RETREAT OF CHALK CLIFFS AND DOWNWEARING OF SHORE PLATFORMS IN THE EASTERN CHANNEL DURING THE LAST CENTURY

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1 Aims

- Measure the rate of chalk cliff retreat and shore platform downwearing using the same method on both sides of the eastern Channel.

2 Summary

Cliff erosion rates for the French and English side have been calculated and show significant variations, averaging from in excess of 0.7 m per year to zero retreat over more than 124 years. Modes of retreat are different between East Sussex (high frequency – low magnitude) and Kent (low-frequency – high magnitude) with the French coast occupying a midway postion.

The lowering of the shore platform was measured by comparing the position of the low water line on maps of different age. Results are not conclusive which is likely to be due to the problems involved in surveying the low water mark accurately. A new method for measuring platform erosion over decadal time scales is described with very preliminary results shown

3 Introduction

The retreat of coastal cliffs and the erosion[1] of the chalk shore platform fringing the eastern English Channel contributes to the beaches along these coasts through the flint released from the chalk; however, cliff retreat also endangers settlements at the top of the cliff (e.g. at Peacehaven and Criel-sur-Mer, Figure 1). While rates of retreat have been calculated by a variety of methods over the past century, no method has attempted to provide a complete coverage that allows for the comparison of retreat rates over the entire coastline.

The cliff retreat data alone helps to identify and increase our understanding of the threat cliff erosion poses to settlements along the coast. When combined with measurements of the flint content within the chalk it contributes to our understanding of the beach sediment budget.

From theoretical considerations the contribution of platform erosion to the sediment budget will be much smaller than the contribution from cliff retreat. In addition the method required to measure platform erosion differs from that for cliff retreat. Therefore, cliff retreat and platform erosion are discussed separately in this report.

The data generated in Phase 1 of BAR provides a baseline value over a set time period to which further more detailed time slices will be added in subsequent phases to assess the trend of cliff erosion rates over the past century. The data for platform erosion only provides general values for the entire coast with detailed measurements of some sections. These will be extended in later phases to include more sections, especially in France.

[1] The term erosion is preferred of downwearing as the later implies more of a gradual process that does not necessarily take large scale block failure into account. Erosion is understood as any form of removal of material.

Figure 1: Houses abandoned on the cliff top east of Criel-sur-Mer (photo taken by U. Dornbusch on April 2001).

4 Cliff retreat

4.1 Background

Measurement of rates of cliff retreat along the eastern Channel coastlines has a long history (Bialek, 1969; Cleeve and Williams, 1987; LCHF, 1972; May, 1971; May and Heeps, 1985; Prêcheur, 1960; Thorburn, 1977). Rates have been determined by comparing the position of the cliff top line on maps of different ages. This was achieved by manually tracing the cliff lines from the maps and then measuring the distance between the lines at a number of points. Most researchers have applied this method to only limited lengths of cliff and the number of points selected for measurement has been small. May & Heeps (1985) for example applied this method to the entire stretch of chalk cliffs from Dorset to Thanet but used only 165 points. The only detailed survey of the entire Sussex coastline is that of Thorburn (1977). Unfortunately this study was based on maps covering the 30 year period 1925-1955 only, which is likely to introduce significantly larger errors due to positional errors on the maps, than if maps covering a longer time span are used. A similar problem of measurement over a short period of time is present in parts of the studies of May (1971) and May & Heeps (1985). They also based some of their measurements on maps surveyed prior to the 1st edition of the Ordnance survey and these are more difficult to overlay with younger maps due to a lack of positional information.

Most probably because of the different methods employed, but possibly also due to temporal variability, retreat rates obtained by different researchers vary considerably. This is illustrated in particular for Ault in France (Figure 2).

Locality	Time period	Average annual cliff retreat rate (cm)	Source
England: Sussex			
East Sussex chalk cliffs	n.a.	30-50, maximum 125	Robinson & Williams (1983) page 61
South Downs	various	38	May & Heeps (1985) table 3
Brighton to Seaford Head			
Peacehaven	1973-1975	45	Castleden (1996), Table 3
Peacehaven (Portobello to Maline Avenue South)	1875-1967?	45.7	Howe (1968), page 1
Peacehaven (Maline Avenue South to Steyning Avenue)	1875-1967?	38.1	Howe (1968), page 1
Peacehaven (Roderik to Steyning Avenue)	1873-1976	29	Cleeve & Williams, page 28[2]
Peacehaven (Steyning Avenue to Southdown Avenue)	1875-1967?	30.5	Howe (1968), page 1
Peacehaven (Southdown Avenue to Cornwall Avenue)	1875-1967?	60.9	Howe (1968), page 1
Peacehaven (Cornwall Avenue to Friars Bay)	1875-1967?	38.1	Howe (1968), page 1
Peacehaven and Telscombe cliffs	1973-1975?	45	Thorburn (1977), page 6
Peacehaven to Newhaven	1925-1955	~30, maximum ~90	Thorburn (1977), illustration nr. 8 [5]
Seaford Head	1973-1975	30	Castleden, Table 3
Seaford Head to Cuckmere Haven	1973-1975?	30	Thorburn (1977), page 7
Seaford Head to Cuckmere Haven	1925-1955	~30, maximum ~126	Thorburn (1977), illustration nr. 8 [5]
Sevensisters and Beachy Head			
Seaford Head to Beachy Head	1872-1962	42	May (1971), page 203
Seaford Head to Beachy Head	1872-1962	42	Castleden (1996), Table 3
Seven Sisters	1873-1962	50.5	May (1971), table 11
Seven Sisters	1873-1962	51	Castleden (1996), Table 3
Seven Sisters	1973-1975	125	Castleden (1996), Table 3
Seven Sisters	1925-1955	~40	Thorburn (1977), illustration nr. 8 [5]
Cuckmere Haven to Birling Gap	1973-1975?	125	Thorburn (1977), page 7
Birling Gap	1875-1961	91	May (1971), page 203
Birling Gap	1875-1961	91	Castleden, Table 3
Birling Gap	1955-1962	99	May (1971), page 203
Birling Gap	1950-1962	97	Castleden (1996), Table 3
Birling Gap	1973-1975	122	Castleden (1996), Table 3
Birling Gap	1925-1955	~90, maximum ~126	Thorburn (1977), illustration nr. 8 [5]
Birling Gap (stretch 70m east and west of the steps)	1873-1976	69	Cleeve & Williams (1987), Fig. 10[1]

Figure 2: Published rates of cliff retreat along the East Sussex chalk coast.

Locality	Time period	Average annual cliff retreat rate (cm)	Source
England: Kent			
Folkestone to Kingsdown			
North Downs	various	12	May & Heeps (1985) table 3
Lydden Spout	1873-1933	51	May & Heeps (1985) table 2
South Foreland	1878-1962	19	May (1971) table 1
Thanet			
Isle of Thanet	Various	30	May (1971), table 1
Thanet		23	May & Heeps (1985) table 3
Pegewell coast guard station	1839-1938	5	May & Heeps (1985) table 2
Kingsgate	1842-1938	15	May & Heeps (1985) table 2
White Ness	1842-1938	5	May & Heeps (1985) table 2
Eastern Epple Bay	1872-1938	14	May & Heeps (1985) table 2
Eastern Minnis Bay	1872-1938	30	May & Heeps (1985) table 2
France:			
Ault	1835-1878	70	Briquet in May & Heeps (1985) table 2
Ault	1825-1912	9-42	May & Heeps (1985) table 2
Ault	1825-1960	8-9	Prêcheur in May & Heeps (1985) table 2
Ault	1825-1960	20-25	May & Heeps (1985) table 2
Ault	1835-1878	70	May & Heeps (1985) table 2
Ault	1883-1895	83	Briquet in May & Heeps (1985) table 2
Ault	??	50	Dallery (1955) in Costa et al (2003)
Ault	??	30-60	Hascoet (1987) in Costa et al (2003)
Ault	??	40	Dolique (1992) in Costa et al (2003)

* see note 5

? The date is assumed from the source but not explicitly named.

[1] Cleeve and Williams (Figure 8) suggest a ‘fairly constant’ retreat rate based on measurements taken from maps with survey dates 1873-74, 1908, 1925, 1960, 1976, 1987.

[2] Cleeve and Williams (Figure 16) show the retreat rate to be fairly constant based on measurements taken from maps with survey dates 1873, 1899, 1926, 1960, 1976.

[3] data for four profiles along 5km of coastline

[4] data for three profiles along ~3km of coastline

[5] retreat rates are estimated from the graph in Thorburn which provides detailed retreat rates for the whole of the cliffed coastline of East Sussex, maximum values with an * are taken from table 1, assuming the data relates to the same time interval

Figure 2: Published rates of cliff retreat along the East Sussex chalk coast.

The technique of manually tracing and overlaying the cliff lines introduces errors associated with the accuracy of tracing the line, the pencil width, and expansion or contraction of the paper (see Anders and Byrnes, 1991; Moore, 2000; Thieler and Danforth, 1994). These errors are further aggravated by the necessity of enlarging or reducing maps to facilitate overlaying of maps of different scales (e.g. the change from imperial to metric scales). In addition, the subjectivity of selecting the points at which measurements are taken invariably will have an effect on the retreat rate obtained. Only rarely, for short stretches of chalk cliffs, has the area of cliff retreat been measured and a mean retreat rate for different lengths of coastline been calculated (e.g. Cleeve & Williams 1983).

Previous estimates of cliff retreat rates for the UK side can be found in May (1971), May & Heeps (1985), Cleeve & Williams 1983, Castleden 1996, Dornbusch et al (in press) and for the French side in Prêcheur (1960), Costa (1997; 2000) Hénaff *et al*., (2002),Costa *et al.* (2004; 2003) and Lahousse *et al.*((2000).

4.2 Methods

The map presented has been compiled using ArcView GIS and is based on comparing areas of retreat rather than measuring linear retreat distances at specific points. The maps were first scanned and georeferenced and then the cliff top lines were digitised on screen from the source maps or orthophotos. The area between the two cliff top positions was converted into a polygon by the following procedure. First, a third line was digitised running between the two cliff top lines. This line was split every 50m and new lines generated at right angles to this centre line. The lines at right angle to the cliff line form borders for the 50m sections into which the area of retreat was cut creating polygons of cliff retreat that are each 50m wide along the coast, but extending for variable distances inland. The area of each polygon was calculated, and divided by 50 to obtain the average retreat in metres; further dividing this figure by the years between the survey dates provides the mean annual cliff retreat rate shown in the map at the end of this document.

4.3 Data sources

4.3.1 Ortho photos

For the UK coast orthophotos were provided by the Environment Agency from surveys flown in May 2001 at a scale of 1:5000. The orthophotos have a ground resolution of 20cm. No details of the positional accuracy are available but by comparing features with those in the landline data set and with GPS surveys carried out by the authors, the positional accuracy is on average ± 0.3m but near the cliff toe can be larger.

For the French coast orthophotos from 1966 and 1995 flown by the Institut Géographique National (IGN) at a scale of 1:10,000 were used, providing a positional accuracy of ± 0.3m.

4.3.2 Historic maps

The earliest maps that could be used for the England side were the 1st Edition of the Ordnance Survey 6-inch scale maps (1:10,560) because these maps are the first to have been surveyed with regard to a geographical reference system that is displayed on the map itself. These maps were surveyed in the mid to late 1870s for the coastline of East Sussex and Kent.

Prior to scanning, the graticule was transferred from the map frame as small markers into the areas to be scanned using a long metal ruler so as to cause the least damage to the maps. Maps were then scanned at 300dpi using an A3 scanner. The maps were georeferenced to the National Grid in ArcView using the markers. Georeferencing was performed using a first order transformation with RMS-errors in most cases <0.6 m. The georeferenced maps were then overlain with the Ordnance Survey Landline data (based on surveys carried out in the 1990s) to check the alignment of features to be found in both data sets. For the maps of Kent it was found that the alignment based on georeferencing using the latitude longitude grid marked on the original maps was poor (offsets of more than 20 m were not unusual). These maps were again georeferenced using features that appeared both in the Landline data set and OS maps. The landline data has an average positional accuracy of 1.1 m for maps surveyed at 1:2,500 (Ordnance Survey pers. comm., Ordnance Survey, 2000).

For the coast at Peacehaven, which is presently defended by a sea wall, maps surveyed prior to the installation of sea defences and the trimming of the cliffs were used. These comprise ground surveys carried out on behalf of Lewes District Council in 1970 and 1996.

The survey accuracy of historic maps can only be established in comparison with modern data. After georeferencing the historic maps to the landline data set, positional errors close to the coast are small and in the range of less than 5 m. However, where the cliff top has not retreated at all, the position of the historic cliff top line can often be found landward of the present line. These 'cliff advances' are most often associated with geometry offsets of the two lines and the absolute offset is only rarely more than 10 m. It is therefore thought to be reasonable to attach a mean positional error for the historic cliff line of ± 5 m (this value is generally better that those suggested in the literature for maps from the US ;e.g. Anders & Byrnes 1991, Moore 2000). Over the time period of 124 years between the historic maps and the orthophotos this amounts to an error for the retreat rate of 4 cm y^{-1}, similar to the values found by Valentin (1954).

5 Results

Rates of cliff retreat for the period 1870s to 2001 for the undefended chalk cliffs of East Sussex and Kent are shown on the map at the end of this document and in Figure 3.

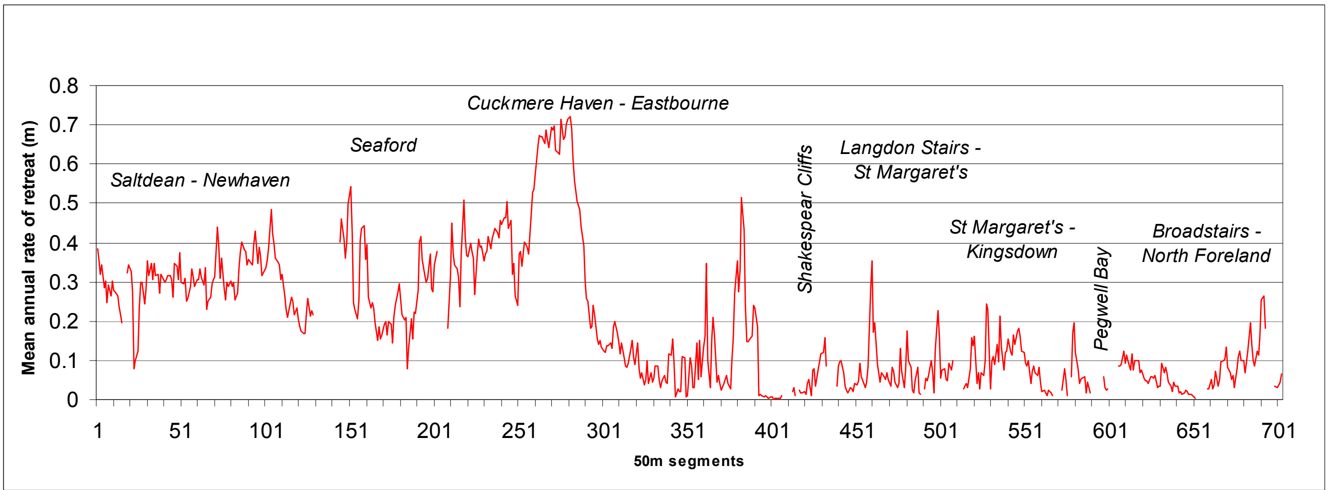

Figure 3: Mean annual rate of chalk cliff retreat along the East Sussex and Kent frontage for the period 1870s to 2001. Names refer to the start and end point of the cliff section; gaps between sections not to scale.

Annual rates of cliff retreat show significant variations, the most pronounced being the much lower retreat rates in Kent (average = 0.07 m y^{-1}) compared to East Sussex (average = 0.27 m y^{-1}). Along the Kent cliffs significant proportions show no retreat at all, which supports findings in May & Heeps (1985). These areas become even larger, when the accuracy of the retreat rates are taken into account which means that all rates < 0.04 m y^{-1} could be the result of the combined map and air photo errors. A similar situation of very low or no retreat exists east of Belle Tout along Beachy Head in East Sussex.

The highest rates, in excess of 0.7 m y^{-1}, are found in the Birling Gap area of East Sussex. Evidence from the remains of cliff falls on the shore platform, visible on the 2001 orthophotos, and from the retreat rates suggest that cliff retreat along the East Sussex frontage occurs as high frequency-low magnitude events whereas on the Kent coast as low frequency-high magnitude events. The frequency of falls in those places that do not show retreat must be >125 years.

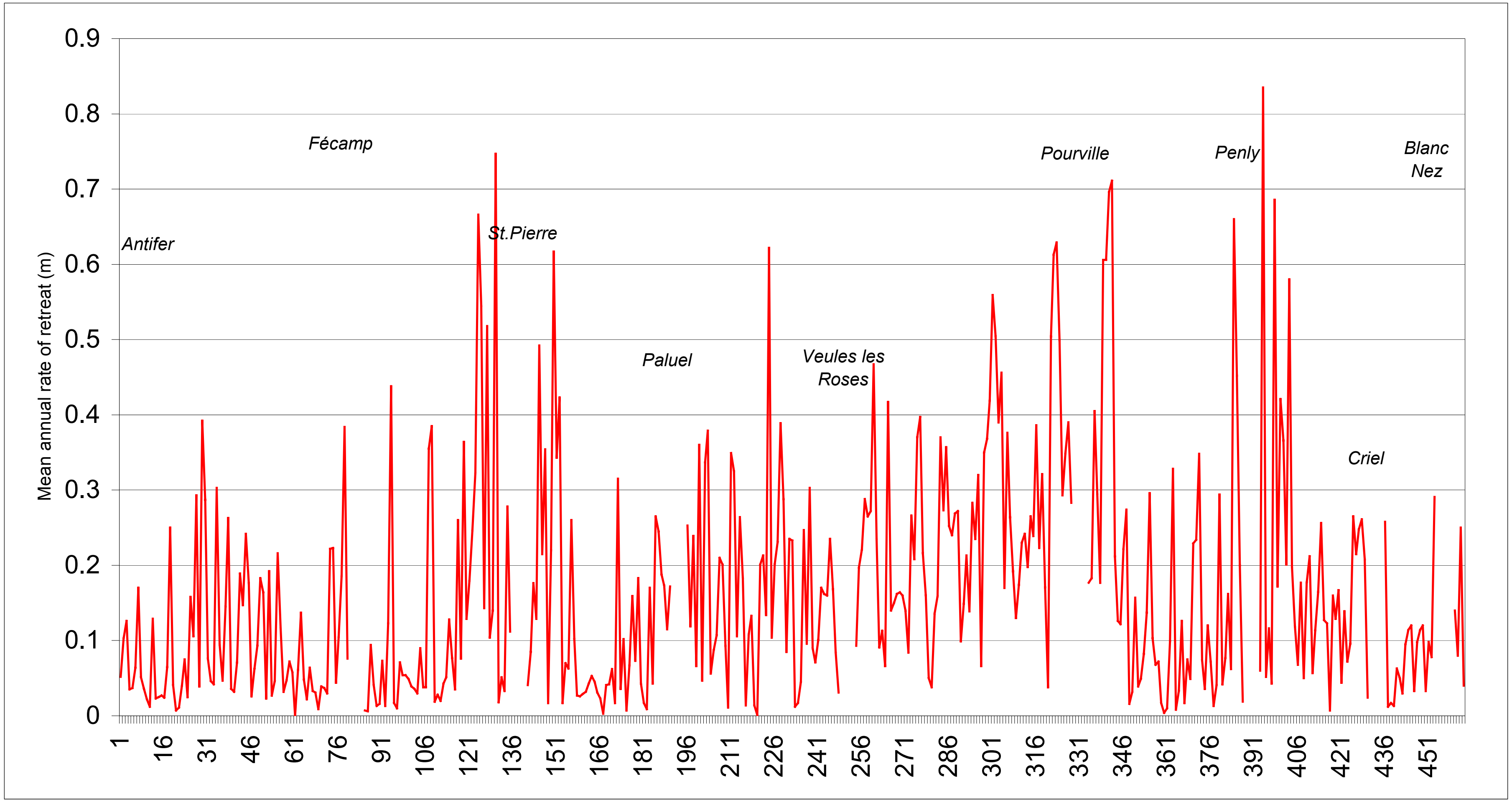

Figure 4: Mean annual rate of chalk cliff retreat along the French coast 1966 to 1995 (1944 to 1999 at Cap Blanc Nez, Lahousse et al 2000). Names refer to locations between cliffed sections; gaps between sections not to scale.

Rates of cliff retreat for the period 1966 to 1995 for the chalk cliffs of France are shown in Figure 4. Unfortunately, these rates cannot be shown in map form as the scale necessary to show the small areas of retreat together with the length of coast would require several A0 sheets.

Retreat rates show high fluctuations over short distances and the overall average annual rate of retreat is 0.16 m y^{-1}. Some spatial variation of the averages for different sections of coast can be observed, for example a higher average of 0.26 m y^{-1} for the section Veules le Roses to Pourville. The large, short distance fluctuations seem to indicate that the frequency of cliff falls is close to or longer than the observation period (29 years) which has been confirmed by Costa et al (2003). Part of these small scale variations may be due to human interference as Costa (2000) has also identified the role of beaches that develop updrift of manmade obstructions like groynes as having an impact on the rate of retreat.

A comparison between the retreat rates on the English and French side should not be made at this point of time as the two data sets are too dissimilar in length of the observation period. However, with regards to the mode of retreat it appears as if the return period of cliff falls along most of the French coastline lies somewhere between that of Sussex and Kent and is dominated by medium magnitude-medium frequency events.

6 Shore platform erosion

6.1 Background

Erosion of the shore platform at the foot of the chalk cliffs has been the subject of considerable recent research, especially during the EU funded European Shore Platform Dynamics (ESPED) project. However, all previous studies were concerned with the gradual downwearing of the platform over short periods of time (usually a few years) which was reflected in the methods used. These were mainly micro-erosion metres (MEM) and other small area/high precision tools like a laser scanner or the analysis of the faecal pellets of limpets (Andrews and Williams, 2000). The results of these methods, although highly accurate for short time scales and specific locations are difficult to extrapolate over all the shore platforms along the coast, so for estimation of base line data a different method has had to be employed.

Only one study (Stephenson, 2001) is known to the authors that has attempted to use air photographs in trying to measure the retreat of features on a shore platform, in this case the low tide cliff.

6.2 Methods

The same method used to measure cliff retreat has been used to compare the position of the low water line in maps from the 1870s and from the landline data set. The positional accuracy of the low water line (LWL) in historical maps is likely to be worse than for the cliff top or even the high water line. However, surveyors in the 19th century were given detailed instructions of when and how to survey a line that was of legal importance (Oliver, 1993; 1996). Unfortunately, the 2001 air photographs were flown at times when water was still covering the lower parts of the shore platform so that the method of extracting the position from the 2001 DEM, described in Dornbusch (2005) could not be utilised. Therefore, Ordnance Survey landline data had to be used on the English side with the difficulty that no precise date can be associated with the surveying of this line. However, from a comparison of the cliff line with in the orthophotos of 2001 and their equivalents in the land line data set, the most likely time period is the early 1990s.

Landward movement of the LWL on the rock platform over time can be attributed to four possible causes. First, to changes in the tidal amplitude, which is of an order that seems to be negligible (Austin, 1991; Woodworth et al., 1991); second, to relative sea level change resulting from a combination of crustal movement and eustatic sea level change, which is in the order of 2 – 8 mm y^{-1} (Barne et al., 1998a; 1998b) and amounts to 0.25 – 1 m over the period covered by maps on the English side; third to changes / errors associated with surveying and fourth to actual lowering of the platform. Of these causes, relative sea level change could have a significant impact as a vertical change of 1 m on a shore platform of 2° would result in a horizontal displacement of ~28 m. As both relative change in sea level and the rate of cliff retreat increase from east to west through East Sussex and Kent, a significant pattern of change in the position of the LWL should be observable from Sussex to Kent with more landward movement of the LWL in Sussex than in Kent.

Survey errors should be random and not obscure any pattern.

At the moment, the French data contains no information on the temporal position of the low water line so that for the French side no data is available on the lowering of large areas of platform.

For the period going back ~30 years, air photographs of sufficient quality and scale exist to allow for a photogrammetrical analysis producing high resolution Digital Elevation Models (DEM). These can be compared through time and allow the measurement of erosion on small scales as the horizontal ground resolution of the air photographs is about 10 cm.

6.3 Results

6.3.1 Comparison of the position of the LWL

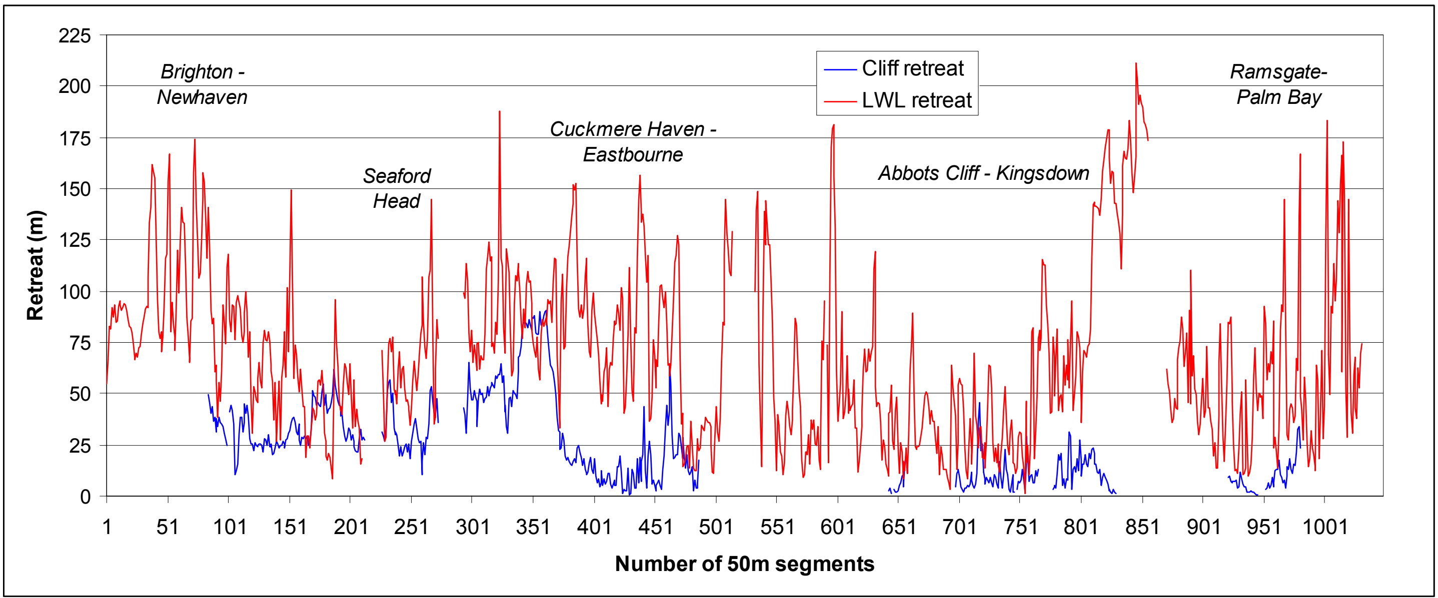

Figure 5: Retreat of the LWL position between the 1st Edition Ordnance Survey maps (surveyed in the 1870s) and the landline data (about 1990s). For comparison the retreat of the cliff for the same period is shown. Gaps between sections of the coast not to scale.

Given the difficulties in surveying the LWL and problems in assigning a survey date to the position of the LWL in the OS Landline data, interpretation of changes of LWL position through time or correlation with cliff retreat need to be made with caution.

The LWL position has on average retreated (moved landwards) 68 m between the 1870s and the 1990s (Figure 5) compared to 26 m of cliff recession. This suggests that either the platform has become more steeply inclined or the difference is due to the surveying difficulties described earlier. The latter is the more likely explanation. The ratio between platform retreat and cliff retreat shows a spatial pattern (Figure 6) with fairly consistent values for the Sussex coast between Brighton and the Seven Sisters and much less consistent values for the Sussex cliffs east of Birling Gap and the whole Kent coast where rates of cliff retreat have been low.

The retreat of the LWL in East Sussex compared to Kent (Figure 5 & Figure 6) is very apparent, but even more apparent are variations within the sections. Visual and statistical correlation between cliff retreat and LWL retreat is relatively poor (r=0.21) though in general the higher and lower rates of both cliff retreat and platform retreat coincide. However, occasionally the relationship may be in the opposite direction as shown near Kingsdown (Figure 5).

	Averages	N	Ratio LWL retreat / cliff retreat
6.3.1.1 Whole coast	**68.8**	**961**	**6.7**
Brighton - Newhaven	76.8	210	1.8
Seaford Head	64.2	47	2.3
Cuckmere Haven - Eastbourne	80.3	221	6.3
Abbots Cliff - Kingsdown	63.9	322	10.8
Ramsgate – Palm Bay	56.9	161	11.7

Figure 6: Average retreat of the LWL line for different sections of the coast

If an average retreat of 68m together with an average angle of the shore platform of 2° is assumed, then lowering of the shore platform during the last ~130 year was in the order of 2.3 m or almost 2cm/year. This figure seems too high because features like the concrete foundation blocks for Volk's Railway between Brighton and Rottingdean (built before 1900) are still largely in place along a stretch with above average rates of retreat of the LWL and consequently a platform lowering of >2m. It must therefore be assumed that the difference in position of the LWL on maps considerably overestimates the amount of platform lowering.

6.3.2 Changes to the shore platform based on photogrammetry

Along the southeast coast of England it appears from observation as if erosion of the shore platform is especially severe close to seawalls and around groynes and that block removal could play a significant role in that erosion. Quantification is difficult because no topographic surveys were carried out prior to the installation of these structures and even if conventional ground based surveys had been carried out, their spatial density would have been quite poor. In addition, observation of parts of the shore platform over several years has revealed that erosion can be quite severe even over a short period of time (Figure 7 & Figure 8).

Developments in softcopy photogrammetry and automatic Digital Elevation Model (DEM) extraction (e.g. Ackermann, 1996) allow for much more detailed representation of the topography of shore platforms. With the software package used (PCI Geomatics Orthoengine) automatic DEM extraction can be performed at the pixel level of the air photograph thus providing a DEM with a ground resolution of ~10cm. The high colour contrast found on the shore platform aids this process. In addition, ground control points for the aerotriangulation can be collected with GPS in sufficient amounts over large areas and with a high accuracy, to allow for more stable bundle adjustments. Fortunately, the Annual Beach Monitoring Survey (ABMS) along the southeast coast was started in 1973 with annual air photograph flights at a scale of 1:5,000. These were flown in the spring at low tide when the shore platform is exposed down to around the mean low water mark.

As a first step, scanned photos taken in 2001 with a ground resolution of 11cm were used together with ground control points obtained from differential GPS surveys to create a 10cm ground resolution DEM. The resulting DEM was compared with a ground survey carried out with a conventional total station in May 2002 and with a DEM of much poorer spatial resolution based on the same photographs but carried out as part of the ABMS surveys. The former resulted in a comparison of 591points over 2.4 km which had a correlation of 0.99, and an average difference of 5cm with a standard deviation of 22 cm. The latter resulted in a comparison of 1092 points over 4.5 km resulting in a correlation of 0.99 and an average difference of 6cm with a standard deviation of 21 cm. In both comparisons the mean difference is small and is likely to be the result of using different ground control systems for the two surveys, which have recently been changed. The standard deviation is again small and shows that the higher spatial density does not lead to a poorer DEM especially as the standard deviation in the latter comparison is a combination of the error of both data sets.

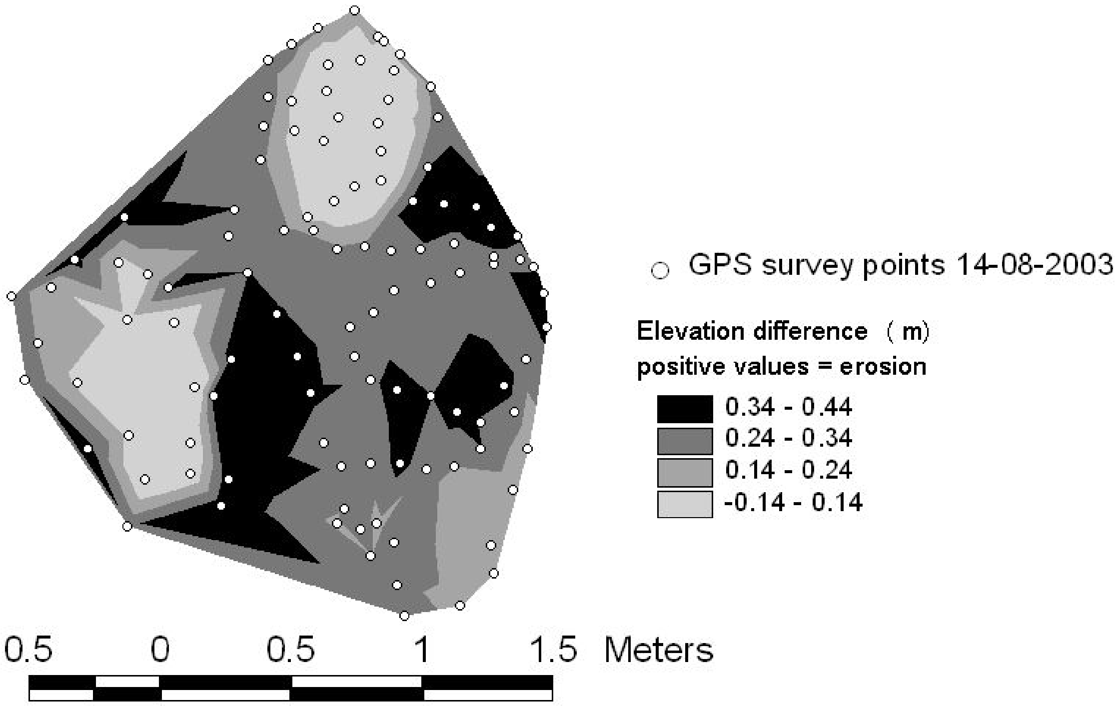

Figure 7: Comparison between GPS points surveyed on 14-08-2003 and DEM generated from air photo flown on 05-05-2001. DEM resolution is 10cm. The comparison shows two areas remaining at the same elevation in 2003 as in 2001 (light grey) with the chalk between eroded which is the same situation as shown in fig 7.


a


b

Figure 8: Photo of chalk shoreplatform on a) 20-09-2001 and b) 14-08-2003. Photos taken from lower right in fig 6. Height of the raised part is ~45cm above the surrounding platform; eroded gap in a) is ~30cm wide.

As a second step, the output DEM was compared with GPS surveys carried out in 2003 of specific features on the shore platform. (Figure 7). Where no change had occurred, the mean difference was in the order of <5 cm and standard deviations in the range of 5 to 20 cm. These error margins are sufficient to detect changes that have been observed in the field within a couple of years (Figure 8).

In a third step, air photos taken in 1973 have been scanned to provide a similar ground resolution to those from 2001. Due to changes in the ground control points (many of the ground control points used for the photos in 2001 were not in existence in 1973) and missing camera calibration information, the first DEM derived from the 1973 black & white photographs is less accurate than that for 2001, so the quantification of change is not as good as it could be. Additional ground control points need to be collected to improve the aerotriangulation. However, first tests at Saltdean are shown in Figure 9.

Changes in the morphology of the shore platform can be seen in the visual comparison of Figure 8a and b in that the platform east of the new rock groyne appears to be more heavily dissected. Also, the ridge between the two large depressions in the lower right hand quarter of the photos seems to have narrowed, especially at its northeastern end.

Comparing the digital elevation models derived from both air photographs, features that have not changed, such as the under cliff walk and sea-wall, show changes in the order of ±0.5 m. Clearly visible are the gains in elevation where new beach material was added in the late 1990s (especially west of the rock groyne) and where the rock groyne replaced the smaller concrete groyne. Changes to the shore platform have mainly occurred around the rock groyne with erosion of ~1 m, however, the platform towards the left side of the fig 8c appears to show some slight gains which would indicate that the absolute change on the shore platform has not been determined accurately enough to determine the absolute change as a consequence of the shortfalls in methodology mentioned earlier. Increased erosion around the rock groyne could be a by-product of the construction of the rock groyne when heavy machinery was used to pile up the boulders. The weight of the moving machinery could have weakened the chalk and made it more prone to subsequent erosion

7 Outlook for Phase 2 of BAR

During phase 2 cliff retreat rates need to be calculated for the French coast over a longer time span of ~100 years or more to enable a meaningful comparison with the data for the English coast. Similarly, retreat rates for the last 30 years need to be measured for the English coast to make the data comparable with the existing French data and detect whether the erosion rate is accelerating, constant or decreasing.

The low retreat rates along the Kent coast would indicate that using maps for the intervening period between 1870s and 2000 would not produce any meaningful results as the change in cliff top position approaches the map accuracy. Therefore map data to assess temporal changes in the cliff retreat rate will only be used for the East Sussex cliffs and to this end maps at a scale of 1:10,560 have already been scanned and await georeferencing and digitisation.

For cliff retreat and shore platform erosion during the past 30 years the original air photographs from the first ABMS flight in 1973 have already been scanned for several type sites in East Sussex and in Kent (flight date 1978) and during phase 2 a ground control point network for these photos will be established and the photogrammetry carried out.

a b c

Figure 9: Airphotos of eastern groynes at Saltdean in a) 1973, b) 2001. C) shows orthophotos of 2001 overlaid with elevation change derived from DEMs created from the 1973 and 2001 air photographs.

8 References

Ackermann, F., 1996. Techniques and strategies for DEM generation. In: C. Greve (Editor), Digital Photogrammetry: an addendum to the manual of Photogrammetry. American Society of Photogrammetry, pp. 135-141.

Anders, F.J. and Byrnes, M.R., 1991. Accuracy of shoreline change rates as determined from maps and aerial photographs. Shore and Beach, 59(1): 17-26.

Andrews, C. and Williams, R.B.G., 2000. Limpet erosion of chalk shore platforms in Southeast England. Earth Surface Processes and Landforms, 25: 1-11.

Austin, R.M., 1991. Modelling Holocene tides on the NW European continental Shelf. Terra Nova, 3: 276-288.

Barne, J.H. et al., 1998a. Coasts and seas of the United Kingdom: Region 7 South-east England: Lowestoft to Dungeness. Joint Nature Conservation Committee.

Barne, J.H. et al., 1998b. Coasts and seas of the United Kingdom: Region 8 Sussex: Rye Bay to Chichester Harbour. Joint Nature Conservation Committee.

Bialek, J., 1969. Le recul des falaises du cap d'Antifer au Tréport, entre 1830 et 1966, Direction Départementale de l'Equipement de Seine-Maritime, Arrondissement de Dieppe.

Castleden, R., 1996. Classic landforms of the Sussex coast. The Geographical association, Sheffield, 56 pp.

Cleeve, J. and Williams, R.B.G., 1987. Cliff erosion in East Sussex. GEMS, University of Sussex, Brighton, 68 pp.

Costa, S., 1997. Dynamique littorale et risques naturels : L'impact des aménagements, des variations du niveau marin et des modifications climatiques entre la Baie de Seine et la Baie de Somme. Thèse de doctorat Thesis, Université de Paris I, Paris, 376 pp.

Costa, S., 2000. Réactualisation des connaissances et mise en place d'une méthode de suivi de la dynamique du littoral haut-normand et picard, Rapport final, Préfecture de Picardie, Contrat de Plan Interrégional du Bassin de Paris (CPIBP).

Costa, S. et al., 2004. Quantification of the Normandy and Picardy chalk cliff retreat by photogrammetric analysis. In: R.N. Mortimore and A. Duperret (Editors), Coastal Chalk Cliff stability. Engineering Geology Special Publications. The Geological Society, London, pp. 139-147.

Costa, S., Legeat, Y., Hénaff, A., Delahaye, D. and Plessis, E., 2003. Origine de la variabilité spatiale du recul des falaises crayeuses du nord-ouest du Bassin de Paris. L'exemple du littoral haut-norman (France). Hommes et Terres du Nord, 2: 22-31.

Dornbusch, U., 2005. 2005-01-Final report_Changes in beach topography.doc, University of Sussex, Falmer, Brighton.

Dornbusch, U., Robinson, D.A., Moses, C. and Williams, R.B.G., in press. Chalk coast erosion and its contribution to the shingle budget in East Sussex. Zeitschrift für Geomorphologie.

Hénaff, A., Leageat, Y., Costa, S. and Plessis, E., 2002. Le recul des falaises crayeuses du Pays de Caux: détermination des processus d'érosion et quantification des rythmes d'évolution. Géomorphologie: relief, processus, environnement, 2: 107-118.

Howe, D.J., 1968. Coast protection – Peacehaven and Telescombe cliffs: Report.

Lahousse, P., Pierre, G. and Lanoy-Ratel, P., 2000. Quantification par analyse photogrammétrique du recul des falaises du Blanc-Nez depuis 1944 (Pas-de-Calais, France). Photo-interprétation, 2000(3-4): 3-9.

LCHF, 1972. Etude de la production des galets sur le littoral haut-normand, Laboratoire Central d'Hydraulique de France.

May, V., 1971. The retreat of Chalk Cliffs. Geographical Journal, 137: 203-206.

May, V. and Heeps, C., 1985. The nature and rates of change on chalk coastlines. Zeitschrift für Geomorphologie, Supplement Band, 57: 81-94.

Moore, L.J., 2000. Shoreline mapping techniques. Journal of Coastal Research, 16(1): 111-124.

Oliver, R., 1993. Ordnance Survey Maps, a concise guide for historians. Charles Close Society, London, 192 pp.

Oliver, R., 1996. Taking to the water: some examples of OS mapping of the coast. Sheetlines, 45: 9-27.

Ordnance Survey, 2000. Technical Information. http://www.ordsvy.gov.uk/productpages/landline/tech.htm#scalesource http://www.ordnancesurvey.co.uk/oswebsite/pai/backgroundinformation.html.

Prêcheur, C., 1960. Le littoral de la Manche : de Saint-Adresse à Ault. Etude morphologique., Norois, n° hors-série: 1-138.

Robinson, D.A. and Williams, R.B.G., 1983. The Sussex coast past and present. In: G.E. Committee (Editor), Sussex : Environment, Landscape and Society,. Sutton, Gloucester, pp. 50-66.

Stephenson, W.J., 2001. Shore platform width - a fundamental problem. Zeitschrift für Geomorphologie, 45(4): 511-527.

Thieler, E.R. and Danforth, W.W., 1994. Historical shoreline mapping (I): improving techniques and reducing position errors. Journal of Coastal Research, 10(3): 549-563.

Thorburn, A., 1977. Report on the problems of coastal erosion. East Sussex County Council, Lewes.

Valentin, H., 1954. Der Landverlust in Holderness, Ostenegland von 1852 bis 1952. Die Erde, 6: 296-315.

Woodworth, P.L., Shaw, S.M. and Blackman, D.L., 1991. Secular trends in mean tidal range around the British Isles and along the adjacent European Coastline. Geophysical Journal International, 104(3): 593-609.