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Dune Movement in the Kwaaihoek Region of the Eastern Cape, South Africa, and its Bearing on Future Developments of the Region

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ABSTRACT

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The Kwaaihoek region of the eastern Cape coast, South Africa, consists of an 8 km long stretch of largely unspoiled dunefield. This dunefield is interrupted by three vegetated rocky promontories, Kwaaihoek 1, 2, and 3. In response to a proposal for a road across this dunefield to a parking lot behind Kwaaihoek 1, the rates and volumes of sand movement in the vicinity of the proposed site were determined by the use of aerial photographs, long term observations, and dune transects. The rate of dune movement of 2.9 m yr^{-1} for a large dune compared favourably with other rates for dune movements in the eastern Cape. At this dune the volume of sand shifted was 23.5 m^3 m^{-1} yr^{-1}. These data were presented to the relevant authorities, resulting in the cancellation of the proposed road.

ADDITIONAL INDEX WORDS: *Dune movement, sand movement, road construction, coastal management, South Africa.*

INTRODUCTION

Boknes (33°43′S; 26°35′E) and Boesmansriviermond (33°41′S; 26°35′E), two eastern Cape, South Africa, coastal resorts, are separated by eight kilometres of largely unspoiled dunefields and beaches, backed by natural vegetation. This extensive dunefield is interrupted by three vegetated rocky promontories, Kwaaihoek 1, 2, and 3 (Figure 1). The dunes are transversely orientated with respect to the wind direction, the steep side or slipface facing downwind. The dunes may be either transverse with straight or curved ridges and axes, or crescentic (barchanoid), convex on the windward side and concave on the leeward, with linked axes (TINLEY, 1985). Because the predominant wind direction is either from the west or from the east at different periods or seasons of the year, these dunes are usually reversing with a second slipface developing nearly opposite the first slipface (LUBKE, 1988).

The Portuguese explorer Bartolomeu Dias erected a 'padraó', or cross, at Kwaaihoek 3 on 12 March 1488 (AXELSON, 1939). Quincentennial celebrations of this event were held in March 1988.

The Boesmansriviermond Municipality proposed the construction of a road to an unspoiled and not easily accessible beach, Andersons Bay, situated between Kwaaihoek 1 and 2. The proposed road would cross the farm Klipfontein, proceed down a blowout and cross the shifting dunes common to this area (HEYDORN and TINLEY, 1980) to a parking lot situated just behind the beach. Construction was planned for the end of 1986. A large area of dunes on either side of the road would need stabilization to prevent the road becoming covered in sand. The road was proposed to improve access to Andersons Bay and to Kwaaihoek 3 for the quincentennial celebrations, and to facilitate access for increased numbers of tourists.

The climate of this area is warm and temperate, and is dominated by an alternating succession of east-moving cyclones budded off from circumpolar westerlies and high pressure anti-cyclones which ridge in behind the lows. Rainfall is low

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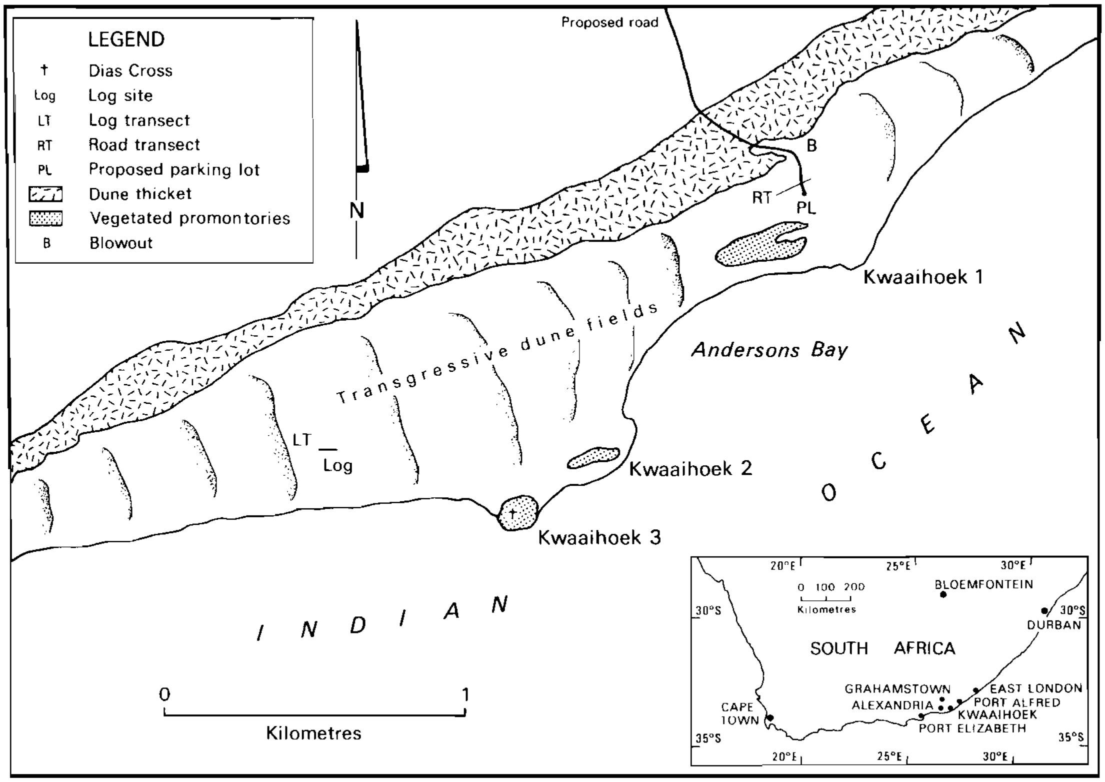

Figure 1. Map of the Kwaaihoek region depicting sites of dune movement measurements.

(600–700 mm per annum) and erratic although mainly occurring in spring and autumn. As indicated in the windroses (Figure 2) in January (Summer) winds of greatest velocity are from the east-north-east and in July (Winter) west to southwesterlies are more frequent. The winter berg winds from the north have little effect on the dune environment. Low rainfall and these high winds cause rapid movement of the dunes either in a westerly or easterly direction, and account for the lack of vegetation cover and vast transgressive dunefields (TINLEY, 1985; LUBKE, 1988). In spite of the extensive dune system the coastline in this region is neither accreting nor receding.

The aim of this study was to determine the rate and volume of sand movement in the vicinity of the proposed road, and to provide advice on whether or not the road should be constructed.

METHODS

Sand movement in the area was determined from the following three sources:

Aerial Photographs

From 1942 to 1986 the region was photographed five times, the most recent being in 1979. These aerial photographs were used to determine historical changes in the dunes near Kwaaihoek 1. The aerial photographs proved unsuitable for accurate quantitative comparison, due to poor resolution and excessive shadowing around clumps of vegetation. However, the approximate rate of dune movement between the blowout and Kwaaihoek 1 could be determined by measuring the exposed area of a clump of vegetation situated within the dunefield, between the blowout and Kwaaihoek 1, in the sequential aerial photographs. The aerial photographs were of different scale, therefore measurements were standardised.

Observations and Sand Measurement at Drift Logs

In 1984 a drift log, 19 m long and 60 cm in diameter, was washed up 800 m to the east of

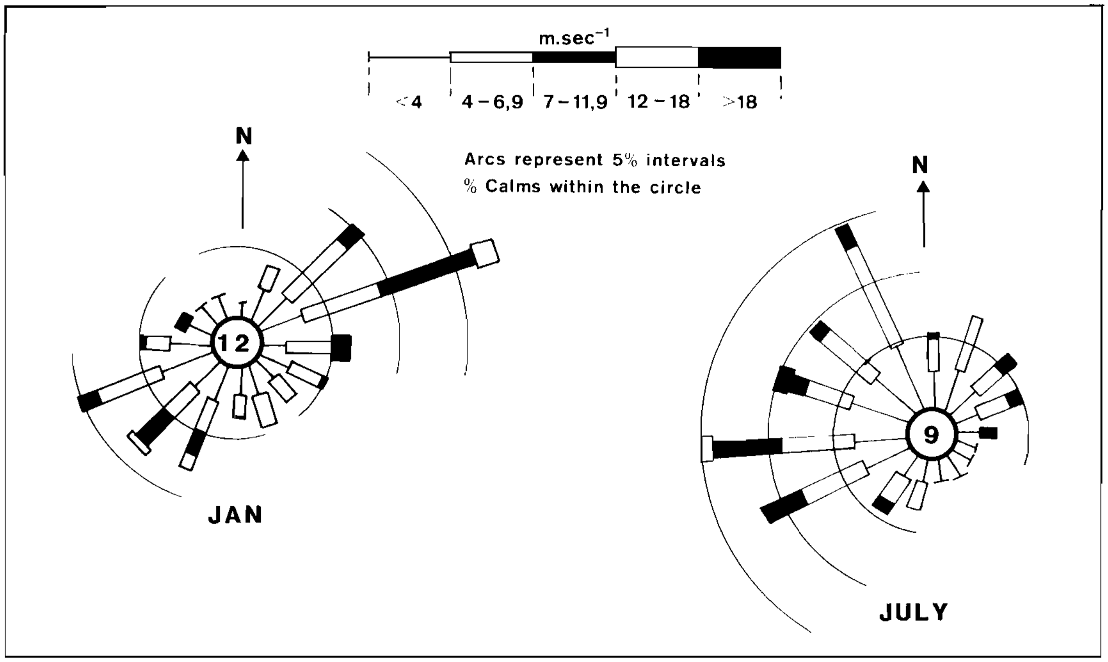

Figure 2. Wind rose diagrams for Great Fish Point Lighthouse showing the wind regime for this region. Data taken from the past 20 years (Schulze, 1980).

Kwaaihoek 3, 100 m from mean sea level (Figure 1). At approximately monthly intervals the position of the sand dune and its height in relation to the log was noted (by MW). From July 1985 to July 1986 its position was determined beneath the sand in relation to the mobile dune by a metal probe. Using these measurements a dune profile could be plotted.

Dune Transects

Two dune profiles were measured monthly from April to September 1986 along transect lines. The first transect was 30 m inland from the drift log, and ran at an angle of 90° for 67 m parallel to the coastline. The second transect was also parallel to the coast, and was situated between Kwaaihoek 1 and the blowout down which the road to Andersons Bay was proposed. This profile was 195 m long, at an angle of 64° from the starting point.

Both transects were through shifting transverse dunes. A point of consistent height to the sides of the profiles was used. The horizontal angle from the theodolite to each point on the profile was recorded. The distance to each point and the elevation of each point were determined using a HEWLETT-PACKARD HP65 Survey Pac 1. The profiles were plotted from these data points, and compared. The height above mean sea level was determined from tide-tables (ANON., 1984).

Due to the proposed construction of the road towards the end of 1986, and the need for the presentation of results before construction commenced, the transects were not measured for the entire year. The exact distances the dunes shifted in a year were therefore not measured.

In order to obtain an estimate of the distance the dunes would move in one year we extrapolated from the data at the log obtained for 1985 and 1986, and applied this conversion factor to both transects. To determine the volume of sand which could be shifted in a normal year at each site, the mean height of each dune was calculated as the mean of the highest and the lowest dune height at each site during the period of the survey. This value was multiplied by the distance the dune would shift eastward, in order to determine the overall volume of sand shifted. Climatic conditions during this period correspond to previous records and therefore one can assume that we

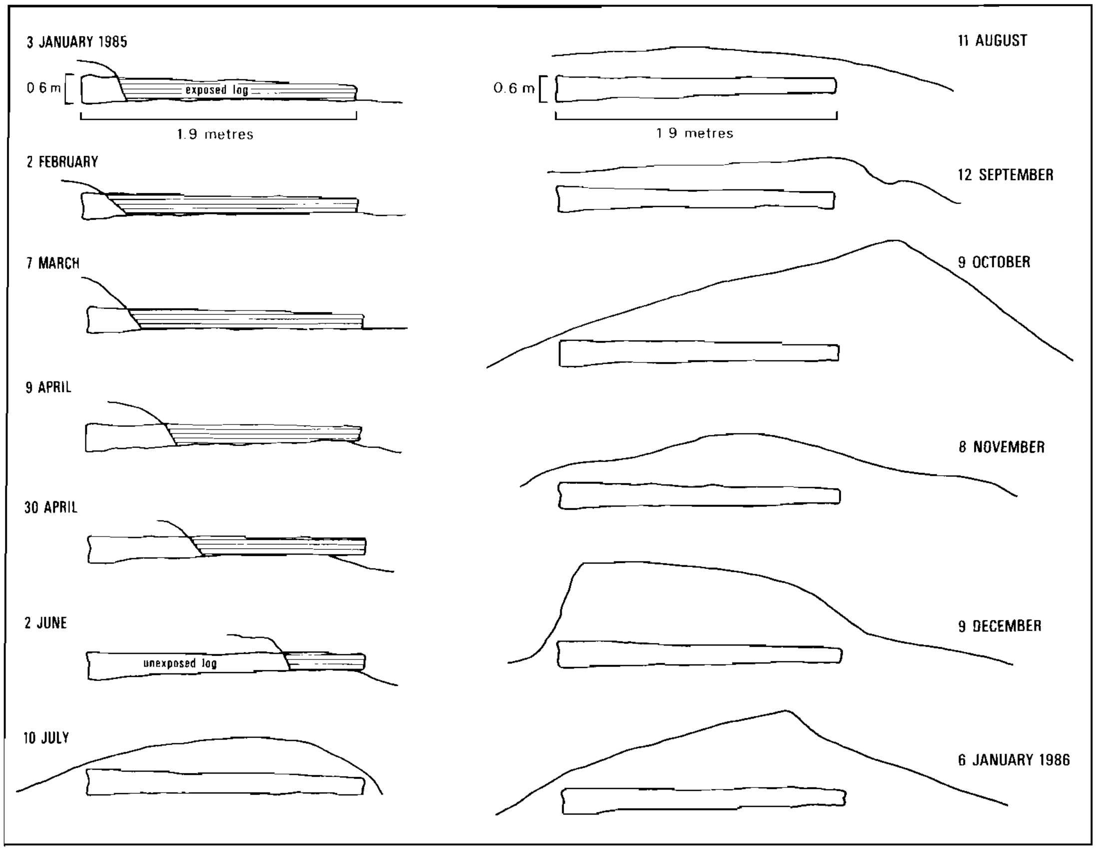

Figure 3. Dune profile at drift log for each month in 1985.

obtained reliable estimates for this section of coastline.

RESULTS

Aerial Photographs

The patch of vegetation situated between the blowout and Kwaaihoek 1 was roughly triangular in shape. In 1942 the base of the triangle was parallel to the crests of the transverse dunes, and the patch was approximately 93 m long. By 1955 the patch was approximately 72 m long, and narrower at the base. In 1966 the patch was approximately 27 m long, and it had been completely covered by 1973. These data indicate a rate of easterly dune movement of approximately 3 m per year in the area between the blowout and Kwaaihoek 1.

Observations Relative to the Drift Log

At the log, the transverse dune shifted 30 m eastward between 3 January and 9 October 1985, but between 9 October 1985 and 6 January 1986 the dune shifted 5.4 m westward, resulting in an overall 24.6 m eastward dune movement in 1985 (Figure 3). The dune varied in height from roughly 0.5 m above the log (11 August) to over 2 m above the log (9 October). Initially the obstruction caused by the log would have resulted in some build up of sand, but once the end of the log was covered, this effect would have been nullified.

Dune Transects

The crest of the dune at the drift log transect site shifted 21 m eastward between 23 April and 22 September 1986 (Figure 4). The average height of this dune was 3 m. This distance was the same

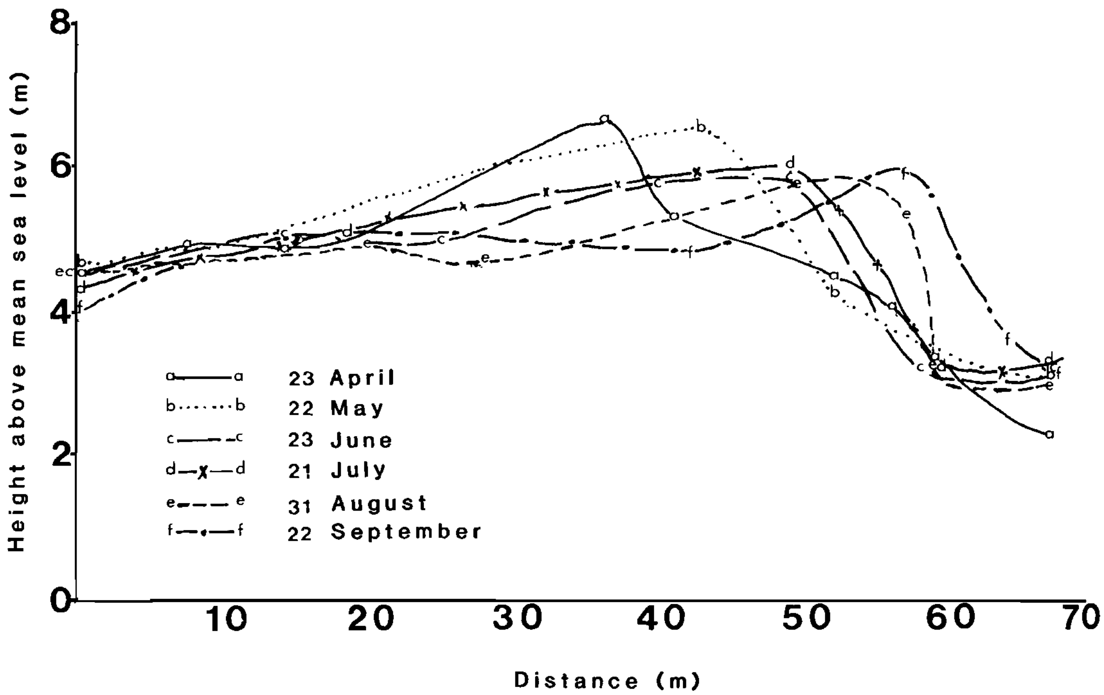

Figure 4. Monthly dune profiles at drift log site.

as the distance the dune shifted over the log in the same time period in 1985, and within a metre of the distance shifted over the log in 1986. The eastward dune movement measured by us constituted 85% of the yearly eastward movement. This correction factor was applied throughout, and implied that this dune would have moved approximately 24.6 m eastward that year.

The crest of the first dune at the proposed road transect site (Figure 5) advanced 2.5 m eastward between April and September 1986, and its height increased from 7.4 m in April to 9.4 m in September. It would advance approximately 2.9 m each year. At this rate, the smaller dune at the eastward end of the transect advanced 8 m eastward during the same period, and would advance 9.4 m in a year. The crest of this dune was 1.5 m high in April, increased to 3 m in July, and then decreased to 1.8 m in September.

The volume of sand shifted at the large dune at the road site was 23.5 m^3 m^{-1} yr^{-1}. The same volume of sand would be shifted at the small dune at the road site, confirming that dune movement rates are inversely proportional to dune height (ILLENBERGER, 1986). At the log transect site 73.8 m^3 m^{-1} yr^{-1} would be shifted eastward in a year.

DISCUSSION

The rates and volumes of sand movement of the Boknes-Boesmansriviermond dunefield determined in this study compare favourably with values determined by other researchers on the eastern Cape coast (Table 1). Although these other dunefields are of different sizes, the dune types and transgressive dunefields are very similar. LUBKE and SUGDEN (1990) reported an annual 3.5 m eastward dune movement to the west of the pier at Port Alfred, and LUBKE and AVIS (1988) reported a 3 m annual eastward movement at Kleinemonde. MCLACHLAN *et al.* (1982) reported an average 4 m per year north-easterly movement of dunes in the dune slacks of the Alexandria dunefield. YOUNG (1987) reported an average annual 2.2 m north-easterly movement of bushpockets in the Alexandria dunefield, based on aerial photographs. These bushpockets were situated in the large dunes, further from the coast than

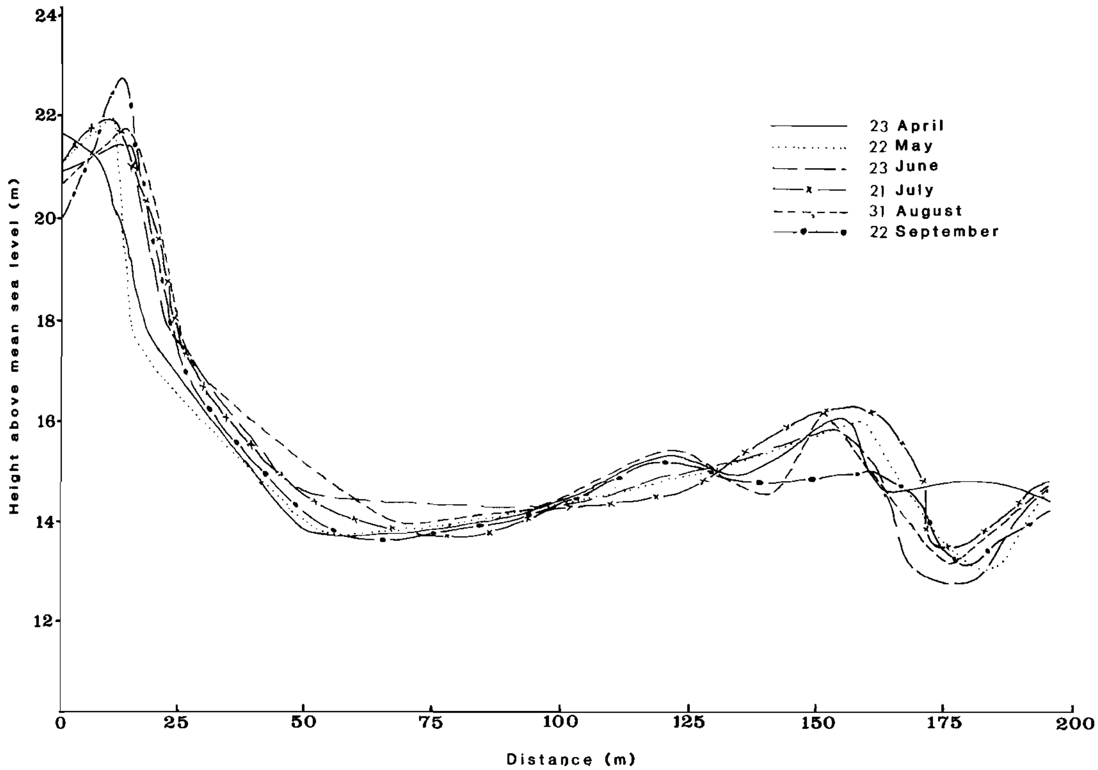

Figure 5. Monthly dune profiles at proposed road site.

the dune slacks or swale hollows studied by McLACHLAN *et al.* (1982).

ILLENBERGER (1986), in an intensive study of the Alexandria dunefields, determined a rate of volume of sand movement of 61 $m^3\ m^{-1}\ yr^{-1}$ for dunes close to the sea. Our values are slightly higher, but correspond closely to the hypothetical value of 75 $m^3\ m^{-1}\ yr^{-1}$ he determined for these areas.

ILLENBERGER (1986) also reported a slower rate of transport with increasing distance from the sea. This wind energy is much greater close to the sea and this explains the higher rate of dune movement at the log site (close to the beach) when compared with the other sites (Table 1). This fact also explains the difference in rate of movement reported by McLACHLAN *et al.* (1982) (dunes close to the sea) and YOUNG (1987) for the Alexandria dunefields (dunes some distance from the sea).

A number of studies (*e.g.* SVASEK and TERWINDT, 1974) have been made relating wind speed to sand movement following the classical studies

Table 1. *Rate and volume of dune movement on the eastern Cape coast, South Africa. (For localities see Figure 1.)*

Author and Locality	Rate of Dune Movement ($m\ yr^{-1}$)	Volume of Sand Movement ($m^3\ m^{-1}\ yr^{-1}$)
McLachlan *et al.* (1982) —Alexandria dune slacks	4	
Young (1987) —bushclumps —Alexandria dunefields	2.2	
Illenberger (1986) —Alexandria dunefields		61 (actual) 75 (hypothetical)
This study:		
Aerial photographs	3	
Drift log observations	24.6	
Dune transects: drift log	24.6	73.8
Proposed road: large dune	2.9	23.5
small dune	9.4	23.5
Lubke & Sugden (1990) —Port Alfred	3.5	
Lubke & Avis (1988) —Kleinemonde	3	

of BAGNOLD (1954). Differential rates of dune advancement, longitudinal dunes moving more rapidly than transverse or barchan dunes, have been reported by TSOAR (1983) in the Sinai Desert. Different rates of advancement of parts of the dune are also reported upon by LANCASTER (1985). In our study details of such a nature were not investigated but these factors may account for the differences we observed in rates of movement of dunes at the proposed road site. PICKARD (1972) from a study of aerial photographs measured the mean rate of movement of a dunefield in New South Wales, Australia, at 8 m yr^{-1} which is comparable to studies in the Eastern Cape. He compared his results to those studies in France, the United Kingdom and the U.S.A. HESP and THOM (1990) in a review paper on transgressive dunefields, also discuss rates of dune movement. On the Oregon coast, for example, they reported transgressive ridges moving slowly at less than 1 m yr^{-1}, whereas slipfaces could range from almost stationery to very rapid (10–20 m yr^{-1}).

The rates of movement determined in this study for the large dunes from the aerial photographs (3 m per year) and from the transects (2.9 m per year) correspond closely, therefore rate of movement of 3 m per year for larger dunes in the area appears to be a reasonable value to take into consideration when future developments in the area are proposed. The construction of a road in the position indicated was determined to be undesirable because of the rapid rate of sand movement and need for an extensive stabilization programme. Moreover, this dune movement supplies sand to the beach at Boesmansriviermond. Any development which occurs in this area should therefore be of a recreational nature with camping sites or hiking trails but without any fixed or permanent structures within the transgressive dunefields.

CONCLUSION

As a result of these data which were presented to the Boesmansriviermond Municipality and the Directorate of Forestry, the road was not constructed. The high volume of sand movement between Boknes and Boesmansriviermond makes any development within these dunes a hazardous undertaking, and we recommended that the area remained undeveloped, retaining its present wilderness character.

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□ RÉSUMÉ □

La région de Kwaaihoek (Est Cap Coast, Afrique du Sud) est constituée par une bande de champs dunaires bien conservés. Ces champs de dunes sont interrompus par trois promontoires rocheux végétalisés: Kwaaihoek 1, 2 et 3. Afin de répondre à la proposition de construction d'une route conduisant à travers les dunes à un parking situé derrière Kwaaihoek 1, on a déterminé à proximité du site, les volumes de sables en mouvement grâce aux photos aériennes, aux observations à long terme, et à des transects. Le mouvement d'une dune importante atteint 2,9 m/an, ce qui est de l'ordre de grandeur des mouvements atteint par les dunes à l'est du Cap. Sur cette dune, le volume de sable déplacé est estimé à 23,5 m^3/m/an. Ces données ont été présentées aux autorités compétentes, et le projet de route a été annulé.—*Catherine Bousquet-Bressolier, Géomorphologie EPHE, Montrouge, France.*

□ ZUSAMMENFASSUNG □

Die Kwaaihoek-Region der östlichen Kap-Küste von Südafrike besteht aus einem 8 km langen Streifen weitgehend ungestörter Dünenfelder. Dieses Dünenfeld wird unterbrochen durch 3 vegetationsbedeckte felsige Küstenvorsprünge, genannt Kwaaihoek 1, 2 und 3. Zur Untersuchung der Frage eines Straßenbauprojektes durch dieses Dünengelände zu einem Parkplatz hinter Kwaaihoek 1 wurden die Beträge und Volumen der Sandbewegung im Umfeld des Bauprojektes unter Benutzung von Luftphotos und langfristigen Beobachtungen auf verschiedenen Querschnittsprofilen untersucht. Der Betrag des Dünenwanderns von 2,9 m/Jahr für eine besonders große Düne liefert vergleichbare Werte auch für die anderen Dünenbewegungen in der Kap-Provinz. Bei dieser Düne betrug das bewegte Sandvolumen 23,5 m^3/Jahr. Diese Ergebnisse wurden den zuständigen Behörden mitgeteilt, woraufhin das Straßenprojekt gestrichen wurde.—*Dieter Kelletat, Essen, Germany.*

□ RESUMEN □

La región de Kwaaihoek situada en la zona del Cabo Oriental, Sudáfrica, está constituída por un cordón de dunas no-perturbadas por la acción humana de unos 8 km de largo. Este campo de dunas está cortado por tres promontorios rocosos, Kwaaihoek 1, 2 y 3. En respuesta a una propuesta de construcción de carretera a través de dichas dunas hacia un aparcamiento situado en Kwaaihoek 1, se efectuó medidas de movimiento de arena en las proximidades de dicha zona usando fotografía aérea, observaciones de largo período y transectos en las propias dunas.

Estos datos fueron presentados a la autoridad competente y dieron como resultado la cancelación de la carretera propuesta.—*Department of Water Sciences, University of Cantabria, Santander, Spain.*