extent than Option 4. It is therefore considered that this option will have a moderate adverse effect (Not scored).

Option 7: Upgraded Existing Roads Landward of Slapton Ley

13.86 The option to upgrade the existing road network well to the west of the Ley would have ongoing implications for transportation in the wider area. The upgrading of the route would cause temporary disruption due to construction and temporary management measures for the period of construction. It is likely that this Option would comprise discrete construction events over a period of years.

13.87 A newly upgraded inland route, combined with the eventual abandonment of the existing route, would lead to a longer journey times for some users, particularly between Torcross and Strete. There would be increased public transport costs if the bus diverts into and out of Torcross. and accessibility to the beach for non-car owners would be substantially worsened. There would be benefits for existing users of the inland routes that would be improved. However, overall this option is considered to produce a large adverse effect (Not scored).

Option 8: New Road Landward of Slapton Ley

13.88 There would be little change in length, journey time or highway safety between the existing a new route just inland of the Ley. Construction traffic would have a greater effect than option 6, possibly as great as for options 2 and 3, but for a one off period. There would be increased public transport costs if the bus diverts into and out of Torcross. Accessibility to the beach for non-car owners would be worsened. It is therefore considered that this option will have a slight adverse effect (Not scored).
Socio- Economic Issues

Baseline

13.89 The population of both Skerries and Stokenham (wards within which Slapton and Torcross are sited) is just under 4,000. To set this within a context, the nearest largest settlements are Dartmouth and Kingsbridge, both with populations in excess of 6,000.

13.90 Within both wards the total number of businesses is just under 150 (as identified via the Annual Business Inquiry (ABI). It should be noted that this source excludes the ‘informal economy’ and as such it is possible that businesses such as self-catering accommodation providers and some self-employed residents will be omitted from these figures. In an area such as South Hams where farming, tourism and lifestyle businesses are a key element of the local economy, these omitted businesses could amount substantially.

13.91 Looking specifically at Slapton and Torcross however, the audit of businesses within the settlements thus far (awaiting input from consultations and Slapton Line Partnership) indicates a total of approximately 50 businesses, of which a significant proportion (over half) of businesses are tourism based. Others provide local services e.g. village stores, pubs etc but these clearly still retain strong links with the tourism sector as this swells the population of the area for significant periods of the year.

13.92 This baseline profile therefore indicates that both the total population and number of businesses within the area are fairly small though clearly this is not to say that any impacts to communities and businesses are insignificant. Surveys and consultations will provide clearer substantiation of the potential impacts of engineering options on local businesses and communities.

Option 1: No Active Intervention

Community & Social Impacts

13.93 Intermittent breaching of A379 would cause diversions and disruption to access/accessibility of services. Examples of these disruptions include bus services, travel to work times, emergency service access. The following impacts may also arise:

- Longer term loss of road and necessary use of other roads may increase drive times to services/facilities e.g. schools, workplace, doctors etc

- Use of minor roads may cause difficulties for larger vehicles – buses, vans, and lorries.

- Lack of planned approach to change and consequential disruption to traffic movements will lead to confusion and difficulties for residents and service providers e.g. bus companies.
The perception of Slapton and Torcross as more isolated communities will increase i.e. not on main road link between Kingsbridge and Dartmouth. This may be significant.

A provisional view, in the absence of the survey results is that the community and social effects associated with Option 1 are likely to be moderate adverse (Overall Appraisal Category = -2).

Business Impacts

The unplanned nature of road diversions would be difficult for businesses to manage and this could affect trade especially for businesses reliant on passing trade e.g. B&B’s and village stores. The following impacts may also arise:

- Ultimate loss of main road link will increase the ‘isolation’ of the villages and this could lead to reduction in trade. Loss of trade may be as a result of reduced passing trade and may be experienced by B&B’s, local stores, ley (visitor attraction). This could also arise as a result of increasing access difficulties or problems with supply chains to/from local businesses.
- Dependant on the importance of the Ley in its freshwater state to tourists, there may be a reduction in visitor numbers.

It must also be noted that there is the potential for positive impacts to be associated with the severance of the road. It is possible that some specialist businesses, e.g. recreational pursuits & natural history related, may actually benefit from the closure if it is perceived by some visitors that the area has been enhanced by the closure. The creation of changing and new fresh water/saline wildlife environments will attract specialist interest, and may be of interest to a more general market if actively marketed and interpreted. Any positive benefits re likely to be realised in the longer term and may require some initial capital investment in a "replacement" tourist infrastructure (e.g. new visitor centres). Furthermore, if the changes to the road structure inland include suitable parking and walking trail development then it may be possible to add to leisure and tourism use of the countryside in the area. If this work takes in existing local businesses then some economic benefits can be gained.

A provisional view, in the absence of the survey results, is however that the business effects associated with Option 1 are likely to be large adverse (Overall Appraisal Category = -3).

Option 2: Beach Nourishment and Option 3: Beach Recycling

Community & Social Impacts

Under these two options, the road would be maintained with a consequential continuation in the through flow of traffic with associated ‘benefits’. These will be quantified/qualified by the
business survey and consultations plus the potential visitor survey [results awaited].
Examples of such benefits include:

- Continuation of access to services e.g. local schools/doctors (i.e. access times not affected)
- Continuation of access by emergency services (i.e. access times not affected)

13.99 It is a reasonable assumption that the community and social effects associated with Options 2 & 3 are likely to be neutral (Overall Appraisal Category = 0).

**Business Impacts**

13.100 The maintenance of the road link should ensure that businesses dependent on the ability of suppliers/customers to easily access the village are not affected. Examples of such benefits include:

- Continuing ability/willingness of suppliers to meet the needs of Slapton area businesses,
- Continuing access by Slapton businesses to customers/markets in the wider area

13.101 The ‘nourishment’ works require some additional truck movements and dredging works. This may have some impact upon the aesthetic quality of the beach environment and therefore upon the numbers of visitors. This is however likely to be fairly minimal.

13.102 It is a reasonable assumption that the business effects associated with Options 2 & 3 are likely to be neutral (Overall Appraisal Category = 0).

**Option 4: Rock Revetment and Option 5: Sheet Pile**

**Community & Social Impact**

13.103 Under this option, as for Options 2 and 3, the road would be maintained with a consequential continuation in the through flow of traffic with associated ‘benefits’. Examples of such benefits include:

- Continuation of access to services e.g. local schools/doctors (i.e. access times not affected)
- Continuation of access by emergency services (i.e. access times not affected)

13.104 It is a reasonable assumption that the community and social effects associated with Options 4 & 5 are likely to be neutral (Overall Appraisal Category = 0).

**Business Impacts**

13.105 As for options 2 and 3, the maintenance of the road link should ensure that businesses dependent on the ability of suppliers/customers to easily access the village are not affected. Examples of such benefits include:
• Continuing ability/willingness of suppliers to meet the needs of Slapton area businesses,
• Continuing access by Slapton businesses to customers/markets in the wider area

13.106 The construction of the revetment under Option 4 would cause some temporary disruption. In the longer term however the impacts of the revetment are likely to be minimal and the aesthetic quality of the beach environment should not be affected given that the revetment will, at least initially, be buried. Over time however the revetment may be exposed with some minimal detriment to the visual environment although it is not considered likely that this will be of detriment to visitor motivations/numbers.

13.107 The sheet pile construction under Option 5 would cause some temporary disruption. Longer-term impacts are difficult to establish. Pile will not affect the erosion of the beach and beach loss will still occur. The combined effect of a loss of beach and the exposure of potentially unattractive sheet piling may be detrimental to the aesthetic quality of the beach environment. The effects of this upon visitor motivations/numbers are however difficult to quantify.

13.108 It is a reasonable assumption that the business effects associated with Options 4 & 5 are likely to be neutral (Overall Appraisal Category = 0).

Option 6: Realign the existing Coast Road

Community & Social Impacts

13.109 The ultimate replacement of the road with another, which is set back approximately 25m from the route of the original, is considered to have minimal impact upon the community though this is of course dependant on the exact location of the road. Should the realignment necessitate purchase of residential properties/businesses, there will clear impacts upon the specific members of the community. If the road is constructed "as and when required", the disruption before a complete replacement is provided could be considerable and temporary traffic management measures may create temporary congestion/increased drive times.

13.110 Overall however the road would be maintained and therefore a continuation in the through flow of traffic with associated ‘benefits’ would be provided. These ‘benefits’ will be quantified/qualified by the business survey and consultations plus potential visitor survey. Examples of such benefits to the community have been outlined in Options 2, 3,4 and 5.

13.111 It is a reasonable assumption that the community and social effects associated with Option 6 are likely to be neutral (Overall Appraisal Category = 0).

Business Impacts

13.112 The retention of a main road link along roughly the same alignment should mean that long-term impacts upon businesses will be minimal although the following impacts may occur:
Some disruption to businesses may occur due to the phasing of the construction of the new road.

It is not clear what the impacts upon the Ley will be as a result of a new road inland. Should the nature of the Ley be changed, there may be some affect upon the number/type of visitor.

Aesthetic impacts of the new road are unlikely to be significantly different to those resulting from the existing road however; this cannot be clarified until the design has been worked up. Should the visual impacts be significant there may be detrimental impacts upon visitor numbers to the immediate locality.

13.113 It is a reasonable assumption that the business effects associated with Option 6 are likely to be neutral (Overall Appraisal Category = 0).

Option 7 and Option 8: Upgraded Existing Roads Landward of Slapton Ley & New Road Landward of Slapton Ley

Community & Social Impacts

13.114 The replacement of the road with another inland of the Ley is considered to have less of an impact upon the community than loss of the road altogether. Any impacts upon the community are however directly dependant on the exact location of the new road. In theory a new inland route, whether a new road close to the Ley, or an upgraded route along existing roads, would remove the need for a coast road. However the additional distance of any new alignment as well as the new route itself will create impacts:

- A lack of through trade to businesses sited adjacent to the original road may have impacts upon the community – businesses close which causes problems to local communities.
- Additional driving distance and travel time to access/receive services will be dependant on the location of new road.
- There may be some changes in the level of service provision within the villages. For example if Torcross was no longer on the main road link the level of bus service provision may be reduced.
- Along the new route, purchase of new land would be required for road building and there will clear impacts upon specific members of the community. The impact of Option 8 may be greater than for option 7
- Disruption during the road-building programme may be considerable and temporary traffic management measures may create temporary congestion and increased drive times. The impact of Option 7 may be greater than for option 8.
13.115 A provisional view, in the absence of the survey results is that the community and social effects associated with Options 7 and 8 are likely to be moderate adverse (Overall Appraisal Category = -2) and slight beneficial (Overall Appraisal Category = +1) respectively.

**Business Impacts**

13.116 The level of impact upon businesses will differ dependent upon their proximity to the new road or upgraded route and the reliance on passing trade. Should businesses be heavily reliant on passing trade e.g. B&B’s, village shops, attractions etc, the relocation of the main road link may have significant consequences:

- Some businesses may benefit from an upturn in business due to their position away from new road – quieter situation.
- Dependent on the new alignment of the road, additional drive times incurred by Slapton area businesses may be problematic.
- The change in the nature of the Ley may have some impact upon the number/type of visitor to the area.

13.117 A provisional view, in the absence of the survey results is that the business effects associated with Options 7 and 8 are likely to be moderate adverse (Overall Appraisal Category = -2) and neutral (Overall Appraisal Category = 0).
14  Option Economic Appraisal

Introduction

14.1 This Chapter first presents an assessment of options in terms of economics.

14.2 The assessment of economic viability and justification presented below has been undertaken in accordance with the requirements and methodology of DEFRA, for coastal defence schemes, as set out in the PAG3 guidance and more recent guidance from DEFRA. This assessment does not assume that DEFRA funding will be available, but the use of the DEFRA approach provides consistent methods of evaluating both costs and benefits of any option.

14.3 The methodology starts with an assessment of the economic damages that would occur if a 'Do Nothing' approach was adopted. Other options are then compared to the Do Nothing case, and to each other, in terms of their whole-life costs and their whole-life benefits (i.e. the damages avoided).

14.4 Both costs and damages are estimated over a period of 100 years, and the totals are discounted using a prescribed interest rate to determine present value costs and damages. Benefits and costs have not been presented for the inland upgrade option. The reason for this is that the benefits will be very small, arising from minor improvements in road junctions and so on, and the costs correspondingly small also.

Do Nothing Damages (Option 1)

14.5 Tangible damages that would be incurred under the do nothing scenario over the next 100 years are likely to be limited to the cost of traffic disruption caused by the break in the transport link if the road is rendered unusable.

14.6 It is possible that some damage to property may occur at a late stage in the strategy period if the barrier beach were to breach entirely, but in terms of flooding this would be limited to a less than 10 properties at worst, and therefore by the time any damages are discounted over time the contribution is negligible. Similarly, perhaps 20 properties at Torcross would be affected in the long term if the barrier retreated rapidly, but again the value of discounted damages resulting from this is a relatively small part of the total damages.

14.7 An estimate of the traffic damages has been made based on the traffic flows determined during the origin and destination traffic survey of July 2004. Based on out of season and peak season daily traffic flows of 1,500 and 2,700 vehicles respectively, an average increase in travel distance of six miles for 70% of journeys and a cost of £0.4 per mile, the annual damages due to traffic disruption have been estimated as £1 million (Table 14.1).
14.8 It should be noted that this estimate of traffic damages presents a much more simplified calculation than might normally be expected for a transport study. However, the level of detail is considered sufficient for the broad scale economic appraisal developed for this Phase of the current study. A more detailed traffic analysis may be required during the next stage, if the analysis identifies feasible options.

14.9 Intangible damages, such as loss of tourism and changes in environmental habitats are more difficult to evaluate. Information on visitor numbers is not currently available. However, it is likely that any visitors who would not travel to the area following a road damage event would find alternative areas to visit. Hence the economic damage to the nation as a whole would be limited, although it could be significant for the local economy. Numbers have been multiplied by 70% as it has been assumed that some will chose not to travel, and others may not be affected.

<table>
<thead>
<tr>
<th>Annual Traffic Damages</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average increase in journey</td>
</tr>
<tr>
<td>Out of season daily traffic flow</td>
</tr>
<tr>
<td>Peak season daily traffic flow</td>
</tr>
<tr>
<td>Percentage of traffic incurring costs</td>
</tr>
<tr>
<td>Out of season period</td>
</tr>
<tr>
<td>Peak season period</td>
</tr>
<tr>
<td>Out of season additional miles</td>
</tr>
<tr>
<td>Peak season additional miles</td>
</tr>
<tr>
<td>Cost per mile</td>
</tr>
<tr>
<td>Out of season cost</td>
</tr>
<tr>
<td>Peak season cost</td>
</tr>
<tr>
<td><strong>Total annual traffic damages</strong></td>
</tr>
</tbody>
</table>

Table 14.1: Annual Traffic Damages

14.10 In total, the traffic damages that can be expected over the 100-year strategy period under the Do Nothing scenario have been estimated as £29.9 million.

14.11 The present value (PV) traffic damages have been determined by applying a probability of failure to the current defences, and hence the road. This has been based on an estimated residual life of 15 years. The PV traffic damages under the Do Nothing option have thus been estimated as £23.1 million.

**Do Minimum and Do Something Damages**

14.12 Since none of the options could absolutely guarantee the structural integrity of the road over the entire strategy period, a certain amount of potential damages are likely to be associated with each option. These have been determined by estimating the probability of damage to the road occurring under each of the options. However, the damages incurred for each road damage event are limited to the cost of repairing the affected road section and the associated traffic disruption and management costs.
14.13 The cost of repairing/realigning a damaged section of the road has been estimated as £200,000 per event based on the cost of the road realignment in 2001. Traffic disruption has been calculated as £83,700 based on a month of disruption and the same parameters as those used for the Do Nothing option.

14.14 For the Do Minimum (Option 6) damages the overall damage has been limited to the cost of traffic disruption since the repair costs are taken into account in the costing for these options. The probabilities have been adjusted such that an event cutting the road is likely on average once every 15 years. For the proactive option the probability has been further adjusted to allow for the fact that works will be carried out before an actual road erosion event takes place. In both Do Minimum scenarios the PV damages due to the abandonment of the road in year 60 have been determined using the PAG3 erosion value calculation sheet. The total PV damages under the reactive and proactive Do Minimum scenarios have been estimated as £4.54 and £4.51 million respectively.

14.15 Damages under the Beach Recharge (Option 2) option have been determined using the standard PAG3 damage cost calculation sheet (exponential) and a defence standard of 1 in 100 years. The total PV damages have been calculated as £85,000.

14.16 The PV damages for the Recycling option (Option 3) have been determined as £481,000, based on the same method as for the Beach Recharge option, but with a proposed defence standard of only 1 in 50 years.

14.17 Similarly, the PV damages for the Hard Defence options (revetment and sheet piles, Options 4 and 5) have been determined using a 1 in 200 years defence standard as £42,000.

14.18 Damages for the Realignment option where the road would be relocated behind the Ley (Option 8) have been based on the potential damages that could occur in the first ten years of the strategy while the new road is designed and constructed. On this basis the PV damages for this option have been estimated as £163,000.

Option Costs

14.19 Option costs have been developed based on a number of assumptions regarding the type, extent and timing of construction required. A brief description of the costs for each of the options is presented below.

14.20 All options include for monitoring of the foreshore and removal of shingle from the road after storms, as well as costs for design and supervision where required.

Keep the Coast Road - Do Minimum (Option 6)

14.21 The reactive Do Minimum costs would involve regular repairs to the road until this was no longer feasible, after which the road would be abandoned and no further work would be carried out. It
is anticipated that the first repairs would become necessary within the next fifteen years between Slapton and Strete Gate. Within a further ten to twenty years a further road damage event could also be expected between Torcross and Slapton, and every ten to twenty years after that. It is anticipated that by year 60 it would no longer be viable to continue with emergency repairs and the road would therefore be abandoned. Monitoring would continue for the entire strategy period in order to evaluate the risk of a breach of the barrier. Due to the emergency nature of the repair works the costs are likely to be higher than for planned works and an allowance of £300,000 per repair has been made.

14.22 Under the proactive Do Minimum option it has been assumed that works would be carried out every ten years to ensure the integrity of the road and reduce the risk of damage to an acceptable level. As with the reactive option, works on the road would be abandoned after year 60. Since these works could be planned reasonably well in advance the cost of each repair has been assumed as £200,000.

14.23 The PV costs for the two Do Minimum scenarios over the 100-year strategy period are £878k and £1,121k for the reactive and proactive options respectively. The reactive approach has a lower cost because works are only undertaken if damage occurs. However, these costs exclude the costs associated with protecting Torcross. A sum of £2.0 million has been allowed for in year 40 for a 250m extension of the sea wall and rock revetment. This increases the PV costs to £1.41m and £1.65m.

Keep the Coast Road (Options 2 to 5)

14.24 The Beach Recharge option for holding the road would require regular placement of a suitable material on the foreshore in order to enable the beaches to respond to storm events without undermining the road. The quantity of material placed should be similar to the annual potential sediment transport rate, which has been estimated as between 75,000m³ and 150,000m³. Since the system is a closed sediment cell, annual renourishment should not be required and a capital recharge scheme of 75,000m³ every ten years, together with some repainting when necessary, should be sufficient to provide the required level of confidence in the natural defences. An indicative rate of £15 per cubic metre of recharge material has been used, which provides a cost of £1.125 million per recharge campaign. The total PV costs over the period of the strategy have been estimated as £4.51 million.

14.25 Beach Recycling would require the transportation of shingle from the Strete Gate end of the line to those areas most at risk from storm damage. This would necessitate a substantial number of truck movements, although this could be timed to coincide with the quieter periods of the year. It is estimated that the transport of around 100,000m³ of material would cost in the region of £400,000. Such a redistribution of beach material every five years should be sufficient to reduce the risk of damage to an acceptable level, although the risk may remain higher than under the beach recharge option. The total PV costs of this option have been estimated as £3.26 million.
14.26 The construction of a Rock Revetment would provide a consistent defence standard along the entire length of the line. However, construction of such a defence would create significant disturbance to the environment, and phased construction would be recommended to reduce this disturbance to short areas at a time. Construction costs for a revetment have been estimated as £2,500 per metre length. Construction of five 500m sections would result in an estimated cost of £1.25 million per section and a total PV cost of £5.51 million.

14.27 A Sheet Pile retaining wall would also lead to disruption of the environment, but again could be constructed in section. The cost of such a wall has been estimated as £1,000 per metre length, leading to a cost of £500,000 per 500-metre section. However, the highly reflective nature of such a wall would lead to rapid draw down of the shingle in front of the wall if it were to be exposed during storm conditions. Exposure of the wall to salt water spray would lead to accelerated erosion and the replacement of the wall every 30 years would be anticipated. The total PV costs of this option have been estimated as £3.65 million.

**Managed Realignment (Option 8)**

14.28 The managed realignment option would involve the realignment of the road inland of the Ley.

14.29 Relocation of the road further inland would negate the need for any further works on the barrier and would reduce the potential damages to zero once the new road has been completed. The cost of such relocation has been estimated as £10 million, with construction taking place in around ten years time. The total PV costs for this option would be £7.66 million.

**Benefit Cost Analysis**

14.30 The benefits and costs of each of the options are summarised in Table 14.2.

<table>
<thead>
<tr>
<th>Options</th>
<th>PV costs (£)</th>
<th>PV benefits (£)</th>
<th>B/C Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Do Nothing</td>
<td>-</td>
<td>17638</td>
<td>13</td>
</tr>
<tr>
<td>2. Keep the Coast Road (Recharge)</td>
<td>1410</td>
<td>1650</td>
<td>11</td>
</tr>
<tr>
<td>3. Keep the Coast Road (Recycling)</td>
<td>3257</td>
<td>4510</td>
<td>7</td>
</tr>
<tr>
<td>4. Keep the Coast Road (Revetment)</td>
<td>5513</td>
<td>3852</td>
<td>6</td>
</tr>
<tr>
<td>5. Keep the Coast Road (Sheet Pile)</td>
<td>7660</td>
<td>12895</td>
<td>2</td>
</tr>
<tr>
<td>6. Keep the Coast Road (Do Minimum - Proactive)</td>
<td>17427</td>
<td>19320</td>
<td>19364</td>
</tr>
<tr>
<td>7. Keep the Coast Road (Do Minimum - Reactive)</td>
<td>19364</td>
<td>17502</td>
<td>17502</td>
</tr>
</tbody>
</table>

Table 14.2: Benefits and Costs of Options

14.31 The Do Minimum options have the highest benefit cost ratios, at between 13 and 11. All other options have ratios of between 2 and 7.

14.32 The appraisal of benefits and costs carried out for this Phase of the study has been fairly limited and should not be used to determine the final management strategy. Instead, the purpose of
this appraisal is to determine whether there is sufficient justification to explore further the possibility of holding the road in its current position.

14.33 Applying DEFRA rules on benefit-costs would result in only 2 options being at all feasible: proactive realignment and reactive realignment. All other options would be ruled out on grounds of inadequate incremental benefit-cost ratio.

Funding Review

14.34 A brief evaluation of the DEFRA priority scores that could be achieved has shown that a minimum benefit cost ratio of 8 would be required in order to achieve a sufficiently high priority score to secure government funding, which is currently around 15.

14.35 Based on this threshold, none of the hard defence options would be likely to achieve the required priority score. Beach recharge and relocation of the road further inland would also not have a sufficiently high benefit cost ratio to justify such works.

Summary of Economic Assessment

14.36 Some form of managed realignment on the barrier would be the preferred option, as it would be the only option meeting DEFRA criteria. The differences between reactive and proactive are marginal.

Overall Technical Option Assessment

14.37 Summarising, the following courses of action have been contemplated:

- No active intervention: does not require funding, but is likely to result in loss of use of road by year 20.

- Keep the Coast Road (Do Minimum - Proactive or Reactive Realignment): highly likely to meet DEFRA economic assessment criteria. Would preserve the road for 50 years or so, but after that road would probably be abandoned.

- Keep the Coast Road (Beach Recycling and Beach Recharge): will not meet DEFRA economic assessment criteria. Would preserve the road for 50 years but after year 50 there is some uncertainty over the technical feasibility if rates of sea level rise increase rapidly. Less technical certainty for these options than for hard defences – rates of recycling and renourishment may vary considerably from initial estimates. Significant adverse impact on beach material for beach recharge option.
- Keep the Coast Road (Sheet piling and rock revetment): will not meet DEFRA economic assessment criteria. Would preserve the road for 50 years, and probably 100 years. Major technical issues with sheet piling.

- Managed Realignment (inland): will not meet DEFRA economic assessment criteria. Would preserve a transport route indefinitely.

14.38 Based on the above it is concluded that a Keep the Coast Road option for a period of 50 years, consisting of localised realignment of the coast road on the barrier, and future protection of Torcross, would meet DEFRA economic assessment criteria. The cost would be approximately £2.0m for the first 40 years, equating to £50,000 per year, plus a further £2.5m in years 40-50.
15 Option Appraisal

Introduction

15.1 This New Chapter first presents an assessment of options in terms of technical issues combined with environmental and socio-economic impact.

15.2 Appraisals were undertaken for the following options:

- **Option 1**: No Active Intervention i.e. no further investment in coastal defences or road maintenance;
- **Option 2**: Beach Nourishment; increase beach width/height to prevent road closure/damage;
- **Option 3**: Beach Recycling; extract beach material from the northern end, transport south and widen beach in front of the existing road at the southern end of the beach;
- **Option 4**: Rock Revetment; construct a rock revetment along the seaward side of the existing road on the upper beach;
- **Option 5**: Sheet Pile; construct sheet pile wall along the seaward edge of the existing road, the top of the piling level with road;
- **Option 6**: Realign the existing road along the shingle ridge; retreat road to evade erosion;
- **Option 7**: Upgraded Route along existing road network landward of Slapton Ley; and
- **Option 8**: New Road landward of Slapton Ley

15.3 In order to compare the various options against each other, a methodology has been adopted using an amended version of a weighted scoring system used successfully for a coastal scheme in Yorkshire. Table 15.1 below shows the weightings for each factor within this assessment.
<table>
<thead>
<tr>
<th>Factor</th>
<th>Weighting (%)</th>
<th>Sub-objective</th>
<th>Weighting (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Technical Considerations</td>
<td>40</td>
<td>Solution longevity</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Cost</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Benefit-Cost</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Technical Robustness</td>
<td>10</td>
</tr>
<tr>
<td>Socio-economics</td>
<td>30</td>
<td>Community &amp; Social</td>
<td>15</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Business</td>
<td>15</td>
</tr>
<tr>
<td>Environment</td>
<td>30</td>
<td>Ecology &amp; Nature Conservation</td>
<td>8</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Geomorphology &amp; Coastal Processes</td>
<td>8</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Landscape &amp; Visual</td>
<td>8</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Archaeology &amp; Cultural Heritage</td>
<td>6</td>
</tr>
</tbody>
</table>

Table 15.1 Scoring and Weighting System

Appraisal Score - Socio-economic & Environmental Criteria

15.4 Given that option development is fairly elemental, within this optioneering study an abbreviated form of the approach described with the TAG methodology has been used as described in Chapter 13. Under the full TAG methodology there are four stages taken in appraising an option. Firstly, the resource is described, and then its value based on an environmental capital approach defined by TAG is assigned. This second stage assigns resources (or environmental features) a value (for ecology this is negligible, lower, medium, high or very high value). Thirdly, likely impacts (e.g. landtake, increased noise etc) are identified and an appraisal of the magnitude of those impacts, based on criteria provided. (for ecology this categorises each impact into major negative, intermediate negative, minor negative, neutral or positive). The value of the resource is then cross referenced in the matrix with the magnitude of the impact on it. The matrix thus indicates the overall assessment score which is included in the Appraisal Summary Table. Within the abbreviated methodology of TAG applied here, the specialists determined the overall appraisal category by joint consideration of the resource value / receptor sensitivity and the magnitude of the potential impact.

![Figure 15.1: Figure illustrating the range of overall appraisal categories](#)

15.5 Further details of the appraisal methodology for environmental criteria are available in the TAG Unit 3.3.1 to 3.3.11. This can be accessed from [www.webtag.org.uk](http://www.webtag.org.uk)
For both socio-economic and the environmental criteria, for each option, the 7-point Overall Appraisal Category (-3 to +3) from the individual assessments has been converted into a multiplier from 0 (poor) to 1 (best). The overall percentage score of the option is the total percentage derived by using the multiplying this figure for each sub-objective by the percentage weighting of that sub-objective and relevant socio-economic or environmental topic.

**Appraisal Score - Technical Criteria**

15.7 Solution Longevity – a score from 0 to 1 has been directly applied according to whether the option provides a long-term solution (1) or a short-term solution (0).

15.8 Cost – a score from 0 to 1 has been directly applied according to the relative total cost likely to be incurred in implementing the option.

15.9 Benefit-cost - a score from 0 to 1 has been directly applied according to the relative benefit-cost ratio which would be achieved by the option under DEFRA rules. This is a measure of value for money.

15.10 Technical Robustness - a score from 0 to 1 has been directly applied according to the relative degree of confidence that the option can achieve its stated aims.
Option Summary Tables: Technical, Environment & Socio-Economic Criteria

<table>
<thead>
<tr>
<th>Option</th>
<th>Description</th>
<th>Impact Level (-3 to +3)</th>
<th>Transferred Multiplier (0 to 1)</th>
<th>Percentage Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>Option 1</td>
<td>No Active Intervention</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No further investment in coastal defences or road maintenance.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**OBJECTIVE**: Solution longevity
- Not applicable

**Technical Sub-total contribution**: 20%

**ENVIRONMENT**: Ecology
- If no shoreline management works or works to the A379 are undertaken there will continue to be some movement of shingle. In localised areas, there could be a loss of areas of vegetated shingle, however, overall there should be no reduction in the area of vegetated shingle within the SSSI/NNR. Other features of the SSSI/NNR would be maintained.
- 0
- 0.5
- 4.0%
<table>
<thead>
<tr>
<th>Category</th>
<th>Description</th>
<th>Score</th>
<th>Weight</th>
<th>Contribution</th>
</tr>
</thead>
<tbody>
<tr>
<td>Geomorphology</td>
<td>No impact on Geological Conservation Review (GCR) interest of beach. Barrier beach will migrate inland, becoming progressively anchored onto hinterland slopes, forming fringing beach. Over time, loss of barrier beach and back-barrier wetlands.</td>
<td>0</td>
<td>0.5</td>
<td>4.0%</td>
</tr>
<tr>
<td>Landscape</td>
<td>The do nothing option would lead to the over washing of the shingle barrier. Visually the impact will result in the degradation of rare and aesthetically outstanding landscape elements over time and their replacement with more commonplace elements.</td>
<td>-2</td>
<td>0.17</td>
<td>1.4%</td>
</tr>
<tr>
<td>Archaeology</td>
<td>This option may directly affect prehistoric sites, post-medieval structures and World War II defensive sites as they may be impacted upon by coastal erosion.</td>
<td>-2</td>
<td>0.17</td>
<td>1.0%</td>
</tr>
<tr>
<td>Environment</td>
<td><strong>Environment Sub-total contribution</strong></td>
<td></td>
<td></td>
<td>10.4%</td>
</tr>
<tr>
<td>Community</td>
<td>Access and disruption to residents/tourists through loss of road.</td>
<td>-2</td>
<td>0.17</td>
<td>2.6%</td>
</tr>
<tr>
<td>Business</td>
<td>Allied impacts on businesses in lost trade. Possible loss of tourist trade</td>
<td>-3</td>
<td>0</td>
<td>0%</td>
</tr>
<tr>
<td><strong>Socio-economic</strong></td>
<td></td>
<td></td>
<td></td>
<td><strong>2.6%</strong></td>
</tr>
<tr>
<td>TOTAL</td>
<td></td>
<td></td>
<td></td>
<td><strong>33%</strong></td>
</tr>
<tr>
<td>Option</td>
<td>Description</td>
<td>Impact Level (-3 to +3)</td>
<td>Transferred Multiplier (0 to 1)</td>
<td>Percentage Score</td>
</tr>
<tr>
<td>------------</td>
<td>------------------------------------------------------------------------------</td>
<td>-------------------------</td>
<td>--------------------------------</td>
<td>------------------</td>
</tr>
<tr>
<td>2</td>
<td>Beach Nourishment</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Description: Increase beach width/height to prevent road closure/damage</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>OBJECTIVE</th>
<th>SUB-OBJECTIVE</th>
<th>QUALITATIVE IMPACTS</th>
<th>QUANTITATIVE ASSESSMENT</th>
</tr>
</thead>
<tbody>
<tr>
<td>TECHNICAL</td>
<td>Solution longevity</td>
<td>Likely to be able to achieve required standard for 50-100 years.</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Cost</td>
<td>High</td>
<td>0.2</td>
</tr>
<tr>
<td></td>
<td>Benefit-Cost</td>
<td>Low-Medium</td>
<td>0.4</td>
</tr>
<tr>
<td></td>
<td>Technical Robustness</td>
<td>Good. Proven technique.</td>
<td>0.9</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Technical Sub-total contribution</td>
<td></td>
</tr>
<tr>
<td>ENVIRONMENT</td>
<td>Ecology</td>
<td>The appropriate placement of imported material on to the beach (in unvegetated areas, around Torcross?) would, over time, protect the existing shingle vegetation and maintain valuable invertebrate habitats further north. There would be no effect on other features of the SSSI/NNR.</td>
<td>0</td>
</tr>
</tbody>
</table>

|            |                | 0.50                        | 4%                        |

<p>|            |                | 25%                         |                          |</p>
<table>
<thead>
<tr>
<th>Category</th>
<th>Impact</th>
<th>Contribution</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Geomorphology</strong></td>
<td>Impact on dynamic behaviour of barrier beach and promotes beach degradation. Beach crest protection will prevent barrier beach migration. As sea level rises, this will lead to a reduction in the relative crest height, an increase in the overwashing ratio (OWR) and increased likelihood of overwashing of the road, crest/beach face erosion and breaching. Introduction of alien material onto the beach i.e. impact on beach composition. Possible impact on barrier permeability i.e. impact on water levels in the Lower Ley.</td>
<td>-3</td>
<td>0%</td>
</tr>
<tr>
<td><strong>Landscape</strong></td>
<td>The site lies within an AONB, the option will lead to a potential landscape change via the importation of aggregate to supplement the existing material of the beach. Landscape change will take the form of a modification in width and profile of the shingle barrier and a possible change in colour and texture of the beach dependant on the source of the aggregates. Visual impact will be most significant during the construction period.</td>
<td>-1</td>
<td>0.33</td>
</tr>
<tr>
<td><strong>Archaeology</strong></td>
<td>The option is unlikely to have an impact on the cultural heritage resource within the immediate vicinity of the area, however, dredging may impact upon unknown archaeological remains within the marine environment.</td>
<td>-2</td>
<td>0.16</td>
</tr>
<tr>
<td><strong>Environment</strong></td>
<td></td>
<td></td>
<td>7.7%</td>
</tr>
<tr>
<td><strong>Socio-economic</strong></td>
<td></td>
<td></td>
<td>15%</td>
</tr>
<tr>
<td><strong>Community</strong></td>
<td>Continuation of existing services and access.</td>
<td>0</td>
<td>0.5</td>
</tr>
<tr>
<td><strong>Business</strong></td>
<td>Businesses will continue trading as normal. Possible drop in visitor numbers due to construction traffic</td>
<td>0</td>
<td>0.5</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td></td>
<td></td>
<td>47.7%</td>
</tr>
</tbody>
</table>
### Option 3
**Beach Recycling**

**Description**
Extract beach material from the northern end, transport south and widen beach in front of the existing road at the southern end of the beach.

<table>
<thead>
<tr>
<th>OBJECTIVE</th>
<th>SUB-OBJECTIVE</th>
<th>QUALITATIVE IMPACTS</th>
<th>QUANTITATIVE ASSESSMENT</th>
</tr>
</thead>
<tbody>
<tr>
<td>TECHNICAL</td>
<td>Solution longevity</td>
<td>Likely to be able to achieve required standard for 50-100 years.</td>
<td>1</td>
</tr>
<tr>
<td>Cost</td>
<td>High</td>
<td></td>
<td>0.3</td>
</tr>
<tr>
<td>Benefit-Cost</td>
<td>Medium</td>
<td></td>
<td>0.5</td>
</tr>
<tr>
<td>Technical Robustness</td>
<td>Fair. Proven technique but volumes/frequency not certain</td>
<td></td>
<td>0.5</td>
</tr>
</tbody>
</table>

**Technical Sub-total contribution**
23%

<table>
<thead>
<tr>
<th>ENVIRONMENT</th>
<th>Ecology</th>
<th>As for Option 2, the appropriate placement of imported material on to the beach (in unvegetated areas, around Torcross?) would, over time, protect the existing shingle vegetation and maintain valuable invertebrate habitats further north. There would be no effect on other features of the SSSI/NNR.</th>
<th>Impact Level (-3 to +3)</th>
<th>Transferred Multiplier (0 to 1)</th>
<th>Percentage Score</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>0</td>
<td>0.5</td>
<td>4.0%</td>
<td></td>
</tr>
</tbody>
</table>
**Geomorphology**

Impact on GCR interest: disruption of longshore beach grading (re-established over time). Increased cliff recession between Strete Gate and Pilchard Cove (possibly temporary impact). Note that beach widening will probably promote increased longshore sediment transport and beach face erosion, because of increased exposure to wave energy.

<table>
<thead>
<tr>
<th></th>
<th></th>
<th>-1.5</th>
<th>0.25</th>
<th>2%</th>
</tr>
</thead>
</table>

**Landscape**

The site lies within an AONB, the option will lead to landscape changes in the width and profile of the beach. The visual impact will be most significant during the construction periods, which will possibly occur for several months each year.

<table>
<thead>
<tr>
<th></th>
<th></th>
<th>-1</th>
<th>0.33</th>
<th>2.7%</th>
</tr>
</thead>
</table>

**Archaeology**

Extraction of beach material may indirectly impact on the World War II defensive sites located within the immediate vicinity of Strete Gate, as earthworks/structures will be at greater risk from coastal erosion.

<table>
<thead>
<tr>
<th></th>
<th></th>
<th>-1</th>
<th>0.33</th>
<th>2.0%</th>
</tr>
</thead>
</table>

**Environment Sub-total contribution**

<table>
<thead>
<tr>
<th></th>
<th></th>
<th>10.7%</th>
</tr>
</thead>
</table>

**Socio-Economic**

**Community**

Road would be maintained allowing for continuation of existing services and access.

<table>
<thead>
<tr>
<th></th>
<th></th>
<th>0</th>
<th>0.5</th>
<th>7.5%</th>
</tr>
</thead>
</table>

**Business**

Businesses will continue trading as normal. Possible drop in visitor numbers due to construction traffic

<table>
<thead>
<tr>
<th></th>
<th></th>
<th>0</th>
<th>0.5</th>
<th>7.5%</th>
</tr>
</thead>
</table>

**Socio-economic Sub-total contribution**

<table>
<thead>
<tr>
<th></th>
<th></th>
<th>15%</th>
</tr>
</thead>
</table>

**TOTAL**

<table>
<thead>
<tr>
<th></th>
<th></th>
<th>48.7%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Option</td>
<td>Description</td>
<td>Impact Level (-3 to +3)</td>
</tr>
<tr>
<td>--------------</td>
<td>------------------------------------------------------------------------------</td>
<td>-------------------------</td>
</tr>
<tr>
<td>4</td>
<td>Rock Revetment</td>
<td></td>
</tr>
</tbody>
</table>

**OBJECTIVE**

<table>
<thead>
<tr>
<th>SUB-OBJECTIVE</th>
<th>QUALITATIVE IMPACTS</th>
<th>QUANTITATIVE ASSESSMENT</th>
</tr>
</thead>
<tbody>
<tr>
<td>TECHNICAL</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Solution longevity</td>
<td>Likely to be able to achieve required standard for 50-100 years.</td>
<td>1</td>
</tr>
<tr>
<td>Cost</td>
<td>High</td>
<td>0.2</td>
</tr>
<tr>
<td>Benefit-Cost</td>
<td>Low</td>
<td>0.3</td>
</tr>
<tr>
<td>Technical Robustness</td>
<td>Good. Proven technique.</td>
<td>1</td>
</tr>
</tbody>
</table>

**Technical Sub-total contribution** 25%

| ENVIRONMENT   | Ecology                                                         | -3 | 0 | 0% |

A rock revetment along vulnerable stretches of the road on the upper beach would, in the long-term, prevent the landward movement of areas of the shingle bank and could result in a localised loss of vegetated shingle and invertebrate habitat.
<table>
<thead>
<tr>
<th>Field</th>
<th>Description</th>
<th>Value 1</th>
<th>Value 2</th>
<th>Value 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Geomorphology</td>
<td>Impact on GCR interest: introduction of alien material onto the beach. Impact on GCR interest: disruption of longshore beach grading (possibly re-established over time). Note that beach widening will probably promote increased longshore sediment transport and beach face erosion, because of increased exposure to wave energy.</td>
<td>-3</td>
<td>0</td>
<td>0%</td>
</tr>
<tr>
<td>Landscape</td>
<td>The site lies within an AONB, the option will lead to a landscape change from a shingle beach and barrier to a shingle beach and a barrier protected by rock armour. The visual impact of this change will be moderately adverse, with significant visual impact during the construction period</td>
<td>-1</td>
<td>0.33</td>
<td>2.7%</td>
</tr>
<tr>
<td>Archaeology</td>
<td>The construction of the rock revetment may impact on buried archaeological remains associated with the World War II defensive sites recorded near to the southern extent of Slapton Road. The revetment may also impact on the setting of the defensive sites recorded in the area. The unknown archaeological resource may also be impacted upon, however, previous construction activities associated with the road will have reduced the potential for any archaeological remains to occur.</td>
<td>-1.5</td>
<td>0.25</td>
<td>1.5%</td>
</tr>
<tr>
<td>Environment Sub-total contribution</td>
<td></td>
<td></td>
<td></td>
<td>4.2%</td>
</tr>
<tr>
<td>SOcio-Economic</td>
<td>Community</td>
<td>0</td>
<td>0.5</td>
<td>7.5%</td>
</tr>
<tr>
<td></td>
<td>Business</td>
<td>0</td>
<td>0.5</td>
<td>7.5%</td>
</tr>
<tr>
<td>Socio-economic Sub-total contribution</td>
<td></td>
<td></td>
<td></td>
<td>15%</td>
</tr>
<tr>
<td>TOTAL</td>
<td></td>
<td></td>
<td></td>
<td>44.2%</td>
</tr>
<tr>
<td>Option</td>
<td>Description</td>
<td>Impact Level (-3 to +3)</td>
<td>Transferred Multiplier (0 to 1)</td>
<td>Percentage Score</td>
</tr>
<tr>
<td>--------</td>
<td>-------------</td>
<td>-------------------------</td>
<td>-------------------------------</td>
<td>------------------</td>
</tr>
<tr>
<td>5</td>
<td>Sheet Piling</td>
<td>Construct sheet pile wall along the seaward edge of the existing road, the top of the rock revetment level with the road</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### OBJECTIVE

| TECHNICAL | Solution longevity | Likely to be able to achieve required standard for 50-100 years. | 1 | 10 |
| Cost | High | | 0.3 | 3 |
| Benefit-Cost | Medium | | 0.5 | 5 |
| Technical Robustness | Poor. Likely to induce accelerated beach lowering due to reflections. | | 0.3 | 3 |
| **Technical Sub-total contribution** | | | | **21%** |

### ENVIRONMENT

| Ecology | The construction of a sheet pile defences along vulnerable stretches of the road on the upper beach would, in the long-term, prevent the landward movement of the areas of the shingle bank and could result in a localised loss of vegetated shingle and invertebrate habitat. Other areas of the shingle bank would be unaffected, as would other ecological receptors. | -3 | 0 | 0% |
| Geomorphology | Impact on dynamic behaviour of barrier beach and promotes beach degradation. Beach crest protection will prevent barrier beach migration. As sea level rises, this will lead to a reduction in the relative crest height, an increase in the overwashing ratio (OWR) and increased likelihood of overwashing of the road, crest/beach face | -3 | 0 | 0% |
erosion and breaching. Impact on barrier permeability i.e. impact on water levels in the Lower Ley.

| Landscape | The site lies within an AONB, the option will lead to a neutral landscape impact as long as the sheet piles do not become exposed. If they do then the piles will produce a moderate adverse effect. The pilling will be highly visible during construction from a number of sensitive receptors, but having no visual impact following the construction period | -2 | 0.17 | 1.3% |

| Archaeology | The construction of the sheet pile may impact on unrecorded archaeological remains. The sheet pile may also impact on the setting of the World War II defensive sites recorded in the area. | -1.5 | 0.25 | 1.5% |

| Environment Sub-total contribution | | | | 2.8% |

| SOCIO-ECONOMIC | Community | Road would be maintained allowing for continuation of existing services and access. | 0 | 0.5 | 7.5% |

| Business | Businesses will continue trading as normal. Possible drop in visitor numbers due to construction traffic | 0 | 0.5 | 7.5% |

| Socio-economic Sub-total contribution | | | | 15% |

<p>| TOTAL | | | | 38.8% |</p>
<table>
<thead>
<tr>
<th>Option 6</th>
<th>Description</th>
<th>Impact Level (-3 to +3)</th>
<th>Transferred Multiplier (0 to 1)</th>
<th>Percentage Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>Realign the existing Coast Road</td>
<td>Realign the existing road along the shingle beach; retreat road to evade erosion</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**OBJECTIVE** | **SUB-OBJECTIVE** | **QUALITATIVE IMPACTS** | **QUANTITATIVE ASSESSMENT** |
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>TECHNICAL</td>
<td>Solution longevity</td>
<td>Likely to be able to achieve required standard for 50 years only.</td>
<td>0.5</td>
</tr>
<tr>
<td>Cost</td>
<td>Low (reactive/proactive)</td>
<td></td>
<td>1</td>
</tr>
<tr>
<td>Benefit-Cost</td>
<td>High</td>
<td></td>
<td>1</td>
</tr>
<tr>
<td>Technical Robustness</td>
<td>Medium. Proven technique, uncertainty on erosion rates.</td>
<td></td>
<td>0.5</td>
</tr>
<tr>
<td><strong>Technical Sub-total contribution</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**ENVIRONMENT** | **Ecology** | | |
| | The landward realignment of vulnerable stretches of road would give rise to a positive impact on the shingle bank, by allowing more natural movement of the shingle. However, the realigned road would result in the loss of areas of vegetated shingle and scrub which provides habitat for dormouse and breeding birds. | 0 | 0.5 | 4% |
### Geomorphology
No direct impact on the GCR interest. Impact on dynamic behaviour if overwash material is removed from road surface and returned to beach face, preventing barrier beach migration. As sea level rises, this will lead to a reduction in the relative crest height, an increase in the overwashing ratio (OWR) and increased likelihood of overwashing of the road, crest/beach face erosion and breaching.

<table>
<thead>
<tr>
<th></th>
<th></th>
<th>0</th>
<th>0.5</th>
<th>4%</th>
</tr>
</thead>
</table>

### Landscape
The option in isolation would lead to the eventual over washing of the shingle barrier and the Ley. Visually the impact will result in the eventual degradation of rare and aesthetically outstanding landscape elements. There will also be construction impacts along the shingle ridge.

<table>
<thead>
<tr>
<th></th>
<th></th>
<th>-3</th>
<th>0</th>
<th>0%</th>
</tr>
</thead>
</table>

### Archaeology
Ground/Construction works are likely to impact on known/unknown archaeology and built heritage dependent on the exact realignment of the route.

<table>
<thead>
<tr>
<th></th>
<th></th>
<th>-2.5</th>
<th>0.08</th>
<th>0.5%</th>
</tr>
</thead>
</table>

### Environment Sub-total contribution

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th>8.5%</th>
</tr>
</thead>
</table>

### SOCIO-ECONOMIC

#### Community
Dependant on exact location this option is likely to have minimal impact apart from the construction phase.

<table>
<thead>
<tr>
<th></th>
<th></th>
<th>0</th>
<th>0.5</th>
<th>7.5%</th>
</tr>
</thead>
</table>

#### Business
Dependant on exact location this option is likely to have minimal impact apart from the construction phase.

<table>
<thead>
<tr>
<th></th>
<th></th>
<th>0</th>
<th>0.5</th>
<th>7.5%</th>
</tr>
</thead>
</table>

### Socio-economic Sub-total contribution

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th>15%</th>
</tr>
</thead>
</table>

### TOTAL

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th>53.5%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Option</td>
<td>Description</td>
<td>Impact Level (-3 to +3)</td>
<td>Transferred Multiplier (0 to 1)</td>
</tr>
<tr>
<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td><strong>7</strong></td>
<td><strong>Upgraded Inland Roads landward of Ley</strong></td>
<td>This is an alternative upgraded route, using (mainly existing roads) which removes the need for the existing coast road</td>
<td></td>
</tr>
<tr>
<td><strong>OBJECTIVE</strong></td>
<td><strong>SUB-OBJECTIVE</strong></td>
<td><strong>QUALITATIVE IMPACTS</strong></td>
<td><strong>QUANTITATIVE ASSESSMENT</strong></td>
</tr>
<tr>
<td>TECHNICAL</td>
<td>Solution longevity</td>
<td>Likely to be able to achieve required standard for 100 years.</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Cost</td>
<td>Very Low</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Benefit-Cost</td>
<td>Medium - Poor. Will not produce significant benefits in reducing trip times. Will not reduce distances.</td>
<td>0.4</td>
</tr>
<tr>
<td></td>
<td>Technical Robustness</td>
<td>Good</td>
<td>0.8</td>
</tr>
<tr>
<td></td>
<td><strong>Technical Sub-total contribution</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ENVIRONMENT</td>
<td>Ecology</td>
<td>The abandonment of the road in favour of an upgraded route inland would allow natural processes along the shingle beach to occur. Construction of the upgraded route new road would possibly result in localised damage to habitats and impacts on sensitive species but outside designated areas.</td>
<td>-1</td>
</tr>
<tr>
<td></td>
<td>Geomorphology</td>
<td>No impact on GCR interest of beach. Barrier beach will migrate inland, becoming progressively anchored onto hinterland slopes, forming fringing beach. Over time, loss of barrier beach and back-barrier wetlands.</td>
<td>-1</td>
</tr>
<tr>
<td>Category</td>
<td>Description</td>
<td>Score</td>
<td>Impact</td>
</tr>
<tr>
<td>------------</td>
<td>-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------</td>
<td>-------</td>
<td>--------</td>
</tr>
<tr>
<td>Landscape</td>
<td>The route upgrade would probably lie, at least in part within an AONB, and the option will lead to a localised landscape change along the new route. Visual impact will be increased from a small number of visual receptors.</td>
<td>-2</td>
<td>0.17</td>
</tr>
<tr>
<td>Archaeology</td>
<td>A unknown number of archaeological and historical sites will be present along the likely up-graded route. These may be impacted upon during groundworks associated with the construction of the route upgrade. The route would road pass through a rural landscape which has in general not been impacted upon by modern development, therefore there is potential for archaeological sites to be discovered during groundworks.</td>
<td>-2</td>
<td>0.17</td>
</tr>
<tr>
<td>Environment</td>
<td><strong>Environment Sub-total contribution</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Business</td>
<td>Possible changes caused by location of upgraded route likely to impact on some businesses level of trade because of additional distances and perceived / actual isolation. Possible disruption during construction.</td>
<td>-2</td>
<td>0.17</td>
</tr>
<tr>
<td>Community</td>
<td>Possible changes caused by location of upgraded route likely to impact on some individuals because of additional distances and perceived / actual isolation. Possible disruption during construction.</td>
<td>-2</td>
<td>0.17</td>
</tr>
<tr>
<td>Socio-economic</td>
<td><strong>Socio-economic Sub-total contribution</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TOTAL</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Option</td>
<td>Description</td>
<td>Impact Level (-3 to +3)</td>
<td>Transferred Multiplier (0 to 1)</td>
</tr>
<tr>
<td>--------</td>
<td>-------------</td>
<td>-------------------------</td>
<td>-------------------------------</td>
</tr>
<tr>
<td>8</td>
<td>New Road landward of Ley</td>
<td>This is an alternative road which removes the need for the existing coast road</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>OBJECTIVE</th>
<th>SUB-OBJECTIVE</th>
<th>QUALITATIVE IMPACTS</th>
<th>QUANTITATIVE ASSESSMENT</th>
</tr>
</thead>
<tbody>
<tr>
<td>TECHNICAL</td>
<td>Solution longevity</td>
<td>Likely to be able to achieve required standard for 100 years.</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Cost</td>
<td>Very High</td>
<td>0.1</td>
</tr>
<tr>
<td></td>
<td>Benefit-Cost</td>
<td>Very Low</td>
<td>0.1</td>
</tr>
<tr>
<td></td>
<td>Technical Robustness</td>
<td>Medium. Potential risks with valley crossing.</td>
<td>0.5</td>
</tr>
<tr>
<td></td>
<td><strong>Technical Sub-total contribution</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ENVIRONMENT</td>
<td>Ecology</td>
<td>The abandonment of the road in favour of a new, landward road would allow natural processes along the shingle beach to occur. Construction of a new road would result in the loss or damage to habitats and impacts on sensitive species, perhaps through key protected areas. Further survey could reveal the presence of notable species that could be affected by the new road.</td>
<td>-3</td>
</tr>
<tr>
<td>Geomorphology</td>
<td>No impact on GCR interest of beach. Barrier beach will migrate inland, becoming progressively anchored onto hinterland slopes, forming fringing beach. Over time, loss of barrier beach and back-barrier wetlands. Hillslopes: impacts on soils, slopes, surface and groundwater – depending on road alignment and design</td>
<td>-1</td>
<td>0.33</td>
</tr>
<tr>
<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td>Landscape</td>
<td>The theoretical route site lies within an AONB and the option will lead to a significant landscape change along the western edge of the Ley and also via the construction of new infrastructural upgrades to junctions and the construction of three new bridges. Visual impact will be increased from a number of key visual receptors and also from the inshore coastal zone.</td>
<td>-3</td>
<td>0</td>
</tr>
<tr>
<td>Archaeology</td>
<td>A number of archaeological and historical sites have been recorded within the immediate vicinity of a possible theoretical alignment including World War II defensive sites and post-medieval features. These could be impacted upon during groundworks associated with construction. Similarly the setting of surviving structures including pillboxes could be affected. The road passes through a rural landscape which has not been impacted upon by modern development, therefore there is potential for archaeological sites to be discovered during groundworks.</td>
<td>-3</td>
<td>0</td>
</tr>
<tr>
<td>Environment Sub-total contribution</td>
<td>2.7%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>SOCIO-ECONOMIC</td>
<td>Community</td>
<td>Possible changes caused by location of upgraded route likely to impact on some individuals because of additional distances and perceived / actual isolation. Possible disruption during construction.</td>
<td>1</td>
</tr>
<tr>
<td>Business</td>
<td>Possible changes caused by location of upgraded route likely to impact on some businesses level of trade because of additional distances and perceived / actual isolation. Possible disruption during construction.</td>
<td>0</td>
<td>0.5</td>
</tr>
<tr>
<td></td>
<td>Socio-economic Sub-total contribution</td>
<td></td>
<td></td>
</tr>
<tr>
<td>---------------</td>
<td>---------------------------------------</td>
<td>-------</td>
<td>-------</td>
</tr>
<tr>
<td>TOTAL</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
16 Funding Review

16.1 DEFRA has overall policy responsibility for flood and coastal erosion risk in England and funds most of the Environment Agency's flood management activities in England. DEFRA also provides grant aid on a project by project basis to the other flood and coastal defence operating authorities to support their investment in improvement projects to manage flood and coastal erosion risk. DEFRA have a fixed national budget for all projects.

16.2 From 2004/05 Government support for capital investment will be described as either Supported Capital Expenditure (Revenue), known as SCE(R), or Supported Capital Expenditure (Capital Grant), known as SCE(C). SCE can be further classified as either single pot SCE(R)/SCE(C) or ringfenced SCE(R)/SCE(C) - although of course this distinction is irrelevant to single purpose authorities and the GLA, who are outside the single capital pot. DEFRA grant aid to local authorities for flood and coastal defence will be paid as ring-fenced Supported Capital Expenditure (Capital) - SCE(C).

16.3 Additional support will be available in the form of Supported Capital Expenditure (Revenue) - SCE(R). For example, if a project costs £10,000 and DEFRA provides SCE(C) at 45% this still leaves £5,500 for the operating authority to fund. Local authorities can apply to DEFRA for SCE(R) to help with this. The eligible amount would be reduced if the authority was also receiving funds from elsewhere, for example a contribution towards the cost from another local authority. DEFRA writes to local authorities three times a year to ascertain their SCE(R) requirement. Authorities will also be asked to confirm details of their SCE(R) requirement as their projects are approved for grant during the year. Once approved by DEFRA, funding dependent on SCE(R) is administered by the Office of the Deputy Prime Minister.

16.4 DEFRA grant aid is available when the flood and coastal defence solutions are shown to be technically, economically and environmentally sound and sustainable, subject to the availability of funds. DEFRA guidance on the appraisal of projects for this purpose is contained in their Project Appraisal Guidance (FCDPAG) series of documents. On top of this basic individual project appraisal DEFRA also apply a system of prioritisation to decide which of all the worthwhile capital projects will be eligible for grant aid. Economic appraisal and prioritisation are necessary where the demand for investment exceeds available resources.
16.5 A preliminary assessment has been made of eligibility of the various options evaluated for DEFRA grant aid as a coast protection project. The guidance contained on the economic assessment contained in the PAG series of documents has been followed and further guidance has been sought from the DEFRA regional Engineer, based in Taunton in this regard.

16.6 The project prioritisation system is based on three criteria:

- economics
- people and
- environment

A priority score is summed for each project based on the individual scores for these three aspects.

16.7 The economic score is calculated based on the benefit/cost ratio for the project:

<table>
<thead>
<tr>
<th>B/C Ratio</th>
<th>Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>Less than 11 to 10.5</td>
<td>01 to 20 (on a linear scale)</td>
</tr>
<tr>
<td>Over 10.5</td>
<td>20</td>
</tr>
</tbody>
</table>

16.8 The people score is calculated based on the number of residential properties benefiting from the provision of defences per £k of project cost. It comprises a base score subject to a maximum value of 8 with adjustment for risk to public safety and vulnerability. The maximum value is 12.

16.9 The environment score is based on the designated area maintained by the project, plus any net gain of National Biodiversity Action Plan (BAP) habitat due to the project works per £k of project cost. It comprises a base environment score recognising the need for the project to maintain an existing designated area with an adjustment for class of designation, plus an additional base environment score with adjustment for a net gain of area of BAP habitat created by the project. An additional score is added for heritage considerations. The sum of the scores is subject to a maximum value of 12, after any additions for heritage considerations. No score is allowed for a net loss of habitat.

16.10 DEFRA use data on project scores and estimated project costs, which have been provided to them by the responsible authorities, to set both their national budgets and the threshold projects scores required to receive grant aid in the current and near future financial years. The threshold scores for 2004, 2005 and 2006 have been revised recently:

<table>
<thead>
<tr>
<th></th>
<th>2005/06</th>
<th>2006/07</th>
</tr>
</thead>
<tbody>
<tr>
<td>2004/05</td>
<td>20 (was 15)</td>
<td>15</td>
</tr>
</tbody>
</table>

16.11 The value of 20 for 2004/2005 above is a firm threshold and will not be subject to further change. The threshold scores for 2005/06 and 206/07 given above are indicative values, and will be subject to possible future revision.
16.12 It should be noted that the source of costs and benefits is important to DEFRA in assessing whether a project is eligible for grant aid. DEFRA have indicated that they will consider contributing to a project in proportion to the type of benefits, which accrue. In this project an outline economic assessment has been carried out and only the tangible benefits have been assessed. The majority of the benefits arising from the various options (more than 90%) are avoidance costs related to the additional journey distances should the A379 be damaged or lost. In this case DEFRA have indicated that it is unlikely that the scheme would be eligible for significant grant aid. A small amount of grant aid may be available in proportion to the non-transport related benefits that would accrue, but the scheme would have to comply with all other DEFRA requirements.

16.13 DEFRA have also indicated that since the majority of the benefits, arising from the options considered are related to the road, they would consider these schemes to be primarily transport schemes. Consequently they would expect the majority of funding to be provided from the appropriate transport agency or body. Initial comments from Devon County Council suggest that Department for Transport funding is likely to be concentrated on major urban area schemes of regional priority, and that sustaining the coast road is unlikely to be seen as a priority highway project, and therefore funding is likely to be very limited or unavailable.

16.14 Funding would potentially be available for the costs associated with protection of Torcross. DEFRA currently only provide a 35% grant aid contribution to South Hams District Council.

16.15 The assessment concluded that it is unlikely that the a road protection project or beach management scheme would be eligible for DEFRA funding, even though such a scheme can be shown to be economically viable using the DEFRA criteria. The property protection element would be eligible.

16.16 In Chapter 14 it was estimated that a technically viable scheme to keep the road for at least 50 years would have a cost in the order of £4.5m over the 50-year period at present day prices. It is likely that the majority of this funding would have to be funded by the Slapton Line Partnership.

16.17 At this stage investigations have not been made into availability of other sources of funding. However the scoping study refers to alternative funding opportunities, and these are summarised below (after Atkins, 2001). More work is required to evaluate possible funding sources, once the option shortlist has been determined.
Alternative funding sources

English Nature

16.18 Potential funding from the Biodiversity Grant Scheme, if the community were to become involved in enhancing the biodiversity at Slapton. Funding through the National Nature Reserve as a result of reserve management, access and interpretation.

European Regional Development Fund (ERDF)

16.19 Possible funding under the South West Objective 2 Programme, representing coastal protection works with the potential to significantly benefit existing tourist attractions such as Slapton Ley SSSI and NNR, and to maintain and improve an important multiple user communication route such as the A379.

Government Office for the South West (GOSW)

16.20 Based on the programme and policies set out in the Devon County Local Transport Plan and the recommendations for the SWARMMS report, it may be possible to access funding from the GOSW.

Leader +

16.21 This programme is EU funded and aims to encourage long-term potential of rural areas through high-quality, original and sustainable projects. Could gain part funding through the Leader programme, as part of a wider partnership project to improve natural environment and economic environment through better transport links in South Devon.

Life Nature

16.22 This is a European Union programme that provides funding to conserve natural habitats and wild fauna and flora of EU interest. Funding could be possible for mitigation works on the sluice, as well as providing an opportunity to enhance the natural biodiversity of the area through management of the shingle ridge during transition phase.

Natural Environment Research Council (NERC)

16.23 Funding awarded for science research of international quality, with the opportunity for scientists to bid for free use of NERC research vessels. Potential funding for marine and environmental research through the academic community, could allow further site investigations into geomorphological processes and ecological interest in and around Start Bay. To assist in appraising the impacts on the habitat and effects on the flora and fauna should the Ley be inundated.
The Countryside Agency

16.24 Grants are available for environmentally based projects that serve to increase peoples enjoyment of the countryside through improved access and landscape features.

The South West of England Regional Development Agency (SWERDA)

16.25 Potential funding available if the A379 route was demonstrated as being of fundamental importance in supporting existing and facilitating further economic development, possibly through tourism development at Slapton Sands and Ley.
17 Conclusions

17.1 The key beach processes affecting Slapton Sands are:

- Short-term storm impacts
- Medium term longshore transport gradients
- Long-term sea level rise causing the shingle barrier to rollback landwards

17.2 Each of these processes was studied. Short- and medium-term impacts are coastal process issues, whereas long-term changes are best considered within a geomorphological framework.

17.3 The cross-shore profile predicted by Powell’s model, at the time and location of the road collapse in January 2001, shows that the storm event was of a sufficient severity (wave height) and occurred in conjunction with a sufficiently high still water level to impact on the crest of the shingle ridge. The breach prediction model of Bradbury suggests that at the time of the road collapse in January 2001, the loss of road was due to beach cut back not due to the mechanism of over washing and roll back. The sensitivity tests showed that neither a sea level rise of 250mm, nor a reduction in barrier cross-sectional area of 30% would significantly increase the chances of this mechanism becoming dominant.

17.4 The January 2001 erosion event can clearly be categorised as cut-back of the edge of the shingle barrier as indicated on Figure 10.25 in Volume 2, and not as a breach of the barrier.

17.5 Examination of aerial photographs from 1999 shows that, compared to adjacent areas, the face of the shingle ridge was further seawards at the central car park and at the location where the road was undermined. Therefore these areas had steeper beaches and were at higher risk of greater erosion than other areas.

17.6 Large changes in beach areas and shoreline position occur over medium term time scales (weeks, months). The observed trends in the amount of beach volume above the mid and high water lines have been of gradual increase to the north of Strete Gate, decrease at the road collapse location and more gradual decrease at Torcross. However, these trends are based on a data set which is probably statistically unreliable.

17.7 Longshore transport rates have been calculated based on a new and comprehensive analysis of 4 year’s data, which includes the effect of varying water levels and thus the influence of the Skerries Bank on the waves and sediment movements. The results show that high rates of net annual sediment transport do occur (of the order of 150,000 m$^3$ per annum), but that the rate and direction varies from year to year and with location along the frontage. Averaged over the 4-
year period, the net transport rates are lower (about 75,000 m$^3$), indicating landward retreat at Torcross and accretion at Strete Gate over this period. Given that a 4-year record is short compared to the expected natural variability of climate over decadal time scales, these results should not be extrapolated to decadal time scales.

17.8 Results from a numerical model demonstrate that quite large changes in the shoreline position (of the order of 5 to 10m) can occur in medium term periods (weeks, months). Model results show that at the time of the road collapse in January 2001, the shoreline position around the location of the collapsed road had receded by about 4m from 1st October 2000 to 10th January 2001.

17.9 At the time of the road collapse event in January 2001, the beach volumes above mid and high water levels at the location were at the lowest recorded value in the 31-year record.

17.10 The storm was an unusual combination of moderately high water levels at Spring tide and a sustained period of high waves from the east. Based on analysis of wind speeds, wind direction, and storm duration from a data set from 1980 to 2004, it is estimated that the storm had a return period of approximately 25 years. The storm of 1995, which was notable but did not cause such extensive damage, was identified by the same analysis of wind data as being the second most severe storm in the 24-year period.

17.11 The overall assessment of the January 2001 event is that it was caused by a combination of beach line recession due to differential longshore transport rates in the preceding autumn and the occurrence of a severe storm, which further cut back the beach profile, with the beach crest reaching road level.

17.12 Because the storm coincided with a period when the beach was at a historically narrow state, its observed effect on infrastructure (road, car park) was greater than it may have otherwise have been.

17.13 Figure 11.51 (Volume 2) shows areas at risk at any time from a single storm event. Using the 2001 storm event, when 5m width of shingle ridge was eroded, it is assumed that a similar event of 1 in 25 year return period would have a similar erosion impact. Therefore a 5m setback from the vegetated crest line has generally been drawn. However, the extent of erosion expected to occur at any particular point along the beach is a function of two other main variables: beach steepness (the steeper the beach, the more likely is erosion of the crest); and the presence of defences (these inhibit erosion of the crest). The steepest beaches occur in the central area near the car park and previous road realignment.
17.14 The figure shows that the main areas at risk are (south to north):

- The length of road immediately north of the rock revetment, including the length where the rock revetment is badly degraded
- The central car park
- The two road sections north of the car park where the new road alignment joins the original road alignment

17.15 Long-term barrier retreat rates have been estimated, based on a conceptual model of the long-term evolution of the Slapton Sands coastline, and a numerical formulation relating sea level rise to barrier retreat rate. The retreat rates calculated are not precise, and for the present day are somewhat higher than observed sustained retreat rates.

17.16 Mean sea level is predicted to be at least 20 cm higher by 2080 (low emission scenario) and may be as high as 80 cm above present level (high emission scenario). The most conservative estimate indicates that water levels that today occur once every 7-8 years are expected to occur, by 2080, about 3 times per year.

17.17 The historical data analysis suggests that in overall terms the Slapton Sands shingle ridge has been largely stable over the last century, but with some net beach accretion at Strete gate and recession at Torcross. Long-term net erosion rates for the crest of the barrier are low, with a best estimate over 100 years of 0.1m/year for the centre of the Bay. Analysis of a number of maps and photographs for different periods of time between 1890 and the present day all indicate little overall movement of the crest. However, over shorter time periods rates of 0.4-0.6m have been found.

17.18 The geomorphologically based estimates for long-term barrier retreat give values of 0.3m/year at the present day, increasing to at least 0.4m/year due to sea level rise.

17.19 The maps shown as Figures 11.52(a-g)(Volume 2), show areas at risk within different time epochs along the shingle bank. In accordance with guidance for Shoreline Management Plans, three epochs have been used: 0-20 years, 20-50 years and 50-100 years. The retreat rates used in preparing these maps are those of a ‘Low Emission Scenario’ and are applicable to the next 100 years.

17.20 The rates used in the Low Emission Scenario are derived from the geomorphology-based retreat rates from the low emission scenario for climate change and sea level rise up to year 100. The geomorphology-based projection suggests more rapid rate in years 50-100, of the order of a further 30m.
17.21 In the geomorphology-based projections for the high emission scenario both sea level rise and retreat rates over years 50-100 are predicted to accelerate rapidly and are higher still. These are displayed on Figures 11.53 (a-g) (Volume 2).

17.22 In using the maps the following should be noted:

- The projections are indicative, with a considerable degree of uncertainty, despite any appearance of precision. The uncertainty increases over time.
- The retreat rates used (even for the lower emission scenario) are higher than the long-term historical change which has actually occurred.
- Erosion may occur landward of the ‘At Risk’ areas in particularly severe events.
- If the high emission scenario becomes reality, or indeed if any scenario occurs other than the low emission scenario, then the ‘At Risk’ areas will rapidly project landwards after year 100.
- The projections are long-term averages, and will only occur if a given period of time has the expected number of severe storm events. It is the severe storm events which drive retreat of the barrier.

17.23 It has been postulated by various authors that the shingle bank is likely to break down irreversibly and breach, forming tidal inlets, within the next 30 to 50 years. This is considered to be highly unlikely. Neither of the storm events which have occurred in the last 10 years have had a major impact on the shingle barrier height or width, and neither has come close to causing a breach of the barrier. The current probability for a breach is considered to be much less than 1 in 100 years.

17.24 Sea level rise and increased storminess will increase the rate of erosion and the risk of a major recession event, but the risk of a breach of the shingle bank will remain low over the next 20 or 50 years.

17.25 Possibly after 50 years, and probably beyond 100 years, a No Intervention scenario will result in breakdown of the shingle barrier, with breaching and forming of intermittent tidal inlets.

17.26 Retreat of the shingle barrier will eventually result in lowered beaches in front of Torcross, and leave the northern part of Torcross exposed to wave attack. Protection of Torcross will require an extension of the sea wall to link up with the retreated barrier location.
The following broad scale options were considered for this study:

- Do nothing (also described as ‘No Active Intervention’)
- Do minimum (keep the coast road for a limited period)
- Hold the line (keep the coast road)
- Advance the line
- Managed realignment of the coast road

At the Strategic level, advance the line was discarded as it offered no advantages and would be excessively costly. All other options were considered further. The hold the line option would involve a commitment to maintain the road on the shingle barrier, either by realignment to accommodate erosion or by provision of defences.

A number of options for keeping the coast road were considered:

- Beach nourishment
- Beach recycling
- Revetment
- Sheet piled retaining wall

Three options for realignment were considered. One option would be to keep the road on the Slapton Line but relocate it further back, thereby increasing the distance between the beach and the road. This could be done in stages to spread out the cost and to deal with the most vulnerable sections first. In the long term the beach is likely to eventually erode entirely, leading to a breach of the barrier beach and hence the road. This option, which could be either a reactive or a proactive realignment, has been evaluated and found to be feasible and to have the minimum cost of any option.

One alternative option would be to relocate the route inland of the Ley, using the existing road network wherever possible and upgrading over time as and when finances allowed. The most radical solution would be to build an entirely new road to the west of the Ley although even if the latter option was technically and environmentally viable it would probably be prohibitively expensive.

A third option would be to abandon the use of the coast road, and make limited upgrades to the existing inland road network.
17.33 A preliminary assessment has been made of eligibility for funding from DEFRA as a coast protection project. The assessment of the economics of each option was undertaken in accordance with the methodology of DEFRA for coastal defence projects. The assessment was a preliminary exercise, using only outline traffic data and excluding environmental and socio-economic costs and benefits.

17.34 Based on these figures, the proactive or reactive Managed Realignment on the barrier option would be the preferred option, and such a scheme would meet the benefit-cost and priority scoring requirements of DEFRA within the next 5 years. All other options would fail to meet the criteria.

17.35 It was estimated that a technically viable scheme to hold the road for 50 years, and protect Torcross for 100 years, would have a cost in the order of £4.5m over the 50-year period at present day prices.

17.36 Since this work was undertaken DEFRA have advised that although it might meet their economic criteria, they would probably not fund the road protection part of the option, as their primary function is protection of people, property and environment. Therefore the cost would have to be borne by the members of the Slapton Line Partnership or through funding from other sources. Initial comments from Devon County Council suggest that sustaining the coast road is not a priority highway project and therefore funding is likely to be very limited or unavailable. It is likely that DEFRA funding would be available for the works required to protect Torcross, as the shingle barrier retreats, however DEFRA currently provide only a 35% grant aid contribution.

17.37 At this stage investigations have not been made into availability of other sources of funding. However the scoping study refers to alternative funding opportunities. More work is required into this, once the Phase 2 approach has been finalised. However, it is critical that the Partnership comes to a decision in principle on the level of funding that it will be able to provide, since it is unlikely that other sources will provide the entire level of funding required to keep the road.

17.38 An outline environmental assessment has been made of the impact of all eight options identified. The evaluation method used for environmental impact is an abbreviated version of the TAG methodology using four environmental criteria (ecology, geomorphology, landscape, heritage and archaeology) and two socio-economic criteria (social & community issues and business impacts). A business questionnaire has been issued in order to quantify impacts of the options on local business both qualitatively and quantitatively. However, returns were not available at the time of preparation of this report.

17.39 The key impacts of the no intervention option are in the socio-economic and traffic areas. Main socio-economic impacts are provisionally:
• Intermittent breaching of A379 will cause diversions and disruption to access/accessibility of services. Examples of these disruptions include bus services, travel to work times, emergency service access.

• Longer term loss of road and necessary use of other roads may increase drive times to services/facilities e.g. schools, workplace, doctors etc.

• Use of minor roads may cause difficulties for larger vehicles – buses, vans, lorries.

• Lack of planned approach to change and consequential disruption to traffic movements will lead to confusion and difficulties for residents and service providers e.g. bus companies.

• The perception of Slapton and Torcross as more isolated communities will increase i.e. not on main road link between Kingsbridge and Dartmouth. This may be significant.

• Unplanned nature of road diversions will be difficult for businesses to manage. May affect trade especially for businesses reliant on passing trade e.g. B&B’s and village stores.

• Ultimate loss of main road link will increase the ‘isolation’ of the villages – may lead to reduction in trade. Loss of trade may be as a result of reduced passing trade – may be experienced by B&B’s, local stores, Ley (visitor attraction). Also may be as a result of increasing access difficulties – problems with supply chains to/from local businesses.

• Dependant on the importance of the Ley in its freshwater state to tourists, there may be a reduction in visitor numbers.

17.40 There is also the potential for positive impacts to be associated with the severance of the road. It is possible that some specialist businesses, e.g. recreational pursuits & natural history related, may actually benefit from the closure if it is perceived by some visitors that the area has been enhanced by the closure. The creation of new wildlife environments will attract specialist interest, and may be of interest to a more general market if actively marketed and interpreted. Any positive benefits are likely to be realised in the longer term and may require some initial capital investment in a "replacement" tourist infrastructure (e.g. new visitor centres). Furthermore, if the changes to the road structure inland include suitable parking and walking trail development then it may be possible to add to leisure and tourism use of the countryside in the area. If this work takes in existing local businesses then some economic benefits can be gained.

17.41 An origins and destinations traffic survey was undertaken during July 2004, and combined with traffic data obtained previously showed that whilst the route between Kingsbridge and Dartmouth via Slapton Ley is not required for all through traffic it does perform an important local movement function and helps maintain the livelihood of businesses reliant on passing trade.
17.42 The No Intervention option will therefore generate significant adverse impacts in the socio-economic and transport contexts. The assessment of ecological, geo-morphological, landscape and archaeological impacts for the no intervention option is however more balanced.

17.43 An integrated approach to assessing the options has been developed which combines the technical, environmental and socio-economic aspects. A scoring system was developed which gives potential scores across a range of issues, and then determines an actual score for each option. The higher the score, the more acceptable the solution.

17.44 The results of the scoring are presented below.

<table>
<thead>
<tr>
<th></th>
<th>Do Nothing</th>
<th>Beach Nourishment</th>
<th>Beach Recycling</th>
<th>Rock Revetment</th>
<th>Sheet Piling</th>
<th>Managed Road Realignment on barrier</th>
<th>Inland Road Upgrade</th>
<th>New Inland Road</th>
</tr>
</thead>
<tbody>
<tr>
<td>Technical</td>
<td>20</td>
<td>25</td>
<td>23</td>
<td>25</td>
<td>21</td>
<td>30</td>
<td>32</td>
<td>17</td>
</tr>
<tr>
<td>Environment</td>
<td>10.4</td>
<td>7.7</td>
<td>10.7</td>
<td>4.2</td>
<td>2.8</td>
<td>11.2</td>
<td>7.7</td>
<td>2.7</td>
</tr>
<tr>
<td>Socio-Economics</td>
<td>2.6</td>
<td>15</td>
<td>15</td>
<td>15</td>
<td>15</td>
<td>15</td>
<td>5.2</td>
<td>17.5</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>33.0</strong></td>
<td><strong>47.7</strong></td>
<td><strong>48.7</strong></td>
<td><strong>44.2</strong></td>
<td><strong>38.8</strong></td>
<td><strong>56.2</strong></td>
<td><strong>44.9</strong></td>
<td><strong>37.2</strong></td>
</tr>
</tbody>
</table>

17.45 It has been concluded that the preferred option is Managed Realignment of the road on the shingle barrier. It is concluded that this option plus Beach Recycling, Beach Renourishment and Inland Road Upgrade should be taken forward to Phase 2, subject to a reasonable expectation that funding will be available. The remaining options either have no prospect of securing funding or are not acceptable from a technical or environmental perspective. It would be appropriate to discard any of the selected options prior to Phase 2 if funding was unlikely to be available.

17.46 The reason for recommending taking forward more than one option are:

- there is no clear distinction between the advantages of some of the options, so it is not reasonable to discard these at this stage

- The final preferred option needs to allow for the, as yet unknown, impacts of climate change and occurrence of severe storms. Therefore the final option may have more than one 'strand' to it, combining elements of several options.
18  The Way Forward

18.1  It is recommended that Consultation is undertaken on the findings of this report. It is suggested that this should be through a presentation to the Slapton Line Partnership Advisory Forum, and through a 2-day open exhibition held in Slapton. The exhibition would give members of the Forum and the public at larger the opportunity to assess the report and to meet members of the Scott Wilson study team and put forward views directly. A questionnaire would be prepared to provide a basis for statistical assessment of comments.

18.2  Following consultation Phase 2 Study should proceed. The purpose of Phase 2 is to identify the single preferred option. The Study will need to include a more detailed assessment of costs, impacts and benefits of short-listed options.

18.3  In the longer term, beach profile monitoring should be continued. This is critical to improving the data set on beach width variability and long-term trends.

18.4  The monitoring should be undertaken in conjunction with aerial photography undertaken every year. Photography provides additional data on changes in position of the line of vegetation.