

CHAPTER 256

REVIEW OF SOME 30 YEARS BEACH REPLENISHMENT EXPERIENCE AT DUNGENESS NUCLEAR POWER STATION, UK

By Dr Roger Maddrell¹, Bill Osmond² and Bin Li¹

INTRODUCTION

Dungeness was formed initially as a shingle bar across a bay that existed between Winchelsea and Hythe at the end of the last glaciation (see Figure 1). The bar was the early coast and caused the landward accumulation of estuarine deposits, which now form the marshes. Shingle continued to accumulation on the seaward side to form the Ness. The present alongshore drift, resulting from refraction and diffraction of the dominate southwest waves, moves shingle eastward, eroding the southern coast and causing accretion along the eastern side (see Figure 2). The past morphology of the Ness, first described by Lewis, 1932, can be seen clearly from the shingle ridges, which represent old coastlines.

In the late 1950's the then Central Electric Generating Board (CEGB) chose the Ness as a nuclear power station site. Studies at that time by Sir William Halcrow & Partners (Halcrow) established that the rate of erosion of the southern shore was of the order of 1.1m annually, but near the point of the Ness, where the Station was to be sited, could be up to 1.5m annually, with an annual rate of drift of about 125,000m³. Various schemes for protecting the Station frontages from erosion, and thus flooding, were examined (Halcrow, 1963) and one of recycling shingle from the accreting east face of the Ness

¹ Sir William Halcrow & Partners Ltd, Burderop Park, Swindon, Wiltshire SN4 0QD, UK

² Nuclear Electric plc, Dungeness 'B' Station, Dungeness, Kent, UK

was recommended. The proposed volume of gravel initially was 15,000m³ annually, but rising to 20,000m³ with the construction of the second station.

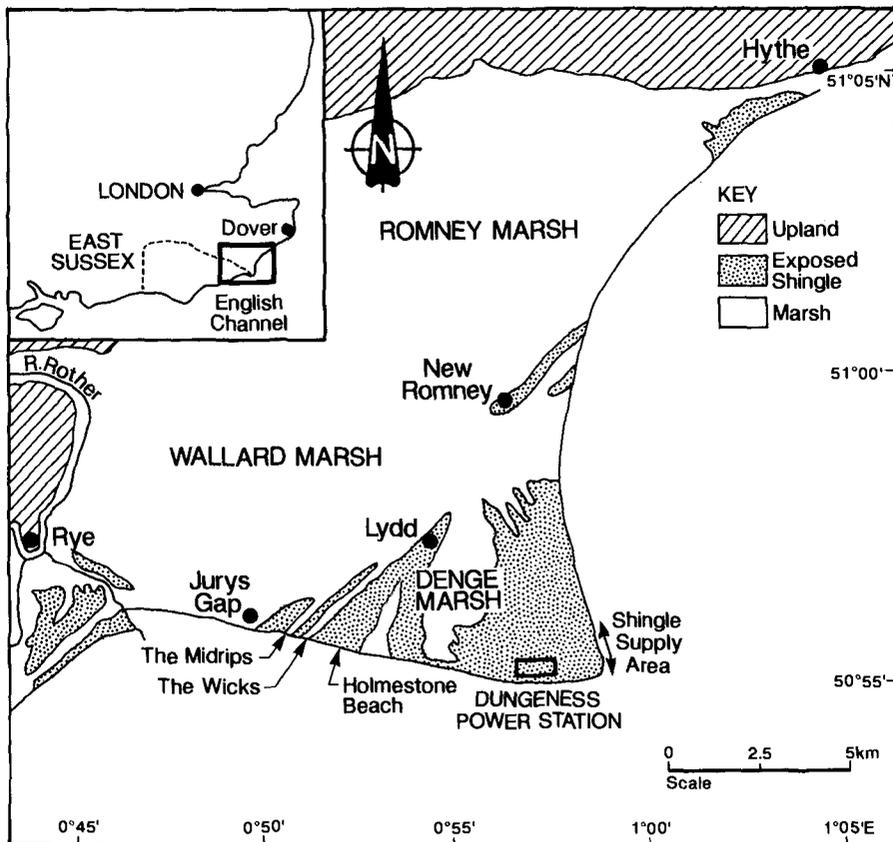


Figure 1 : Site Area

Beach feeding has been continuous since 1965, concentrating mainly at the western, updrift, end of the site. As the updrift coast eroded, the recharge area became more and more out of regime, requiring additional shingle to hold it. Recent studies recommended that a policy of coastal retreat or coastal set back should be implemented. This has resulted in a considerable saving to the amount of gravel required for beach feeding and a

reduction in the impact of winning material from the supply area.

EVOLUTION OF DUNGENESS

The post-glacial marsh and shingle deposits attain a thickness of some 30m and are derived from a combination of terrestrial and marine sources (Long, 1994). Between 4000 and 2000 BP sea-level was relatively stable at about -2.5m OD, but during the last 2000 years it rose by about 2.5m. There has also been considerable subsidence, which in the last 4000 years has been between 1-2mm per year (Shennan 1989; Long and Shennan, 1993). The net relative sea level rise is predicted to be about 0.4m by the year 2050 (Maddrell and Burren, 1990).

Shingle probably entered Romney Bay by 5300-6000 BP, although radiocarbon-dated shells collected from -34m OD beneath the Station are only 3000-2000 years old (Greensmith and Gutmanis, 1990), which suggests that the shingle in this area is considerably younger than 2000 years old. The shingle is driven in a west to east direction by the dominant SW waves and the chronological development of the Ness can be seen in the remaining ridge pattern (see Figure 2). However, the dating is tentative as the time of shingle deposition can only be established where the shingle is underlain by organic sediments, which can themselves be dated by radiocarbon or where shoreline positions can be estimated from historical and archaeological sources. Unfortunately, the former condition is rarely met, while the latter provides only an approximate chronology, which tends to be restricted to the last 1500 years. Lewis and Balchin's 750? shoreline (see Figure 2) was based on Ward's 1931 interpretation of two Saxon Charters, which indicate the approximate position of the coast at this time. The 1600 shoreline is based on M Pokers' 1617 map of Romney Marsh, which is one of the earliest relatively accurate maps, while the 1800 shoreline is obtained from the 1794 Ordnance Survey. The 1990 BP coast is from recent radiocarbon dating.

There are three areas of low-lying marsh deposits to the west of the Station eg The Midrips, which have been interpreted as evidence for 'several oscillations of level from the late Neolithic times to the Bronze Age' (Lewis and Balchin 1940). There are also raised ridge levels north of the Station, which are taken as evidence of more severe climatic conditions during the Middle Ages.

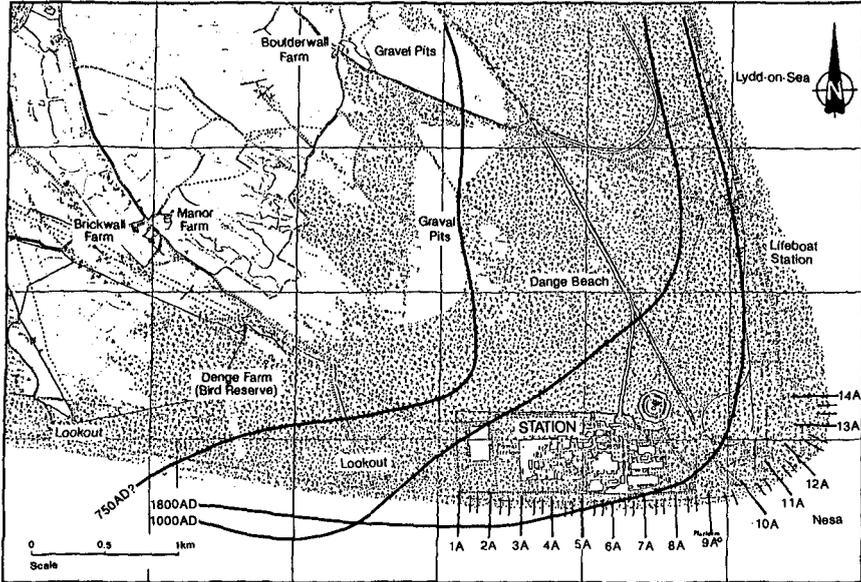


Figure 2 : Historical Coastline at Dungeness and the survey lines at the Station

The Ness is a continually evolving feature, as can be seen on Figure 2, with shingle erosion on its southern face and deposition on the east. The siting of the Station at the tip of the Ness close to the south coast, while morphologically controversial, was mainly because of the close proximity of deep water (-30m OD) adjacent to the Ness.

BEACH FEEDING

General

Southeast England is subsiding which, when combined with the rise in mean sea level, has meant a requirement for an increased level of coast protection for the southern

eroding face of the Ness in front of the Station. Inundation was seen during construction in 1960 and 1961 and more recently in local areas adjacent to the site in 1983, 1984, 1989, 1990 and 1992. The need for flood protection is reflected in the increase in recharge volume, which increased from some 15,000m³ at the beginning to some 70,000 m³ in 1992. Breastwork and two local groynes were constructed for emergency protection, but are now buried.

The volumes of beach feed material required has been established by surveying specific sections of the beach at the end of the winter, with the recommended shingle being placed on the beach over the following winter period. Initially this was done by ground surveys, but in recent years has been done by photogrammetry.

The idea of recycling shingle for use as beach protection was unique at the time and has been the subject of regular review. The most recent review indicated that not only was this the most effective method of protection (costing less than the interest payment of a more formal method of protection), but was also environmentally friendly.

The southern coast of Dungeness is being held at two points, the Station and at Jurys Gap, some 8km to the west (see Figure 1). An erosive bay has formed between these two stable points, decreasing the alongshore supply of shingle to the Station frontage over the years. Thus, the main point of beach feed, which lies at the western end of the station, was becoming more and more exposed as the up drift coast has receded and the natural supply of shingle dwindles. Consequently, in recent years the amount of beach feed required was in excess of 50,000m³ annually.

The beach feeding scheme has operated for 28 years during which time Halcrow have produced annual reports describing the work done during the previous season and recommending the quantities and positions for shingle feeding during the forthcoming season. Until 1972 the amount lost during the year was replaced at locations which had suffered the greatest erosion and was distributed in roughly equal proportions at a series of points. After 1972 it was realised that a more efficient method of protecting the beach would be to place most of the recharge at the western end, allowing natural movement to distribute the shingle over the frontage.

The levels along each of the cross-sections are now established on the 42 sections, which are at 100m intervals, by photogrammetric methods. It is considered that the 1:5000 scale of photography normally used allows individual beach levels to be determined to an accuracy of within approximately ± 0.20 metres (assuming no errors in the control grid). There are 14 sections each with three sub-sections (see Figure 2), 9 in front of the station and 5 downdrift in the supply area. One of the major advantages of the beach feeding scheme has been its flexibility and the ability to respond quickly to potential problems and periods of intensive storms. Figure 3 shows the gross losses, the quantities of material deposited and the volume changes each year since beach feeding began in 1965. The total volume of shingle between profiles 1A and 9A has increased by some 102,394m³ between 1965 and 1993/94, resulting from an average annual recharge of about 30,000m³, with an average annual gross loss of about 26,500m³. The records clearly demonstrate that the beach feeding successful stabilised the beach and that the build up of the profiles have been sufficient of balance the increased losses in extreme years. A typical profile of the build up of shingle over the years can be seen on Figure 4.

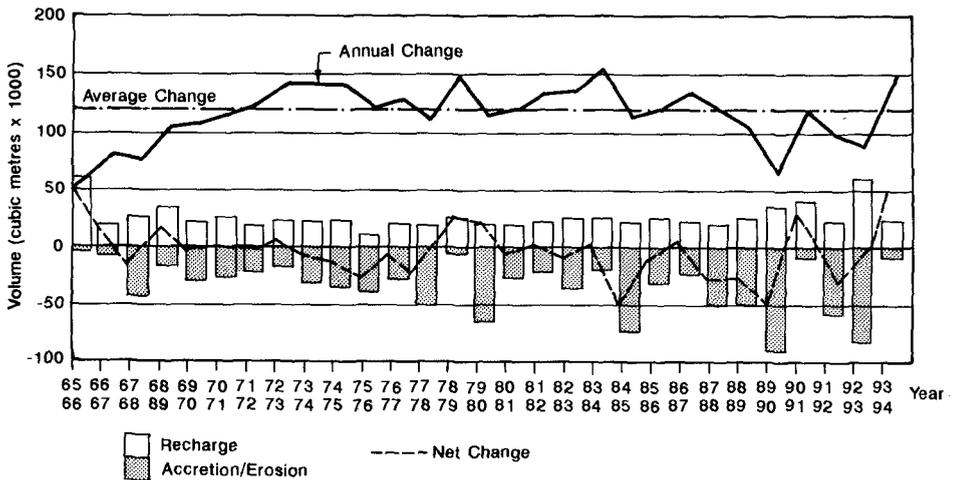


Figure 3: Volume changes from 1965 to 1994

The beach feeding programme has been effective in preventing flooding and damage to the Station. Prior to 1983 there appear to be no records of serious flooding, apart from during construction, but there has been flooding adjacent to the site on:

- 28th January - 1st February 1983
- February 1984
- November 1984
- Winter 1989-1990
- February/March 1990
- August 1992

This increase in the potential flood risk may be related to an increase in wave energy during the period (see Figure 5) and has led to a change in the "emergency" and "normal" profiles. These profiles for sections 1A to 9A were conceived nearly 30 years ago. The original concept was that the "normal" profile should be the minimum cross-section of beach to be maintained, where the "emergency" profile represented conditions which could lead to major overtopping of the beach and flooding, hence requiring "emergency" works. The levels were increased last year to take account of the impact of a tsunami wave, which has a 1 in 10,000 year return period.

Past Investigations

In an effort to reduce the annual costs associated with the beach feeding programme, and any adverse environmental impacts, Halcrow have for many years attempted to relate beach loss to local meteorological conditions. It was originally hoped that this would allow predictions of required recharge volumes to be made without the expense of conducting an annual aerial survey. While this would never totally replace the need for surveys, it would allow their frequency to be reduced to say once every two or three years.

The 1969/70 Halcrow report described an early attempt to relate the incident energy flux to the quantity of shingle moved, but this proved unsuccessful because only four years of records were available. The 1978/79 study the

correlated the observed shingle loss and wind gusts which exceeded 47 knots ie storm conditions. This proved to be reasonably successful, but in the early 1980's it was proved less so. One of the difficulties in trying to establish any correlation stems from the fact that the average annual gross loss, represents a fairly thin layer over the surface of the total shingle volume of approximately 1.25 million m³ contained within the survey section limits ie the losses are only approximately 2% of the total. Furthermore, the computations do not allow for irregularities in the beach profiles between the measured cross-sections which are at 100m centres. The gross loss has to be determined by the difference of these total volumes, over successive years, so that small errors in the determination of the total volume have a significant effect on the calculation of the gross loss for any one year. It was concluded that no simple relationship exists between beach losses and non-directional wind intensity.

Analysis of Beach Erosion

It was originally predicted in 1963 that the natural supply of littoral material from the west of the station, which was about 120,000m³ would slowly reduce with time, requiring a commensurate increase in beach feeding. This effect results from the gradual formation of a shallow bay between the stabilized sections of the coast at Jury's Gap and the Station. This was confirmed by beach plan shape modelling, which shows the yearly gross shingle loss along the Station is rising, on average, by some 880m³/year. The previous analysis of the seven year rolling means in 1984 showed the annual rate to be 540m³.

The cumulative average annual gross loss of beach material upto 1992 was 29,490m³. However, the average over the past five years has been 42,000m³. In the previous five years it was 30,000m³ ie 1983 to 1987, 25,000m³/year from 1978 to 1983, and 24,000m³/year for 1973 to 1978.

Wave Data

Offshore wave data were derived using a parametric wave model based on wind measurements between 1971 and 1990. Such models are limited to hindcasting of locally generated waves within defined fetches. To determine the importance of swell, wave data were obtained from the British Meteorological Office's wave model for the years 1989 to 1992. The swell wave portion of the wave spectrum,

coming up the Channel from the Atlantic was found to be 25%.

Section 7A (see Figure 2)

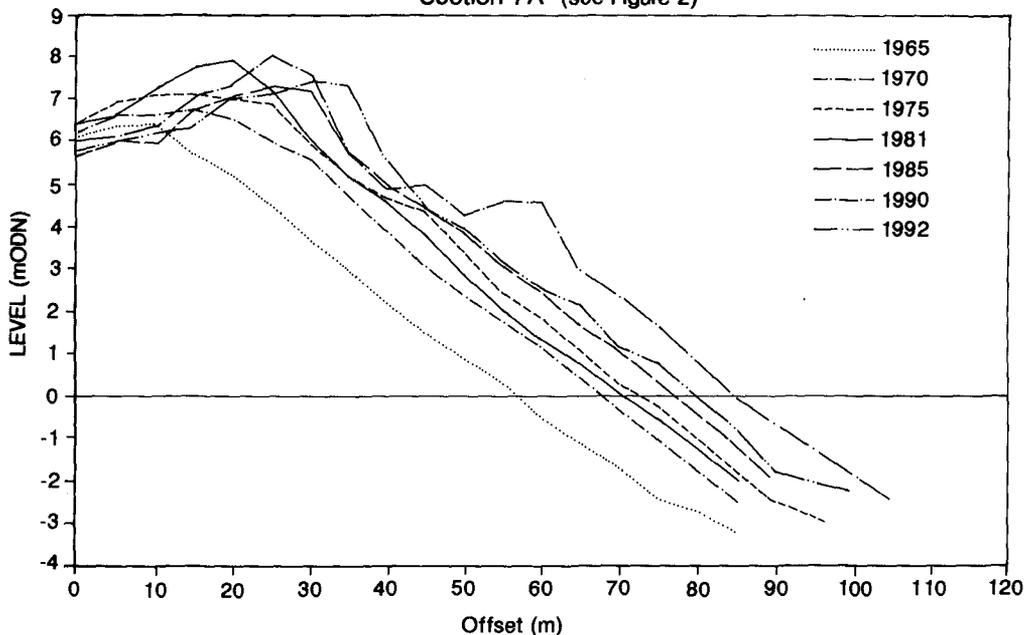


Figure 4: Beach Movement 1965-1992

The available wind wave data were statistically analysed to produce seasonal, directional, yearly and average values of wave energy, with only the last four years including swell waves. Values of alongshore energy were derived for each year and used to produce a trend analysis as shown in Figure 5. Despite the wide scatter of data there is clearly an increasing trend in longshore wave energy. The gradient of the graph is approximately 16 KN/year.

The increase in wave energy may in part account for the increased rate of annual shingle loss also shown in Figure 5. For example, equating the long term average gross beach erosion to the long term average alongshore drift gives a figure of approximately 500m³/year increase in beach erosion, which can be directly attributed to an overall increase in wave energy. Subtracting this figure from the

880m³/year derived from the trend analysis of gross erosion gives a figure of 380m³/year, which may be attributed to the changes in alongshore drift at Station.

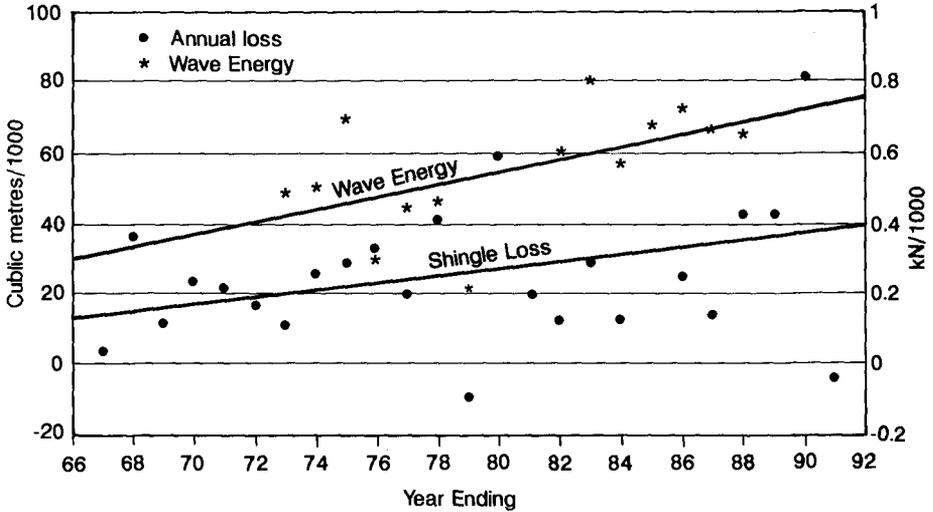


Figure 5: Annual Shingle Losses and Wave Energy

While the trend lines show a clear correlation between increasing beach loss and wave energy, the comparison of individual years shows large deviations and therefore little predictive capability based on annual results. Figure 5 shows alongshore wave energy plotted against beach loss for the years 1989-1990, 1990-1991, 1991-1992 and 1992-1993. While there is a good fit for some years, the energy available for 1989-1990 underpredicts the beach loss. However, the winter of 1989-90 was marked by a series of four gales, some with hurricane force winds, all of which coincided with spring tides which weakened the beaches. Had not the gales of 1989-90 occurred on spring tides, the measured gross loss of material at the Station would have been much less. Thus, a simple analysis of alongshore energy will tend to underpredict beach losses for those years affected by extreme water levels.

The past studies have shown that while there was a reasonable relationship between wave energy and the littoral transport, it was not a simple one. Predictions can vary depending on the coincidence of high wave energy

and surges during the period and the predicted and actual volume, could vary by as much as a factor of 2.

ALONGSHORE TRANSPORT

The present alongshore shingle transport rate of about 90,000m³ was established using an existing beach plan shape model. Studies were also carried out using electronic pebbles to monitor shingle movement during the storms and the transport rates of different sizes of shingle. These 'smart' pebbles show, rather surprisingly, that the larger shingle travelled at a faster rate possibly because of the greater area of exposure of the larger shingle in a mixed grading. Studies of the grain size of material on the beach also showed significant changes both in relation to storm and the size of the feed material.

BEACH PLAN SHAPE MODELLING

There is sufficient gravel accreting on the eastern coast of the Ness which can be used to improve and strengthen the beach at the Station. However, it was realised that taking increasing amounts of gravel could adversely affect the downdrift coastline, especially as it is the source area for beach feeding elsewhere. Consequently, there was a review of the beach feeding, which included, in particular, a sediment transport model in order to predict the drift rates and future changes in coastal morphology.

Three schemes were adopted for examination during the model study, namely:

- Scheme 1 - supply beach feed at Section 1A (see Figure 2) to maintain the existing beach line. This corresponds to the present beach feeding policy.
- Scheme 2 - supply beach feed at Section 4A (see Figure 2) to maintain the existing beach line east of it. Beach sections to the west of Section 4A are allowed to evolve naturally.
- Scheme 3 - Construct a long strong point at Section 9A (see Figure 2),

at the downdrift end of the site and use accumulated material to maintain the beach east of Section 1A as in Scheme 1.

The model was run to simulate fifty years operation of each of the above schemes. The feed quantities envisaged for each scheme are shown on Table 1.

Year	Scheme 1 Feed at Section 1	Scheme 2 Feed at Section 4	Yearly Saving in m ³
1	40,000	13,172	26,828
5	41,000	18,494	22,506
10	41,119	23,816	17,303
20	42,548	28,902	13,646
50	46,627	35,970	10,657

Table 1 Predicted Feed Quantities (m³/year)

As can be seen, Scheme 2 shows considerable savings over Scheme 1.

ECONOMICS OF BEACH FEEDING AND ALTERNATIVES

The economics of beach feeding at the Station were last examined in detail in 1983 in connection with studies for a proposed new station. As discussed earlier, in the last five years beach recharge quantities have increased significantly, and it was considered necessary to reassess the economics of the present operations compared with alternative forms of coastal protection.

From the earlier beach recharge quantities and trends, it was concluded that the base estimate for quantities should be 40,000m³/year ie the situation before managed coastal retreat or set back, using upper and lower bound figures of 125m³/year and 500m³/year for the rate of increase of beach recharge.

The above figures were used to calculate the Net Present Value (NPV) of the following cost of beach recharge discounted over a period of 50 years:

Initial Recharge	Rate of Increase	NPV in £
40,000m ³ /yr	125m ³ /yr	3,033,471
40,000m ³ /yr	500m ³ /yr	3,469,502

The alternative forms of coastal protection considered in the 1983 review of coastal protection included:

- beach feeding
- several forms of groyne and breastwork
- artificial headlands and an initial beach fillings
- an armoured revetment

The comparison of various options was based on Net Present Values for 35 year and 105 year life spans. These are summarised in Table 2.

SCHEME		Net Present Value £ X 10 ⁶	
		35 Year Life	105 Year Life
1	Beach Feeding	2.1	2.7
2	Timber Groynes and Breastwork	4.8	5.7
3	Mass Concrete Groynes and Timber Breastwork	5.7	6.5
4	Armabrade Steel Sheet Piled Groynes and Timber Breastwork	8.2	9.4
5	Two Strongpoints and Initial Feeding	4.3 plus cost of lee scour	4.3 plus cost of lee scour
6	Revetment of Armour Units	15.3	15.3

Table 2 Net Present Values of Coastal Protection Schemes at Dungeness, 1983 Prices.

These costs clearly demonstrate that the existing practice of beach feeding is the most economic form of coastal protection. The present policy of managed retreat or set back enhances the benefits.

CONCLUSIONS

Review of Beach Feeding

- The beach feeding campaign has been effective in preventing flooding and damage to the Station.
- It is the most cost effective method of protection.

Beach Movement and Meteorological Conditions

- An analysis of wave data derived from wind hindcasting showed a recent increase in wave energy and a clear correlation between increasing wave energy and increasing beach loss. However, the comparison with values for individual years did not show a good correlation with measured beach losses and wave energy. The inclusion of swell waves provides a more reliable predictive method for calculating beach losses in all but the most extreme years.
- In the past five years beach feed quantities have increased dramatically. Recent studies have concluded that there has been an increase in the number of severe storms affecting Wales and Southern England, although this does not form part of a clear statistical trend. Moreover, these recent storms would not have appeared to be so unusual had not the 1970's and early 1980's been so mild.

Economics of Beach Feeding and Alternative

- A net present value of beach feeding for the 1992-1993 season over a lifespan of fifty years was established using an updated base estimate of the annual beach feed quantity and the future annual increases.

- Beach feeding, ignoring the benefits of coastal retreat, is still significantly cheaper than the other forms of coastal protection.

Coastal Retreat

- The concept of coastal retreat has lived upto its expeditions, significantly reducing the quantities of shingle required, thus reducing costs and any adverse environmental and geomorphological impacts that might stem from shingle extraction from the supply area.

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