SCOTTISH NATURAL HERITAGE

COMMISSIONED REPORT

Beaches of East Sutherland and Easter Ross

Commissioned by the Countryside Commission for Scotland, 1973.

J.S. Smith, A.S. Mather

For further information on this report please contact:

Advisory Services
Scottish Natural Heritage
2 Anderson Place
Edinburgh EH6 5NP

This report should be quoted as:

Mather, A.S., Smith, J.S., Ritchie, W., April,1973. Beaches of East Sutherland and Easter Ross. Department of Geography, University of Aberdeen, for the Countryside Commission for Scotland. Reprinted 2001 by Scottish Natural Heritage as a Commissioned Report.

SCOTTISH NATURAL HERITAGE

COMMISSIONED REPORT

Beaches of East Sutherland and Easter Ross

J.S. Smith, A.S. Mather
First published by the Countryside Commission
for Scotland, 1973.

Acknowledgements

The authors of this report would like to acknowledge the financial support given by the Countryside Commission for Scotland.

Sutherland County Planning Office and Ross and Cromarty County Planning Office provided useful information during the study while the Nature Conservancy Council through Mr. Andrew Currie, Assistant Regional Officer, North Region, kindly provided current information on conservation proposals.

The production of the report and the provision of technical services were under the direction of Mr. Charles Wilson of the Department of Geography, University of Aberdeen.

Particular gratitude is expressed to Mrs. Doreen Jeffrey who was responsible for the cartography. Messrs. J. Livingston, D. Robertson and A. Newlands carried out the graphic arts photography, and T. Cook, H. Ross and W. Bragg were responsible for the printing and binding.

Professor Walton's advice and permission to use the facilities of the Department of Geography, University of Aberdeen, are also gratefully acknowledged.

December 1973. J.S.S. and A.M.

For further information on this project contact:
George Lees, SNH, 2 Anderson Place, Edinburgh EH6 5NP.
george.lees@snh.gov.uk

For further information on the SNH Research & Technical Support Programme contact:
The Co-ordination Group, Advisory Services, 2 Anderson Place, Edinburgh. Tel: 0131 446 2400

Contents

List of Figures

List of Tables

1. Introduction

This report describes low soft coastlines in East Sutherland and Easter Ross. It is the eighth report in a series commissioned by the Countryside Commission for Scotland.

The report is designed as an environmental inventory emphasising the physical characteristics of beaches and adjacent landward areas. It includes information on morphology, habitat characteristics, land use, tenure and accessibility. The dynamic relationships between process and landform are described for each beach unit. The factors considered in the assessment of the geomorphological relationships include the natural ones of coastal materials and processes, together with man-induced factors such as land use and recreational activities.

The authors were invited to express objective opinions on such issues as conservation of coastal resources, management, recreational provision and the effects of current or proposed developments in so far as they may affect the coastline. The report should be regarded as a descriptive scientific study of particular coastal assets.

Purpose and Methods of Study

The field and laboratory studies seek to gauge the stability of each beach complex together with the types and impacts of human activities. From this base, predictions can be made of future stability as related to natural and human activities. Particular attention was paid to the mapping and analysis of landforms and the observation of current processes. Field data were also collected on ecological status, land quality and existing leisure uses.

The beach complexes were mapped on a scale of approximately 1:5000, the base maps being enlarged from the published 1:10560 Ordnance Survey sheets, and supplemented by recent aerial photography where available. Comparison of First Edition Ordnance Survey maps, aerial photographs of differing dates and the current 1:10560 series allows assessment of changes in shoreline position, dune-edge and machair stability. These sources have been supplemented where possible by a scrutiny of historical literature.

The geomorphological maps constructed in the field are presented in the text together with a selected range of photographs. The maps are reproduced at a scale of approx: 1:5000, and symbols are explained in the key sheet at the end of the report. A glossary of technical terms is provided in Appendix I.

Interpretation of the landforms and physical processes currently active was aided by laboratory analysis of sand samples. The analysis of particle size distribution and the other textural indices within Appendix II provides information on the effect of the physical processes acting upon the coastal materials. Other appendices include quantitative information on beach shelter and habitat diversity, together with estimates of beach stability.

The descriptions of the individual beach units have been arranged in two sections (Chapters 6 and 7), with the Dornoch Firth as the central boundary. The Firth is the present county boundary between Ross and Cromarty and Sutherland, and to some extent also acts as a physiographical divide separating groups of beaches with differing characteristics. General recommendations are presented in Chapter 8, while specific recommendations regarding individual beach units are given near the end of the appropriate sections.

2. The Coast and Development

The Scottish coastline is at present facing considerable pressures for development stemming from a general increase in recreation-based activities and from industrial projects of varying scales which are demanding the advantages of a coastal site. Although it would be an oversimplification to categorise these two demands as caravans and oil fabrication yards, recent events have shown them to be the main large-scale users of coastal resources. Although there is at present little conflict between these two users, in the future one could envisage recreational interests and industrial interests coveting the same site. Both industrial and recreational land uses are regarded as important to both regional and local economies and it is undesirable that holiday caravans should be sited adjacent to the noise and disturbance associated with large-scale industrial developments.

In both types of development, questions of amenity and conservation consistently arise in addition to the possible environmental side-effects of superimposing new or increased public or industrial pressures onto the complex interrelationships of process and landform which are characteristic of low soft coasts. The nub of the current planning problem in the Highlands lies in the similarity of site demands for recreational and industrial usages. Both parties are interested in soft accreting coasts, where agricultural land capability is generally low, where access by road is relatively easy, and where offshore and/or onshore movement of materials by mechanical means is possible. Where large-scale developments do take place, as in the Easter Ross context, housing provision falls seriously behind job opportunities, and thus existing coastal caravan sites are filled up by residential caravans which replace a seasonal dune pressure by all the year round pressure.

A similar problem exists at the Morrich More, in this case at a larger scale. In this instance a planning decision taken in the South of England has repercussions in Easter Ross. The Third London airport displaces the military interest from Shoeburyness, and the ripples reach Easter Ross in the form of an application for the use of the Morrich More as an Army shelling range.

In a fluid situation of intense development pressures such as now exists in Northern Scotland, an inventory of coastal resources forms the starting point for both regional and national forward planning. Few beaches and dune systems can be regarded as sacrosanct for any single land use. The Reporter's conclusions regarding Dunnet Bay clearly indicate that scheduling of the bay for recreational use in the past is no argument against change of projected use to industrial purposes, as technology changes site requirements.

Estimates of likely demands for oil production platform sites in the Scottish Highlands indicate that about 28 sites will be required over the next ten years. Distribution of likely sites is widespread, and in the face of rapidly changing construction technology, zoning of recreation and industry, while desirable, is unlikely to take place in the near future. Apart from basic environmental hazards which require early consideration, social and cultural factors are additional problems associated with the arrival of large-scale developments in sparsely populated areas. These latter problems are only now becoming apparent.

It is clearly not possible to 'hold' areas with recreational potential apart for future development as only a developed recreation will act as a counter-argument against the zoning of such a site for industry.

It may prove necessary to invest in recreation ahead of industrial development pressures purely to prevent a change of land use to industry – a curious inversion of forward planning.

Location of beach units

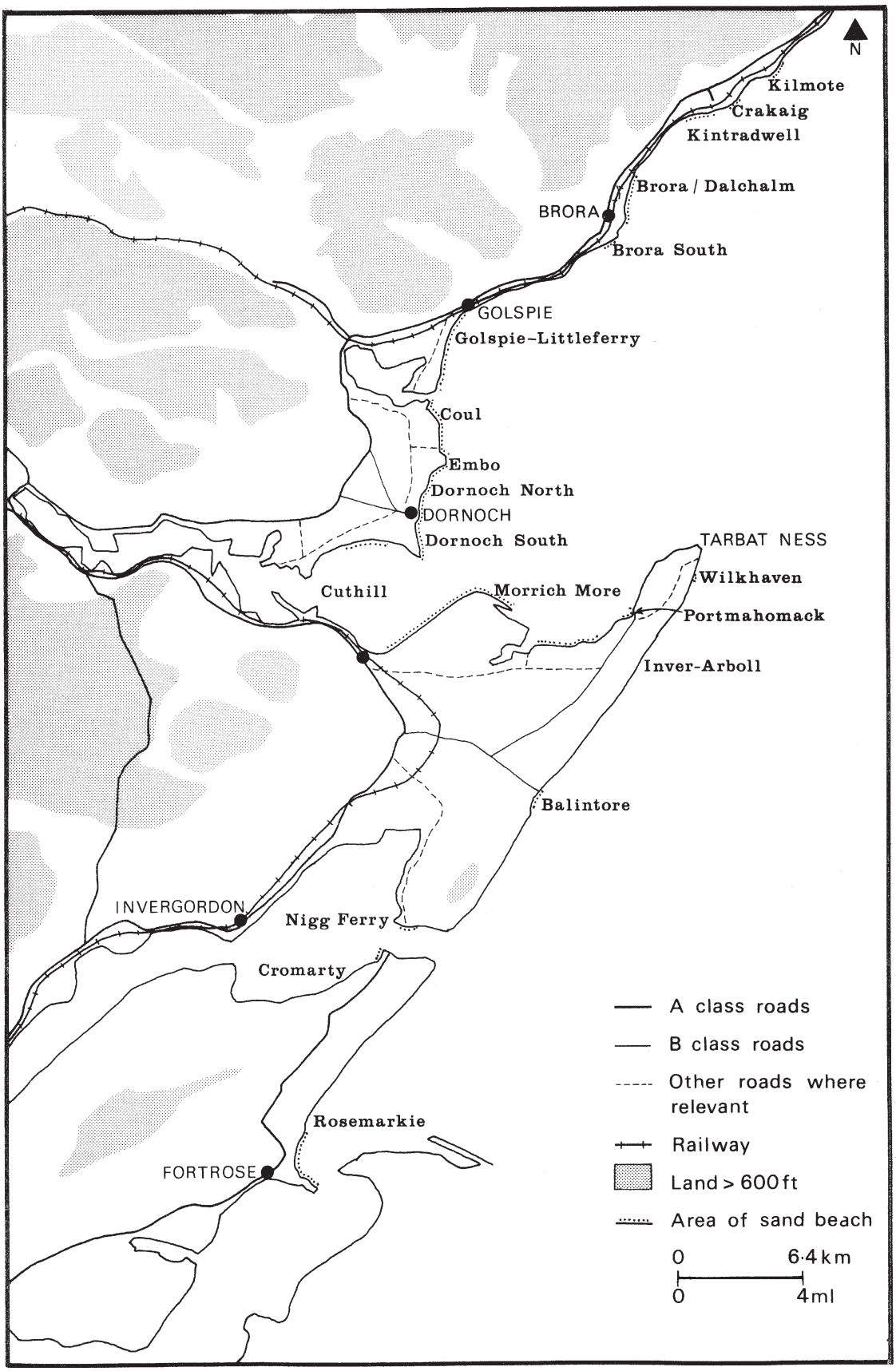


Plate 1 The use of the aerial photograph in mapping. This vertical aerial photograph taken in 1966 illustrates the strongly prograding dune capped bars on the outer Morrich More, together with an extensive sandflat, partially fixed by a surface algae.

In this report, Easter Ross and East Sutherland are treated separately in Chapters 6 and 7, but together in Chapter 8, in anticipation of the new regional administrative units. The coastal parameters set out in Table I indicate that if one excludes the inner coasts of the great firths, which are largely fronted by sandflats, East Sutherland carries approximately twice the length of sandy coastline of Easter Ross. In addition, the units north and south of the Dornoch Firth differ in environmental characteristics (Chapters 6 and 7). In particular, the Easter Ross units are small, with extremely limited dune and machair areas. In Sutherland, the units are much larger, with long stretches of uninterrupted sand beach. The type and intensity of recreational pressure desirable in the beaches is closely related to this contrast. Only certain beach units can be regarded as having potential for expansion of recreational opportunities. The extent and physical attributes of the beach units described in this report create a ceiling of possible recreational opportunities which should not be exceeded. In addition, the beaches in the East Highlands*, compared with the remainder of the Highland Mainland, are undistinguished in scenic quality, although paradoxically they are less fragile than most other Highland beaches.

In site selection, the demands of the production-platform fabricator are extremely rigorous, and involve a vastly different scale of capital investment compared with recreational uses. The quantifiable monetary benefits resulting from industrial establishment are much higher than those accruing from a purely recreational development and thus such projects are likely to be front runners for any site considered suitable. In Easter Ross there is already an example of the hierarchy and competition engendered by agriculture, conservation, recreation and industrial interests. Large-scale industry has taken priority as a result of these quantifiable monetary and employment benefits mentioned above. The planning process has difficulty in reconciling the essentially secret decision-making of large industrial companies with the open public debate which precedes conservational or recreational land-zonation.

Table 1 indicates that total length of coastline is no measure against which to set loss of land from recreation or conservation interests. In Easter Ross, excluding the Morrich More, only 5% of the coastline is in the form of sandy beaches. The remaining 95% is seldom visited for recreation apart from the minority interests of wildfowling and cliff walking.

The case of Dunskaith beach and dune system (see Figure 1 for location) illustrates the spin-off effects of development on a large-scale, where coastal resources for recreation are few. The construction of the Highlands Fabricators site in 1971 (see Plate 2.1) removed just under one mile of sandy beach from the total Easter Ross beach resources, that is just under 8% of the total sandy beach resources within Easter Ross. Subsequently the dune system at Nigg on the eastern side of the site has been utilised for residential caravans and squatters associated with the yard. The result of this has been to gradually run down the pre-existing amenity of the locality for recreation. The immense traffic associated with the site, the floating dormitory and the physical presence of a huge industrial complex, place obvious barriers to utilisation of the area for recreation. Accepting this, the cumulative total loss of Dunskaith and Nigg Ferry to recreation becomes 13% of the total sand beach resource within Easter Ross. Repercussions have also become apparent at Balintore, where the existing mainly holiday caravan site is now almost fully occupied by residential caravans, occupied by Nigg workers. Increased use of the site all the year round will result in the progressive wear of the nearby dune system. If the site continues to be fully committed to residential caravans, the summer tourist trade may suffer. Were this to occur, it would be reasonable to conclude that

(* The combined area of Easter Ross and East Sutherland)

an initial loss of 8% of the sand beach resource through spin-off induced by large-scale development had repercussions on an additional 13% of the local coastline, a grand total of 21%.

The large-scale development in relatively sparsely populated areas has cumulative spread effects beyond its immediate site. Changes in established recreational habits by both visitor and resident are involved. Development in one part of the Highlands could conceivably increase pressures on more distant and possibly more fragile beaches. Experience suggests a clear need for forward planning of coastal resources on a regional and national scale.

Table 1 Coastline Length and Composition

East Sutherland	
Total coastline length	87.2km
Outer coastline length excluding Dornoch Firth and Loch Fleet	44.1km
Length of sandy-beach coast	23.6km
Sandy-beach length as percentage of total coastline	27.0%
Sandy-beach length as percentage of outer coastline	53.6%
Easter Ross	
Total coastline length	248.0km
Outer coastline length excluding Munlochy Bay, Cromarty Firth and Dornoch Firth	72.1km
Length of sandy-beach coast	21.1km
Length of sandy-beach coast excluding Morrich More	12.6km
Sandy-beach length as percentage of total coastline if Morrich More excluded	8.4% 5.0%
Sandy-beach length as percentage of outer coastline if Morrich More excluded	29.2% 17.5%

Figure 2 Geology

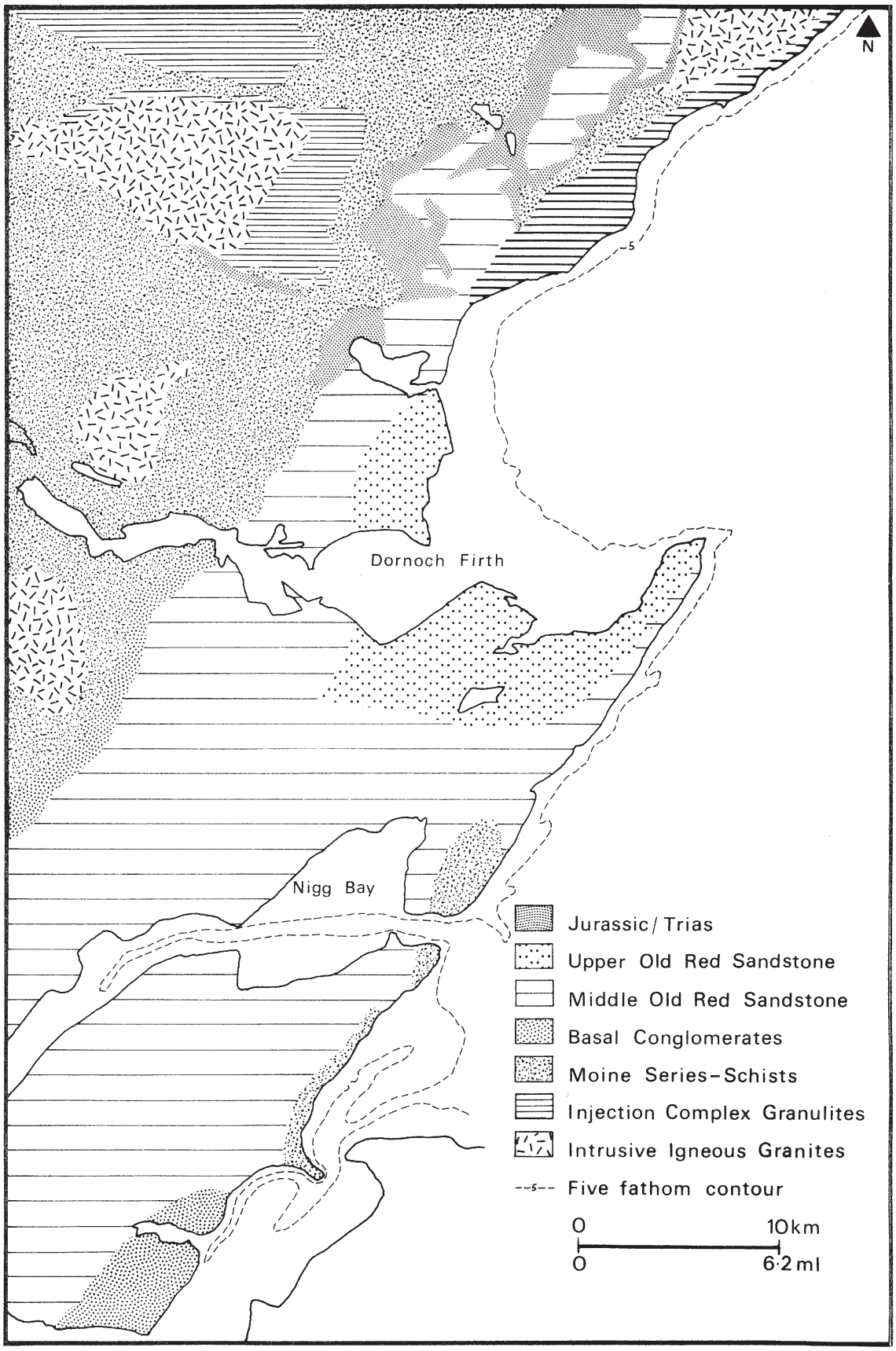


Plate 2.1 The Highland Fabricators Drydock under construction in 1972. Note the comparative ease and speed of remodelling the Dunskaith foreland (shown in its original state in 7.6.1) into an oil rig fabrication yard.

Plate 2.2 The present situation (September 1973) due west of Nigg Beach with dredging still in operation.

3. Tourism, Recreation and the Coastline

The pattern of tourist and recreational use along the East Highland coastline differs from that on the west and north coasts. On the east coast, the local population is larger, and hence local recreational demand is greater. Also, on the national level, the area is less well known as a potential holiday area than, for example, Skye or Wester Ross. Thus the area is visited by fewer touring holiday-makers than some parts of the Highlands, but nevertheless a number of seaside centres offer large amounts of accommodation in hotels and caravans. Much of this accommodation seems to be taken up by holiday-makers spending a week or fortnight in the area, rather than by overnight tourists.

Intensity of recreational use varies greatly from beach to beach in Easter Ross and East Sutherland. One of the primary influences on intensity is level of accessibility. In the first instance, this is controlled by the road pattern in relation to the location of sandy beaches. The road network is dominated by the A9 (T) Inverness to Thurso route, which follows the inner edge of the Moray Firth coastal plain along much of its length, but only to the north of Loch Fleet does the A9 approach closely to sections of the coastline where sandy beaches occur. A number of other roads lead off the A9 towards the Black Isle and Easter Ross peninsulas, but these roads have blind endings and do not attract large numbers of touring holiday-makers. Even the A9 carries only a modest tourist traffic: the section in East Sutherland, with an estimated flow of 5000–10000 tourist-vehicle journeys per week in summer is less popular than, for example, the Wester Ross loop between Gairloch and Braemore Junction, with a weekly flow of between 10000 and 15000 journeys (Carter 1971).

The road pattern is not the only control on accessibility. Even where a major tourist route approaches closely to a sandy beach, it does not necessarily follow that the beach is easily accessible. Real or perceived barriers such as railways, fenced land, built-up areas or golf courses may intervene between road and beach, and may effectively deter tourists from reaching the shore. A good example of the effectiveness of these barriers occurs at the north end of Brora (Dalchalm) beach, where the beach is only a few metres from the A9, but is separated from it by the railway. Thus at the local scale, slight variations in physical ease of access are extremely important in controlling intensity of recreational use, and their manipulation by the provision of footpaths and car parks offers an effective tool in the planning of developments in beach recreation.

Parts of the sandy-beach sections of the East Highland coastline are intensively used for caravanning. The pattern of caravanning activity is strongly concentrated in two main centres, around Dornoch and Embo in East Sutherland, and Fortrose-Rosemarkie in the Black Isle. Brora is emerging as a third but, as yet, smaller centre. Within 3.5km of the centre of Dornoch, there is site capacity for over 500 caravans*, forming a concentration unique in the Northern Highlands. The other main concentration on the East Highland coastline is around Fortrose and Rosemarkie, where there is capacity for over 150 units*. These concentrations are not only unusual in size, but are also characterised by high proportions of static units. Around Dornoch, 37% of the stances are for static caravans, while the proportion rises to 58% at Rosemarkie-Fortrose. With the exception of Brora, most of the other coastal caravan sites are small and widely scattered. The resultant pattern of caravanning is thus strongly concentrated at a small number of points located near sandy beaches.

(* These figures are calculated from the Caravan Club Sites Directory and Handbook 1973)

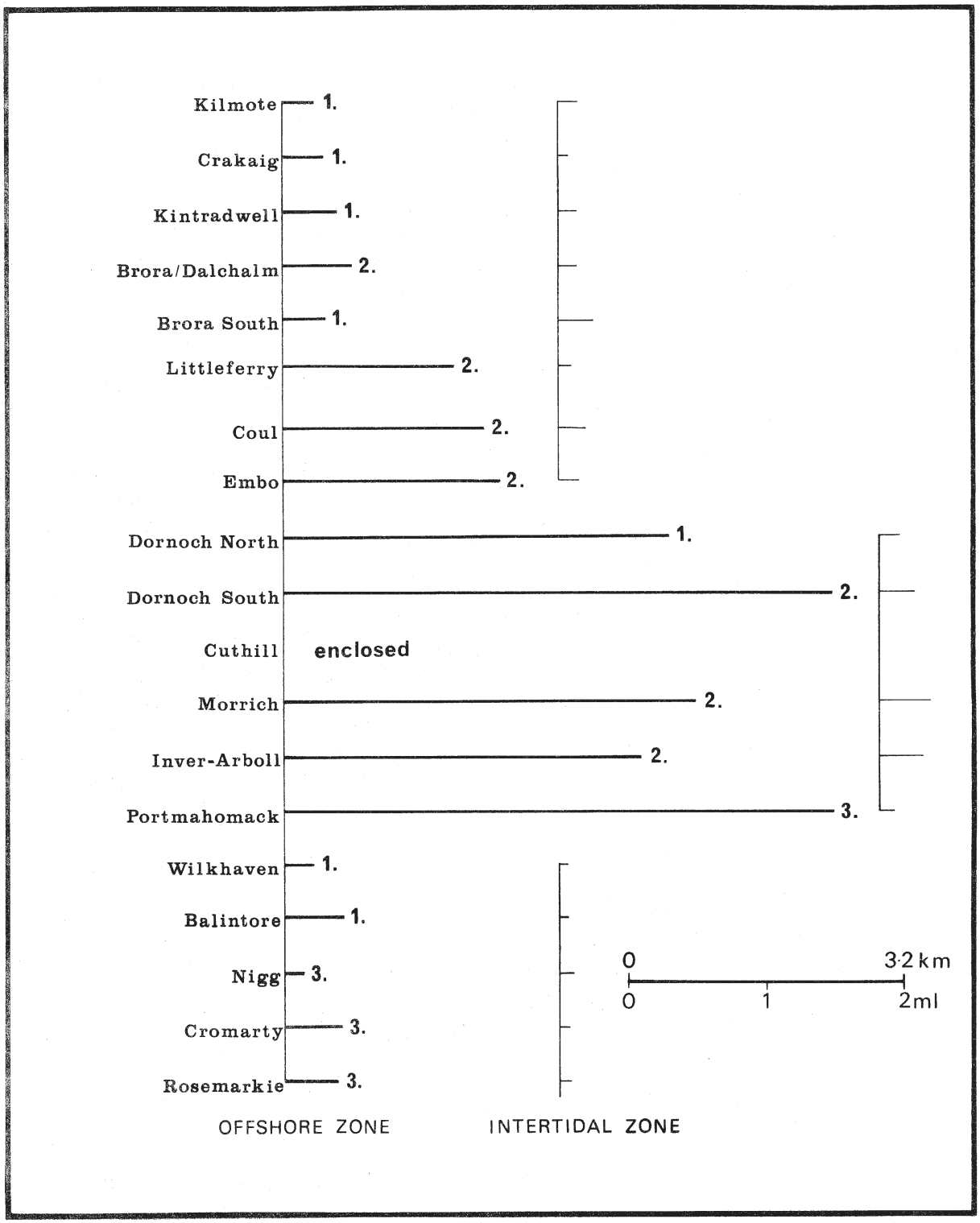
The patterns of distribution of other holiday accommodation are also strongly concentrated in a small number of centres. Large hotels catering for the golf and seaside holiday markets are mainly confined to Dornoch, Rosemarkie and Brora. Other types of residential accommodation, orientated more towards the overnight market, have broadly similar patterns of distribution. Thus the pattern of tourist accommodation closely resembles that of caravan sites; a small number of points offer most of the available accommodation along the East Highland coastline, and potential pressure on sandy-beach resources is strongly peaked around Dornoch, and, to a lesser extent, at Rosemarkie and Brora.

Population density in Easter Ross and East Sutherland is higher than in other parts of the Highlands, and the local population is at present rapidly increasing. Thus local demand for beach recreation is greater than along most of the north and west coasts, and must be considered in addition to tourist demand. Few beaches, however, occur in close proximity to the main population centres along the north shore of the Cromarty Firth, and car journeys of 30 minutes or more are necessary if beach recreation is to be enjoyed. Accessibility, and in particular the relationship between road and beach, is therefore almost as strong an influence in the pattern of local recreational use of beaches as it is in tourist use. Local demand tends to supplement tourist demand rather than complement it, and is likely to reinforce the potential pressure at Rosemarkie, and eventually, if a Dornoch Firth bridge is constructed, also at Dornoch.

Both local and tourist demand exists for golf, and a large proportion of the sandy-beach coastline is backed by golf courses. Characteristically, the golf course occupies the links and raised-beach zone landward of the sandy beach. The relatively intensive management associated with many golf courses often means that trampling damage or blow out development is quickly checked in its early stages, and in general terms the golf course type of land use is in close harmony with the physical environment.

In summary, the pattern of tourist activity is one of strong concentration near two or three sections of sandy beach. Local demand tends to emphasise this concentration, and the combination of increasing local population and an improvement in communications in the area may lead to a build up of pressure at these centres. Such a build up is most imminent at Rosemarkie.

Figure 3 Width of offshore zone and inter-tidal zones



Note

The width of the 'offshore zone' gives an indirect measure of gradient, probability of material availability within wave base, and potential for bathing. The beach units are numbered 1, 2, or 3 in relation to the types established in 4.2

Plate 3 Balintore – a typical cliff-foot beach and dune system. A considerable part of the original dune and machair system has been covered with settlement land uses.

4. The Physical Background

4.1 Geology

The geological structure of East Sutherland and Easter Ross is depicted on Figure 2. It comprises the two major geological provinces of the Moine basement and the Upper and Middle Old Red Sandstone beds which rest on top of it. Younger Triassic and Jurassic beds survive in the immediate vicinity of the coast. They have been preserved in a downfaulted position beside the north-east to south-west trending Great Glen fault which forms the trend of the outer coast. The fault-scarp cliff coastline of the outer coast is in striking contrast to the elongated firths which occupy structural depressions within the sandstone beds.

The coastlands are generally underlain by Old Red Sandstone beds or more recent rock series (see Figure 2) and the underlying Moine schists only outcrop at the coast in the North and South Sutors, the entrance to the Cromarty Firth. The sandstone varies in the calibre of constituent materials from place to place, but in general, the basal conglomerate beds outcrop on the western margins of the sandstone outcrop, notably at the head of Loch Fleet where they form upstanding tabular hills such as the Mound Rock. The south-eastern scarps of the Black Isle behind Kessock and extending north towards Avoch, together with the Struie Hill ridge, form additional examples of the relatively vigorous relief typical of the basal conglomerate beds.

The finer-grained sandstones, on the other hand, dip eastwards at low angles, and form more monotonous relief as in the Dornoch coastlands or the Black Isle. North of Golspie, the sandstone-based coastal plain is replaced by the varied beds of the Triassic and Jurassic series, but these younger rocks are largely masked by Pleistocene deposits, and the main landscape units in the area are the basal conglomerate scarps behind Brora.

While varying lithologies and rock types have important effects on the rock coasts within the area, the soft coasts described within this report are seldom affected by such variations, except through the distribution of rock outcrops which act as headlands or hinge points for the accretionary beach and dune complexes. With the exception of Kilmote, Crakaig and Kintradwell in East Sutherland, and Wilkhaven and Balintore in Easter Ross, which are cliff-girt and fronted by abrasion platforms, most beaches are built up around Pleistocene glacial and marine deposits. Abrasion platforms, where present, reduce offshore gradient, and are associated with high shell contents of the beach, dune and machair sand. For example, Wilkhaven has the highest proportion of shell-sand in both beach and machair in the whole area. In general, bedrock adds dimension to beach scenery, provides shelter from onshore winds in cliff-foot situations, but is seldom an important factor in beach evolution or sediment supply.

The Pleistocene deposits, on the other hand, are vital to an understanding of the formation of beach and dune complexes, and probably also form the source of offshore supplies both at present and in the post-glacial period. These deposits are discussed in 4.2.

Plate 4 Part of the parabolic dune system of the Morrich More. The system continues to evolve and is of the highest physiographic interest.

4.2 Regional Coastal Forms

The coastal landform associations within East Sutherland and Easter Ross are closely correlated with the pre-existing major embayments of the Cromarty Firth, the Dornoch Firth, and Loch Fleet. These form the 'inner' coastline as compared with the 'outer' coastline mentioned in 4.1., which is delineated by the northerly prolongation of the Great Glen fault. The topographic expression of the faultline is in the degraded fault-line scarp, which forms the back to many East Sutherland beaches, for example, Kintradwell.

Changing late and post-glacial sea levels in conjunction with isostatic recovery of the land following on deglaciation has resulted in the re-sorting and re-distribution of glacial materials from both land and offshore situations to create the low soft coastline which form the subject matter of this report. The re-sorting processes include wave, wind and running water. The size, constitution and situation of the beach and dune complexes are closely related to availability of material, exposure to wind attack, and offshore gradients. Most of the major soft coast complexes are built out seawards at the post-glacial level and extend right down to the present zone of land-sea interface.

As the post-glacial shoreline was displaced seawards following on the Main Flandrian transgression, the Firths shallowed and functioned as sediment traps for both land and sea-derived materials. Shoreline simplification proceeded through the construction of spits and strandplains where material was continuously available. The partial barring of Firth entrances by composite shingle bars, as at Loch Fleet, further increased rates of sedimentation, and the sandflats and saltmarshes began to build up. Frequently the barrier beaches which underlie the blown sand accumulations in the strandplains are composed of shingle, re-sorted from offshore fluvio-glacial deposits lying beyond the present coastline. Such deposits form a firm base on which the dune systems of Coul Links and Ferry Links have accumulated. Cuthill Links and the Morrich More strandplain form equivalent formations within the lower Dornoch Firth. The strandplain formations in the Lower Dornoch Firth are a unique physiographic record of shoreline change over the last ten thousand years.

On cliff-girt 'outer' coastlines such as Tarbat Ness and the Black Isle, the physical opportunities for the creation of extensive beach and dune systems are reduced by greater offshore gradients (see Figure 3) and there is less opportunity for longshore movement of beach materials. The extent of low landward topography is restricted, and in such situations, the beach tends to be straight or slightly convex seawards. The foredune system is long and narrow and rests on top of the post-glacial beach, itself generally composed of shingle. Wilkhaven, Kintradwell and Balintore form clear examples of this type of coastal situation. The steep topography to the landward prohibits the development of an extensive machair.

The clear majority of soft coastlines with recreational potential lie on the 'outer' coastline, with only Cromarty, Portmahomack and Nigg Ferry lying within the inner coast, sitting in the shelter of their respective headlands. Where sand availability is combined with exposure to westerly winds, as at Dunskaith-Nigg, a major dunefield resulted with old grey dunes running up the side of the Hill of Nigg. In the other two cases specified, lack of sand supply in the past prevented a substantial dune system forming. Dunskaith in its original form before development had many of the characteristics of a West Highland beach.

The major part of the inner coastline consists of sandflat, lag shingle beaches or saltmarshes. Both the Cromarty Firth and the Inner Dornoch Firth fall into this category despite their very different depths. The scale of the firthland inter-tidal zone is immense. The total inter-tidal area between Nairn and Dornoch is

approximately 9600ha, of which 3250ha is within the Dornoch Firth, and an almost identical area within the Cromarty Firth. Although the interpenetration of land and sea is a regional attribute, recreational interest is clearly localised along the outer coastline.

As can be seen in Figure 3, the offshore gradients are lowest in the Dornoch Firth, and highest in the cliff-girt coastlines. There is also a broad correlation between the breadth of the offshore zone to the 5 fathom mark and the physical area of the beach and dune complexes.

Analysis of offshore sediment frequency from existing Admirality charts indicates that sand deposits within the 5 fathom line are very frequent between Dornoch Point and Tarbat Ness, low between Dornoch and Brora, and almost non-existent south of Tarbat Ness.

Table 2 Offshore Sediment Frequency Analysis*

	r	s	fs	s.sh	fs.sh	other	No. of observations
Percentages							
Brora to Dornoch Point	4.6	36.4	29.6	15.9	2.3	11.2	44
Dornoch Pt.–Tarbat Ness	–	76.0	20.0	–	4.0	–	25
Tarbat Ness – Rockfield	–	100.0	–	–	–	–	6

(r – rock, s – sand, fs – fine sand, sh – shells.)

*Refers to deposits between low water mark and the 5 fathom line.

While the data given above are sparse and unsatisfactory, the map evidence supports the field impressions of rapid and continuing accretion at the beaches of the Lower Dornoch Firth, and very limited sand reserves off Wilkhaven.

Broadly, the East Sutherland and Easter Ross beaches can be classified into three types on the criteria of general situation and landform association, namely the cliff-girt beaches backed by old degraded cliffs, the large composite strandplains which have substantial components at both post-glacial and recent land-sea relationships and the small beaches fringing post-glacial raised shorelines, frequently with old grey dunes blown up the relatively subdued topography which backs them (see Figure 5).

Table 3 Beach Types

1) Cliff-girt beaches	2) Strandplain-composite spit beaches	3) Cuspate-foreland beaches
Balintore	Brora Dalchalm	Cromarty
Brora South	Coul	Nigg Ferry
Crakaig	Cuthill Links	Portmahomack
Dornoch North	Dornoch South	Rosemarkie
Kilmote	Embo	
Kintradwell	Inver-Arboll	
Scart Craig	Littleferry	
Wilkhaven	Morrich More	

There are very large differences in scale between these groups. In general, the cuspate foreland beaches are backed by historic settlements which occupy much of the land behind the beach. These settlements were developed for recreation because of situation on road networks, available services which could be utilised by visitors, and frequently piers or harbours which could be used for mooring small craft. Tourism has not required substantial investment. In all cases, the existing development of recreational facilities is close to the threshold of saturation. Modification of old fisher houses which is an increasing trend in these settlements requires careful planning to prevent erosion of the architectural character of the village.

The cliff-girt group have generally been less developed for tourism. This can be viewed as a response to inaccessibility induced either by topography or by sheer distance from the road. Balintore is physically one of this group, but falls into the third group in terms of its recreational facilities and resultant pressures. The remainder of this group, with the possible exception of Scart Craig (Rosemarkie), would require considerable investment were tourist development considered desirable. Several of them, notably Wilkhaven, have very limited beach resources.

The strandplain group is by far the largest in total area and size of individual units. The low energy nature of the coastline has created low dune ridges, despite the plentiful supplies of offshore sand, and the units are relatively flat and open. Development in such situations, whether for recreation or industry, is thus often visible for considerable distances. All of the strandplain beach and dune systems rest on intrinsically stable post-glacial forelands. However the blown sand deposits which overlie the shingle deposits are frequently thin and are liable to respond unfavourably to man-induced pressures. Such a landform association is attractive for gravel extraction, but it should be noted that almost all the strandplains have exceptional physiographic interest. The area is well endowed with sand and gravel deposits, and alternative supplies always exist within a short distance.

With the exception of the Morrich More where both erosion and accretion are locally rapid, most of the strandplain beach and dune systems are stable in contrast with most other Highland beaches. The size of the units in this group is also unusual in the Highland context. They offer a reserve of relatively stable resources which could withstand additional pressures provided the appropriate safeguards are ensured. However the complexity and undeveloped nature of the strandplains result in a wide range of flora and fauna in addition to their physiographic interest, which is regionally, and sometimes nationally, unique, and therefore conservation interests occur here which require protection. (Chapter 8, Figure 8).

4.3 The Climatic Factor

The coastal strip of East Sutherland and Easter Ross enjoys a climate characteristic of east coastal locations. The hill masses to the west provide some shelter from the prevailing westerly winds, and the climate is dry and relatively sunny.

Perhaps the main climatic characteristic is dryness. Tarbat Ness is one of the driest rainfall recording stations in the country, having a mean annual rainfall of only 560mm. Although rainfall increases slightly both northwards and southwards (to 850mm at Brora and 625mm at Nairn), precipitation is modest along the whole length of the coastline. As well as being low in total, rainfall is relatively infrequent. On average, rainfall of more than 0.1mm occurs on 12 days* per month at Kinloss in Morayshire, which is the nearest station for which detailed figures have been analysed (Plant, n.d.).

Despite a slight tendency for a summer maximum of rainfall, with 52% of the total occurring from April to September inclusive, the low total precipitation suggests that the climate is favourable for tourism and outdoor recreation. It also implies that beach and backshore sand is relatively infrequently moistened by rainfall, so that sand is free to blow for much of the time, provided that wind strengths and directions are suitable.

Sunshine incidence is moderately high. Forres and Fortrose have average daily totals of bright sunshine of 3.69 and 3.48 hours respectively, compared, for example, with 3.64 hours for Edinburgh (Royal Botanical Gardens) and 2.96 hours for Lerwick. Fog incidence is low, and appears to decrease westwards and southwards along the Moray Firth. The average annual number of mornings with fog at 09.00 hours is 5 at Tarbat Ness, 3 at Fortrose and 4 at Nairn. By comparison, the figures for Wick and Rattray Head are 9 and 11, respectively. Mean annual temperatures are 8.2° and 8.8°c at Golspie and Fortrose, as compared with 7.9° and 8.0°c at Wick and Rattray Head. The climate is thus relatively sunny and warm, and its dryness is reinforced by strong evaporation rates. There is a net moisture deficit along most of the coastline, and the vegetation on dunes and links must be adapted to this dryness as well as to the immature, excessively drained soils on which it develops.

The nearest recording stations for which detailed wind statistics are available are at Kinloss and Wick, situated respectively 38 and 83km from Dornoch. The coastline of the East Highlands lies between these stations, but since local relief may modify wind regimes, it cannot be assumed that either set of statistics, or even their intermediate values, can be directly applied to all the beaches of East Sutherland and Easter Ross. Since these stations are the only ones available, however, their statistics must be accepted, and in general terms are probably applicable.

Figure 4a illustrates the main characteristics of the wind regimes, and illustrates the contrasts between Kinloss and Wick. At Kinloss, the prevailing winds are from the south-west; 38.8% of all winds, and 41.0% of the winds stronger than 25mph blow from between 200° and 250°. At Wick, however, only 16.2% of the winds are from the south-west, and the most frequent wind, blowing 22.2% of the time, is from the south-east. Thus it is clear that the wind regime varies considerably along the north shore of the Moray Firth. The coastline of the inner Moray Firth probably experiences a regime similar to that of Kinloss, but north of Dornoch the regime is possibly more similar to that of Wick (Plant n.d.). Most of the East Highland beaches

(* A day is here defined as the period between 07.00 and 17.00 hrs.)

face south-east (Figure 9), so that south-easterly winds function as the onshore winds for most of the beach units. Thus the frequency of onshore winds probably increases northwards. The relative frequency of strong winds from the south-east is also much higher at Wick than at Kinloss. At Wick, 22% of all winds stronger than 25mph come from the south-east, while at Kinloss only 5% of the strong winds come from this direction. Thus the beaches in the north part of the East Highland coastline are exposed to higher energy conditions than those further south.

Average wind velocity is higher at Wick than at Kinloss. The median velocity at Wick is 12.5mph, while that at Kinloss is 11.0mph. Wind velocity is under 11mph for 50% of the time at Kinloss, but only for 40% of the time at Wick (Figure 4b). Since velocities of less than 11mph are unable to move sand (Zenkovitch 1967), it follows that wind conditions are suitable for sandblow for a shorter proportion of the time where the regime is similar to that of Kinloss than where it resembles Wick. Thus wind conditions are likely to be suitable for a sandblow for a longer period of time on the beaches north of Brora than, for example, at Balintore.

Onshore winds of sufficient strength to move significant quantities of sand from beach to dunes are probably less frequent on the East Highland coastline than on much of the Atlantic coast, despite the fact that higher and more frequent rainfall in the west and north inhibits the movement of sand grains more often than in the east. Many of the dune zones in East Sutherland and Easter Ross are composed of relatively small quantities of sand, and with certain exceptions they are subdued, low energy forms. Only where the influence of westerly winds is felt, as in the more exposed parts of the Morrich More, Coul Links and Dornoch Point, have bigger and steeper dunes evolved.

Figure 4a Annual Percentage Frequency of Wind Direction and Velocity – Kinloss and Wick

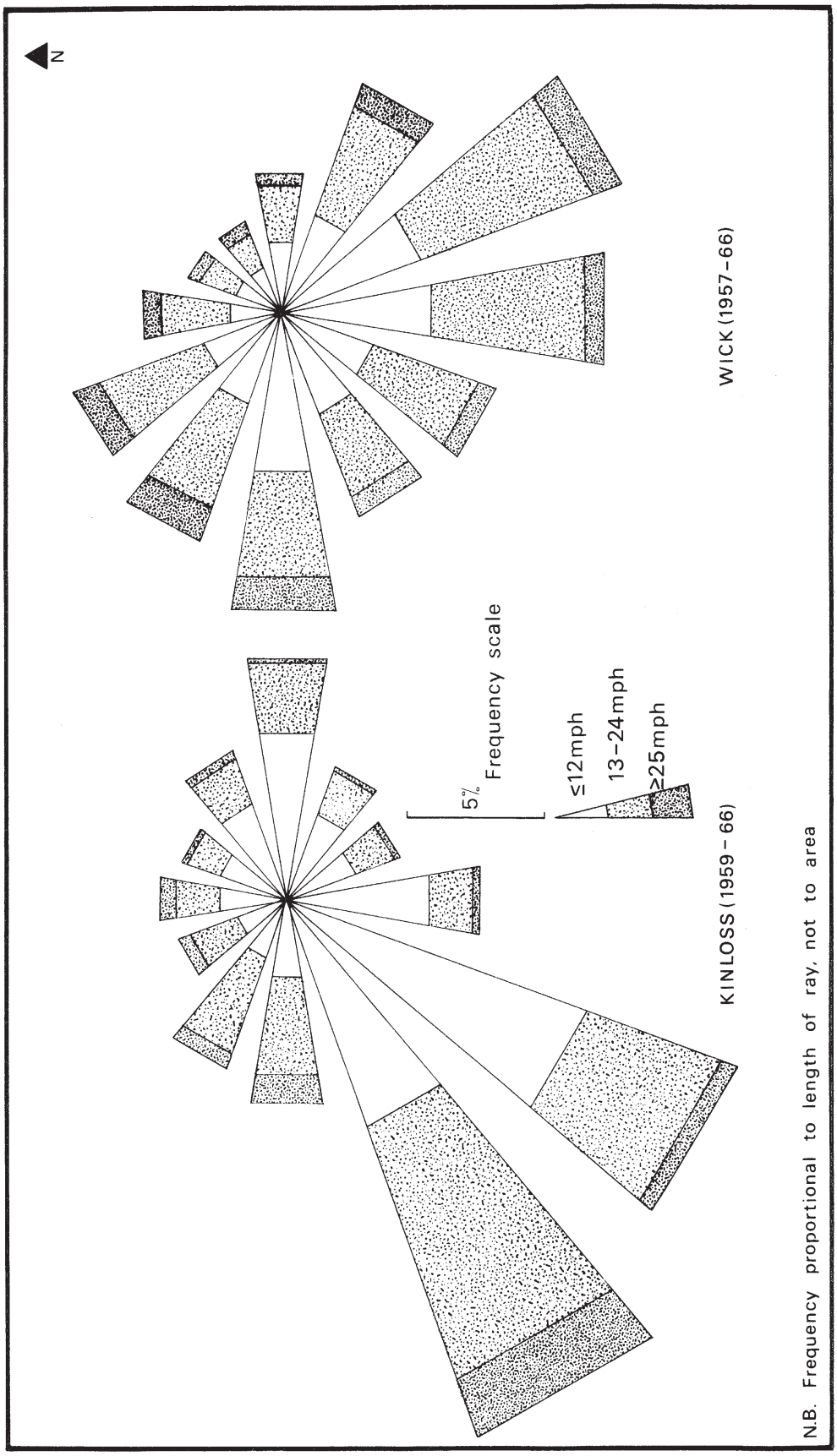
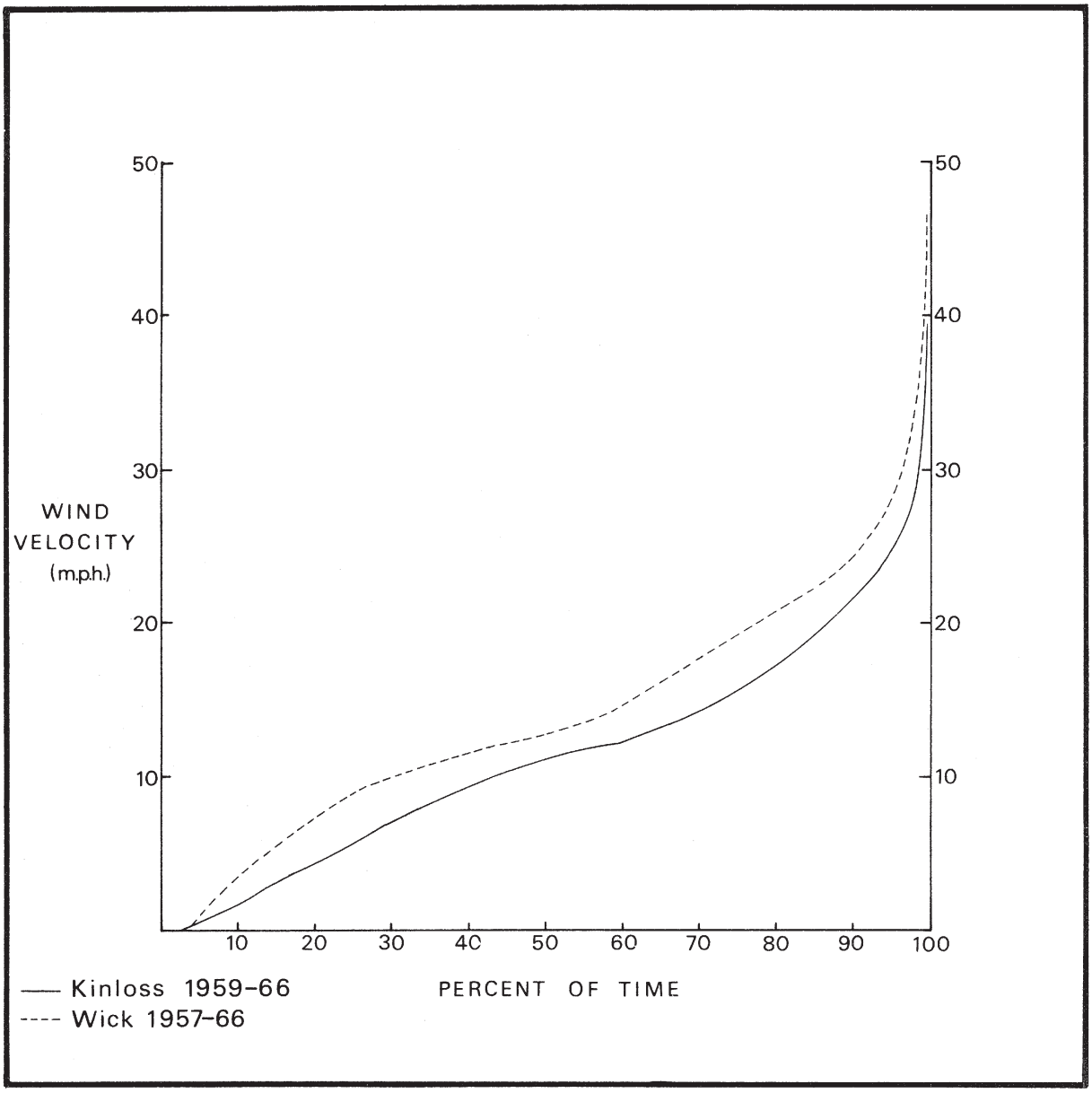


Figure 4b Cumulative Frequency of Wind Velocities at Kinloss and Wick



5. Access to the Coast

The successful provision of recreational facilities on the coast is dependent not only on the intrinsic amenity of the individual beach unit and its tolerance to withstand pressures satisfactorily, but also on its accessibility from the point of view of proximity to main tourist routes, ease of physical access, and freedom from restriction of access resulting from adjacent land uses. The recreational uses of beach and dune complexes can be as either a holiday camping and caravanning site, a recreational area for casual visitors, or a combination of both. Frequently the casual visitor takes advantage of the access provided for the caravan site. In addition, military interests or conservation measures may impose restrictions on access at certain periods. Examples of such restrictions include bombing or the nesting of terns. The rational utilisation of beach and dune resources will allow for the co-existence of present land use interests with planned recreational development, judiciously improving and negotiating access where necessary.

Various categories of accessibility may be recognised and Table 4 indicates conditions of accessibility for each beach unit in East Sutherland and Easter Ross.

a) Access to beach direct from tarmac road – car parking facilities provided.
b) Access to beach at one end only – walking required.
c) Access to beach by path down steep cliff.
d) Access to beach from car park or caravan site – moderate walking required.
e) Access to beach impeded by golf course, railway, fenced agricultural land.
f) Access to beach restricted by military or conservation interests.
g) Access to beach hindered by distance from vehicle to beach.
h) Access to beach hindered by lack of parking facilities nearby.

It should be noted that these categories are not mutually exclusive and any single beach unit may fall into several of the categories. Where a beach unit can be entered from several points, it is categorised in Table 4 on the basis of the easiest access point.

The existence of ease of accessibility constraints form a useful zoning device, although ingress at only one end of a beach can lead to 'overpopulation' at a particular point. The decision to improve access should thus be taken on the basis of full knowledge of existing physical resources and pressures *within the region*, as well as the predicted capacity of a particular beach unit.

The b and g status of the Morrich More is an advantage in that conservation and military interests are protected at present without 'policing the ground'. The Arboll section of the Inver-Arboll beach is relatively fragile because the accretion of sand in the yellow dune phase is vigorous and liable to rapid change – a characteristic of this particular stage in dune formation. A yellow dune phase responds unfavourably to high recreational pressures. Safe development of the Inver-Arboll beach and dune resource thus becomes possible only with careful planning of improved access *via* the size and type of caravan site, its position in relation to Arboll, and the size of the car parking facilities provided for day-visitors.

In other words, there exist at present differing degrees of accessibility which can be consciously changed to manage the natural drawing attributes of a particular beach unit which lies at a distance from the tarmac road. Beaches which are immediately accessible from the road (category a) are extremely difficult to

conserve in the face of visitor pressures. Beaches which are at some distance from the road (categories c, e, g and h) are naturally zoned, and their levels of use by the general public can be planned through a decision to improve access by a certain degree, or alternatively, by planning not to improve access. Such decisions involving access improvement should be taken on a regional and national overview of the coastline rather than on purely local considerations.

Natural zoning can be modified by the degrees of publicity released by the Scottish Tourist Board, the Highlands and Islands Development Board and the local and regional tourist associations. The decision to include a photograph of a particular beach in advertising literature or guide books will have repercussions on its popularity with the summer visitors of a particular year. In some cases, it would be useful to overcome the natural rivalry existing between regional tourist associations to attract visitors by underplaying the attractions of particularly popular beaches which are either fragile or overpopulated. There is clearly scope for manipulation of the push and pull effects implicit in public desire to visit a particular stretch of coastline.

Restraints exist as barriers on the ground (categories e and c) as well as in terms of the public knowledge of the existence of a particular beach. Forward planning might well review beach resources in the Highlands on this latter basis. It is a concept already familiar to those concerned with the management of National Parks and National Nature Reserves, where conservation of the resource requires unequal distribution of public pressures.

Table 4 indicates those beach units within the area of study which have existing ready access from a tarmac surface. In these cases, should deleterious pressures become apparent, only severe restrictions could be employed as remedies. Such restrictions would be difficult to enforce. On the other hand, other beaches are less accessible, and an opportunity exists to be selective in 'opening them up' as recreational centres.

Table 4 Accessibility

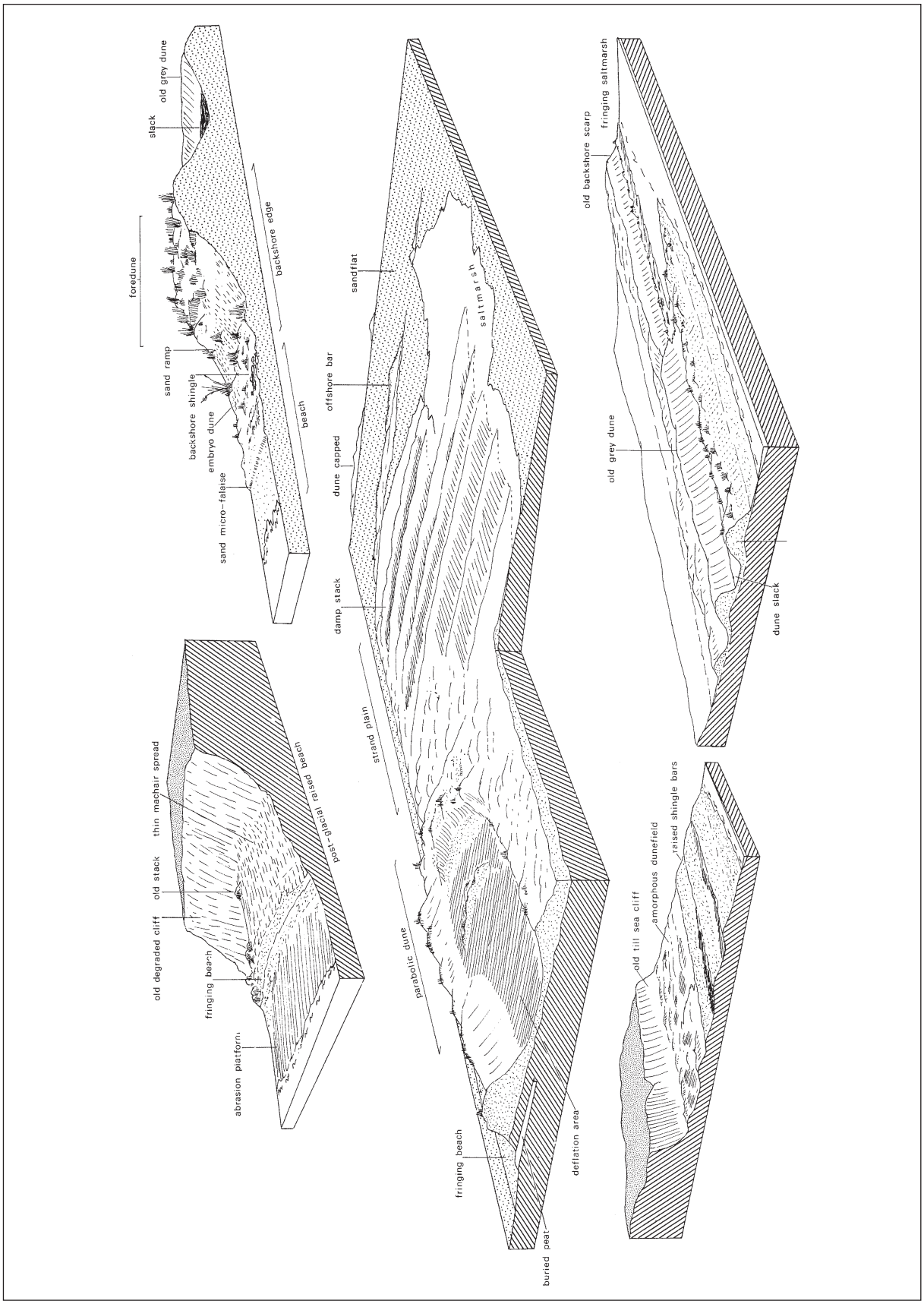
	Accessibility categories a-h							
Beach unit	**a**	**b**	**c**	**d**	**e**	**f**	**g**	**h**
Kilmote					✔		✔	
Crakaig								
Kintradwell			✔		✔		✔	✔
Brora Dalchalm		✔		✔	✔			✔
Brora South				✔		✔		✔
Golspie-Littleferry	✔	✔			✔			
Coul		✔			✔		✔	
Embo	✔							
Dornoch North		✔		✔	✔			
Dornoch South	✔	✔						
Cuthill Links		✔			✔		✔	✔
Morrich More		✔				✔	✔	✔
Inver-Arboll		✔					✔	✔
Wilkhaven				✔				
Portmahomack	✔							
Balintore		✔						
Nigg Ferry		✔						
Rosemarkie	✔							
Scart Craig	✔							
Cromarty								

In the ensuing beach descriptions, East Sutherland beaches are discussed in Chapter 6 and those of Easter Ross in Chapter 7. Within each Chapter, the beaches are numbered sequentially, commencing in the north. The same section number denotes Plates and Figures – for example, Brora (Dalchalm) beach, discussed in Section 6.4. is illustrated by Plate 6.4. and Figure 6.4.

As far as is practicable, each component of a beach unit is systematically discussed under standard headings as follows:

1 General setting
2 Beach and coastal edge
3 Dunes
4 Machair
5 Dynamic relationships
6 Vegetation
7 Land use
8 Recreational use
9 Recommendations
10 Summary

Figure 5 Nomenclature and model beach type in East Sutherland and Easter Ross



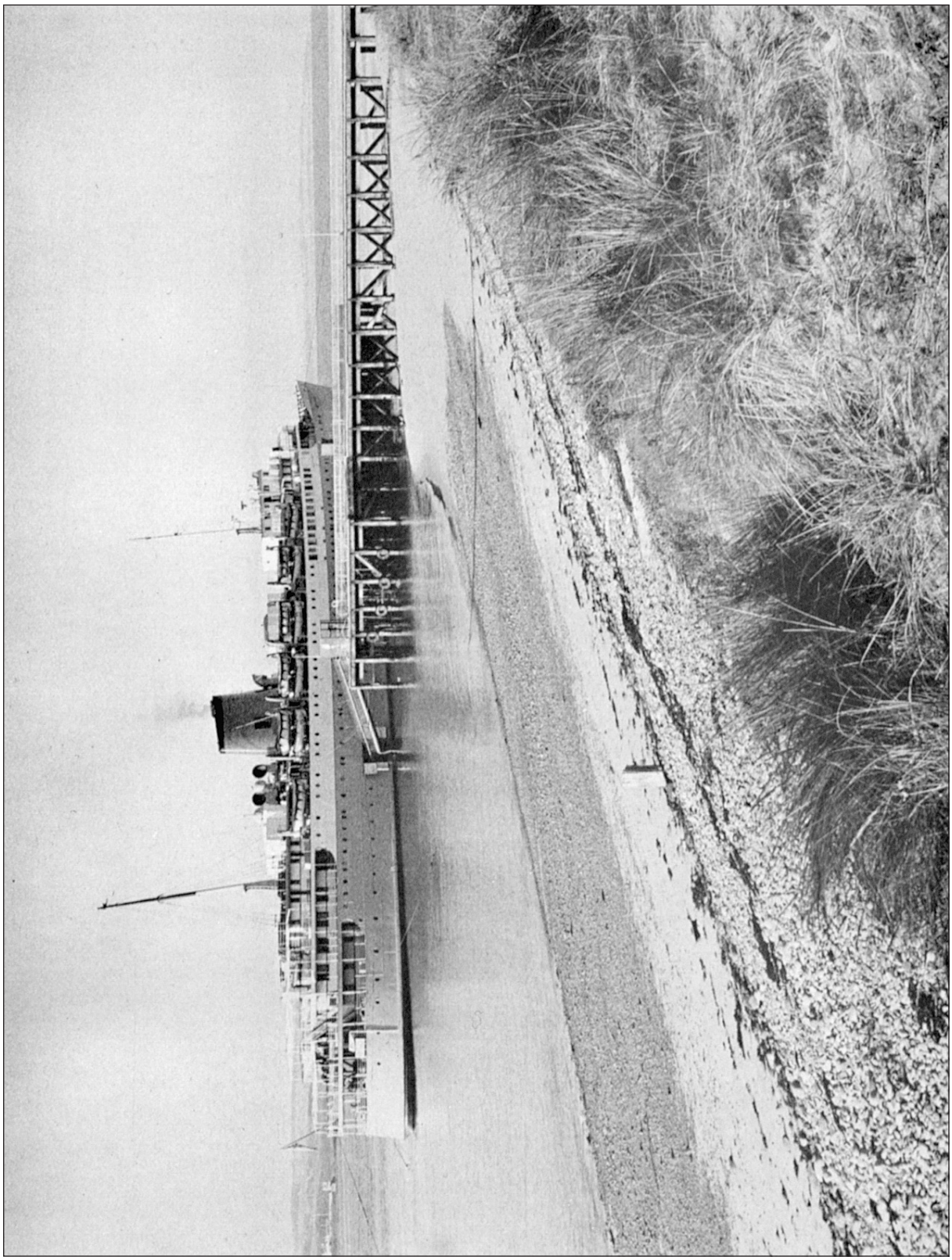


Plate 5 The Highland Queen, Nigg and Nigg beach.

6. Regional Description of Coastal Areas – East Sutherland Beaches

Typical Characteristics

A high proportion of the length of the East Sutherland coastline is in the form of sandy beaches. Of the coastline between Dornoch Point and the county boundary near Helmsdale, 38% is sandy beach, and if the coastline around Loch Fleet is excluded the percentage increases to 50. Thus sandy beaches are relatively more important components of the coastline than elsewhere on the Highland mainland. Within East Sutherland, the longest stretch of sandy beach extends for almost 14km from Dornoch Point to Golspie, interrupted only by the outlet of Loch Fleet and by a few reefs near Embo. This is the longest stretch of beach in the mainland of the Highlands.

Most of the beach units are strongly influenced in their morphology by raised shorelines, notably those of the post-glacial sea level. Beaches backed by distinct relict cliffs include Kilmote, Crakaig, Kintradwell, Brora South and Dornoch North, while Golspie-Littleferry and Brora (Dalchalm) have been constructed against raised shingle ridges. Although bedrock outcrops in or near many of the beaches in the form of low reefs, rocky headlands are poorly developed, and few of the beaches are of the bayhead type common on the west and north coasts.

The offshore gradient steepens from south to north. Most of the offshore zone (to 5 fathoms) in the south half of East Sutherland is sand covered, but in the steeper north sector the sand cover becomes less complete. Estuarine processes play important roles in beach construction at the mouths of Loch Fleet and the Dornoch Firth, but elsewhere fluvial processes are generally weak and relatively insignificant in beach development.

Most of the beaches of East Sutherland are characterised by subdued dune topography, and indeed some of the beach units lack a dune zone. Shelter from both sea and wind is generally relatively strong although it probably decreases northwards, and most of the beach units are less dynamic than their counterparts in the north and west. Most of the links or machair areas are composed of a thin layer of blown sand overlying raised-beach gravels, and in many beach units there is a very gradual transition between dune and links zones.

6.1 Kilmote

Kilmote beach consists of a long sandy fringe backed by a narrow dune zone, behind which is a relict cliff cut mainly in glacial deposits. Towards the north end of the beach, this cliff rises in height to over 60m, but in the central and southern sectors of the beach it is very much more subdued. The beach extends to approximately 1900m in length, but is relatively narrow, not exceeding 60m at its central point. A series of rocky reefs and lag deposits of inactive cobbles interrupt the beach plan and divide it into a number of quasi-separate sections. The railway follows the raised beach at the base of the relict cliff, and marks the effective landward limit of dune development. Between the railway and the A9 (T) lies a belt of cultivated farm land. There is neither track nor footpath to the beach, and access from the main road is difficult. Hence the intensity of recreational use of the beach complex is extremely low.

The beach is composed primarily of medium sand (median diameter 0.39mm) with a lime content of 40%. North of the mouth of the Culgower Burn, fresh shingle has accumulated discontinuously near high water mark, while at the stream mouth itself a mixture of sand, gravel and coarser sediments has built up. On the lower beach, lag sediments, mainly in the form of immobile cobbles are exposed in places. At the extreme north end of the beach, these sediments rest directly on a platform of Jurassic sandstones and shales. Indeed the whole length of the beach seems to be thin, with limited quantities of sand overlying a subsurface rock platform veneered with cobbles and boulders washed from glacial deposits. The distribution of sand on the beach and infra-tidal zones is likely to be highly variable; after a period of strong onshore winds, for example, the amount of sand is likely to diminish. Thus the distribution of sediments indicated in Figure 6.1 refers to a specific point in time; considerable seasonal changes are almost certain to occur. The gradient of the central part of the beach is steep, at 9°, although the beach segment contained between reefs at the extreme north is more gentle at 6°. In general, however, the beach is steep and narrow, especially when compared with other beaches in East Sutherland and Easter Ross. Likewise, the backshore is also narrow although some widening occurs near the stream mouth. The rate of accumulation of sand appears to be very limited at the present time, but on the other hand there is no evidence that supply was ever particularly copious. During the post-glacial period, vigorous erosion of morainic material along the coast must have yielded considerable quantities both of sand and of coarser material. The cliffs of the post-glacial coastline are now isolated and insulated from continued erosion by more recent beach and aeolian accumulations.

The lower section of the Culgower burn has a gentle gradient, and seems unable to supply large quantities of sediment, although its northern section may have been an important contributor in the past. At the present time, much of the mineral fraction of beach sand probably comes from the remaining transportable material offshore, together with the recirculation of material from the undercutting of the modern dune front.

At the extreme south end of the beach, the coastal edge is in the form of a low cliff, not more than about 2m in height, while further north towards the stream mouth, erosion gives way to deposition as the dominant coastal edge process. North of the stream mouth lie alternating sections of low (1–2m) inactive cliffs cut into mature dunes, and higher edges of about 7m, which are neither advancing or retreating. At the extreme north end of the beach, the coastal edge heightens rapidly, reaching a maximum of about 12m in a rapidly retreating, undercut dune edge. In general terms, the coastal edge seems to be retreating rather than advancing, but this retreat is irregular and is not occurring over the whole length of the beach. There does, however, appear to be a slight tendency for straightening in the beach plan, with retreat at either end and relative stability in the centre.

The dunes at Kilmote are for the most part low and subdued, and are almost entirely fixed. Blow out development is almost completely lacking, and at present the dune zone is stable with respect to wind action. South of the stream mouth, the height of the dunes rarely exceeds 6m. The main ridge crest is separated from the coastal edge by a relatively gentle slope of about 12°; landwards, the frontal dune ridge merges into a rather featureless zone of low, Marram-clad hillocks, terminating abruptly against the low relict cliff line of the post-glacial sea level. Only for approximately 100m immediately south of the stream mouth are there signs of recent dune accretion; even here the rate and amount of accretion are insignificant. North of the stream mouth, dune height rises from about 6–10m before decreasing once more to the former level. The backslope is relatively gentle at 3–4°, and the dune zone, which terminates sharply against the base of the high relict cliff line, is fixed and stable. At the extreme north end of the sandy beach, however, dune morphology changes very abruptly. Here exposure to south-west winds is much greater, and the dunes become much higher and steeper. A maximum height of approximately 15m is attained, with an actively cliffed seaward face and a steep backslope of 15° or more. This dune section is under attack by rapid marine erosion, and the dune face appears to be retreating rapidly. There is no indication of blow out initiation, although conditions on the exposed seaward face are ripe for blow out development.

The dune zone grades almost imperceptibly into a narrow belt of dune pasture, which in turn terminates sharply against the relict cliff line. This dune pasture is in the form of low hillocks, capped in Marram, rather than in the level machair plain familiar in west coast beaches. The thickness of blown sand is irregular, but for the most part it forms a very thin mantle over raised-beach deposits. Landward of the railway, blown sand is extremely limited both in extent and in thickness, although a small amount has accumulated against the base on the relict cliff towards the north end of the beach. Like the dune zone, the area of dune pasture is characterised by an absence of blow outs. At one or two points, the vegetation cover has been broken, but the breaching has been caused by animals rather than directly by wind action.

The Kilmote beach complex, as a unit, is not highly dynamic, and the blown sand components are at present inactive and relatively stable. In contrast, the beach itself is likely to undergo frequent changes in profile and distribution of sediments as the limited quantity of sand on the beach is redistributed according to prevailing marine conditions. Should there be a prolonged period of marine conditions favouring the combing down of the beach, there would be a real possibility that the dune zone might be endangered should a south-east gale occur. This possibility cannot be ruled out, and must be borne in mind despite the present dune stability. Drift-line pioneers are very limited in occurrence, and consist mainly of orache. The dune zone and the transition dune pasture area lying behind it are clothed in Marram-dominated communities, with a mature sward of herbs, grasses and mosses. Marram tends to die out landwards, and bracken is invading from the relict cliff whose upper parts are clad in gorse heath. The present tendency is thus for dune heath to expand at the expense of Marram dominated communities.

The principal land use is rough grazing: sheep are wintered in the links. There is no indication of deleterious effects resulting from this form of land use, except for a very small number of sheep scrapes. Rabbits are not a problem at present, although a few burrows occur on the sand-veneered base of the relict cliff. Faint traces of former military use survive in the form of a small number of inconspicuous huts. Landward of the relict cliff line, and of the railway behind the central part of the beach, the agricultural land is fenced and cultivated.

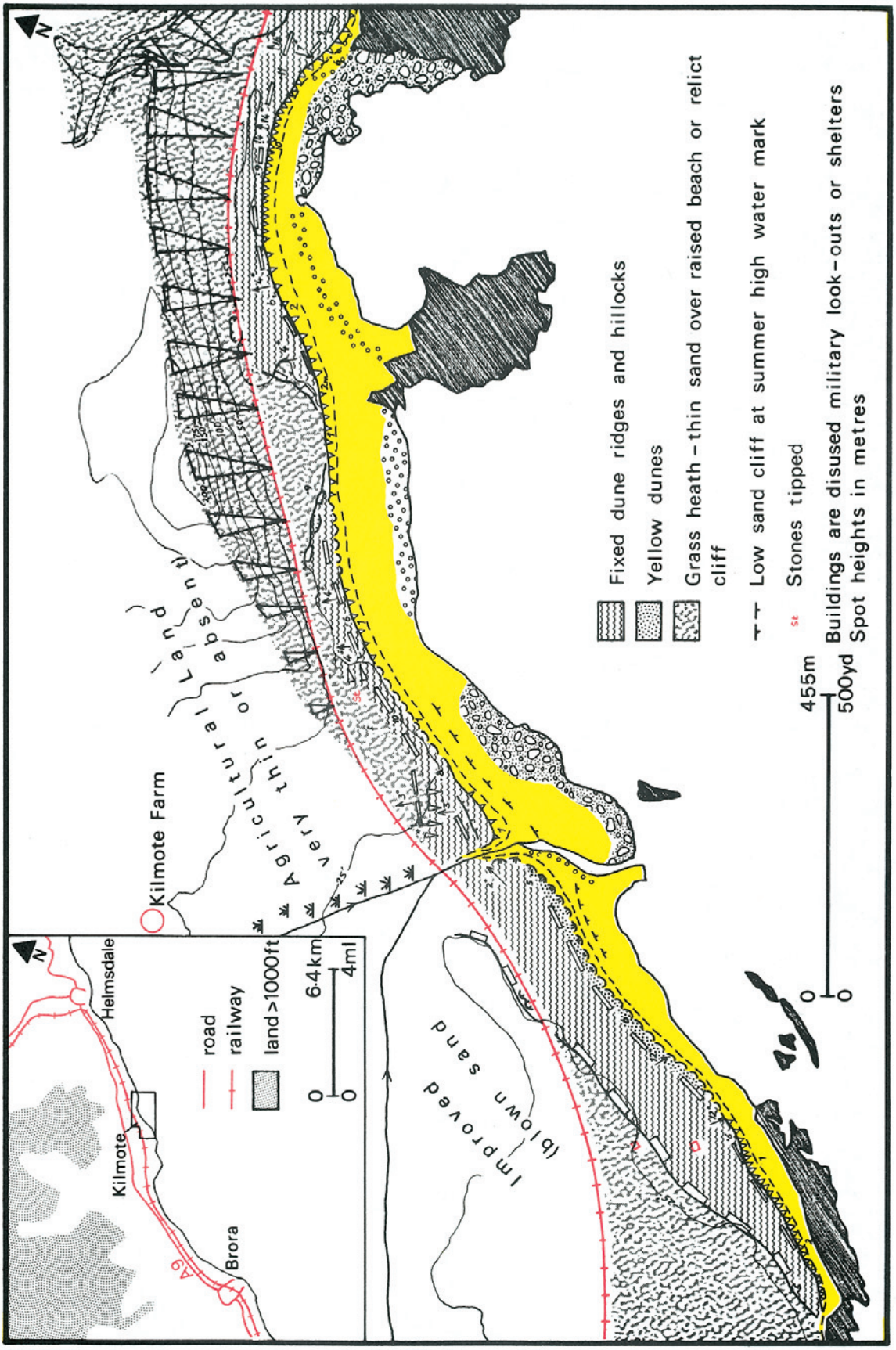
The beach complex is moderately attractive but not outstandingly so. Although the reefs in the lower inter-tidal zone lend some interest to the beach, the relatively steep gradient of the beach makes it correspondingly

less suitable for bathing. The present intensity of recreational use of the beach complex is extremely low, mainly because of difficult access. Neither vehicle track nor footpath leads to the beach, and access is possible only through fenced fields and across the railway line. Undoubtedly if access were improved, recreational use would increase, but although the A9 (T) is only about 800m distance, the beach is not clearly visible from it. Several other beaches in East Sutherland are better placed for improving access, and are, if anything, slightly more attractive for recreational purposes. Kilmote is not unsuited to an increase in recreational use, and is certainly physically more resilient than many beaches in the west and north of Sutherland.

If the decision were ever taken to develop Kilmote beach for recreational use, the primary prerequisite would be an access road or track. It is suggested that access should be *via* a point near the railway bridge across the stream, and ideally vehicular access would terminate on the landward side of the railway line. The dunes behind the extreme north part of the beach are the most vulnerable part of the beach complex, and nothing should be done there to permit or encourage trampling or indeed any other recreational repercussion.

The Kilmote beach complex is long and narrow. The beach is variable in profile and sediment distribution, but the relatively narrow blown sand accumulations are stable at present. Although not remote, the beach complex is inaccessible, and the intensity of recreational use is very low. The main deterrent to increases in recreational use is inaccessibility. The beach complex is not unsuitable for moderate levels of recreational intensity, but at the same time it is no more attractive than other undeveloped beaches on the East Sutherland coast.

Figure 6.1 Kilmote (Loth)



6.2 Crakaig

Crakaig beach occupies the south-east edge of the triangular promontory of Lothbeg Point, and extends to approximately 600m in length and 50m in width. A very narrow belt of sand forms a fringe at the top of the rock platform on the west side of the promontory, but only on the south-east side has a significant beach complex evolved. A small dune and machair zone has developed between the main beach and the relict cliff associated with the post-glacial raised beach. The relict cliff forms the seaward margin of a low plateau which is till capped but rock cored, and behind this small plateau, a flat-floored depression extends back to the main highland mass, along the base of which runs the A9. The beach complex is not visible from the A9, but vehicular access is possible and a small caravan site has recently been developed.

The main beach (ie. the south-east facing segment) is composed principally of coarse sand (median diameter 0.65mm) with a carbonate content of 29.6%. A narrow fringe of similar sand extends around Lothbeg Point to the mouth of the Loth Burn, where a mixture of sand, gravel and coarser sediments has accumulated. At the extreme north-east end of the main beach, sand gives way to pebbles and cobbles as the dominant sediment grade, but the shingle is restricted to a very narrow belt between high water mark and the low coastal edge.

The main beach segment occupies a shallow embayment between the calcareous sandstone platform of Lothbeg Point, to the south, and a platform cut in sandstones and shales but veneered with sand and lag boulders to the north. In this embayment the rock platform lies only a short distance below the beach sand, which is thin and variable in distribution (Plate 6.2.2). During periods of destructive wave conditions, the beach will be combed down, with a resultant increase in the area of exposed rock platform; conversely, during more constructive periods with gentle offshore winds, sand is likely to build up and hence the area of sandy beach increases. The beach is relatively steep, at 8.5°, and is correspondingly narrow, although at the time of fieldwork during fine weather in July, a flat backshore of about 20m width had built up. Both plan and profile are strongly influenced by the rock platforms which flank and underlie the beach.

The offshore ground (to 10 fathoms) is also relatively steep, at 1 in 33, and is mainly rocky or gravel covered. Little sand is likely to be supplied from offshore, and the amount of local marine erosion, another potential source of sediment, is insignificant. The major source of sediment for both the raised and present beaches at Crakaig and Kintradwell to the south is likely to have been the Loth Burn, which has cut deeply into thick glacial deposits. Supply of debris from this source, however, is much less than formerly, and very little sand is now being added to the Crakaig beach complex.

The nature of the coastal edge behind Crakaig beach supports this conclusion. Although active retreat is confined to a short section near the north end of the beach, much of the edge is in the form of a low, now inactive cliff. Very little accretion is taking place, even in summer, and although the rate of retreat of the sand-built coastal edge is not rapid, the edge is characterised by retreat rather than advance.

A low but continuous dune ridge has evolved behind the main beach segment. This ridge, reaching a maximum height of about 7m, is subdued in form, but is strongly asymmetric in profile, with a steep seaward face and a gentle backslope averaging 4°. The strong asymmetry may be due in part to the partial removal of the seaward part of the dune by marine erosion, but at the same time, the topographic shelter from the west afforded by the relict cliff would favour the maintenance of a gentle backslope gradient. The dune ridge

is fixed under mature Marram communities, merging into dune pasture near the base of the backslope, and there is no evidence of continuing sand accretion. Despite some marine undercutting, blow outs have not developed, and the dune ridge is stable in relation to wind action. Trampling has resulted from increasing recreational use, however, and has destroyed the vegetation along a skeletal network of paths. If this type of damage is allowed to continue unchecked, the present stability could easily be upset. West of Lothbeg Point, a thin layer of Marram-clad blown sand has accumulated against the lower slopes of the relict cliff, which here closely approaches the shoreline. Free-standing dunes have not formed, and the blown sand dies out westwards.

A narrow zone of machair extends from the base of the dune-ridge backslope to the relict cliff line. This machair is in the form of a thin overlay of blown sand over raised beach deposits, but has a rather irregular surface. The influence of the underlying topography is strong, but a number of blown sand hillocks stand above the general sloping surface. The thickness of the blown sand beyond the summit of the relict cliff is extremely limited, and indeed the overall development of machair is poor. There is little resemblance to the free-standing machair plains familiar in many west coast beaches.

Like the dune zone, the machair is relatively stable with respect to wind action; neither its composition nor its situation favour severe wind erosion.

The Crakaig beach complex is at present quiescent. Accretional development appears to have ceased, and rapid deterioration has not set in. In the very long term, the stability of the beach complex, and the volume of sand which it contains, are more likely to decrease than increase, but changes are likely to be very gradual rather than rapid. Of the components of the beach complex, the dunes and machair are much less dynamic than the beach, but changes in the latter could trigger off an erosional episode in the former. A storm from the south-east, for example, could sharply undercut the dune front, and prepare the way for the development of blow outs on the exposed face. Uncontrolled trampling could likewise undermine the present stability of the beach complex.

Maritime influences on the vegetation are relatively weak, with the usual beach-complex species and communities occupying only a small area. Drift-line vegetation is sparse and few species are represented, while mobile dunes with young Marram communities are almost completely absent. Likewise, sea lyme grass (*Elymus arenarius*) is very poorly represented. The main dune ridge is clothed in mature Marram-dominated communities, with Marram tending to die out in the lower part of the dune backslope. Nowhere does its growth seem particularly vigorous. As dune merges into machair, a fescue turf takes over from the Marram sward, and bracken heath is beginning to invade from the relict cliff-face. On the west edge of the Lothbeg promontory, a thick gorse heath has developed near the mouth of the Loth Burn.

The area lying between the railway line and the coast is uncultivated, and consists of grass heath together with some patches of scrub, with a narrow belt of trees along part of the railway line. Agricultural use is confined to rough grazing for sheep and cattle. There is no evidence that this use is having an adverse effect on the stability of the beach complex. A small amount of extraction has taken place from some of the sand hillocks near the base of the relict cliff, but again there is no evidence of resulting damage. A few bunkers and mast bases bear witness to the former military use of the links and adjacent area, but these remains are not particularly prominent and do not greatly detract from the visual amenity of the beach complex.

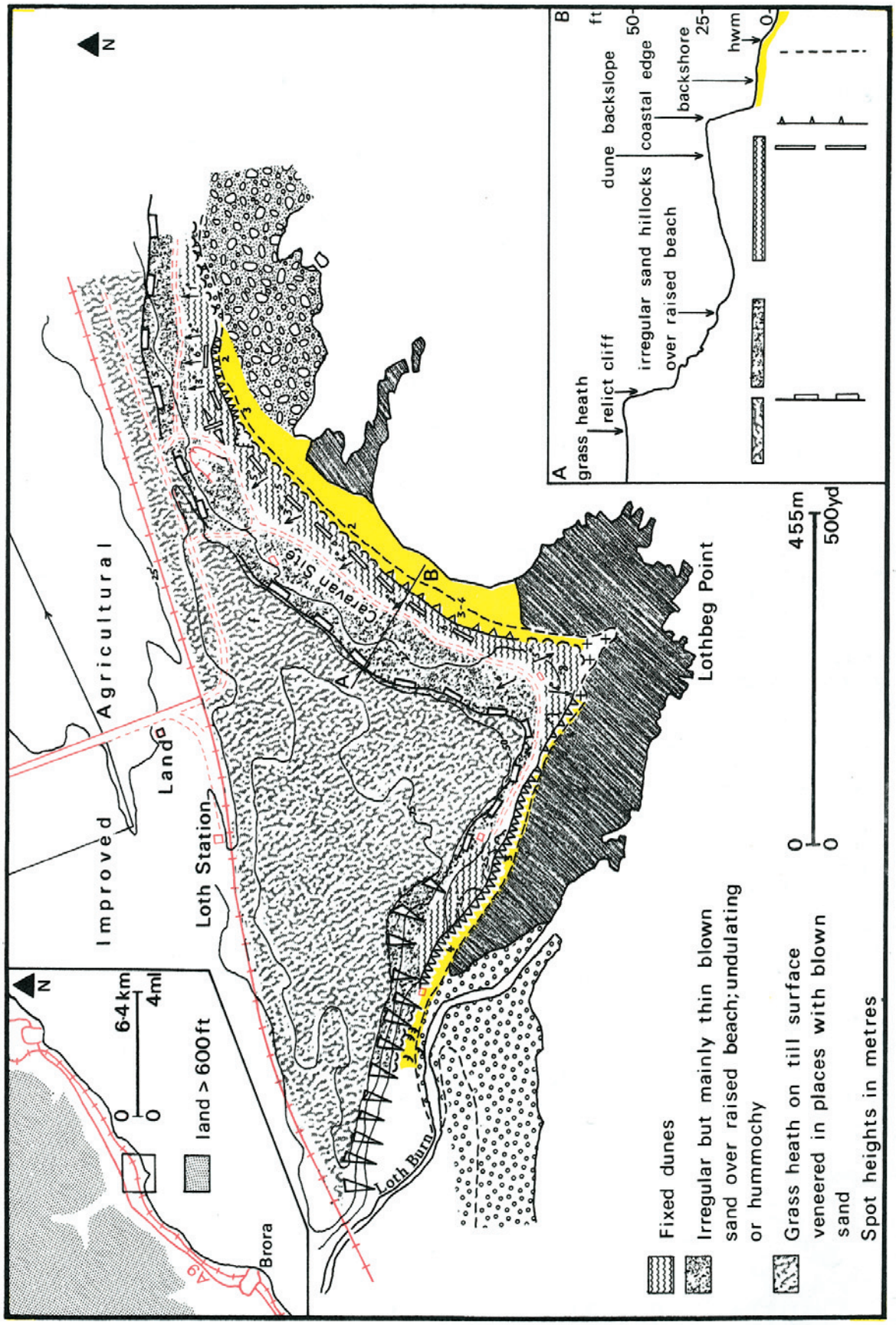
Crakaig links have recently been developed as a small caravan site, with licensed capacity for 15 caravans. Although the site is not ideally located to attract passing traffic, the beach complex is physically well suited for such use. Effective screening from the main road is provided by the relict cliff line, and the site is sheltered from the north and west. The physical stability of the site is relatively high, with a thin, sloping machair over raised beach deposits. The dangers of machair deflation resulting from caravanning pressures are much less than at many west coast beaches.

Similarly, Crakaig is physically not unsuited for greater intensities of informal day recreation, although at present, demand is greatly restricted by the off-road location. The scenic quality of the beach complex is perhaps not outstanding, but the beach is sheltered and relatively clean, and in the future, as demand for both caravanning and day recreation grows, the intensity of use may be expected to grow.

It is suggested that a few simple management measures could greatly reduce the risk of erosional instability of the beach complex, and at the same time increase the safe carrying capacity of the site. The most fundamental of these measures is the fencing of the potentially vulnerable dune edge. The objective of this measure is to control access from dune and machair to beach, and hence restrict the development of trampled path-ways. If access is confined to a very small number of points, then trampling damage can be much more easily monitored and counteracted. The highly vulnerable coastal edge could, for example, be protected by a sleeper stairway, and any especially badly damaged dune section should be replanted and then protected by duckboards. It is not suggested that these latter measures are essential at the present moment, but trampling damage is already visible and should be checked by dune-edge fencing as soon as possible. If such measures were undertaken, it is suggested that the intensity of use could be considerably increased. Although fixing of numerical carrying capacities is fraught with difficulty and danger, the present caravanning capacity might reasonably be doubled, provided that management measures were implemented. It must be emphasised, however, that this suggestion is based only on the physical characteristics of the site, and does not relate to demand or any other consideration.

Crakaig is a small beach complex constructed at the base of a relict cliff and lies about 1km off the A9. The beach complex is relatively stable, and has been developed as a small caravan site. It is suggested that physical conditions are suitable for more intensive recreational use, provided that some simple management measures are implemented.

Figure 6.2 Crakaig



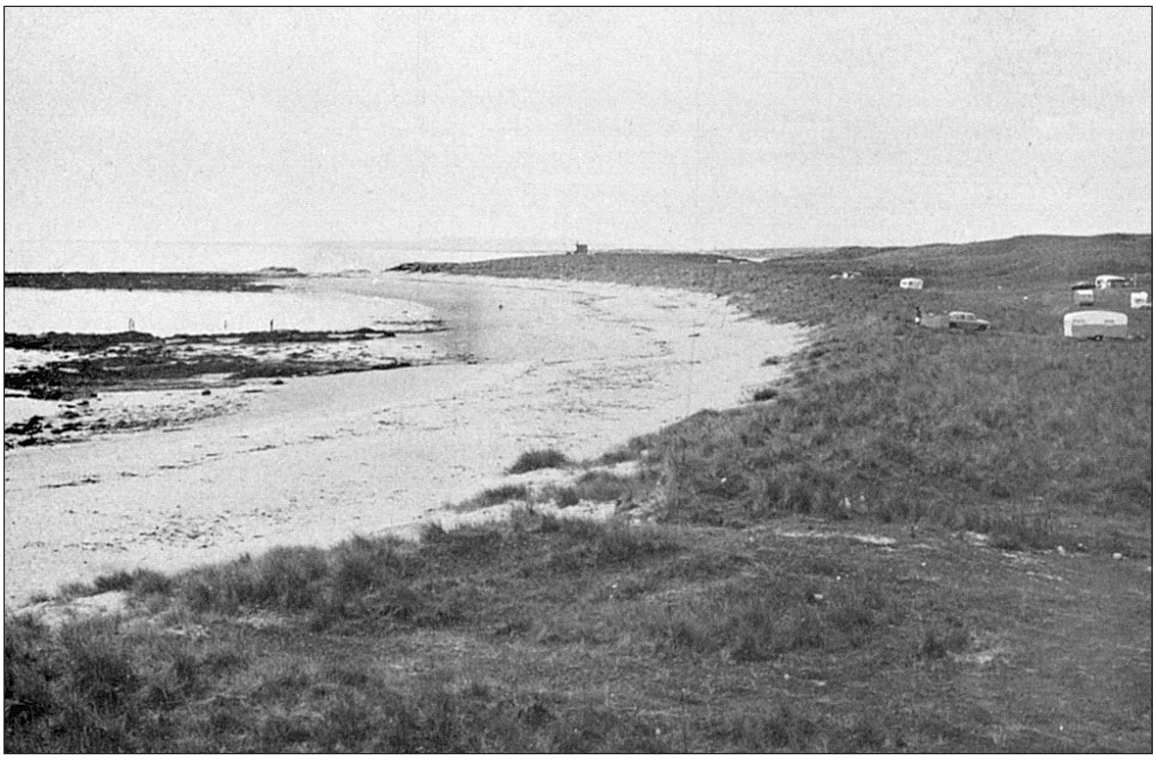


Plate 6.2.1 Crakaig Links – a small caravan site occupies part of the links between the low foredune and the relict cliff. Note some trampling damage in the foredune in the foreground.

Plate 6.2.2 Crakaig beach – much of the sand cover is thin and discontinuous, especially in the lower beach.

6.3 Kintradwell

Kintradwell beach and dune system lies 6km north of Brora, below a relict cliff line. The beach faces south-east and is virtually straight in plan. Although the beach lies only 400m from the main A9 road, it is physically separated from the tourist by the steep cliff, the railway, and its concealed situation. The dunes are old grey ridges, and the main beach sand accumulations lie out of sight of the main road. A poorly developed footpath across agricultural land leads to the beach at its south end, but access in the central or northern parts involves a descent of 70m or more.

A narrow fringing sand beach with backshore shingle is replaced northwards by a wider sand beach with a 6° gradient, fronted by a rock platform with lag boulders strewn on its surface. The beach sand is medium grained (median diameter 0.30mm) with a carbonate content of 39.9%. The upper beach is flat topped with some wrack accumulation of sand. In general, however, the backshore is neutral with a half-metre erosion scarp developed for less than 100m towards the central part of the beach backshore. Two small streams originate in gullies in the degraded cliff line but neither show evidence of significant runoff. Shallow cutting at the point where they enter the beach, however, reveals that the backshore shingle probably underlies the first foredune ridge for the whole length of the beach. The dune edge is seldom reached by wave attack and even when storm waves do reach the backshore, erosion is reduced by the occurrence of the concealed shingle deposits. The blocks and cobbles found on the platform and at the beach back include conglomerates, gneisses and Jurassic material. Much of it is derived from till deposits. Despite the flat top of the beach, blown sand seldom occurs against the dune edge, and the whole system is apparently quite stable.

Marram and sea lyme grass occur sporadically where sand is locally accreting on the backshore, particularly at the northern end of the beach in the vicinity of the stream outlet. A particularly significant feature of Kintradwell beach is its wide backshore.

The dune system at Kintradwell consists of an almost continuous foredune, wholly vegetated with Marram and mosses, backed by discontinuous lows, and old vegetated sand ridges. Slopes are generally less than 12°, and dune heights vary from 4–8m O.D. The system is wholly undistinguished and is somewhat amorphous in character. This amorphous character suggests that the blown sand is rather thin, and is probably underlain by shingle bars. This theory is strengthened by the occurrence of sand-masked terraces in the northern part of the system, and of pockets of slightly impeded drainage landward of the main foredune. A mantle of blown sand extends back to the fringe of the old cliff line with a gradient of 14° where it has banked up against colluvium. An area of old stock burial pits within the blown sand apron was sufficiently active in the past to necessitate shuttering to prevent sand blow onto the railway line, but although extensive bare sand areas still occur, there is only very limited wind scour. Beach shingle occurs at the base of the old deflation areas, further supporting the idea that the Kintradwell dunes system has accumulated on top of and around pre-existing raised beach features. A considerable amount of bracken has colonised into the Marram in the inner dunes, and there are signs of very limited grazing by cattle and sheep within the dune system. The whole system is markedly stable.

There is a very small area of machair where blown sand has accumulated up against the fringe of the old cliff line. Some erosion has been activated in the past by excavation, but shingle probably lies at less than 2m below the machair surface.

Clearly the dune system rests on a pre-existing topography, thus explaining the amorphous character of the whole system. Only a very limited amount of blown sand now reaches the dune edge and the whole system is almost static. Ultimately the Marram will fade out in the inner parts of the system and be replaced by bracken. The beach profile suggests a high energy beach, but the high-tides fail to reach the dune edge.

There is no strandline vegetation, and only occasionally does Marram and sea lyme grass appear to be colonising the backshore. The range of dune species is very low with Marram predominant, and bracken colonising from the cliffs behind.

The dune and machair is tenanted from Gordonbush estate, and grazed occasionally for ewes and cattle in winter. It is ungrazed in summer. The area is unfenced but the very limited grazing leaves little effect on the vegetation.

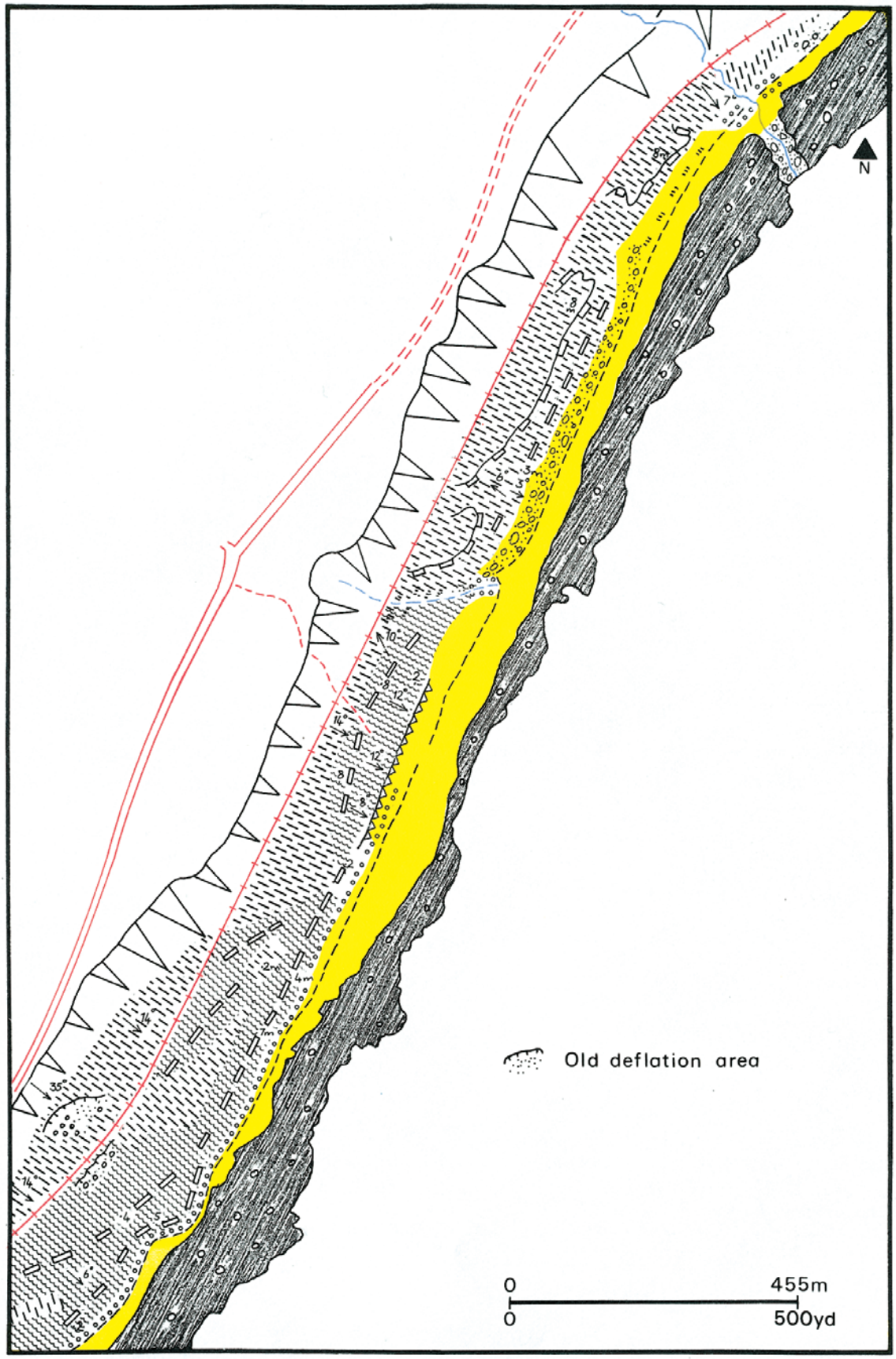
As a result of the general inaccessibility and invisibility of the beach from the road, recreational usage is minimal. Furthermore, the long stretch of Brora (Dalchalm) beach occurs just south of Kintradwell, and is clearly visible from the road.

While the beach unit is not particularly attractive, it could carry large numbers of visitors without deleterious effects. Better access would have to be provided from the main road, with signposting and car parking facilities. Dual utilisation by recreation and farming would be facilitate, if part of the dunes were enclosed by a stock fence. The unit is topographically unsuited for caravans.

Kintradwell is a long straight beach backed by old grey dunes. The whole beach-dune system is highly stable. It carries very few visitors and is used for wintering ewes. With the adjacency of more attractive beaches to the south, tourist pressures are unlikely to increase unless a conscious effort is made to attract visitors. The beach unit is physically suitable for a considerable increase in tourist numbers.

Plate 6.3.1 Kintradwell – general view looking south.

Figure 6.3 Kintradwell



6.4 Brora Dalchalm

Brora beach stretches 3km from the mouth of the Brora River northwards to a point near Kintradwell, and forms the outer member of a series of beaches built around the extensive glacial deposits of the area immediately north of Brora. The beach hinges on rock platforms at either end, and is backed by a relict cliff line and a raised shingle ridge related to the post-glacial shoreline. The main beach faces just south of east (100° true), but a short segment of beach between the Brora River mouth and the rock platform opposite the golf clubhouse has a more southerly orientation. Both the A9 (T) and the railway converge on the beach at its north end, but further south are up to 1km to the landward. The beach complex is characterised by subdued relief and an absence of dune development.

The dominant beach material is relatively fine sand (median diameter 0.25mm) with a carbonate content of 27.5%. The sand is well sorted, but is interrupted by occasional patches of gravel and pebbles. The upper beach at the north end is composed of shingle, built into ridge form, and semi-active patches of cobbles also occur on the rock platform and river mouth at the south end of the beach.

Both the offshore ground and the beach itself are relatively gently graded. In the central part of the beach, the low overall gradient is reflected in the development of a ridge and runnel system seaward of a sizable berm with a slight reverse gradient of 1–2°. The backshore is gently sloping and extends to over 20m in width, and in general terms the beach appears to be fairly well nourished. This generalisation does not, however, extend to the south-facing segment of the beach near the river mouth. Here the beach is much thinner and is poorly nourished.

Much of the offshore ground is of sand and sand with shells, but this sediment cover is thought to be rather thin, with patches of rock ground protruding through the sand in places. The greater part of the present sediment supply probably comes from this source, which represents a seaward extension of the thick glacial deposits which mantle much of the Brora area. The River Brora may also have been a significant contributor of sediment, although the loch some distance inland drains it of much of its load.

Brora beach is better nourished and is probably less variable than the beaches lying to the north of it. Seasonal changes in the beach profile undoubtedly occur, but since the thickness of the beach is greater than at Crakaig or Kilmote, for example, changes in profile are less likely to be accompanied by extensive exposures of the underlying rock platform or coarser sediments.

The nature of the coastal edge supports the conclusion that the beach is relatively well nourished at present. Although the edge is very low, most of its length is stable and is showing very little sign of retreat. Instead, a sloping apron of colonising sea sandwort builds up in front of the edge during summer. The northern third of the coastal edge consists of a thin veneer of sand overlying shingle, which is likewise stable, but the extreme south end of the coastal edge is very different (Plate 6.4.3). Here the dominant process is rapid retreat, and a very active cliff averaging about 3m in height has been cut. Some measure of protection has been given by the construction of a wave screen, but the cliff shows little sign of stabilising. This anomalous coastal edge behaviour may in some way be associated with a diminution of sediment supply from the River Brora; in any case the extreme south part of the edge is very different from the remainder.

One of the most characteristic features of Brora beach is the complete absence of a dune zone; machair

abuts sharply against the beach. Only at one other beach in the north of Scotland, at Burrafirth in Unst in Shetland, is the same relationship observed of stable or slightly prograding machair front closely juxtaposed with the beach, and successional status and relationships are not known with any certainty. It is possible that a dune ridge once existed and has since been removed; at the extreme south end of the links a machair ridge parallel to the coastal edge may represent the surviving remnant of a dune ridge. It is equally possible, however, that a dune ridge never existed along the greater part of the beach. Instead, the rapid supply of sediment over a short period of time may have favoured the direct evolution of a machair plain by means of the prograding sloping apron to which reference has already been made.

Irrespective of the reasons for the absence of a dune zone, the practical implications are clear. The dune component of a beach complex is the most vulnerable part, and when there is no dune zone, the stability and carrying capacity of the beach complex are correspondingly increased, although at the expense of the absence of the interesting dune environment.

The machair zone is extensive and subdued in relief. Relief is not totally lacking, however, and the dominant feature is a system of ridges sub-parallel to the shoreline. These ridges, whose summit levels rise to approximately 10m, consist of shingle veneered with machair sand. At either end, the ridges hinge on the relict cliff line of the post-glacial shoreline, and partially close the former embayment through which the Clyne Burn now drains. The machair of the present beach complex thus rests on raised shingle ridges, which form an effective basement for deflation.

At present, the machair is stable, but numerous scars exist of recently active blow outs. Air photographs taken in 1946 indicate that many of the blow outs were then more active than at present, although even then activity appeared to be subsiding. Today, most of the blow outs have almost completely healed, but a few deflation faces are still very slightly active. The more active spots have been treated by the erection of corrugated-iron fencing across the blow out throats, and this treatment has proved fairly effective despite the impermeable nature of the fencing material.

The absence of a dune zone means that sand can readily blow from the beach onto the seaward part of the machair surface, and hence the general height of the surface is still very slightly increasing. Over much of the area, however, either the water table or a shingle basement lies within 2m of the ground surface, and deep blow outs are unlikely to develop even if instability is resumed. Landwards of the raised shingle ridge which forms the backbone of the machair, the water table is much closer to the surface, and here the damp machair is highly resistant to the development of blow outs.

Brora beach complex is relatively stable in respect of both marine and aeolian processes. The only highly-dynamic area is at the extreme south end, where rapid retreat of the coastal edge is being accompanied by signs of re-juvenation of blow outs normal to the shoreline. The deflection of the mouths of small streams draining through the machair suggests that the residual direction of drift of beach material is southwards; nevertheless it is clear that the extreme south end of the beach is now receiving inadequate nourishment to maintain its present form. In the long term, inadequacy of nourishment may spread northwards and be reflected in undercutting of the present stable coastal edge. It is most unlikely that the extreme north end of the beach, where the coastal edge is protected by shingle, will be thus affected except possibly in the far distant future.

The most unusual feature about the beach complex is the absence of a dune zone, and hence of significant amounts of Marram. The sloping, prograding apron at the coastal edge is dominated by sea sandwort with sand sedge and some sea couch grass, but much of the rather sparse growth dies back in winter. The machair sward, which closely abuts on the coastal edge, has been modified by cutting and fertilising, as well as by grazing. Gorse and juniper occur in small patches in the landward part of the machair. Efforts are being made to establish a small shelter plantation of Corsican pine close to the coastal edge near the south end of the beach.

The main land uses of the greater part of the links area are golf, and the common grazing of sheep and cattle. The golf course is well maintained, and incipient blow outs have been checked with fencing. Minor landform modifications have resulted from the laying out of tees and greens, but have had no adverse repercussions. Indeed watering and fertiliser application have had beneficial results on the stability of the machair. The links are part of the Dalchalm common grazings. The intensity of grazing pressure does not seem unsuitably high, and apart from a few animal rubbings, there have been no detrimental repercussions. Cultivated croft land adjoins the links at Dalchalm, while improved farm land lies to the landward side of the road and railway at the extreme north end of the beach.

The intensity of recreational use is greater than at most other beaches north of Loch Fleet. Golf is the main form of recreation. Golf course management probably tends to enhance rather than diminish the stability of the beach complex.

Part of the Dalchalm croft land behind the links is used for caravanning. The caravans are situated well back from the most fragile machair zone, and little erosional damage is likely to result. The caravan stances are visually exposed neither to the A9 nor to the beach.

A series of beach huts formerly lined the coastal edge at the extreme south end of the beach. Retreat of the coastal edge, however, has undermined many of the huts, and only parts of their foundations remain. Two huts have been relocated slightly to the north, where retreat has been much less marked. These beach huts reflect the heavy concentration of informal beach recreation near the south end of the beach, where access is easiest. Vehicular access is possible along the road leading to the golf clubhouse and the Links Hotel, and the walking distance from this road to the beach is very short. It is unfortunate that recreational pressure should be concentrated on this part of the beach, where stability is lower than elsewhere. Trampling of the already undercut coastal edge is resulting in the formation of blow outs; similar intensities of trampling on the much lower, more stable coastal edge further north would have little effect.

With the exception of its extreme south end, the beach complex is not being used to maximum capacity. The stability of most of the beach complex is high, and more intensive use would have little adverse effect. This is true both for caravanning (provided that the sites were similarly situated to the existing ones) and for informal day recreation. The main limiting factor to increasing intensity of use is accessibility. Vehicular access combined with a short, barrier-free walk to the beach is possible only at the extreme south end of the beach. At the north end, where the A9 (T) approaches the beach very closely, the railway line forms a formidable barrier greatly limiting use by passing tourists. Similarly, there is no easy or obvious means of access to the beach from Dalchalm (except for people resident on the caravan sites). Indeed it takes a rather determined effort for passing tourists to find their way to the beach; although signposted, the village road at the extreme south end is well off the main route, and the passing motorist is unlikely to be diverted.

Brora beach is in marked contrast to many west and north Sutherland beaches. Although adjacent to a large village, access, and especially vehicular access, is difficult: cars and caravans cannot drive onto the machair. Yet rather ironically, the physical stability and suitability is far greater than in most of the west coast beaches where vehicular access is so much easier. It is not recommended that vehicular access to Brora links be made possible, but it is suggested that there is unused capacity for recreational use. If it is desired to utilise this capacity, the key to development, as well as the means of controlling it, is accessibility. To improve accessibility, a car park situated by the A9, and footpaths from there to the beach are required.

Scenic quality is perhaps only moderately high, and the two pipe outfalls on the beach (one of which is broken) do little to enhance it. Yet the long stretch of sand and the easy walking terrain along the dune-free coastal edge are recreationally attractive. It is to be hoped that fuller use can be made of the beach.

The beach is about 3km long and is backed by low, gently undulating links. Natural stability is relatively high, and there is little evidence of recreational or land-use damage. It is suggested that informal day recreation could be greatly increased if access were improved. Expansions of caravan facilities, in the vicinity of the existing sites, would also be compatible with the physical nature of the beach complex.

Note:

A possible construction site for oil production platforms has been identified at the north end of the beach complex. It is considered that, from the viewpoint of landform conservation, the site is not unsuitable for such use. The most vulnerable part of most beach complex environments, the dune zone, is not represented at Brora, and hence the dangers of sand blow associated with site preparation are correspondingly reduced. Blown sand underlying the machair is relatively thin, and either the water table or a basement of cobbles and gravel would prevent the development of deep blow outs. A detailed assessment of the land-form and general environmental implications would obviously depend on the nature of the plans for site preparation, but at first sight the environmental repercussion of a fabrication yard would be less than, for example, at Dunnet Bay. It could also be argued that since the links are relatively resilient and are also relatively simple in morphology, rehabilitation of the site after the termination of production would also be easier than in sites where a dune zone is present. On the other hand, development of the site would shorten the golf course. Furthermore, the site is visually exposed and would be clearly visible from the A9 (T).

Figure 6.4a Brora (Dalchalm)

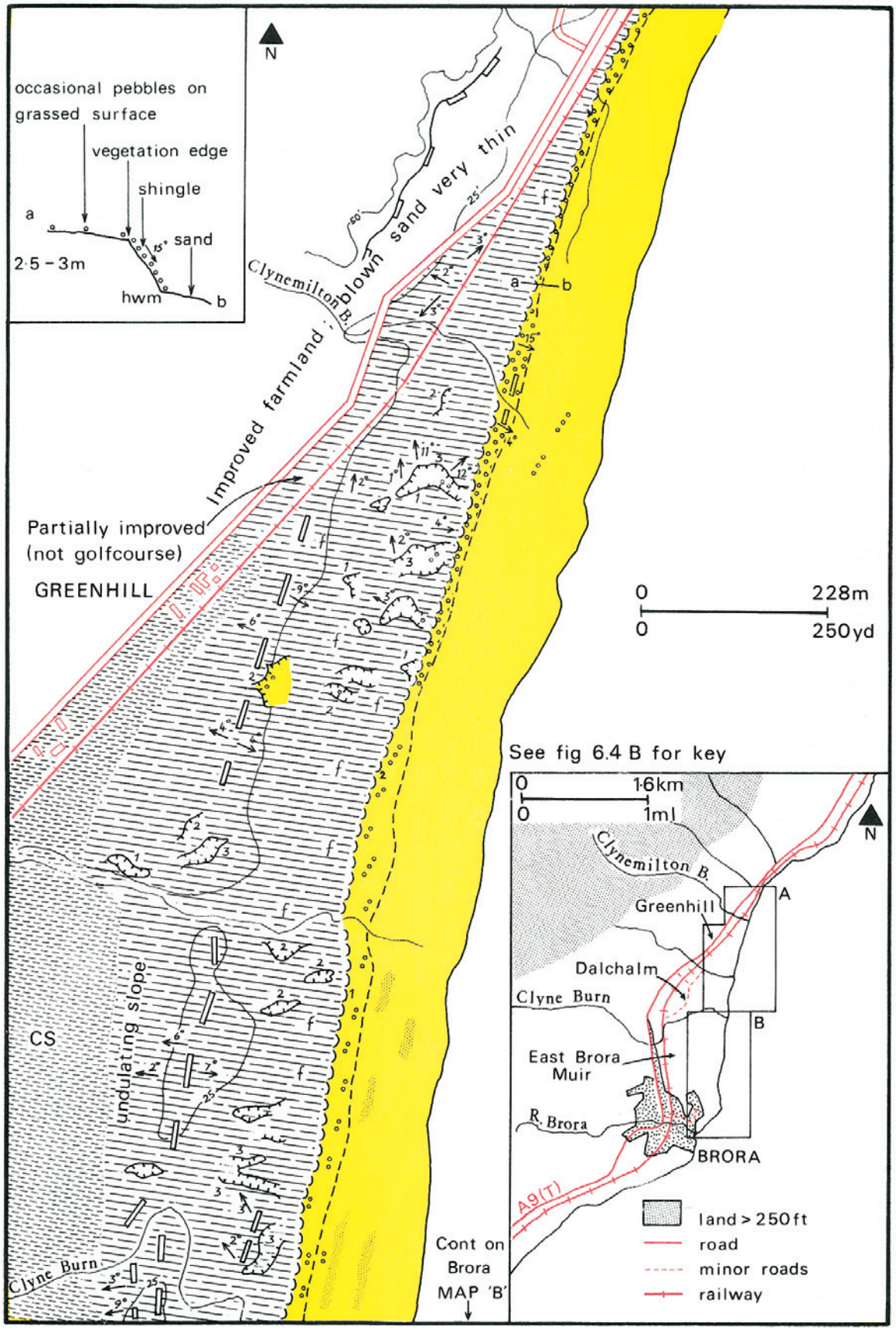


Figure 6.4b Brora (Dalchalm)

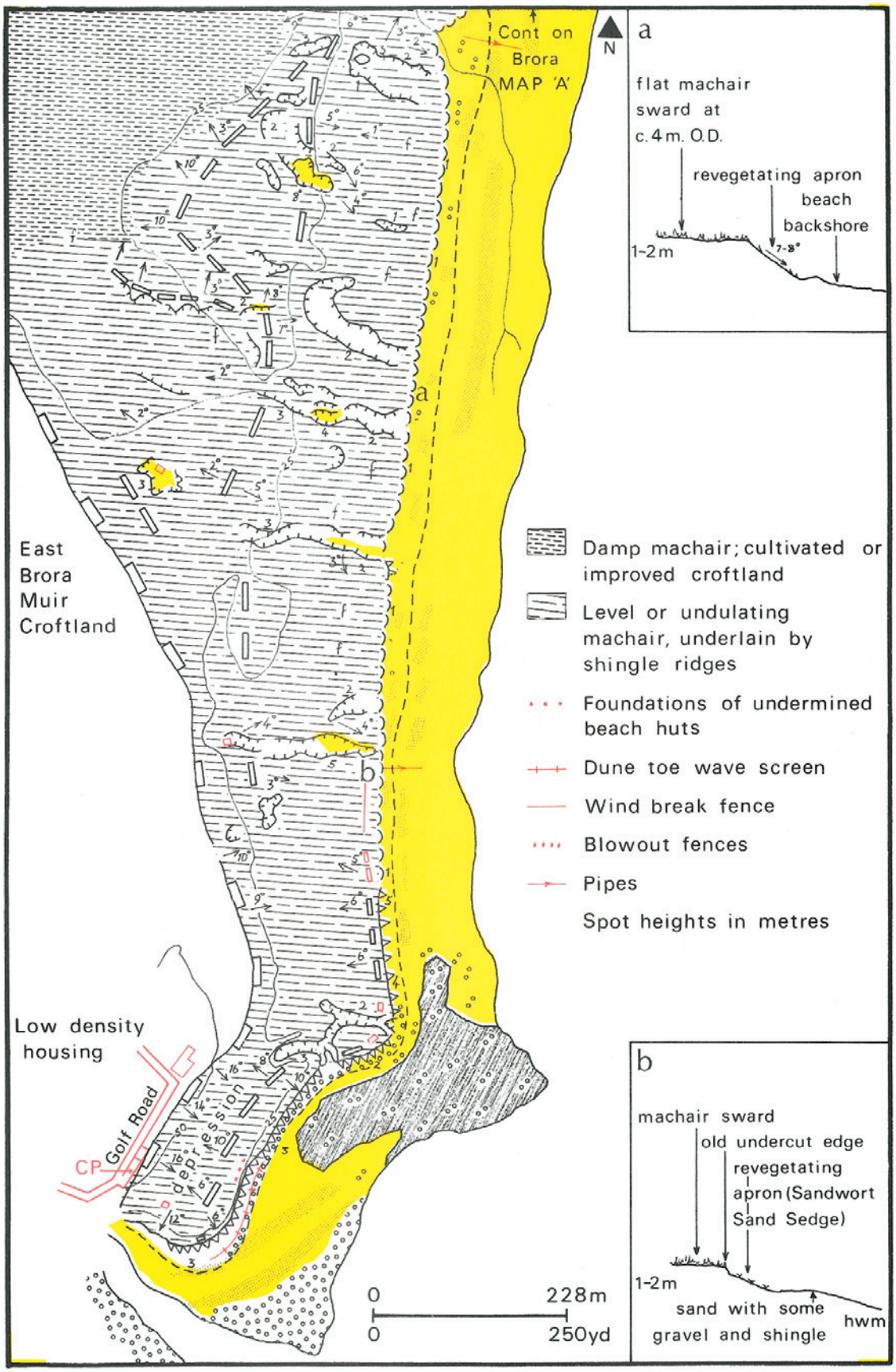


Plate 6.4.1 Brora (Dalchalm) – beach and links, note the absence of a dune zone.

Plate 6.4.2 Brora (Dalchalm) – The coastal edge is in the form of a prograding, sloping platform.

Plate 6.4.3 Brora (Dalchalm) – the extreme south part of the beach, near the mouth of the River Brora. The coastal edge is rapidly retreating, and a wave screen has been constructed.

Plate 6.5.1 Brora South – the sandy beach forms a narrow fringe at the top of a rock platform. Note the relict cliff line.

6.5 Brora South

A small fringe of sandy beach and machair has accumulated between the relict cliff line and the inter-tidal rock platform south of the mouth of the River Brora. The blown sand area is very small, and the narrow sandy beach dies out towards the south-west. The beach complex, which is orientated just east of south, is dominated by the relict cliff line, along the top of which runs the railway.

Cobbles, gravel and sand-grade sediments all occur on the beach, which forms a narrow fringe at the top of a wide rock platform. The sand is concentrated near high water mark, and is relatively fine with a median diameter of 0.29mm. Carbonate content is 41.5%, and sorting is poor. Seaward of the sand, which is interrupted by patches of shingle, a belt of coarse sand and gravel occupies the upper part of the rock platform, the remainder of which is covered with patches of thin sand and shingle. The gradient of the sandy beach is 6°, but the general slope of the inter-tidal zone is flatter and is strongly influenced by the rock platform.

The volume of sand contained in the beach complex is very limited, and it is unlikely that the beach was ever copiously nourished. At present, nourishment is very poor. Much of the coastal edge is retreating with an active sand cliff of about 4m in height. Indeed the protection of the radio station at the east end of the beach by gabions testifies to the reality of coastal retreat, and it may be expected that retreat will continue until a new equilibrium is attained.

A distinct foredune ridge is not present; retreat of the coastal edge has cut into a mature grassy sward with senescent Marram. Drift line colonisation is as sparse as might be expected from the nature of the retreating coastal edge, but in the central part of the main beach segment, where retreat has halted (probably temporarily), sea lyme grass is beginning to invade.

Although there is no foredune ridge, a transverse, west-trending ridge has evolved near the west end of the beach complex. It is possible that this ridge may represent the attenuated remains of a longitudinal dune.

The machair surface is irregular and undulating, and the area of flat ground is very small. For the most part, the undulations relate to former blow out activity; the scars of old blow outs as well as redeposition mounds are still visible. The blown sand of the machair overlies the raised beach deposits at the foot of the dominating relict cliff line, which forms an abrupt inner margin to the beach complex. The thickness of the machair probably rarely exceeds 4m, but the surface has been modified by some earthmoving in the distant past as well as by deflation.

The beach complex appears to be in the decreasing phase of the cycle of development. The beach is very poorly nourished, and the blown sand accumulations are being attacked by marine erosion. A few small blow outs are developing on the retreating coastal edge near the pipe outfall, but the main episode of wind erosion is probably now past. The present tendencies are likely to continue, although of course if coastal protection works are extended west of their present position, further evolution will be checked.

The greater part of the beach complex is under a mature grassy sward with some senescent Marram. Grazing is light, and the vegetation is relatively rank. The beach is littered with large quantities of seaweed, mats of which provide bases for emphemeral embryonic dunes in summer. Gorse and bracken heath is expanding into the landward margin of the machair area from the relict cliff.

The dominant use of the south Brora beach complex is as a military radio station. Much of the machair area was formerly under a large number of radio masts, of which basal anchor blocks still remain. Although the installations are not particularly unsightly, the scenic quality of the beach is not enhanced by them. A neighbouring tenant farmer uses the links for rough grazing. No detrimental physiographic effects have resulted from the present pattern and intensity of grazing. One of the most unfortunate features of the beach unit is the tipping of refuse down the relict cliff-face; this practice, combined with the pipe outfall across the beach and large amounts of rotting weed, does little to improve the scenic quality.

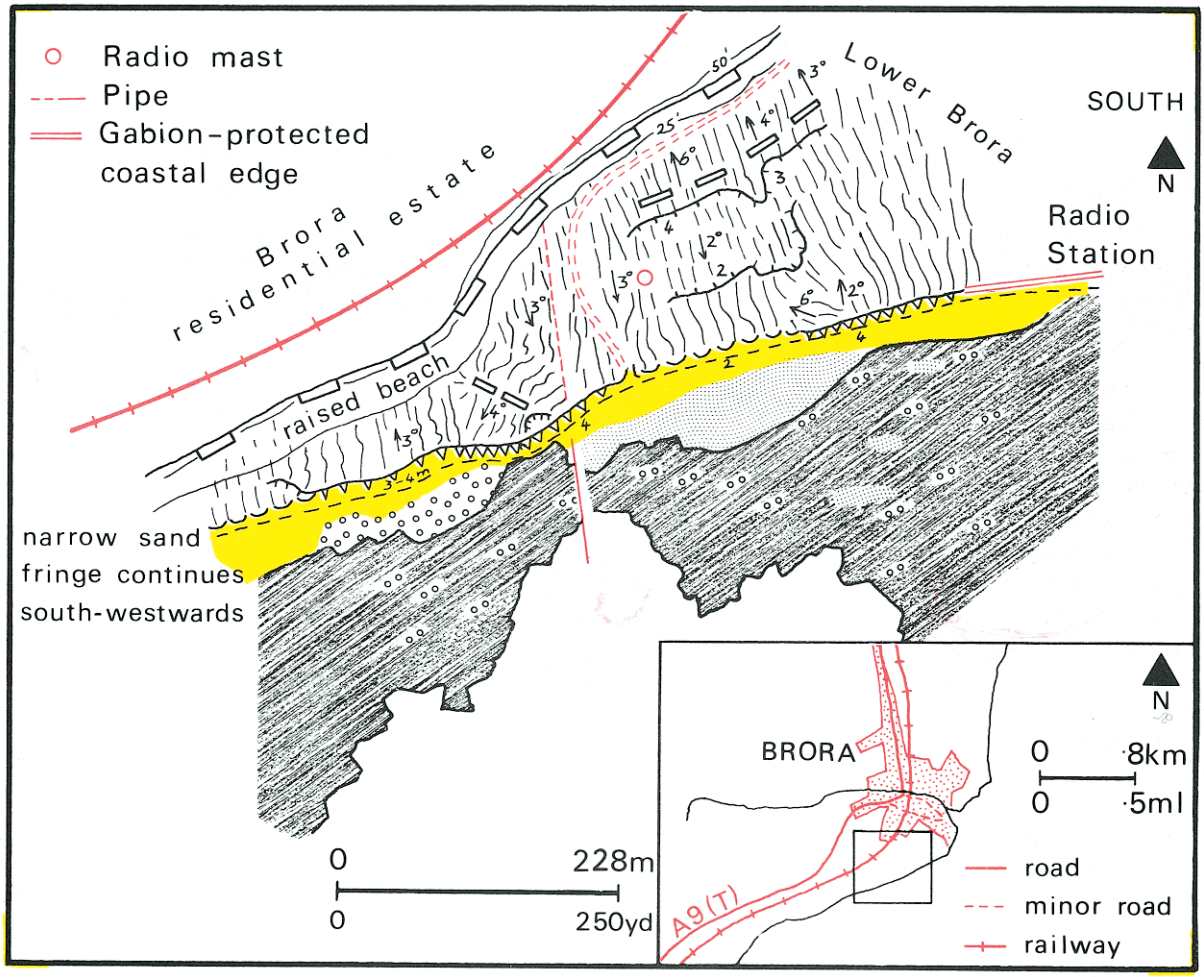
The main form of recreational use is low intensity informal use by local inhabitants, especially children. It is doubtful if many tourists know of the existence of the beach, and in any case Dalchalm beach to the north of the river mouth is larger and more attractive. Although there is slight blow out development associated with a track at one point on the coastal edge, it is thought that this was caused by constructional vehicles involved in the laying of the sewage outfall pipe rather than by recreational traffic. There is no evidence that recreational use is having significant adverse effects.

The first priority is to improve the visual amenity of the beach complex by controlling tipping on the relict cliff face, by removing or replacing derelict fencing, and if possible, by removing mast anchor blocks. At the present level of recreational use, it is not considered that other specific management measures are essential, but if use increases, then control of access on the coastal edge will be necessary to prevent proliferating trampling damage. Such control can be implemented by the simple expedient of fencing the edge, with all access channelled through one or two points where damage can be prevented by sleeper stairways.

In many ways, the landward part of the machair is well suited for a small caravan site. Seclusion is provided by the high relict cliff, and the surrounding machair is now relatively stable. Vehicular access could be easily provided by upgrading an existing track. Despite the physical suitability, a site is unlikely to be developed in the near future, but nevertheless the long term potential is there.

The beach complex is very small and is suffering coastal edge retreat, but the blown sand accumulation is stable. Scenic quality is impaired by tipping and by military use, but physiographically the complex is not unsuited to greater intensities of use.

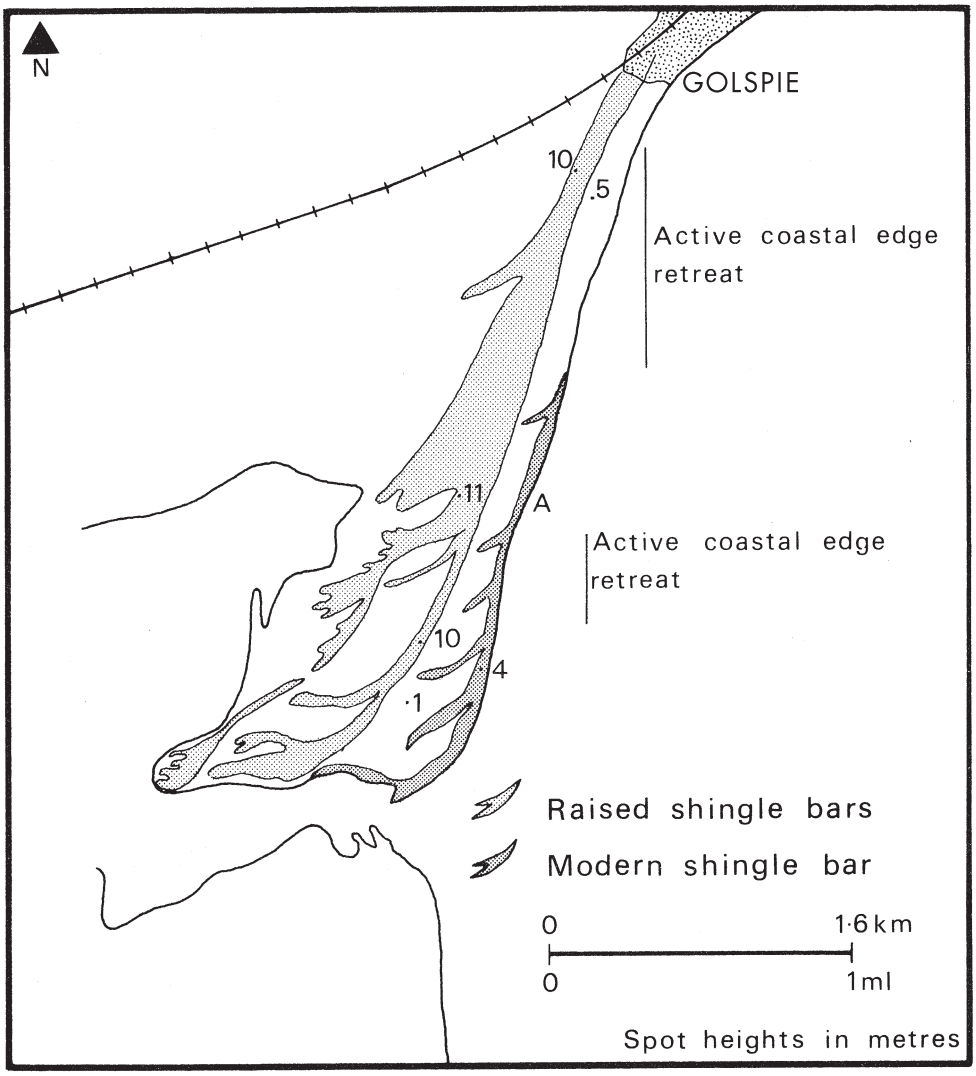
Figure 6.5 Brora (South)



6.6 Golspie-Littleferry

The 5km long beach extending from the village of Golspie to Littleferry at the mouth of Loch Fleet is one of the longest sandy stretches in the Northern Highlands. Despite the length of the beach, however, the dune and machair zones are poorly developed, and the beach complex consists basically of a modern shingle bar constructed against the series of raised shingle ridges of which the Littleferry peninsula is composed. The modern shingle bar stands above a sandy beach, but the latter has not supplied large quantities of sand for dune and machair construction.

Although access to the beach is very easy at the north end, the south and central parts are less visited. Vehicular access is not difficult, but the peninsula lies off the main A9 (T) and few tourists digress off their main route. Nevertheless a caravan site has recently been established, mid-way along the beach complex, and the amount of recreational use may increase in the future.



The beach has three main altitudinal components. The highest part is a shingle bar which forms the backbone of the modern beach complex, and rises to 2–3m above high water mark. Most of the inter-tidal zone is of medium sand (median diameter 0.29mm), with a carbonate content of 20.1%. Much of the lower

beach has little sand cover, and consists of lag deposits of almost immobile pebbles and cobbles. This lower zone is not continuous, but is well developed at either end of the beach, and also near its centre, where the sandy beach is very narrow. The total volume of sand contained in the beach appears to be limited, and both the beach gradient and the distribution of sediment may be expected to be highly variable. In general terms, however, the beach gradient is gentle. During the period of fieldwork, in fine weather, a wide berm had built up immediately below high water mark. This berm had a steep outer edge of 8°, but gave way seawards to a flat zone some 40m wide. The lower beach gradient was also gentle at 2°. These slope values pertain to the central part of the beach, and there is considerable variation from place to place as well as through time. Nevertheless, both the beach gradient and that of the offshore ground are relatively gentle, and suggest relatively low wave energy conditions.

Although much of the offshore ground is apparently sand floored, the beach is not particularly well nourished with sand, and insufficient quantities of sand have been supplied for the construction of a well developed dune and machair zone.

The coastal edge is low and subdued, and along most of its length consists of a very thin veneer of blown sand over shingle. Positive evidence of accretion exists only in a few very short sections, notably at the extreme north end adjacent to Golspie village, where a breakwater and pier provide very sheltered conditions. Much longer sections of the coastal edge are undergoing active retreat. Retreat is especially marked in the northern part, alongside the golf course, and also near the point of inflexion in the central part of the beach (bottom of Figure 6.6.b.). The tip of the shingle bar near the entrance to Loch Fleet is also being trimmed back, with the material being reworked into a short stubby spit building out into the main channel. Much of the growth of the shingle bar and associated beach in recent times has probably been at the expense of coastal edge retreat at the north end of the beach. Material eroded from the area of the root, immediately to the south of Golspie, has drifted south prior to incorporation in the Ferry Links part of the complex. This simple pattern of root erosion and tip accretion is complicated, however, by the bend near the central part of the beach. This bend appears to become more pronounced, and divides the total beach into two functional units for the purposes of sediment circulation; at the northern end of each unit is a zone of marked coastal edge retreat. The beach at this point of inflexion is very poorly nourished with sand, and consists mainly of lag deposits of cobbles. This lag deposit, probably resting on a rock platform, is now functioning as a hinge point in the continuing evolution of the shingle bar. The latter is probably continuing to migrate very slowly landwards, but at rates which vary along its length.

Dunes are very poorly developed, and are concentrated near the south end of the beach complex, where a sharp crested, south-west trending ridge reaches a height of about 6m. At the north end of the beach, dunes are completely absent; elsewhere they are in the form of sand-veneered shingle with a capping of Marram and sea lyme grass. These shingle-cored ridges also extend landwards from the main coastal ridge at a number of points, where small hooks have formed at various stages in the evolution of the modern beach.

Since the dunes are simply sand-capped shingle ridges or hooks, they tend to be stable, and blow outs do not readily develop. The most likely point for blow out development to occur is at the extreme south end, where steep landward gradients of up to 16° have formed in free-standing dunes undercut on their seaward face. Even here, however, there are no active blow outs.

Like the dunes, the machair is poorly developed both in relief and in sand thickness. Characteristically, the blown sand simply veneers the landward slope of the modern shingle bar and the flat shingle pavement, or sandflat, which lies between the modern and raised bars.

The greatest thickness of machair is attained near the north end of the beach complex, in the area of the golf course. Here a maturely vegetated sand-built platform rises to 8m at a few points, but lies mainly around 5m. Relief amplitude is greatest immediately to the south of the built-up area of Golspie, where a low ridge parallel to the shoreline is backed by a small zone of steep but low hummocks. These hummocks become less distinct southwards, and the platform ends abrubtly in a series of low, west trending ridges near the south end of the golf course. These ridges may represent hooks formed during the growth of the modern spit; the northern part of the machair is probably the oldest as well as the best developed portion.

In this northern portion, a number of blow outs have been cut into the retreating coastal edge by winds from the east and south-east. Many of these blow outs have now healed, but the active cliffing on the coastal edge offers conditions highly conducive to the development of further blow outs along the seaward margin of the golf course. Landwards from the coastal edge, there is little likelihood of damage resulting from wind erosion.

South of the golf course, the sand-built platform gives way to a sand-veneered shingle ridge and shingle pavement. Blown sand is very thin, and merely infills the shingle interstices. The shingle pavement, merging into a sand flat in the extreme south in the area of Ferry links, is close to mean sea level, but is divided into a series of almost enclosed compartments by a number of hooks leading landward from the modern shingle bar. Much of the landward slope of the coastal shingle bar and many of the west pointing hooks support Marram growth, but elsewhere the grassy sward is thin and short, and is being invaded by heath spreading from the raised shingle bars to the west.

This machair zone thus bears little resemblance to typical machair. The influence of the underlying shingle topography is very strong, and the stability of the zone is very high. There is little opportunity for blow outs to develop, and even if recreational pressures caused trampling damage, it is unlikely that erosional damage would follow.

The evolution of the peninsula at the north-east end of Loch Fleet has been very complex. The main phase of growth of shingle bars southwards from Golspie was during the post-glacial period of high sea level; this process has continued at modern sea level with the construction of the outer, sand-faced bar. At present, the beach plan is continuing to change with retreat of the north end being the most dominant feature. It also seems probable that slow landward retreat of the modern shingle bar may be taking place, but not at a rate likely to significantly influence recreational planning or management.

Marine processes have been much more important than wind in the evolution of the Golspie-Littleferry complex. One of the main characteristics is the poorly developed dunes and machair, which are normally the most vulnerable part of a beach complex. Since these components are so poorly developed, and consist merely of sand veneers over shingle, it follows that the probability of damage resulting from wind erosion is slight. Hence the overall carrying capacity is high, at least from the view point of geomorphological processes. At the same time, the degree of control which can be exerted over marine processes is less than that possible over wind erosion, and little can be done to control coastal retreat on the north part of the beach except by unrealistically expensive coastal defences.

The typical forms of beach-complex vegetation are rather poorly represented. In the north, the grassy sward of the golf course, on which sheep are grazed, extends right to the coastal edge with no intervening zone of Marram or other dune species. In the south part of the beach complex, sea lyme grass, which has

colonised the sand-capped crest of the modern shingle ridge, gives way on the landward slope of the ridge to rank, ungrazed Marram-dominated communities. The raised shingle bars are clad in dry heather moor, on which pines have been planted, and heath is tending to spread seawards from the raised beach onto the shingle pavement separating it from the modern shingle bar. Ling and crowberry are the main species involved in this invasion, but the vegetation covering much of the pavement is sparse and short.

Most of the Golspie-Littleferry peninsula is composed of recent deposits of pebbles, gravel or sand, on which soil formation has not progressed far. Therefore the agricultural value of the land is very low, and agricultural use of the beach complex is confined to rough grazing, and some partially improved land near the west edge of the peninsula. Most of the peninsula is under dry heather moor, a large part of which has been afforested. Small amounts of gravel are extracted from the raised shingle bars north of Littleferry. Most of the peninsula is owned by Sutherland Estates.

The intensity of recreational use tends to decrease southwards. The extreme north part of the beach, adjacent to Golspie, is used for informal day recreation, while the zone between the beach and road forms a golf course. There is no evidence of erosional damage resulting from either of these uses. The central and southern parts of the beach are little used, although recently a small caravan site has been opened immediately to the south of the golf course. This site stands on the flat shingle pavement between the raised and modern bars. The coastal edge adjacent to the beach is in the form of a shingle bar, in which there is little danger of serious trampling damage. Thus site conditions are admirable from the point of view of avoiding environmental damage. The site is also well screened from both the Littleferry road and the A9, and is sheltered from strong winds by shingle bars on either side.

South of the caravan site lies a rifle range, which has involved some landform modification but no damage, while the Ferry Links area is used only for occasional picnics and by birdwatchers and anglers. Again, there is no evidence of physical damage.

The present pattern of use is in harmony with the beach environment, but the beach complex is not used to its full capacity. The area in which the present caravan site is situated is eminently suitable for caravanning, since there is little likelihood of trampling damage from vehicular or pedestrian traffic. The existing site is not used to full capacity, but should demand increase in the future, expansion to the south could readily be made without fear of serious environmental damage. The main problems are likely to result from the provision of drainage for the site rather than from trampling damage. It is suggested that planting of trees and shrubs in and around the existing site would overcome its present rather bleak appearance.

The beach adjacent to Golspie village is also underutilised, and it is suggested that greater use of the beach resource could be made by the provision of better signposting combined with a campaign to improve the tidiness of the environs of the beach (Plate 6.6.1). The combination of sheltered sandy beach, easy access from a main road, and shopping and catering facilities is infrequent in Sutherland; their coincidence at Golspie could be more thoroughly exploited. Increased day-time recreational use is unlikely to require much investment or management effort in the short term, but eventually the provision of a coastal path leading some distance south of the village, combined with controlled access down to the beach, might be desirable.

The south part of the beach complex, around Ferry Links and Littleferry, is also both stable and little utilised. The ecological interest inherent in the area, however, is considerable, and a Scottish Wildlife Trust Reserve

was declared in 1970. It is suggested that no steps should be taken to increase recreational use. Eventually a small picnic site near the Littleferry road end might be provided in the hope that it would deter deeper penetration along the numerous tracks leading into Ferry links. Likewise, a similar site near the mouth of the Culmaily Burn (inset to map B), which is already a popular stopping point, might reduce pressure on Ferry Links. Pressure at the present time is light, and environmental damage resulting from recreational use is much more likely to take the form of disturbance than of trampling-induced erosion.

The pattern of recreational use in the golf course area is unlikely to change, and little damage is likely to result. The development of blow outs on the coastal edge should, however, be monitored, and if necessary be checked by the erection of chestnut paling or vinyl net fencing.

The beach complex consists of a sand-veneered shingle bar constructed at present sea level against a foundation of raised bars formed when the sea level stood higher. Wind-built landforms are poorly developed, and the beach complex is highly stable.

Little recreational use is made of the beach unit, apart from the golf course, but a small caravan site has recently been developed. It is suggested that the capacity of this site could be greatly increased without fear of serious erosional damage. Greater use could also be made of the Golspie end of the beach, which is very easily accessible. (The north end should be retained for informal day use, with residential use concentrated in the area of the existing caravan site).

The south end of the beach, at Ferry Links, has a strong ecological interest and it is suggested that nature conservation should have priority over recreational development. In any case, there is ample capacity in the foreseeable future for the latter in the central and north parts of the beach.

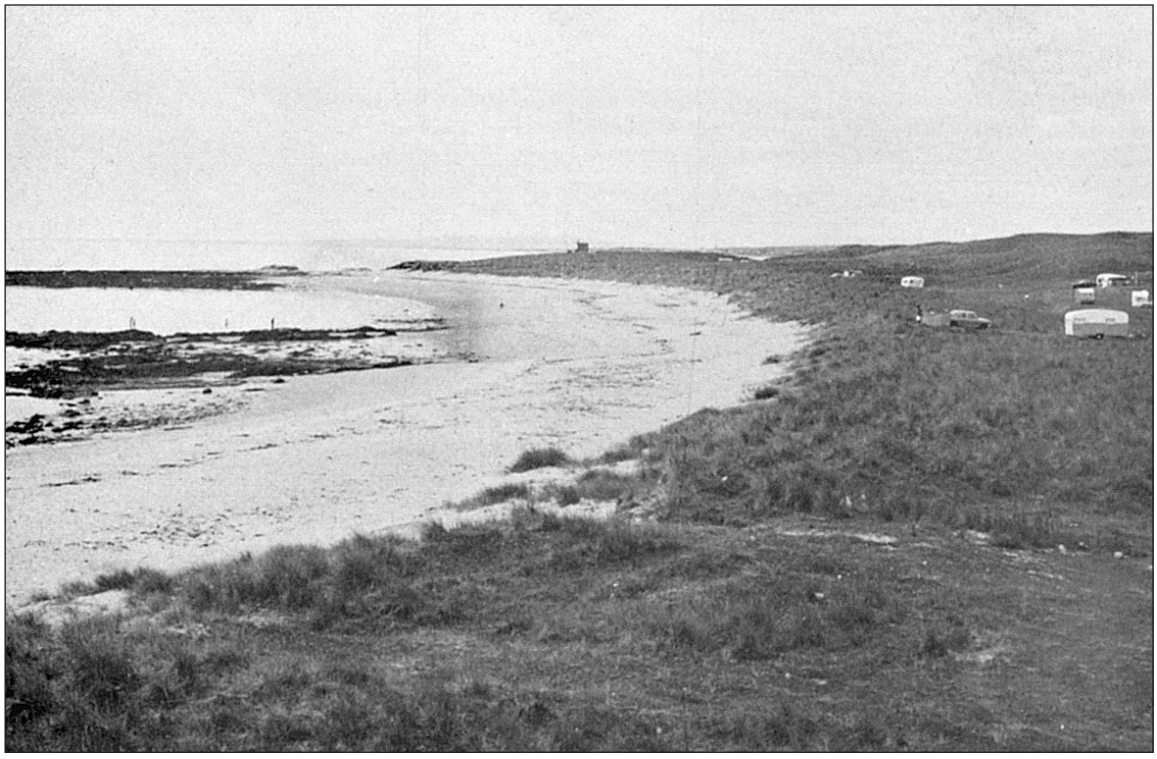


Plate 6.6.1 Golspie-Littleferry – Ferry Links.

Key for Figures 6.6a–e


Plantago-Armeria colonisation on sandflats (near h.w.m.)


Dune slacks – mainly wet grassland


Sand plains (dune slacks) – wet heath with scrub invading


Steep, deeply dissected dunes clad in dune heath and scrub


Belts of sand hillocks or dissected dune ridges (dune heath vegetation)


Low sand hillocks or low undulating sand platform (mainly dune heath or scrub vegetation)


Improved or semi-improved grassland on sand or gravel surface


Dry flat dune pasture or machair


Low sand hillocks, with dune heath vegetation, on raised beach

Figure 6.6a Golspie-Littleferry

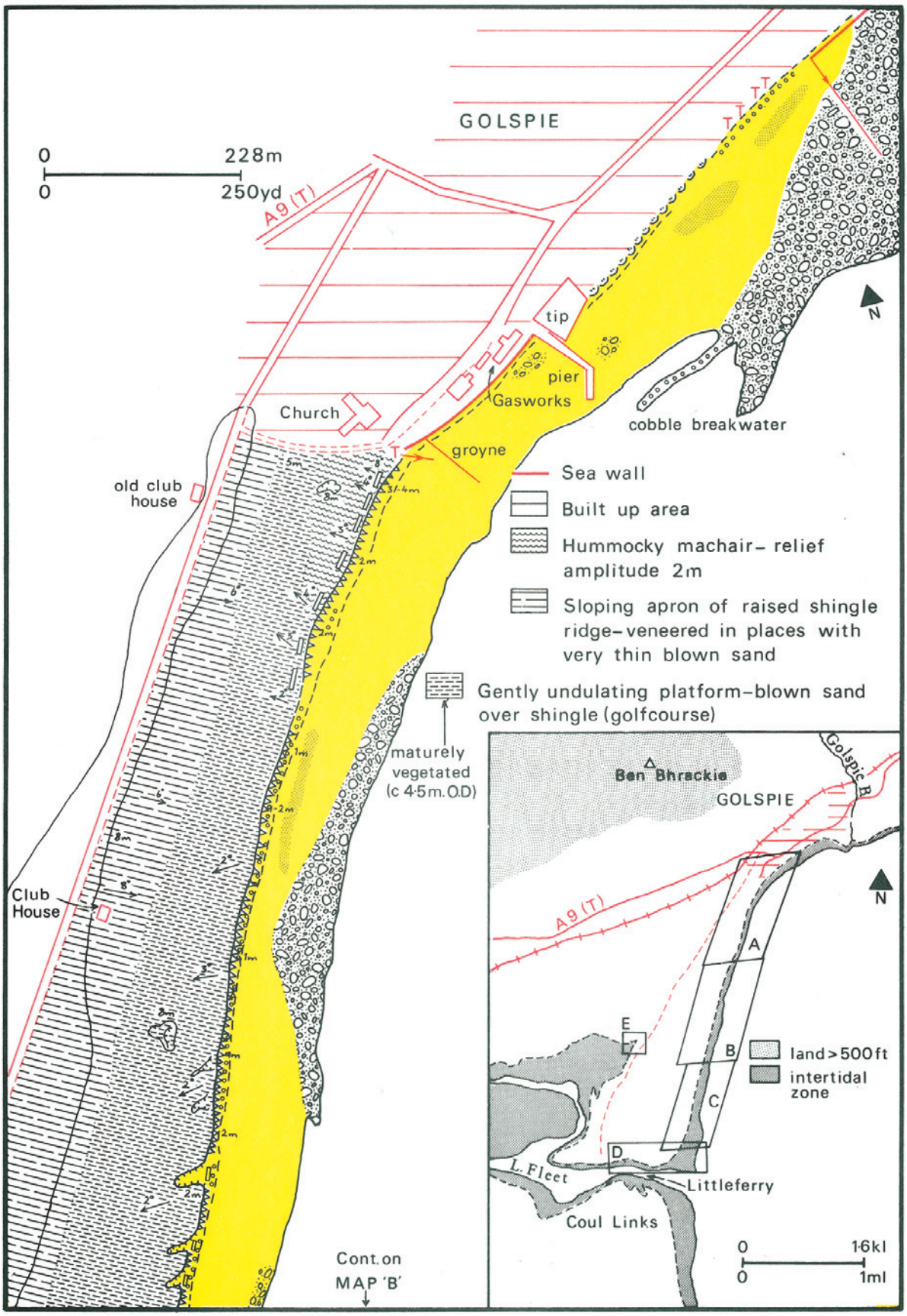


Figure 6.6b and e Golspie-Littleferry

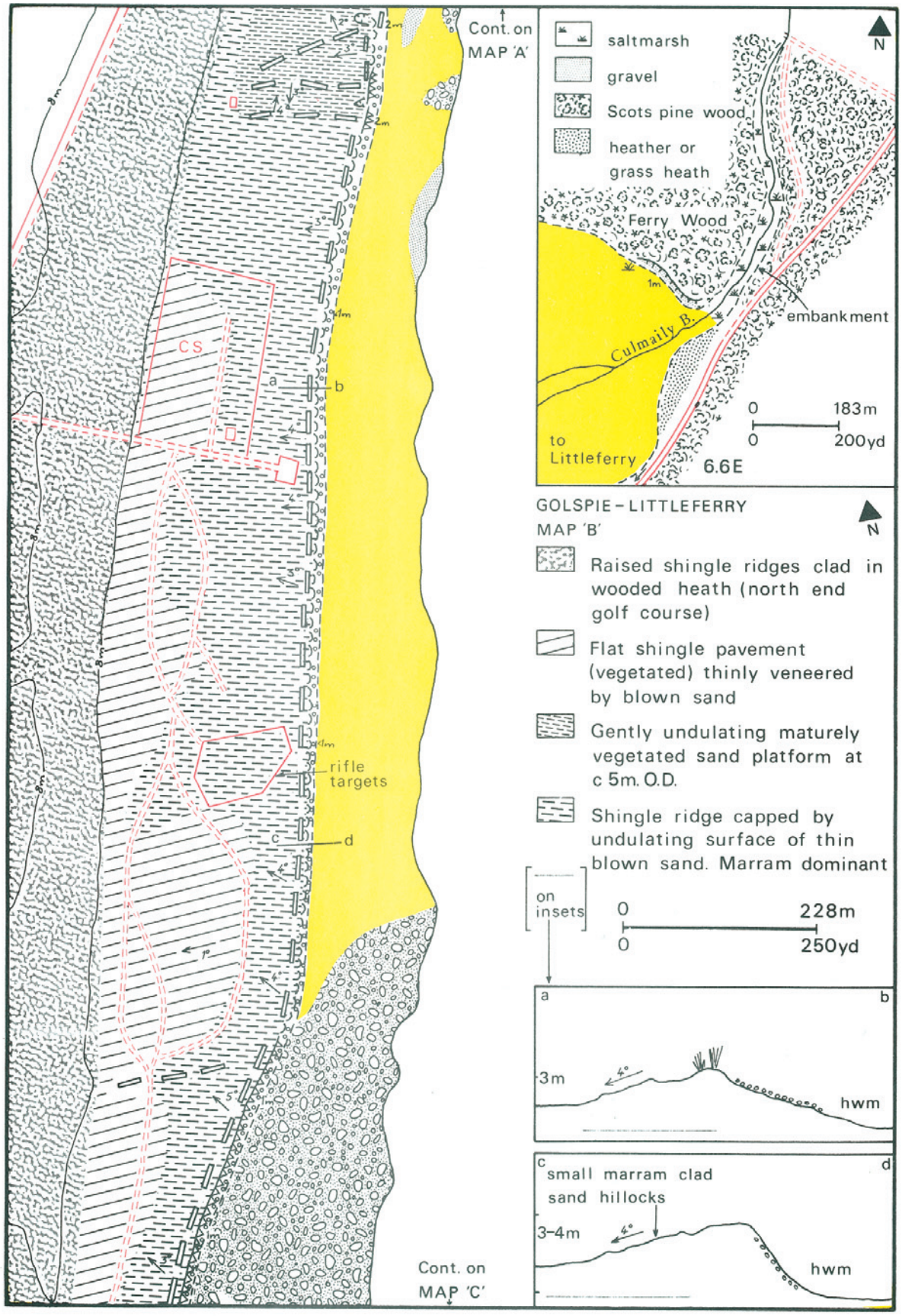


Figure 6.6c Golspie-Littleferry

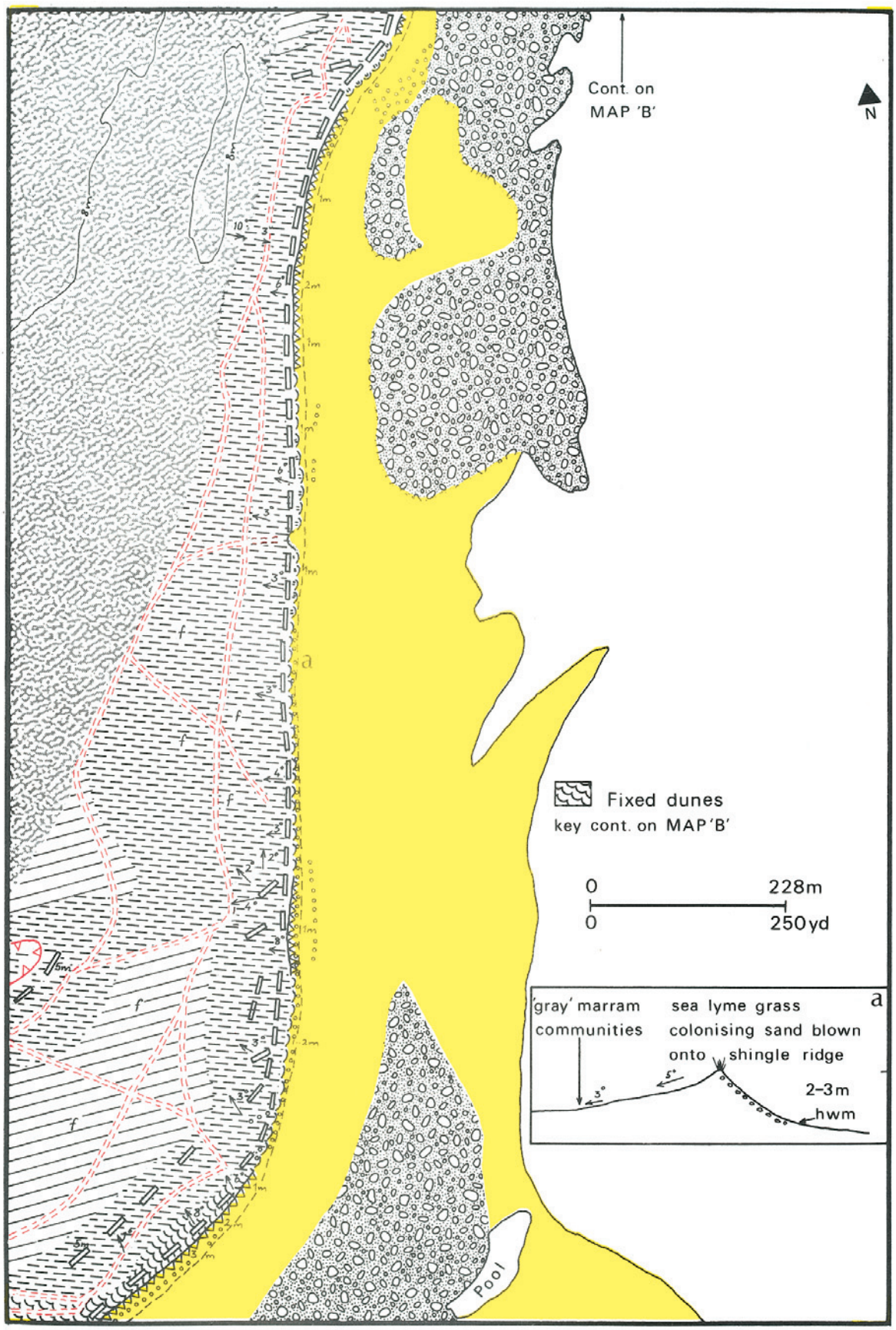


Figure 6.6d Golspie-Littleferry

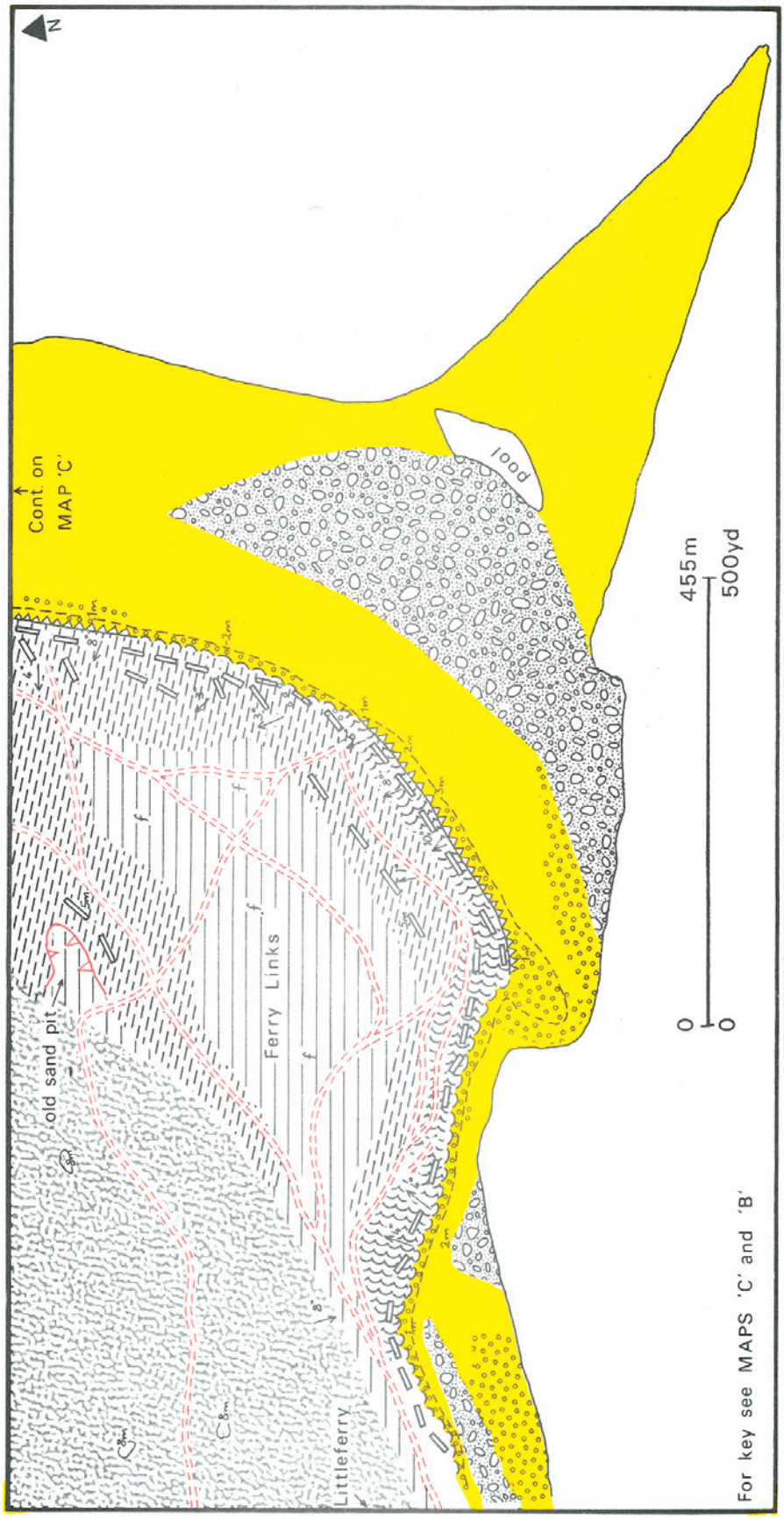


Plate 6.6.2 Golspie-Littleferry – the north end of the beach at Golspie village.

Plate 6.6.3 Aerial view of Golspie-Littleferry, with Coul Links at bottom of picture. Note heath clad raised ridges of shingle. (Reproduced from Ordnance Survey aerial photograph, with sanction of the controller of H.M. Stationery Office, Crown Copyright Reserved).

6.7 Coul

The area lying between Embo and the mouth of Loch Fleet contains one of the most complex dune systems in the north of Scotland. A large marine foreland has been constructed at the south side of the loch entrance, and a series of curved dune ridges has been built up and subsequently modified. The beach unit is large and contains a rich variety of dune landforms and habitats, on which has developed an interesting vegetation succession.

Coul Links lie off the main tourist routes in East Sutherland and are little used for recreation. The unclassified road from Dornoch to Skelbo skirts the beach unit, but although vehicular access is possible from a track near Skelbo Station, few tourists other than anglers and birdwatchers visit the beach.

The beach is convex in plan, and extends to about 3.5km in length. The north beach, on the Loch Fleet shore, contrasts sharply with the east beach extending northwards from Embo, but the most important beach section, from the viewpoint of the continuing evolution of the beach complex, is the north-east part marked A on the accompanying sketch map (page 35). It is in this section that the main physiographic development is at present taking place, so that the beach processes in operation are highly significant in influencing the direction in which this development will occur.

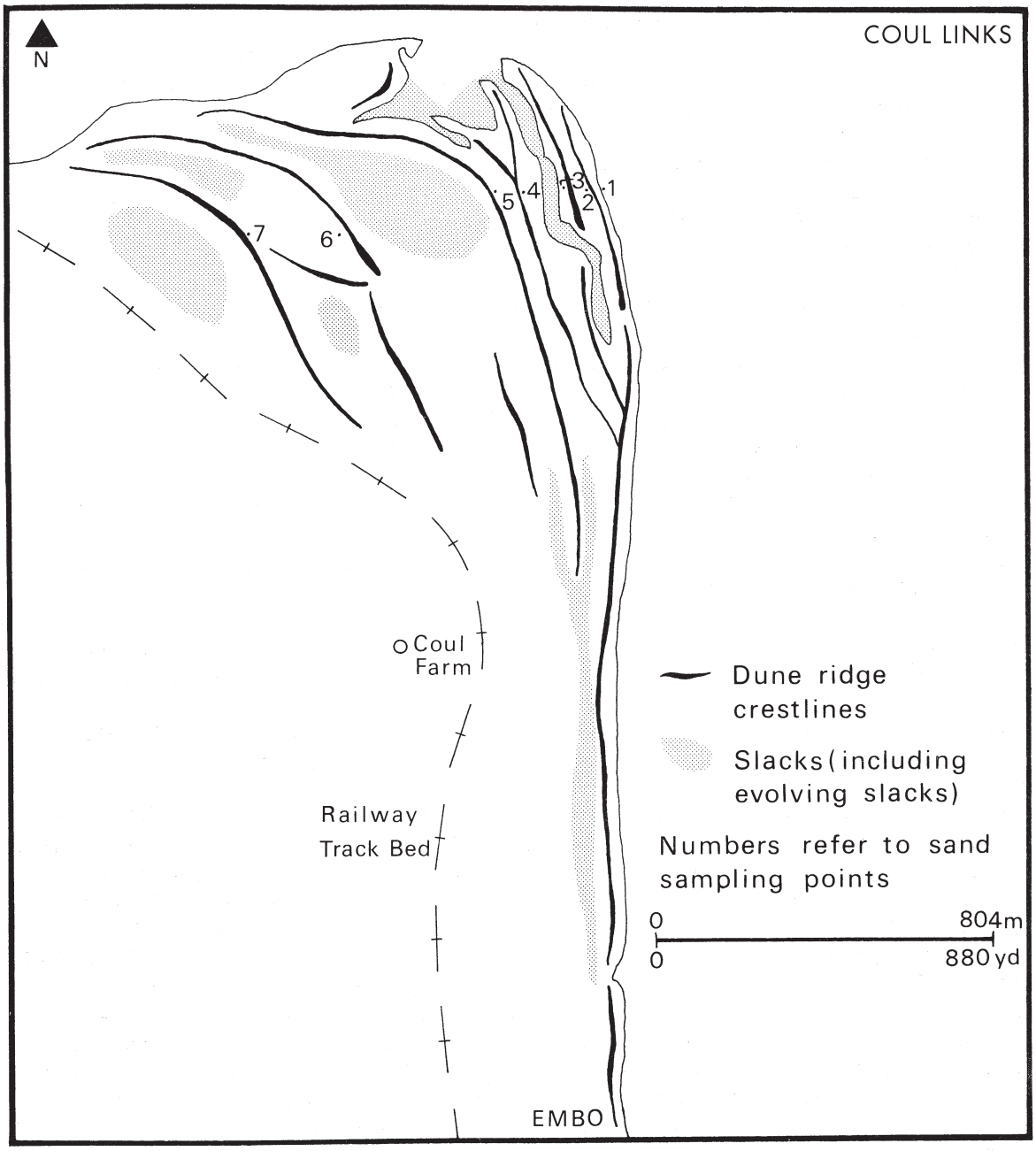
Air photographs and Admiralty charts clearly show a large deltaic structure in the lower parts of the inter-tidal zone and the infra-tidal zone at the mouth of Loch Fleet. The upper part of this delta consists largely of pebbles and gravel which now appear to be immobile, but the foreset beds are believed to be of sand. The delta has probably developed over a long period of time, with its inner part being constructed mainly of fluvio-glacial sediments which are not now readily moved. The profile and distribution of sediments on the inner, inter-tidal part of this submarine delta are highly dynamic, and vary with prevailing marine conditions. It is thought that mobile sand ridges, built up near or below low water mark, migrate landwards over the deltaic surface in rather irregular fashion. These migrating ridges are the source of nourishment for the upper part of the beach, which although thick and flat is sharply defined from the lower, thin beach by a sharp break of slope.

The sediment supply system at the entrance to Loch Fleet is extremely complex, and cannot be fully understood without long and detailed monitoring. In general terms, however, construction is the dominant process on this part of the beach, but the accumulation of sand seems to proceed irregularly.

The coastal edge adjacent to this section of beach is mainly accreting, although the tip of the outermost spit has been trimmed back by basal undercutting. Rates of accretion vary considerably even over short distances; some sections display vigorous backshore colonisation by sea lyme grass, while others are much more static, and the behaviour of the coastal edge probably varies through time as well as from place to place. Episodes of poor sediment nourishment, perhaps associated with the irregular landward migration of sand bars, may occasionally interrupt the dominant process of accretion.

The south part of the beach, from point A to Embo, is much simpler in plan and profile. Both beach and offshore ground are gently sloping, and a submarine bar, lying about 500m off high water mark and extending southwards from the submarine delta at the mouth of Loch Fleet, helps to dissipate wave energy. The offshore ground is sand covered, and the beach is well nourished although both nourishment and beach

width tend to decrease in the extreme south near Embo. Most of the coastal edge behind this section of beach reflects the relatively copious nourishment of the beach. The edge ranges from 6–10m in height, and is accreting along most of its length. Under-cutting is absent except for a very short section near the stream mouth to the north of Embo.



The north beach, fronting onto the Loch Fleet shore, is very different. Strong scouring action in the entrance channel removes most of the fine-grade material, and pebbles and lag deposits form the main beach materials. Some sand and shell fragments have accumulated in the sheltered inlets between the dune-capped spits, but the beach does not readily supply suitable sediment for dune construction.

The processes operating on the beach are extremely complicated, and involve not only the 'normal' marine agencies but also the estuarine process around the mouth of Loch Fleet. The relative intensities of these marine and estuarine processes have varied through time as the Littleferry spit has developed, and their operation has proceeded through changing sea levels and fluctuating rates of sediment supply. Sand supply for beach and dune construction, however, is probably still being maintained south of the loch outlet, but the rate of supply is likely to vary and episodes of retreat may intervene between longer periods of accretion.

The most interesting feature of Coul Links is the richly varied and highly developed system of dunes. In the south part of the beach complex the dune system is relatively simple, and has the form of a single ridge. At a point approximately 500m north-east of Coul Farm, this single ridge fans out into a series of ridges, in which the younger outer members have a smaller radius of curvature than the older inner ones.

The outer members of the series of ridges have partially coalesced, but only the outermost ridge is still active. The others are now fixed under a mature Marram turf, and stability is relatively high. Active blow outs are concentrated in a small area where the foredune ridge is very narrow and fragile. Accretion is the dominant process in the foredune ridge, but all the outer set of ridges are modest in height, mostly lying below 8m, and the input of sand has resulted in widening rather than heightening. Partially vegetated sandflats, occasionally inundated during very high-tides, separate the dune ridges in the north-east corner of the beach unit. Eventually these flats may be sealed off by further growth of the dune ridges to the north-east, and may thus gradually evolve into dune slacks. If north-westwards growth of spit and dune is still continuing, however, it is proceeding very slowly, and complete closure is not imminent. Nevertheless it seems probable that the Coul beach complex has grown towards the north-east by repeated spit extension and dune-slack enclosure. The next stage in its evolution, the sealing of the embayment B, may well be delayed by the proximity of the actively scoured entrance channel to Loch Fleet, which may tend to inhibit the accumulation of sufficient sand to effect the sealing.

The inner dune ridges (nos. 5, 6, 7) are more massive and widely spaced. All three ridges are highest in their central parts, reaching to over 15m, and become lower and more subdued towards their flanks. The highest sectors coincide with the points where there is least topographic shelter; dune height is closely associated with exposure. Heath and scrub have replaced dune pasture, but the dunes have not yet become completely fixed. A number of active blow outs have cut deeply into ridge 6, and fine parabolic forms have developed. Steep "alpine" dune topography, with precipitous slopes, has been created by opposing easterly and westerly winds. Parts of the ridges have become almost obscured in areas of streamlined sand hillocks, possibly derived from sand eroded and transported from other dunes. The rather featureless zone of hillocks between ridges 5 and 6 may, for example, have come from the destruction of the southern part of ridge 5 during an erosional episode. Similarly, rather featureless accumulations of now fixed blown sand conceal raised shorelines to the landward of ridge 7.

Large flat-floored slacks separate the innermost dune ridges. Much of the area of these slacks is now under wet moor or scrub, but the lowest slacks (notably the one to the landward of ridge 7) are winter lochs and support more hydrophytic vegetation.

The series of dunes and slacks may have evolved in a manner similar to that of the outermost dune area. The development of each dune ridge, resting on a sand spit, eventually enclosed a flat-floored depression which now forms a slack. With greater availability of sediment during the post-glacial period, not only would the process of closure be faster than at present, but larger dune ridges could also form.

The dunes at Coul Links are very varied in form, and subtle variations in exposure seem to have exerted important influences in the development of relief. At present, the dunes are relatively quiescent, although by no means completely stabilised. The complexity of the links is such that if instability is triggered off in any part of the area, its effects could be transmitted in magnified form to all other parts.

The simple model of a beach complex composed of beach, dunes and machair does not apply at Coul because of the formation of multiple dune ridges. There is no clear distinction between the dune and machair zones, but on morphological grounds, the gently undulating areas lying to the west, south and south-east of dune ridges 6 and 7 may be regarded as a form of machair. This machair is however very different in appearance from typical west-coast machair.

The undulating sandhills have been constructed during periods of windblow from the surrounding dune ridges, but their surface is now fixed under dune heath in which some scrub is invading in places. The influence of the underlying relief is slight, except in the extreme south where there is only a very thin cover of sand over raised beach deposits or bedrock, and where the landward extent of sand is sharply defined by a relict cliff line. Elsewhere, blown sand is thicker and masks the underlying topographic features, while the relict cliff line is poorly developed to the north and north-west of Coul Farm.

Coul Links have evolved under the interaction of extremely complicated marine and aeolian processes, operating on an irregular pre-existing landscape during changing sea levels. The beach complex has tended to grow gradually towards the north-east as strongly curved, dune-capped sand spits have been added. This growth is probably still continuing, but at an unknown rate; the next major stage in evolution may be the closure of the incipient slack area at B by the westwards growth of the outermost spit.

Some of the existing dunes are still being modified. Of the inner, older ridges, ridge 6 is the most active. The central part of this ridge is relatively strongly exposed to both the east and the west, and the opposing winds have formed very steep dune topography. Most of the large parabolic blow outs face west, but eastwards sand drift from them has been resisted by east winds and the redeposited sand has been formed into "alpine" dune features.

The main foredune ridge is also being modified. The seaward part of the ridge is still unfixed, but blow outs are few except in the section immediately north of Embo where rapid deflation is occurring. There is more trampling damage in this section of the dunes than in any other part of Coul Links, and the instability may have been triggered off by this damage. The links have a strong ecological interest in the form of a long vegetation succession, from embryo dunes through dune pasture to heath and scrub.

Sea lyme grass is the main pioneer species and grows vigorously on the embryo dunes at the top of the backshore. The main foredune ridge is clad in Marram, with increasing proportions of mosses, herbs and grasses landwards. Ridges 3 and 4 are also fixed under dune pasture, in which Marram growth is less vigorous, while dune heath occurs landwards from ridge 5. Large areas are dominated by ling and bell heather, but crowberry, rose scrub and juniper are also widespread. Part of the dune heath zone has been burned, but recolonisation is taking place. Soil development increases landwards, with increasing horizon differentiation and acidity and decreasing carbonate content.

		$CaCO_3$%	pH
	Beach sand	12.7	–
1	Embryo dune	8.9	9.1
2	Yellow foredune	8.6	7.3
3	Fixed dune	5.7	6.6
4	Fixed dune	2.5	6.4
5	Fixed dune	0.0	5.9
6	Fixed dune	0.0	5.6
7	Fixed dune	0.0	4.7

(Numbers refer to sampling points indicated on map on page 35)

With increasing age and stage of soil and vegetation development, the proportion of carbonate decreases and acidity increases. The point where carbonate ceases to exist in the soil coincides with the transition between dune heath and dune pasture, and the soil continues to become more acid as heath species become more dominant. In parts of the inner dune area, the heath gives way locally to scrub, which is more extensive than in most other beach units in the north of Scotland. Scrub is the last stage in the succession towards tree growth, and may have survived at Coul Links because of low grazing intensities.

The dune slacks are also ecologically interesting. The lowest areas in the north-east of the beach complex are still occasionally inundated by salt water, but are being colonised by thrift and plantain (Plate 6.7.2). In more highly developed and more typical dune slack behind the main foredune ridge, the marshy grassland is occasionally flooded to form winter lochs. The wet moorland in the large flat slack between ridges 5 and 6 has been partially improved by surface cultivation and slagging, while scrub grows extensively in the slack between ridges 6 and 7. A variety of scrub species, including broom and birch, grows in the better drained but sheltered zones between the older dunes and slacks.

The links are owned by Cambusmore Estate, and are used for low intensity rough grazing, and especially for the outwintering of cattle. A number of fences have been erected to divide the links into compartments, and the more vulnerable section of the dunes in the extreme north-east has been completely fenced off. Weeds have been introduced, especially around the silage pit and feeding area in the north-west, but there is no evidence that the agricultural use of the links has resulted in adverse physiographic effects.

Arable land is confined to the west of the access road to Coul Farm, but efforts have been made to improve the grazing of parts of the drier dune slacks by surface cultivation. A small area due east of the farm has been afforested.

Small quantities of sand are taken from a number of points in the north and north-east parts of the beach complex, but physiographic damage has not resulted.

Coul Links are little used for recreation except by anglers and birdwatchers. Informal beach recreation is largely confined to the extreme south section of the beach complex adjacent to Embo. Both recreational activity and trampling damage are very strongly concentrated in this small area, where physiographic and ecological interest are probably less than elsewhere.

Vehicular access is possible from the north-west, but only by means of a rough track protected by an unlocked gate near the former Skelbo Station. Knowledge of such a means of access is confined to locals or to tourists with large-scale maps, and numbers using the track are small. Vehicular access is not possible at the south end of the beach, but pedestrian access from Embo is easy.

The scientific interest of Coul Links is more outstanding than its recreational potential. Therefore it is suggested that the present pattern of use should be maintained, and no action be taken to promote recreational use.

The links are at present relatively stable, but probably less so than the beach complexes at Golspie-Littleferry or Dornoch. Likewise, access is not difficult, but the Dornoch and Golspie beaches are better located in relation to the main tourist routeways. The provision of a service infrastructure is also better at both Golspie and Dornoch. Thus the recreational attractiveness of Coul is less than at the neighbouring beaches, but the scientific interest is outstanding not only locally but also regionally and probably nationally. Therefore it is suggested that the present pattern of use be retained, and no action be taken to promote recreational use.

The existing intensity of recreational use at the north end of the beach complex is not incompatible with conservation, and can be permitted to continue without implementing specific management measures. Some trampling damage has resulted from recreational use of the dunes immediately north of Embo, however, and there are indications that stability is deteriorating. Most of the damage is concentrated in a dune-crest pathway, and cannot be effectively remedied without closure of the pathway by fencing, and diversion of the pedestrian traffic either along the beach or else along the more stable lower part of the dune backslope. Such action is probably not immediately necessary, but may become imperative in two or three years if the present intensity of use is maintained. If remedial action is not then taken, much of the dune ridge for about 300m north of Embo could be mobilised.

Current agricultural use is causing little environmental damage, but if pasture improvement were to proceed on a large-scale there could be a danger that successional patterns in vegetation might be concealed and hence the scientific interest of the links seriously impaired. Afforestation over large areas would have a similar effect. Burning of the dune heath is also highly undesirable since it carries a real risk of triggering off dune instability and uncontrollable sand blow.

Despite the strong physiographic and ecological interest of the links, very little detailed investigation has yet been made. It is suggested that a detailed scientific investigation of the area is desirable.

Coul Links is unique in the north of Scotland because of its number of concentric dune ridges. The dune scenery is highly diverse, and physiographic and ecological interest is strong. The links are used as rough grazing, but recreational use is very limited. It is suggested that conservation be regarded as the primary use, and no effort be made to promote recreation.

Key for Figures 6.7a–c


Plantago-Armeria colonisation on sandflats (near h.w.m.)


Dune slacks – mainly wet grassland


Sand plains (dune slacks) – wet heath with scrub invading


Steep, deeply dissected dunes clad in dune heath and scrub


Belts of sand hillocks or dissected dune ridges (dune heath vegetation)


Low sand hillocks or low undulating sand platform (mainly dune heath or scrub vegetation)


Improved or semi-improved grassland on sand or gravel surface


Dry flat dune pasture or machair


Low sand hillocks, with dune heath vegetation, on raised beach

Figure 6.7a Coul

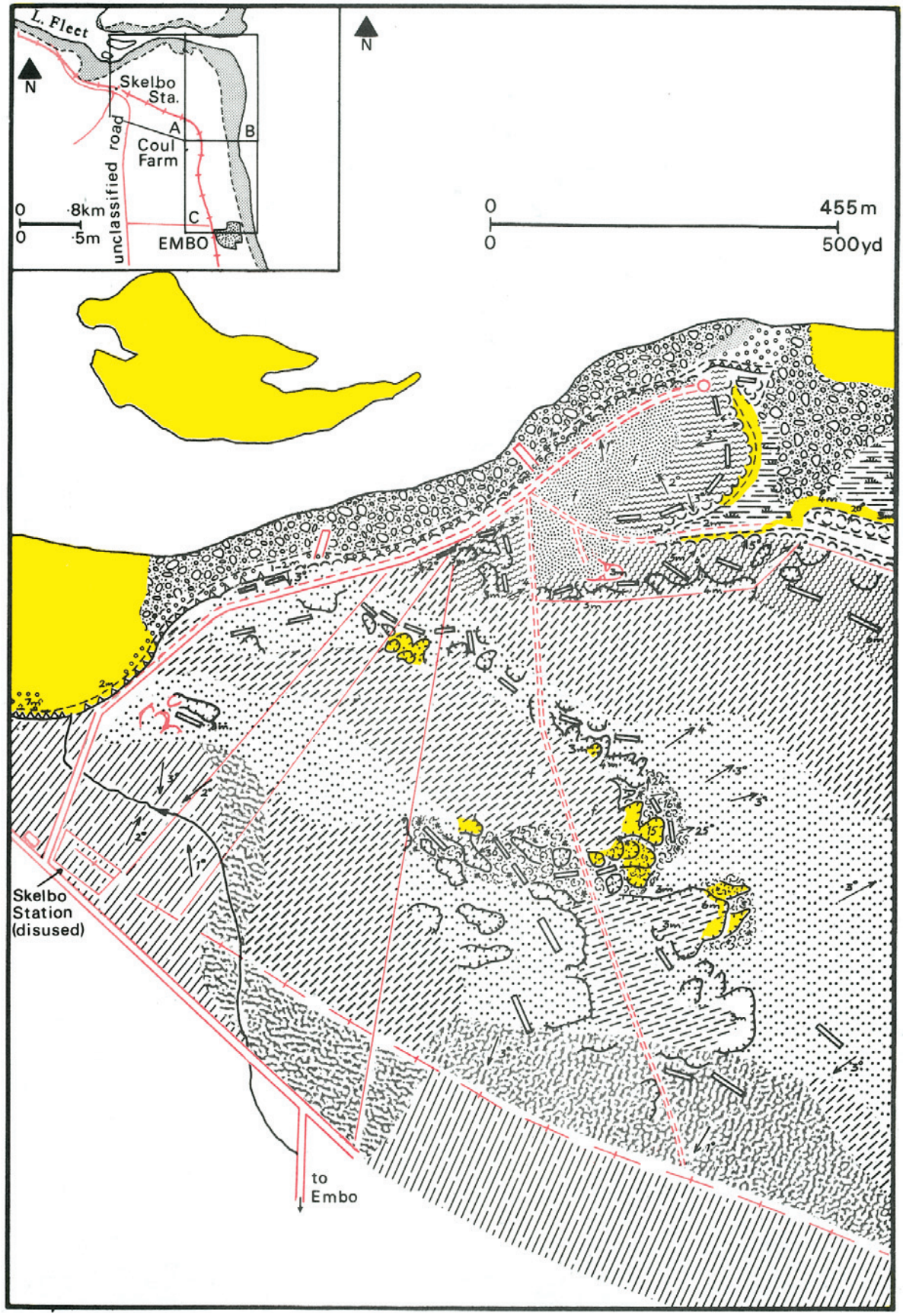


Figure 6.7b Coul

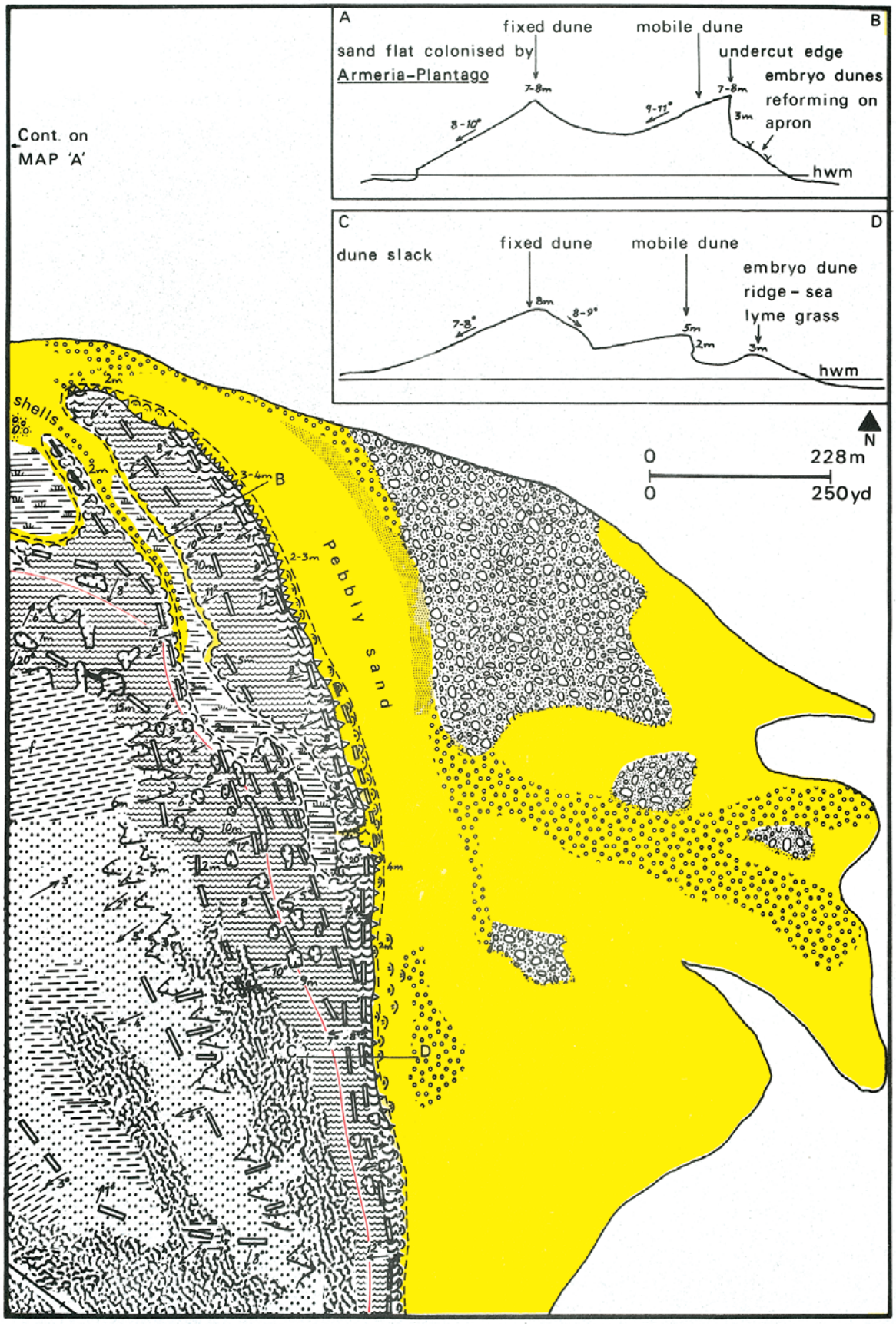
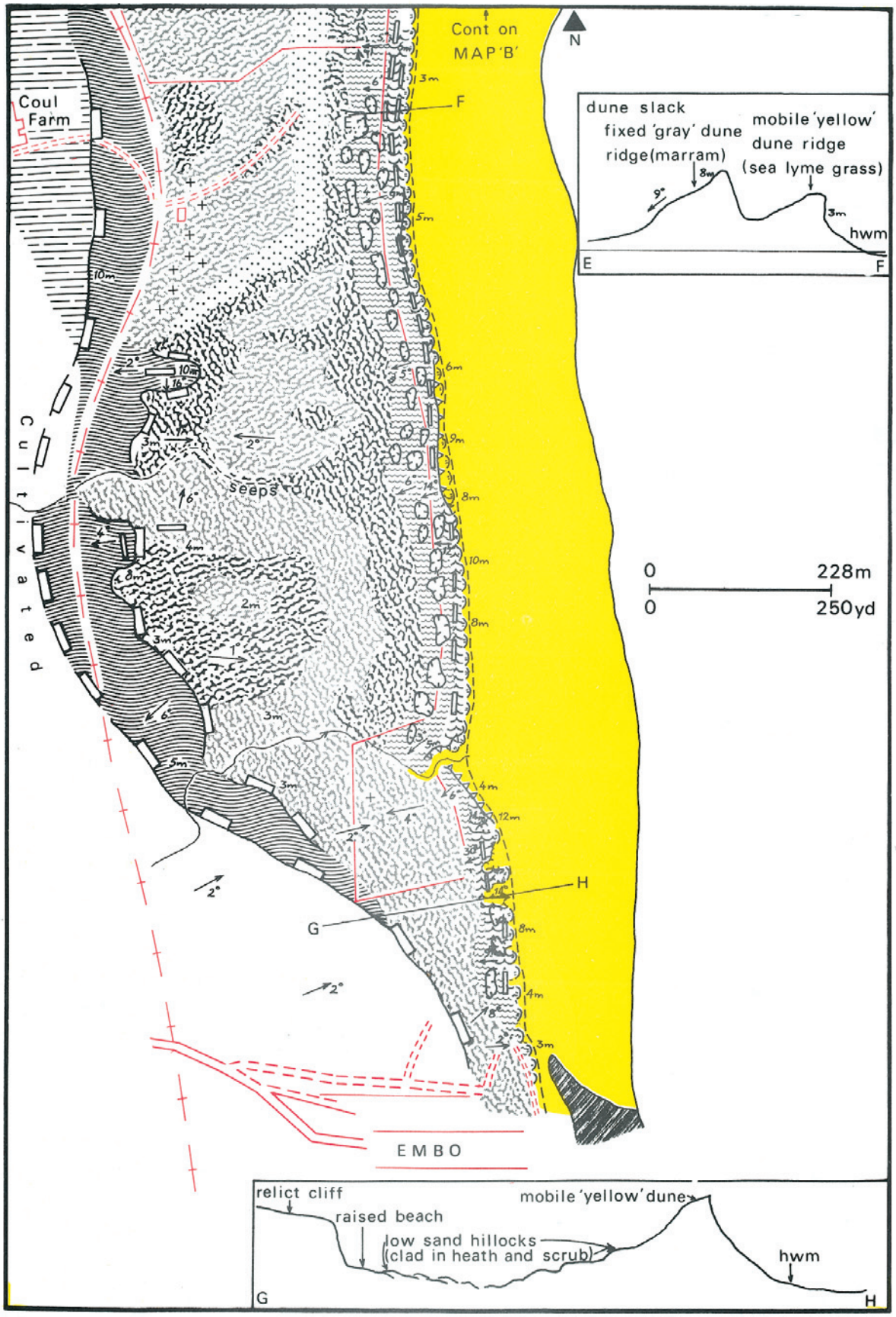


Figure 6.7c Coul



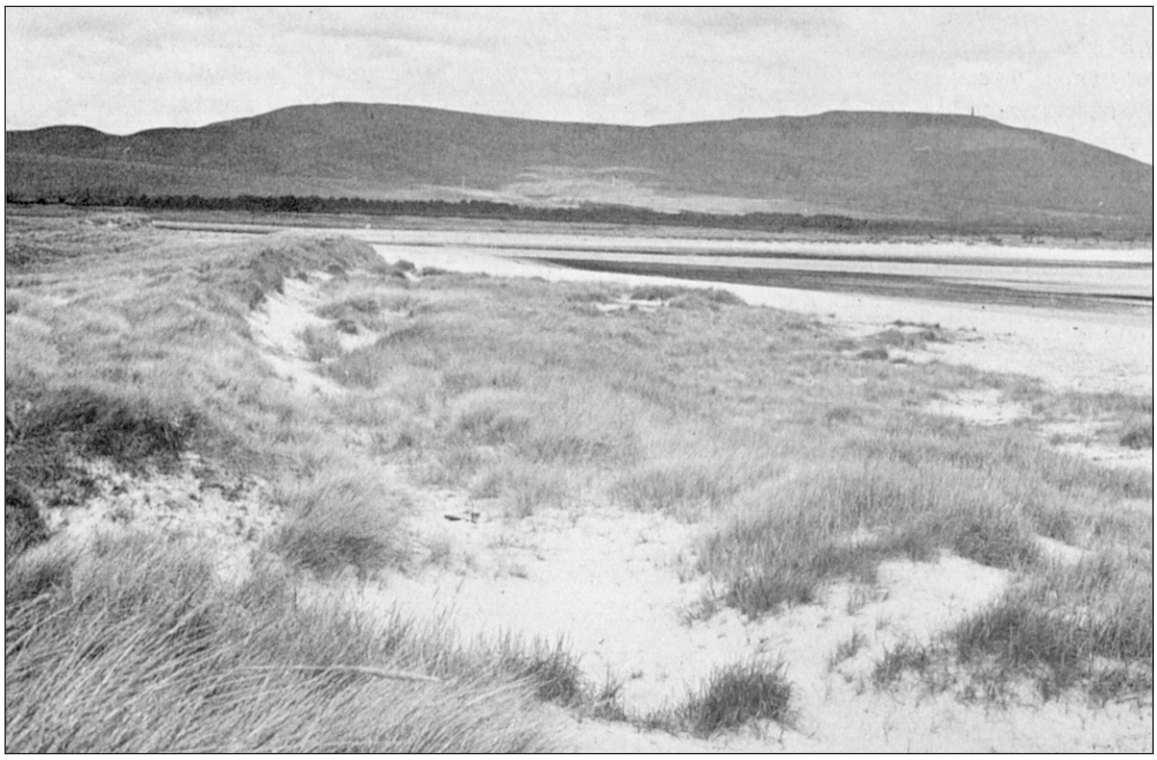


Plate 6.7.1 Coul Links – rapid accretion on the coastal edge near the north-east corner.

Plate 6.7.2 Coul Links – vegetating sandflat, still very occasionally inundated, between dune ridge.

Plate 6.7.3 Coul Links – scrub invading damp slack behind high parabolic dune.

Plate 6.7.4 Coul Links – south end near Embo village. A path has been trampled along the dune crest.

Plate 6.7.5 Coul Links – note the wet slack, and the contrast between dune heath and dune pasture areas.

6.8 Embo

The coast between Loch Fleet and the Dornoch Firth is low and sandy, and is backed along much of its length by a dune ridge of variable height. For approximately 2km south from Embo, however, the sandy beach is very thin and narrow, and occurs only in the form of a narrow fringe at the top of a rock platform. Dunes are poorly developed, and there is no continuous foredune ridge.

A very large caravan site has been established on Embo Links, and both the beach and the adjacent links are intensively used. Trampling damage is obvious in some parts of the beach complex, but the unit is relatively resilient, and instability has not been transmitted from the damage areas to other parts of the beach unit.

In contrast with the neighbouring beaches of Coul and Dornoch, Embo beach is narrow and thin. Most of the lower part of the inter-tidal zone has been swept bare of sand, and the beach is poorly nourished. Patches of rock alternate with sand ground offshore.

The beach consists of three main sectors, with different orientations and sand characteristics. In the most northerly sector, from Embo village to the pier, the sandy beach becomes narrower and thinner southwards. Rock outcrops first appear in the inter-tidal zone opposite the north end of the village, and the proportion of sand cover decreases southwards. Near the pier, the sand beach is only a few metres wide, forming a very narrow fringe at the top of the rock platform. The second sector runs north-east to south-west and also consists primarily of a rock platform, with a narrow sandy fringe. The rock platform is covered in places with immobile lag cobbles, and large quantities of sea weed have accumulated near high water mark. At the west end of this sector, near the stream mouth, the rock platform dips and is overlain by thicker sand. The third sector, running north-south, similarly consists mainly of a rocky inter-tidal zone with a narrow fringe of sand and some shingle in places.

The sandy beaches in all three sectors are thus very narrow, and the supply of sand to the beach is extremely paltry. Despite the relative uniformity of the beach, the nature of the coastal edge varies widely. Behind the north beach sector, part of the coastal edge is in the form of a sand cliff up to 5 or 6m in height. The base of the cliff is undercut by wave action, and turf blocks slump down the cliff face, aided in their movement by trampling. At the extreme south end of this sector, near the pier, a low terrace of made ground has been built out, and the natural coastal edge is no longer visible. The coastal edge behind the north sector is, however, one characterised by instability and retreat, and reflects the poverty of sand supply to the beach.

In contrast, the coastal edge behind the east-west beach sector shows more signs of accretion, despite the narrowness of the sandy beach fringe. Accretion is not occurring throughout the length of this section of the edge, but is confined to the west end and a section near the centre. The remainder of the coastal edge is nevertheless relatively stable (in relation to wave action) although a previous episode of retreat is evidenced by a low grassed-over cliff landward of part of the present edge.

The coastal edge behind the north end of the south beach sector is prograding in the form of a low embryo dune ridge about 2m in height, and backed by a now-healed cliff edge of about the same height. Further south, the coastal edge becomes more neutral as shingle begins to occur at the top of the beach, but the neutral stretches alternate with sections in which there is a slight tendency to accretion.

There is less erosion along the coastal edge than might be expected from the nature of the beach. There are

indications, however, that more active episodes of retreat have occurred in the relatively recent past, and the present quiescence may well be only short lived.

Characteristics of dune morphology and processes correspond to a large degree with the three main beach sectors.

Behind the north sector, a low, maturely vegetated ridge slopes gently landwards. The ridge may represent the attenuated remains of a former foredune ridge, much of which has been consumed by coastal edge retreat. Morphologically, the ridge is very subdued, and its surface is firmly fixed by a close turf. Stability remains comparatively high despite high intensities of trampling pressure, which is manifested on the seaward edge by severely trampled pathways which would probably have developed into active blow outs but for infilling with stones (Plate 6.8.1).

The foredune ridge is better developed behind the east-west sector, and both height and slope are much greater than on the first or third sectors. Most of the dune ridge is fixed, but part of the dune has been seriously affected by a large, active blow out (Plate 6.8.2). This blow out may have formed from the coalescence of several linear blow outs formed by trampling, and indeed such linear blow outs are in evidence near the pier. This dune section is the part of the beach complex most urgently in need of management, and unless remedial measures are implemented the damaged area is likely to grow inexorably. A second, lower ridge runs parallel to this foredune ridge some distance to the landward. Although the ridge is fretted by a number of healed blow outs, stability is relatively high at present, and the ridge serves the useful function of providing some screening and shelter.

Dune height tends to decrease southwards along the third beach sector, and indeed a definite foredune ridge dies out about 300m south of the stream outlet. The limited extent of dune in this sector is at present stable in relation to aeolian processes, but there is clear evidence of undercutting in the past.

The dune component of the Embo beach unit is thus, like the beach itself, rather poorly developed. The foredune ridges have been partially consumed by coastal retreat or by wind erosion associated with trampling damage, but instability is limited by the subdued forms of the dunes and by relatively mature vegetation cover.

The foredune ridges, or their attentuated remains, grade almost imperceptibly into a flat or gently undulating links area. In the transition zone between dunes and links, Marram growth of very poor vigour is widely separated by areas of low grassy sward. Much of the machair is thin, especially towards its landward margin where it overlies raised beach deposits. The relict cliff line of the post-glacial beach sharply defines the landwards extent of machair behind the south sector of the beach; the landward limits behind the central and north sectors are much more gradual.

Morphologically, the machair consists of a smooth surface broken only by low fixed dune ridges running in an east-west direction behind the foredune ridge of the central beach sector, and a very faint ridge normal to the north sector. Both these ridges are securely fixed under a close turf in which Marram growth is poor, and the level machair is similarly stable. Despite the high pressure of recreational use, little serious damage has resulted from trampling of the links. This resilience is thought to be due to a combination of subdued, maturely vegetated surfaces, a relatively low energy environment, and the paving of the potentially most vulnerable vehicular tracks with protective gravel.

The beach unit is probably at a late stage in its development, during which the main tendencies in further evolution are likely to be coastal retreat associated with the partial decay of wind-blown sand built features. The beach is thin and poorly nourished, and the coastal edge is exposed to wave action. The wide rock platform, however, dissipates much of the wave energy, and retreat, where it is taking place, is relatively slow. The main process operating in the dune zone is the decay of the foredune ridge behind the central sector of the beach. Erosional activity is prominent at present, and is likely to continue in operation unless remedial measures are implemented. Such measures are likely to be moderately efficacious; on the other hand little can be done to check coastal retreat short of expensive coast protection works.

In general terms, however, the overall stability of the beach unit is higher than might be predicted from examination of the beach alone. Damage is concentrated into a number of small areas, and the threshold of recreationally induced instability elsewhere is relatively high.

One of the main features of the vegetation on Embo Links is the vigorous growth of sea lyme grass along much of the coastal edge. Despite the poverty of sand supply, sea lyme grass is growing luxuriantly along some sections of the coastal edge, and is succeeding in forming an embryonic dune ridge in places. Without such growth, it is likely that coastal undercutting would be a more active process than it is in at present.

The area of actively forming, yellow dunes is, however, very small, and most of the dune area is fixed under a grassy sward with senile Marram growth. Weeds associated with cultivation have been introduced by earth tipping along parts of the coastal edge.

Most of the links carry dry grass communities in which fescue species play important roles, but gorse heath is invading from the landward, where the blown sand thins out against raised beach deposits and a relict cliff line. A wet slack zone lies between the dune backslope and the relict cliff edge south of the stream.

Formerly, the primary land use of the links was agriculture, and traces of drainage-ditch patterns are still visible, especially in the damper landward area now under gorse heath. Part of the stream flowing through the area has been straightened in an effort to improve the drainage of the arable land behind the links. Agricultural use of the links is now confined to rough grazing, and there is no evidence that detrimental effects have resulted. The area is part of Embo Mains Farm.

Embo links now form one of the largest caravan sites in the north of Scotland, centred around a site shop and restaurant on the south-east corner of Embo village. The total capacity of the site is 200 (75 static, 125 touring caravans). A network of metalled tracks has been laid out around the site, and a number of toilet and washing blocks constructed. The intensity of use of the site is high, but relatively little damage has resulted. Damage has been concentrated along the vulnerable coastal edge, where trampling has initiated blow out development in places. Remedial action has been attempted by tipping stones and earth in the damaged spots. Damage has been most serious along the central sector of the coastal edge, west of the pier. Here initially linear blow outs have coalesced to form an extensive damage area. Further deterioration is likely to occur since the blow out forms an attractive, sheltered playground for children from the caravan site.

Despite the localised damage, Embo Links are not unsuited for this type of intensive recreational use. Provided simple management measures are implemented, the current pattern of use can be maintained without serious environmental deterioration. Internally, there is little screening for the caravans, but the site is not strongly exposed to view from the Dornoch-Skelbo road and is almost invisible from the A9.

Embo Links are probably one of the Highland beach units most suited for intensive recreational use, and there is no reason why caravanning should be seriously curtailed. Some relatively minor management measures are, however, required, and should be implemented as soon as possible. The first of these measures is the construction of an impassable fence along the coastal edge behind the north beach sector. The objective of this measure is to control trampling damage along the coastal edge by channelling all access through two or three points which can be protected by a sleeper staircase or other means. If such control is effected, there would be very much less danger of blow out development resulting from trampling, and the need for tipping stones in the incipient blow outs would be removed.

Damage has progressed further in the dune zone behind the central beach sector, and will be less easily controlled. The first priority should be the exclusion of people by the construction of a ring fence around the damaged area and its environs: thereafter a suitable grass seed mixture should be sown and ideally protected by either latex or bitumen films. Sea lyme grass should be transplanted around the dune toe and lower part of the seaward slope.

The condition of the stream flowing into the central sector of the beach is unsatisfactory, especially since children play in its vicinity. Some of the toilet blocks on the caravan site at present discharge into it, *via* septic tanks, and the stream is turbid and unpleasant. It is understood that the site operator has alternative arrangements in mind, and it is to be hoped that these can be implemented as soon as possible.

The sandy beach at Embo is in the form of a long narrow fringe at the top of a rock platform. The dune area is small, but the extensive gently sloping links are intensively used as a large caravan site. The beach unit is relatively suitable for such use, but some trampling damage has occurred along the vulnerable coastal edge. It is suggested that this damage could be at least partially controlled by simple management measures.

Figure 6.8 Embo

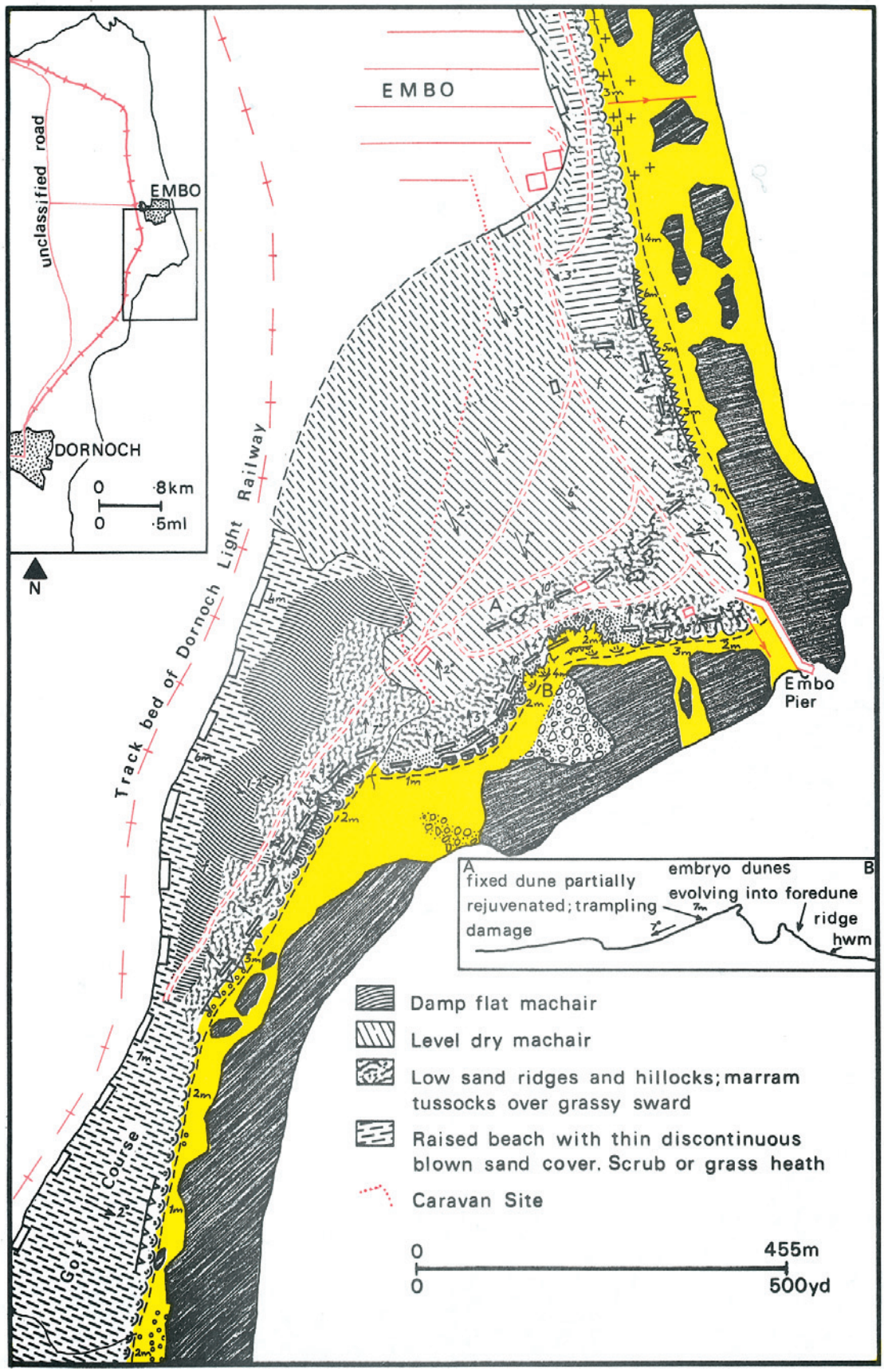


Plate 6.8.1 The coastal edge at Embo caravan site. Stones have been tipped to counteract trampling damage.

Plate 6.8.2 Embo beach and dunes – central section. A large active blow out, in which trampling has accelerated rates of deflation.

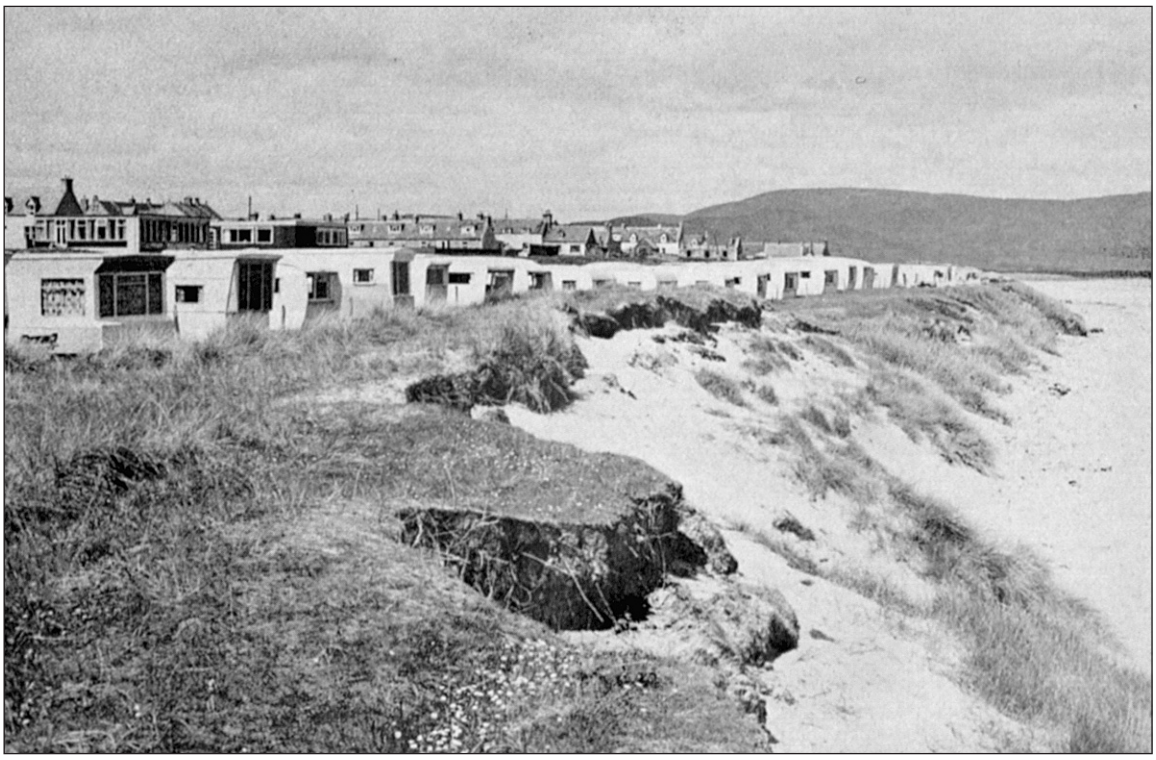


Plate 6.8.3 Embo – caravan site and beach.

Plate 6.8.4 Embo beach and dunes – south and central sections, note narrowness of sandy beach fringe.

6.9 Dornoch North

The north beach at Dornoch lies to the north-east of the burgh and consists of a simple beach arc hinged on rock platforms at either flank. A continuous ridge of low foredunes has evolved, but the blown sand forming the links is thin and does not extend landwards of a very distinct relict cliff line which dominates the beach complex. The links form part of Royal Dornoch golf course, but the beach and dune zones are used for recreation at a lower intensity than the neighbouring beach to the south.

The beach, which faces east, extends to approximately 1km in length and 150m in width. Its plan is uninterrupted by rock outcrops except on the flanks, and the beach material is moderately sorted medium sand (median diameter 0.22mm) with a carbonate content of 17.5%. The offshore ground is sand floored, and shelves very gently at a gradient of approximately 1 in 375. The beach gradient is also gentle, at 4°, and a wide flat backshore consisting of a series of berms has been built up near high water mark. The main source of sediment appears to be the offshore ground, and supply is being maintained along most of the beach. At the north end of the beach, however, the sand is very thin, and a rock platform, thinly overlain in places by immobile larger deposits, is exposed. Rock exposure may increase in the future if sand supply diminishes, but at present the beach is relatively thick and well nourished. The coastal edge is low and stable, and is characterised by accretion along almost the whole of its length, reflecting the ample nourishment from the thick beach and wide backshore.

A continuous dune ridge has formed along the whole length of the beach, but dune morphology is subdued both in height and in slope. A maximum height of about 7–8m is attained opposite the point where the backing relict cliff is lowest, and hence exposure to winds from the west is greatest. Backslope gradient also reaches a maximum at this point where there is maximum interaction between winds from west and from the seaward, but the slope is mainly gentle, rarely exceeding 6°. The seaward slope is also relatively gentle, mostly lying between 10–16°, and terminates in a belt of vigorous colonisation by sea lyme grass. The morphology of the dune ridge is thus conducive to stability, since there is an absence of steep slopes vulnerable to wind erosion. A number of healed blow outs scallop the dune backslope and lend to it a hummocky appearance, but there is very little activity at present on either the landward or seaward faces. A few incipient linear blow outs have developed at the south end of the beach, but these features have been initiated by trampling on the coastal edge rather than by purely natural processes. Control could be effected relatively easily.

The links or machair zone occupies the narrow corridor between the base of the dune backslope and the dominating relict cliff cut by the post-glacial sea. The links have been extensively modified by the construction of tees and greens on the golf course, but are divided into two parts by a low and deeply serrated edge 1–2m in height running parallel to the main relict cliff. This edge is probably associated with a former sea level, and the blown sand cover behind it appears to be very thin. Most of the machair is thin, and is thought to be underlain by raised beach gravels. Apart from a few low, fixed sand hillocks, the machair is rather featureless, and like the dune zone, is characterised by a high degree of stability. This stability is reinforced by the intensive management of the golf course.

The beach complex is not a highly dynamic unit, and most of the marine and aeolian processes are of a low intensity. The main process operating in the beach unit is the continued development of the foredune ridge as sea lyme grass colonises vigorously along the coastal edge. The condition of the beach indicates

that this process is likely to continue in the foreseeable future, but there are some indications on the flanks of the beach that sand supplies are beginning to dwindle very slightly. If sand supplies were significantly reduced, accretion would be replaced by erosion as the dominant coastal edge process. The danger that instability might be triggered off can never be ruled out since it is always possible that extreme marine and climatic conditions may coincide; nevertheless the beach unit is relatively stable, and physiographic changes will probably be slow and gradual.

The narrow seaward face of the foredune ridge is yellow and unfixed, with vigorous colonisation of the top of the backshore by sea lyme grass. The transition to the grey dune, dominated by Marram communities, is abrupt, and most of the dune ridge is firmly fixed. Marram dies out towards the base of the dune backslope, where some broom and small amounts of rose, gorse and juniper are beginning to invade. This scrub growth is kept in check by mowing; indeed a feature of the links vegetation is the heavy modification by golf course management. Much of the relict cliff-face is gorse clad.

Traditional uses have been almost completely replaced by recreation, and are not of significance for the physiography of the beach unit. Small quantities of sand are taken from the dune backslope (see 6.9.8) and some gravel is taken from the terrace to the landward of the main relict cliff line. There is no evidence that extraction has had detrimental effects.

The primary land use of the beach complex is now recreation; Royal Dornoch golf course occupies almost the entire links area. The golf links are intensively managed, and the landform-vegetation complex has been extensively modified by the laying out of tees, greens and fairways, and by mowing, fertilising and watering. This modification has tended to enhance the stability of the beach complex.

The south end of the beach unit is readily accessible on foot from Dornoch beach car park, and is popular for informal day recreation. A path has been trampled along the top of the south part of the dune ridge. This path is parallel to the shoreline, and hence normal to the potentially most damaging onshore winds. Thus blow outs have not developed along the path itself, but some trampling has occurred between the path and the beach, and a few linear blow outs have been formed on the vulnerable coastal edge. Most of these blow outs are small and only moderately active, and their further development could be halted by the construction of a dune-edge fence to prevent further trampling damage at the most sensitive points, and to channel beach access towards more resilient parts of the coastal edge.

Near the north end of the beach complex, some vehicle tracks have been incised into the dune backslope. Sand blow has occurred in places, but activity has now largely ceased and most of the bare areas have grassed over. Some of the tracks lead to small sand pits cut into the landward slope of the dune ridge, but quantities of extraction have been small, and the sand has been used mainly for golf course purposes.

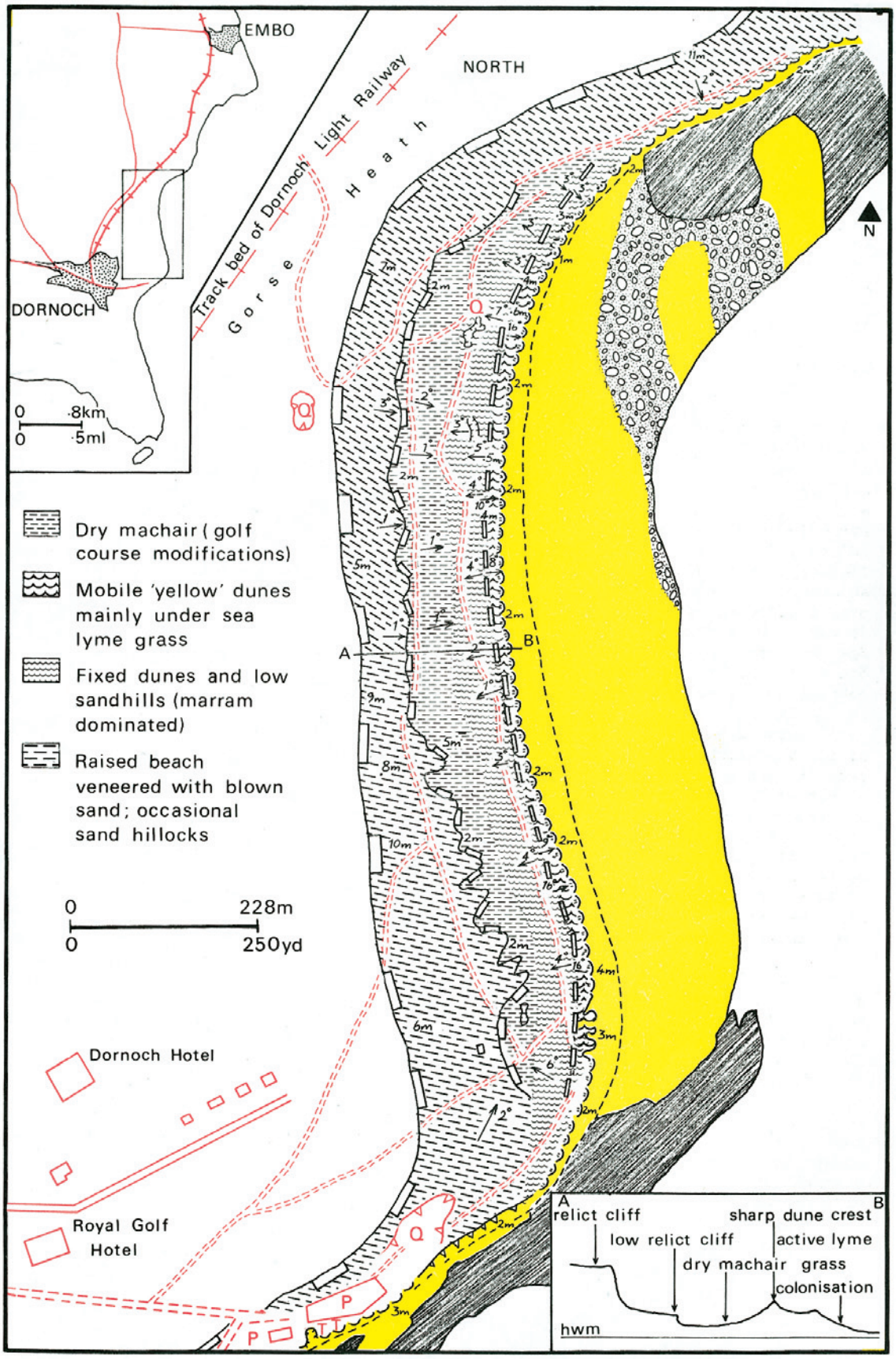
The condition of the beach complex is satisfactory and the present uses may be continued with little fear of serious adverse effects. The main focus of management effort should lie in the trampled parts of the dunes at the south end of the beach; little need be done about the dune-crest path unless its condition seriously deteriorates. Completely free access alone the whole length of the coastal edge should be curtailed by the construction of a fence along the length of about 150m where trampling damage is concentrated. Pedestrian traffic could thus be channelled towards less vulnerable parts of the coastal edge, such at the rock-cored section between the south end of the beach and the main car park. A watch should be kept on the vehicle

tracks and small extraction pits at the north end of the beach unit, but no action need be taken unless their condition deteriorates.

The beach complex is bounded by a well defined relict cliff line and consists of a well nourished beach, a broad but low dune ridge, and a links section of blown sand thinly overlying raised-beach deposits. The beach unit is stable, and is used primarily as a golf course with some informal day recreation towards its south end. These recreational uses are not resulting in significant damage, and there is no reason why they should not be continued.

Plate 6.9.1 Dornoch North – note the wide beach, and subdued foredune ridge.

Figure 6.9 Dornoch North



6.10 Dornoch South

The mouth of the Dornoch Firth is defined by two large marine-built forelands. On the south side, the Morrich More has grown outwards from a point near Tain; its equivalent on the north shore is the foreland of Dornoch Links. The foreland consists of three components, a wide, east-facing sandy beach, a long narrow zone of low dunes and an extensive flat grassy plain. A large caravan site has been established on the north part of the links, and the adjacent dunes and beach are very intensively utilised for recreation.

The most attractive part of the beach complex is the flat, wide sandy beach which extends 2km southwards from the south-east of Dornoch burgh. The beach material is primarily medium sand (of median diameter 0.24mm) with a carbonate content of 14.6%. A few very small patches of gravel occur on the lower part of the beach near its south end, but rock outcrops are confined to near the car park at the extreme north end. Low water mark off the centre of the beach is approximately 350m from the dune front, and the beach is thick and very gently sloping. A wide backshore, consisting of a series of coalescent berms, is built up during fine weather. The upper part of the inter-tidal zone has a gradient of only 3°, and the gradient decreases seawards towards and beyond low water mark. Gentle gradients are maintained offshore, where the average slope to the 5 fathom line is approximately 1 in 500. This slope is even flatter off the Point, where the sand banks of Gizzen Briggs are exposed during very low-tides. Most of the sand flooring the offshore ground is thought to have emanated from the Dornoch Firth. Beyond the deep scoured outlet channel large quantities of sediment have accumulated in submarine-delta form from which material is supplied for the construction of both the Morrich More and Dornoch Links.

As well as providing a major reservoir of sediment within wave base, the gently shelving offshore ground helps to protect the beach and coastal edge from destructive wave action, and both the beach and the coastal edge are characterised by constructional features.

Unlike Dornoch North beach, the south beach is convex outwards in plan, and has the form of a sand spit growing southwards. Near its tip, the spit trends south-westwards, forming a hook which is still only partially developed. The plan of low water mark also suggests another evolving, south pointing spit, and this embryonic feature will probably migrate landwards to coalesce with the main dune-capped spit.

The beach is stable in the sense that present processes are producing constructional rather than destructional forms. It is by no means static, and the south end in particular is rapidly evolving. The coastal edge reflects these constructional conditions, and for most of its length is low but rapidly accreting. There have probably been a few short and highly localised erosional episodes in the past, but the few undercut edges are now protected behind embryonic ridges except where there has been some edge trimming by the southwards-deflected mouth of the Dornoch Burn.

The beach is backed by a continuous and wide foredune ridge, the seaward part of which is yellow and unfixed. Dune morphology tends to be subdued, but varies along the length of the ridge. At the north end, the ridge is mostly below 4–5m in height, and both landward and seaward slopes are gentle, rarely exceeding 6°. South of the stream mouth, both heights and slopes increase, attaining values of 8m and over 18°. Steepening of the dune relief seems to coincide with increases in exposure as the topographic shelter provided by the relict cliff to the north decreases. Although altitude tends to decrease again southwards towards the Point, the central and southern sections of the dunes contain much higher energy forms than the

north part, and their stability is correspondingly lower. Despite heavy trampling, no large blow outs have as yet formed in the north dunes, but several transverse deflation hollows have breached the foredune ridge in its southern half. Many of these hollows are now wholly or partially healed, but their occurrence demonstrates the potential instability of this section of the dunes.

Accretion along the coastal edge is reflected in a wide band of unfixed, yellow dune along the seaward face of the ridge. Accretion is still rapidly occurring, with very vigorous growth of sea lyme grass at the top of the backshore. Accretion and dune evolution have been most dramatic at Dornoch Point itself, where two small dune "islets" have formed on the hooked spit tip. Although these islets are low and fragile, they are increasing in size, and may be expected eventually to coalesce with the main foredune ridge.

The links behind the foredune ridge are interrupted by a number of faint Marram-clad ridges standing 1–2m above the surrounding level. These low, flat ridges probably represent the attentuated remains of former foredune ridges constructed at earlier stages in the evolution of the foreland.

An extensive, rather featureless area of links has formed behind the shelter offered by the foredune ridge and its predecessors. Evolution is continuing at present in the lee of the dune "islets" at Dornoch Point; the level of the sandflats in the lee of the spit tip is gradually raised and vegetation colonises as the frequency of salt-water inundation decreases.

This young machair is thus low and poorly drained; drainage improves northwards towards the higher, older machair, with a corresponding gradation in soil and vegetation development. Machair formation probably began during a higher sea level; the machair at the extreme north end of the links is rooted on a relict cliff, and is separated from the adjoining links surface by a scarp 1–2m in height. Apart from a few low and completely grassed scarps, the links are flat, featureless and stable. The north-east corner of the links has been heavily modified by the tipping of hard dry refuse between the main machair scarp and the dune backslope, so that the ground surface is now raised above its former low-lying, damp level. This part of the links has also been modified by stream migration, and latterly by the cutting of a new, straight channel for the burn.

The beach unit is continuing to evolve by the growth of sand spits to the south and south-west. These spits eventually become dune-capped, providing shelter behind which the extensive sandflats gradually dry out to form links or machair. This evolution is the result of the interaction of estuarine, marine and aeolian processes, and relative or absolute changes in the intensities of any of these processes could readily alter the rate or direction of development. At present, however, there is no indication that the current pattern of development is likely to change. The dune "islets" near the spit tip will probably eventually coalesce, forming even more sheltered conditions in the sandflats behind, and thus encouraging the growth of the machair to the south of its present limit.

Dornoch Point is only one of a series of marine-built forelands in and around the Dornoch Firth. Its most distinctive feature is the almost complete absence of shingle. Normally the absence of a shingle foundation for the spit-dune complex would tend to lessen its stability and resilience to erosional pressures. The general stability of the beach unit is, however, high, although it decreases towards the more dynamic south end. It is fortunate that access is easiest at the north end, and that recreational activity has been concentrated there.

The vegetation pattern is strongly influenced by landform and particularly by slight variations in drainage conditions. Sea lyme grass is colonising very vigorously along a wide band at the coastal edge, and dominates much of the seaward face of the foredune ridge. Marram communities dominate the fixed landward section of the dunes, and extend, in senile form, to the old dune ridges landward of the main ridge. The drier parts of the links are vegetated by fescue-dominated grassy swards, but the vegetation cover on the youngest, lowest parts of the machair is incomplete and is largely confined to thrift and plantain. Agricultural weeds have been introduced in large quantities by tipping in the caravan site.

The links are owned by Dornoch Town Council. Until recently their main use has been as rough grazing, but letting of the grazing is now sporadic. A few very small plots are cultivated in some of the drier parts of the links to the south-west of the area shown in Figures 6.10. There is no evidence that agricultural use has resulted in any physiographic damage.

An airstrip has been laid out in an east-west direction across the central part of the links, and its construction has involved some landform modification. The east end of the strip is cut into the dune backslope and the foredune ridge thus narrowed and steepened. Fill is most noticeable along the strip's south edge. The construction of the level surface has effaced the contrasts in drainage, soil and vegetation between the old dune ridges and the intervening damp machair hollows.

Recreational use is very intensive, but is concentrated in a small area in the north-east corner of the beach complex. A large caravan site, with a capacity of 200 caravans, was developed rapidly during the 1960s, and the adjacent sector of the beach and dunes is intensively utilised for recreation by both caravan-site residents and day-visitors.

The part of the links on which the caravan site is situated has been modified by the straightening of part of the Dornoch Burn, and by tipping to provide harder and drier standing. A network of metalled tracks has been laid out, and has precluded deep wheel-track rutting which might have developed into dangerous blow outs. Despite the high intensity of use, no serious damage has resulted from the laying out of the site or from vehicular access, but pedestrian traffic between caravans and beach has caused trampling damage in the intervening low dune ridge. Trampled pathways criss-cross the dunes, but the development of blow outs has been inhibited by the subdued dune topography combined with the high degree of topographic shelter from the neighbouring relict cliff. If the same level of trampling damage had been incurred south of the stream mouth, it is almost certain that widespread erosional damage would have resulted.

The north part of the beach and the adjacent dunes are also used intensively by day-visitors, and during fine days in summer up to fifty cars may be seen in and around the car park at the end of the beach road. Trampling damage is widespread along much of the adjacent coastal edge, part of which is fortunately rock-cored and relatively resilient. Blow outs are nevertheless developing around some of the worst trampled points, and the entire section of coastal edge between the car park and the burn bears the imprint of heavy pressure. This pressure has thus far resulted in remarkably little wind erosion; had it been located on less stable physical conditions, the environmental repercussions might have been grave.

Part of the links to the west of the caravan site is used as a nine-hole golf course, and it is understood plans have been drawn up to extend the course to eighteen holes. The stability of the links is very high and physiographic damage is unlikely to result from golfing use.

The absence of symptoms of severe damage, despite high intensities of use, reflects the suitability of much of the beach unit for recreation.

It is recommended, however, that high-intensity use should not be permitted to extend southwards from its present focus. The central and southern parts of the dunes are much less stable than the north part, and the introduction of trampling at intensities comparable to those on the north part of the dunes would almost certainly trigger off severe erosion. It is suggested, therefore, that the caravan site should not be expanded southwards, and that vehicular access for tourists should not be permitted beyond the south end of the existing site. The central and southern parts of the dunes are popular with family groups seeking less crowded conditions than exist opposite the caravan site, and there is no reason why access should be prohibited, provided that the people walk rather than motor to their favourite spots.

In the north dunes, near the caravan site and car park, trampling damage could be reduced by the simple expedient of channelling pedestrian traffic through a small number of controllable points. To achieve this objective, a strong fence should be constructed along the top of the coastal edge, with not less than six gaps left for through access to the beach. The gaps at the car park end should be protected by sleeper staircases; those nearer the stream would be best safeguarded by duckboard walks, which could if necessary be extended backwards across the dune ridge if trampling damage becomes severe. These measures would help to reduce many of the signs of wear and tear around the beach margin, and at the same time would permit the safe continuation of the present intensities of use.

The condition of the Dornoch Burn is not satisfactory. The stream is slow-flowing, turbid and encumbered with weed. Part of the course between Littletown and the west side of the caravan site has already been straightened, and this has helped to improve the flow in that part of the stream. But the real problem lies in the section between the caravan-site bridge and the outlet, and particularly at the point where the stream breaks through the dune cordon. Southward drifting sand blocks the stream mouth and deflects it to the south, with the resultant ponding back of flow and trimming of the neighbouring coastal edge. Canalisation of this section of the stream might result in some improvement, especially if flow could be confined to a narrow channel, but it is very doubtful if any real cure can be effected. Such a cure would involve the halting of south-drifting sand by a groyne to the north of the mouth. While this might help to improve stream discharge, it would also reduce sand supply to the beach and dunes further south and might well trigger off erosion of the coastal edge and the development of vigorous wind erosion of the dunes. The disadvantage would thus exceed the benefit, and therefore the construction of a sand trap is not recommended.

Dornoch Links is a large, sand-built foreland, with a sandy beach and foredune ridge along its eastern margin. Stability is relatively high, and reaches a maximum at the north part of the beach, where a large caravan site has been developed. The present pattern and intensity of use are not discordant with the physiography, and minor management measures could ensure the effective conservation of the main recreation area. It is recommended that the caravan site should not be further extended to the south, as dune instability might be triggered off by the passage of people between site and beach.

Figure 6.10a Dornoch South

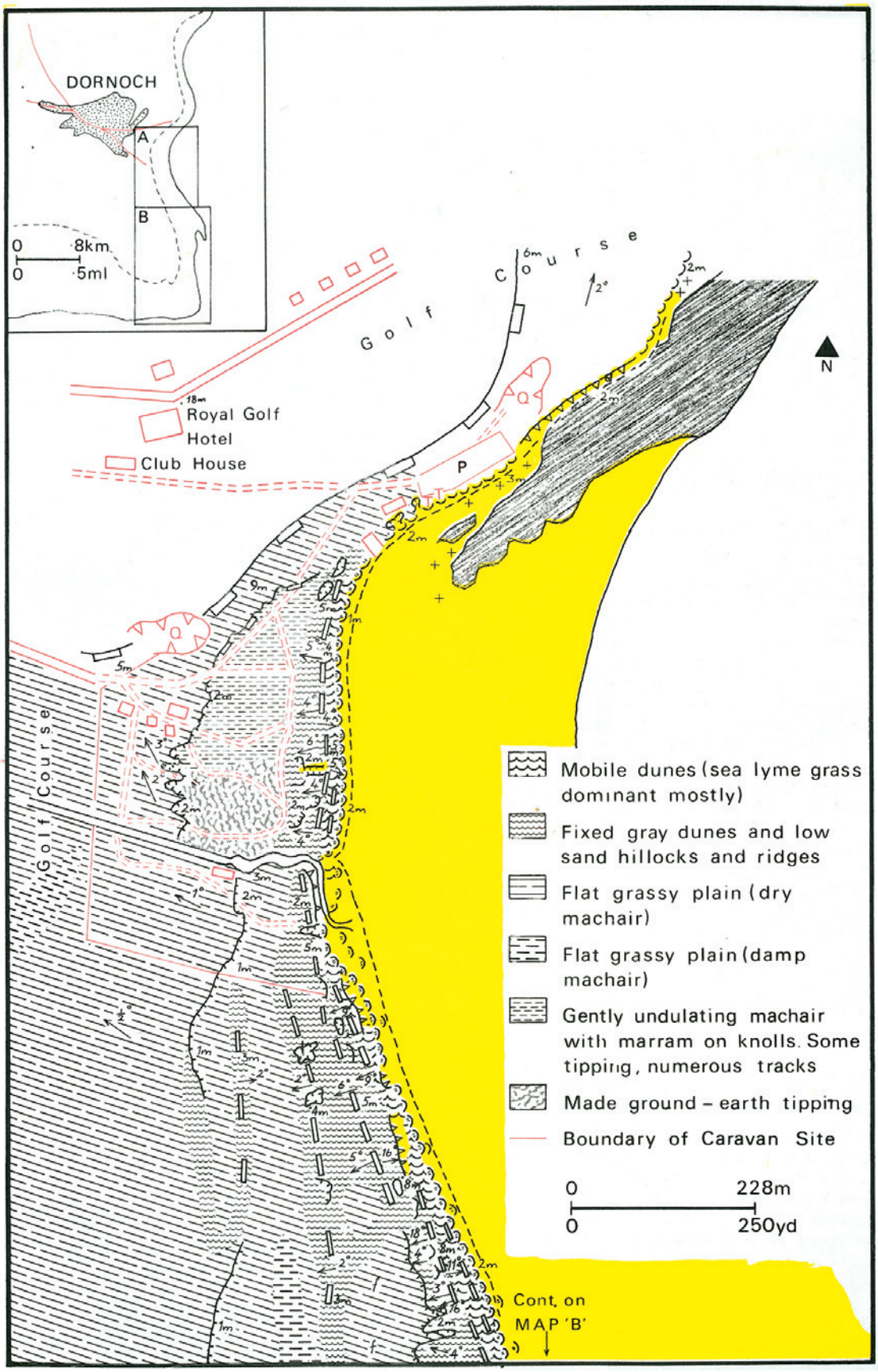


Figure 6.10b Dornoch South

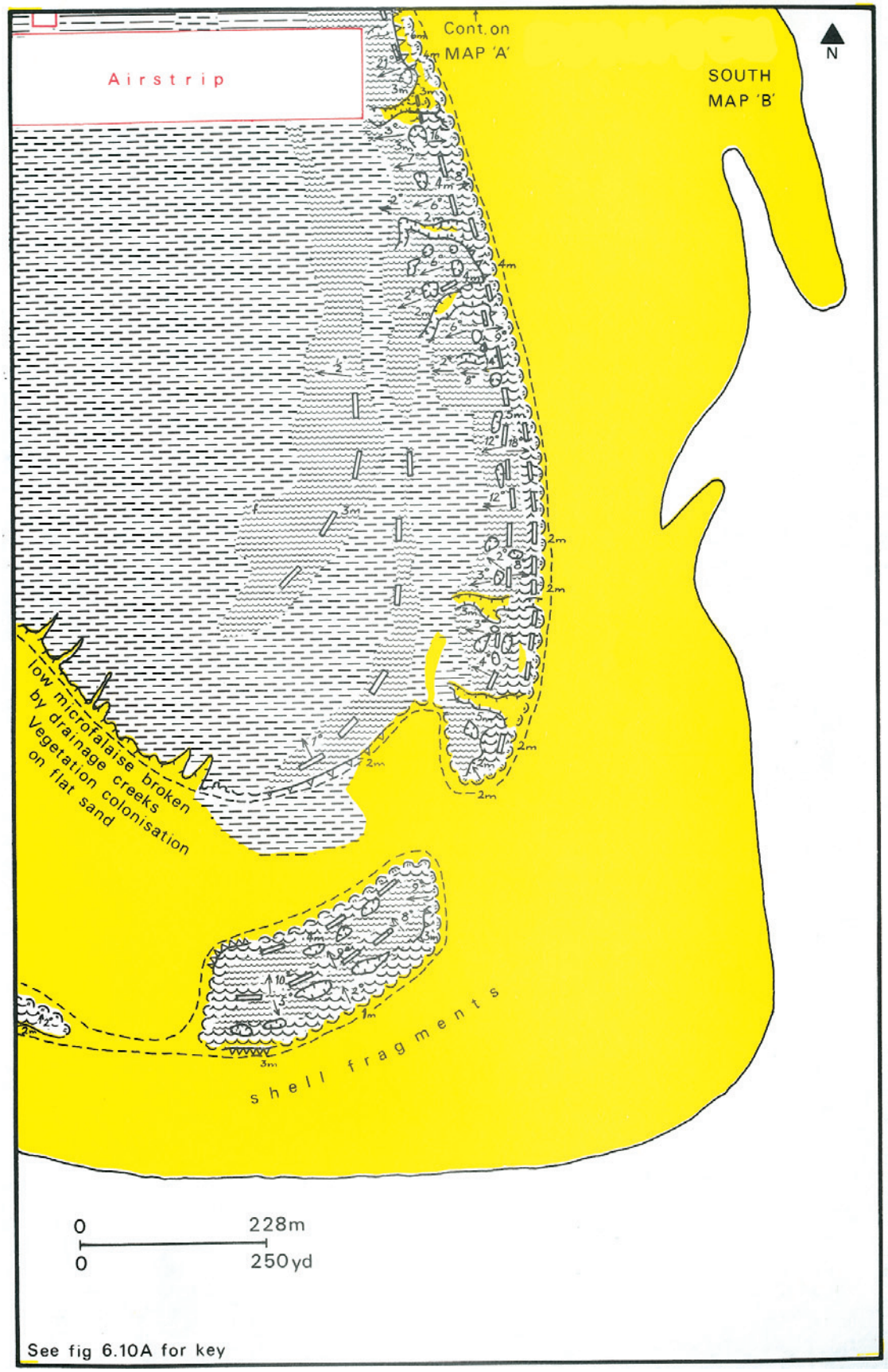


Plate 6.10.1 Dornoch South – note vigorous accretion along the coastal edge.

Plate 6.10.2 Dornoch South – Note trampling damage in foreground.

Plate 6.10.3 Dornoch Point (1959) – the caravan site occupies the area near the top of the picture, mainly on the north side of the stream.

6.11 Cuthill Links

The northern shore of the outer Dornoch Firth consists of a wide inter-tidal sandflat with a narrow fringing beach of mixed sediments. Landwards of the backshore, there extends a wide post-glacial strandplain consisting of raised shingle beach ridges on which varying thicknesses of blown sand have accumulated. The present characteristics of the shoreline are not favourable to sand accretion by wind blow from the beach, and it consists of a mixture of erosion and deposition, with erosion of the backshore dominant at present. The coast is more than half a mile from the secondary road which runs from Dornoch to Cuthill, and the beach is physically concealed by the belt of partly improved agricultural land and heath which runs along the coast, widening towards Dornoch. Access to the shore is possible by vehicle at the Ferrytown end at two points, but the foreshore is shingle and gravel, with rather sterile raised shingle bars behind. In the centre of this shore complex, agricultural land reaches the backshore at all points where sand occurs on the fringing beach. The shore is open and exposed and looks across the Dornoch Firth towards Edderton. The beach itself is discontinuous and narrow and has very little recreational potential. The heathland at the west end is used for casual recreation and picnicking, while the pier at the west end is used for pleasure boating. At low-tide, the immediate foreshore is dwarfed by the wide expanses of sandflats.

The fringing beach runs for less than half of the coastline depicted in Figures. 6.11.a and b. The material is highly variable and could best be regarded as mixed sediments. Beyond the narrow fringing beach, extensive sandflats occur. In many of the small re-entrants, fringing saltmarsh has developed, often resting around or on top of lag shingle. Wave stripping of the saltmarsh is active in most parts. The coastal edge generally takes the form of a low degraded scarp cut into either machair or subdued heathland terrain. The extent of the low machair, and of the Marram dunelets, indicate that sand has been more freely available in the past. A number of small streams, mainly field drains, enter the shore but they have no significance in the beach or backshore morphology. Occasionally the narrow fringing beach rests on top of the saltmarsh. Backshore erosion increases towards Dornoch Point. The machair areas are usually unfenced and sheep graze on both saltmarsh and beach.

Amorphous dunes occur on the backshore top with Marram quickly replaced by a heathland *Calluna* association. The width of the heathland increases eastwards but it has been improved from the landward margin, and partially fenced. There are signs of old erosion scars in the form of small blow outs orientated west-east.

The heathland forms part of a linear strandplain which stretches from Ferrytown eastwards to Dornoch. It consists of thin blown sand over raised shingle bars. It is generally fringed by a narrow shingle beach, passing seawards into sandflats. The area is dominated by heather and whin, and there is a predominance of lichens in the shingle bar lows. The links are grazed by cattle, and there is a very high density of rabbits. The blown sand layer is thin, and is easily removed to expose underlying gravel, making the area attractive for extraction. The area is not outstandingly interesting in terms of its botany, but the physiographic interest is high, and there is scope for day-visitor recreation, especially at the Ferrytown and Ard na Cailc end of the system.

Narrow fringing areas of machair exist behind the backshore scarp. They have low landwards gradients of 2–3°, and are encroached upon by gorse and whins. Parts of the machair system have been partially improved. All are grazed but at a low intensity.

The old raised shingle and sand strandplain formed at the post-glacial level has been deprived of its sand supplies through the shallowing of the Firth by accelerated sedimentation when land-sea relationships stabilised. At present the shoreline is adjusting, with both saltmarsh accretion and localised coastal edge erosion taking place. Fresh sand is freely available only where backshore erosion has undercut blown sand deposits and here Marram finds conditions favouring its growth. The whole system is fossilised, being created under substantially different conditions from those of today.

Apart from the salting species, the vegetation is largely of a heathland type characterised by heather, broom and whin. This forms an effective barrier to human penetration. The grazing of the heath at its present level is having no deleterious effect on the heathland vegetation. Improvement by fencing and re-seeding is steadily taking place at the eastern end, but the western end around Ferrytown remains in a semi-natural state. The machair area is not shell rich and the turf is undistinguished and partially improved.

The beach and heathland zone is backed by improved agricultural land, and the process of reclamation can be expected to continue. Gravel extraction takes place both within the shingle bars and on the beach at the Ferrytown end.

Because of the physical barriers of gorse and fence, only the western end of the Cuthill Links system is utilised by visitors. In fact, this part has no fringing sand beach. Its popularity is a result of relatively easy vehicular access to the shore and seclusion and isolation amongst the low dunes and shingle bars. It has a wilderness quality not apparent in any of the other beaches covered in this report. Apart from this, its intrinsic qualities for recreation are low, and pressures are not expected to increase.

The part of the unit with no fringing beach (ie from Ferrytown to Lonemore) is included in the Nature Conservancy's proposals for a Lower Dornoch Firth National Nature Reserve. The portion covered on Figure 6.11 falls outwith the proposals, and has at present virtually no visitors at all because of the inaccessibility and lack of intrinsic beach qualities.

There is no potential for recreation in the Lonemore-Dornoch stretch despite the presence of a narrow fringing beach of mixed sediments. The semi-natural vegetation of the Ferrytown-Lonemore stretch of the strandplain, on the other hand, proves attractive to day-visitors. As the surface is resilient to trampling pressures, the optimum use for this stretch of the Dornoch Firth coast is conservation of the physiographical interest coupled with a slight improvement of the ingress facilities for visitors.

It is recommended that no further extraction of gravel should be permitted to take place in the Ferrytown-Ard na Cailc area, and that the ingress tracks be improved to allow safer vehicular access. Camping and caravanning should not be permitted in account of the high fire risk. The ingress tracks should be gravel-surfaced in keeping with the general terrain. There is considerable scope here for increasing visitor pressure without deleteriously affecting the scientific value of the area.

The sand beach and machair components of the northern shore of the Dornoch Firth occupy a very small part of the total acreages of heath and scrub land which are developed on shingle with a thin veneer of blown sand. Inaccessibility prohibits the usage of the sand beach which in any case is relatively unattractive to visitors. The accessible parts of the heath are resilient to day-pressures by visitors, but the summer fire risk is high. Only very limited improvement of car accessibility at the western end is recommended.

Figure 6.11a Cuthill Links

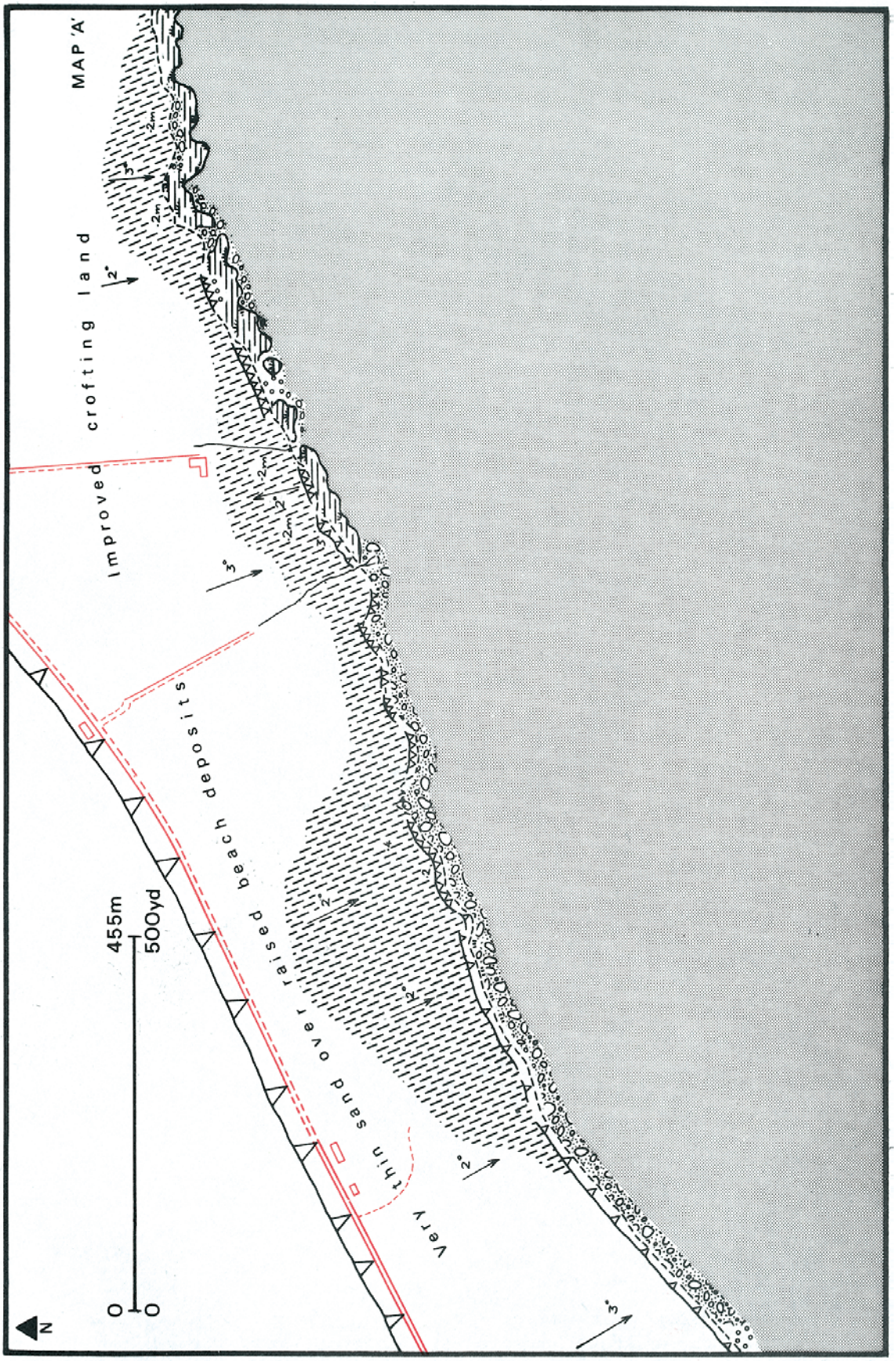
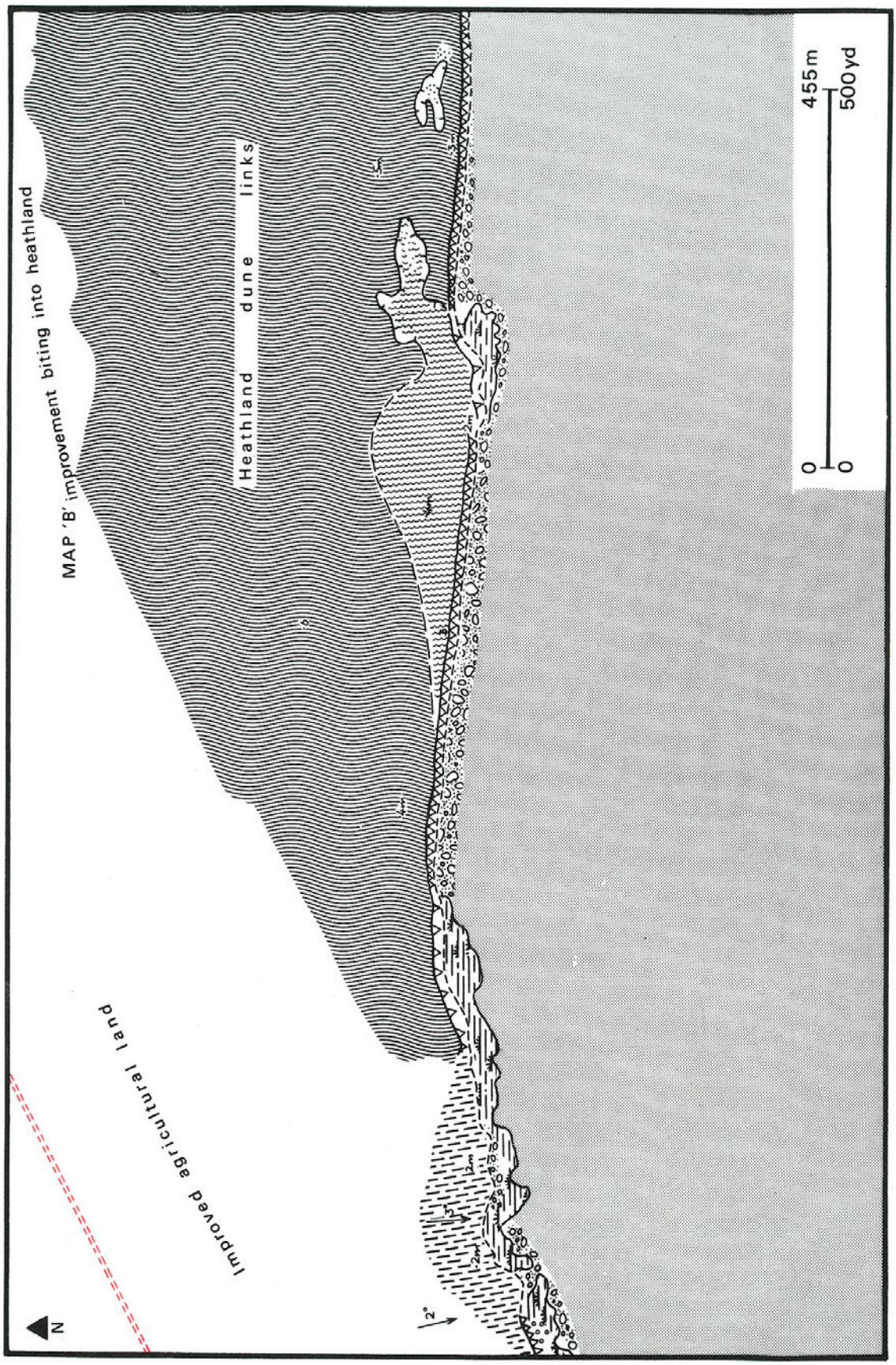


Figure 6.11b Cuthill Links



7. Regional Description of Coastal Areas – Easter Ross Beaches

Typical Characteristics

As can be seen in Table 1, Easter Ross carries a relatively short stretch of sandy coastline in comparison with East Sutherland, and also in comparison with its total coastal length. The most extensive beaches occur within the Lower Dornoch Firth where coastal progradation has formed extensive forelands and strandplains, often fringed by sandy beaches and capped with dunes.

Changing land-sea relationships in the past have resulted in much of the blown sand accumulations occurring on raised sand or shingle bars, frequently backed by old cliff lines. Rosemarkie, Cromarty, Nigg and Portmahomack are all beaches fringing late and post-glacial forelands of varying size and complexity. Other beaches backed by restricted dune or machair systems occur in cliff-foot situations, as at Balintore and Wilkhaven. The development of a wide dune complex has been restricted by the presence of the old cliff line behind, together with the prevailing offshore winds. Only where sand blow can occur *along* the coast have high dunes been formed in such cliff-foot situations. In such narrow dune systems, plant communities originally dominated by Marram are eventually replaced by other species colonising down from the cliff behind. The originally subdued system thus becomes increasingly less dune-like. In plan the beaches tend to be straight or slightly convex-seawards, and there are few bay-head beaches, which are so common in other parts of the Highlands.

Where the offshore zone is shallow (see Figure 3), as in the Lower Dornoch Firth, changing land-sea relationships have provided sufficient material to construct highly complex strandplains on a scale unusual in a Highland context (see Figure 5). These occur in the relatively exposed lower firths. The inner parts of the Firths are dominated by estuarine processes, and continued sedimentation over the last few thousand years has created extensive sandflats. The size of the Morrich More strandplain indicates availability of both sand and shingle in the past, and of sand at the present time. As a general rule, sand appears to be available to the strandplain beaches at present, while the smaller cuspate foreland beaches have very small offshore supplies. Streams and cliff erosion play a very minor role in the evolution of beach and dune systems in Easter Ross.

The east coast situation, together with landward shelter often provided by cliffs, has resulted in subdued dune topography and stable situations. Most dune systems are completely stable, and many are separated from the beach by small coastal edge erosion scarps. Supply is thus effectively cut off from beach to dune. In such circumstances, Marram is progressively replaced by herbs and grasses. In general, the rate of coastal retreat is minimal, although there are localities where it gives grounds for concern. The slowness of coastal edge retreat is partly due to the shingle substrate on which many dunes systems have accumulated, which forms backshore protection to the dune edge.

Many dune and machair complexes back onto agricultural land and have been partly improved from their landward margin. The division between low dune, machair and partly improved agricultural land is often very indeterminate, and marked only by a fence line. Other beaches are backed directly by roads and small settlements, and in these cases, artificial coastal edges of concrete and stone have generally been constructed.

Almost all the beaches could be termed low energy beaches in that the distribution and amount of beach materials change little from year to year. Only in the case of the Morrich More is coastal accretion rapid.

The area of wind-blown sand and the amplitude of the dunes themselves are small in comparison with the Western and Northern Highlands. Existing organised recreation has tended to be confined to the smaller and less distinguished beaches beside villages like Balintore, Rosemarkie, Portmahomack, which carry 50% of the beach-back caravan capacity of Easter Ross.

7.1 Morrich More

The Morrich is a low-lying parallelogram of post-glacial and recent sand ridges resulting from long-term progradation north-eastwards from the well-marked post-glacial cliff line. The parallelogram occupies a substantial proportion of the southern shore of the Lower Dornoch Firth and extends from Tain to Inver. The Inver-Arboll beach and dune system is physically separated from the Morrich by Inver Bay and is considered separately in 7.2. Shoreline features associated with continued seaward growth of the Morrich More extend east of Inver and are closely related to the continued evolution of the Arboll dune and beach system.

The Morrich is genetically a 6km broad strandplain (see Chapter 4.2) fronted seawards on its north-eastern margin by dune-capped offshore bars which are separated from the main strandplain by sandflats. The offshore bars are actively accreting. The total feature thus represents a long period of continued accretion within the last seven thousand years (since the maximum of the Flandrian transgression which cut the landward cliff). The strandplain consists of alternating slacks and sand ridges orientated at right angles to the maximum seaward fetch (see Figure 5 and Plate 7.1.1). The ridge system is truncated by backshore erosion on its north-western side, in contrast to the continuing sandflat and offshore bar accretion on its north-eastern shore.

The scale of the strandplain is immense by Highland standards, having a total area of 30km^2. It contains a range of flora from inter-tidal sandflat species through to *Juniper-Calluna* association on the oldest landward ridges. The system is backed landwards by agricultural land.

The area is grazed in common by neighbouring farms, and a large part is utilised as a bombing range by the military aircraft based at Lossiemouth. Although these are the two major land uses represented, an area of accidented dunes just west of Tain Golf Course has been afforested. The size and openness of the Morrich in combination with the bombing which necessitates restricted access, means that there are very few casual visitors, and the area is only regularly visited by geographers, botanists and ornithologists. Access is negotiated with the Range Safety Officer (Range Control N.G.R.823821). There is seldom any military use of the range during weekends.

Although the strandplain is almost entirely built of sand, traditional beaches (freely drained sand thrown up by waves, with seaward gradients in excess of 3°) are restricted in size and distribution. The major sand areas are in the form of inter-tidal sandflats (1000ha) or alternating ridges and slacks (Plate 7.1.8), largely colonised with vegetation. The type of vegetation association at any point varies according to salinity, age of ridges, and altitude.

The major beach units occur on the north-eastern shores in the form of elongated offshore islands capped with rapidly accreting yellow dunes. Small sand bars also occur on top of the most recent saltings, where spring-tide wave action and currents have disturbed the pioneer Puccinellia cover, and resorted the sand substrate into ephemeral sand bars.

A very narrow fringing beach along the western margin of the strandplain extends from Tain to Rubh'na h Innse Moire (Plate 7.1.2). It is less than 6m broad, and is composed predominantly of shell fragments washed out of the backshore face of post-glacial deposits. The shell content is locally as high as 95%. The narrow beach is fronted by sandflats 1200m broad with a minimal seaward gradient. The sandflats are

patterned into mega-ridges and runnels running sub-parallel to the high water mark, and carry extensive fields of *Enteromorpha* and *Zostera* sp. Erosion along this western shore is traceable in historical accounts of Tain and has been responsible for the clear truncation of the typical Morrich ridge system which runs approximately at right angles to the north-easterly trend of the shore. Active backshore scarps often in excess of 3m in height are undercutting the Forestry Commission fence. The rate of backshore erosion is less where peat outcrops on or at the back of the fringing beach. The peat pre-dates the Flandrian transgression and probably underlies much of the ridge and slack system.

Small areas of coastal machair occur north-east of the parabolic dune system. The machair is generally relict in the sense that it is cut off from beach sand supplies by a low coastal edge. Very restricted parts are, however, fed from the beach via a backshore sand ramp (Plate 7.1.3). A machair fringe occurs along about one eighth of the western shore, but extends inland for only a few hundred metres. Experimental shore protection east of Tain to protect the Golf Course using wire cages filled with stones set near the seaward edge of the fringing beach has proved to be successful in arresting backshore erosion.

The outer islands on the north-eastern shore consist of sand beaches elongated from north-west to south-east, separated from the main strandplain by sandflats and shoreward fringing saltmarsh (Plate 1). The sandflats between the saltings and the offshore islands have a relatively high water table and do not dry out at low-tide. The upper layer of sand is colonised by a microscopic green algae which, in conjunction with the essential wetness of the sandflat system, precludes sand blow. The sandflats in this part of the Morrich are thus highly stable in their natural state.

The offshore islands, particularly Innis More, are nourished by sand thrown up into bar form by wave action. The bar has a gradient of 7° seaward, with a slight reverse slope landwards. As the bar emerges and extends laterally, increased area and possibilities of the drying out of the upper sand layers favour sand blow, and accumulation around shore wrack is replaced by small sea lyme grass dunes 2 or 3m high. These are especially well marked at the western end of Innis More (Plate 7.1.5). The sand bar is fronted both seawards and landwards by featureless sandflats, but the progressive steepening of offshore gradient seawards allows sand to reach the bar. The sea lyme grass dunes progressively are replaced by Marram. In the field, the succession of progradation is represented by concentric patterns of dune ridges, especially well marked on the inland side of Innis More (see Plates 1 and 7.1.4). The outer dune island of Innis More represents the present stage in shoreline progradation in operation. It forms a model of the way in which the strandplain has been formed. The Innis More dunes are higher and more continuous than on any other sand ridge within the system, and clearly indicate a longer period of shoreline stability than has occurred during any previous phase in the formation of the strandplain.

Eastwards, the offshore islands are hinged to the sand-based salting and consist of sea lyme grass dunes with Marram behind, and randomly distributed embryonic dunes. This bar is less exposed to the open sea than Innis More and has a very much reduced beach gradient of 2°. Despite this lesser beach gradient, accretion of sand seems to be taking place rather more slowly than in the case of Innis More, but small dune islands extend sporadically as far east as Arboll. Although the scale of these smaller dune-fringed bars is less than that of Innis More, the speed of evolution is nonetheless considerable and changes can be detected on the ground, post-dating aerial photography in 1966. The system is again fed by relatively mobile seaward sand bars thrown up at wave breakpoint, which on this gently shelving inter-tidal zone may be 800m or more from the high water mark.

This frontal part of the Morrich More system thus continues to evolve at a rapid rate with the offshore bars building eastwards, a pattern clearly visible in the ridge system of the strandplain. Inland of the bar, the salting is a mixture of windblown sand accumulation and salting pioneer species. The salting carries pioneer *Puccinellia maritima*, but the plant cover is incomplete, with many bare patches and small sand accumulations (see Plate 7.1.7). The ground is uncharacteristically hummocky for salting designation, and spring tide waves followed by strong winds seem to be capable of creating conditions favourable to sand blow, as small *Agropyron* and *Ammophila* dunes occur scattered through out the *Puccinellia* colony. Clearly dune formation here is highly likely, given the right combination of circumstances. Indeed there are low open *Ammophila* hummocks occurring in juxtaposition with *Puccinellia* salting. These are not entirely ephemeral as they do carry mosses and lichens. Landward of this fluctuating zone, the pattern is of ridge and slack with thin cappings of dune sand, with *Ammophila* dominant on the ridges.

On the eastern margin of the strandplain facing Inver Bay, the shore is entirely of a more typical type of saltmarsh. Here the balance between erosion and deposition (at the saltmarsh front) is finely balanced, and parts of the saltmarsh pass into sandflat via a micro-falaise indicating frontal erosion to be dominant at the present time. The slack communities of the Morrich are drained and fed with salt water by a pattern of tidal creeks running parallel to the sand ridges (see Plate 7.1.9). The relief amplitude is very low, a difference of 2m differentiating slack and ridge. Frequently the same species occur on both ridge and slack, but their proportions differ. Certain of the inland slacks carry standing water, and these carry plant species indicating base richness which results from a combination of shell-rich sand and gull guano.

In summary, the Morrich More strandplain indicates progradation north-eastwards for a period of almost 7000 years, a process which continues at present. More recently, backshore erosion has occurred on the westerly shore and continues at present. The succession of shorelines from the post-glacial cliff to Innis More is controlled directly by the changing relationships between post-glacial isostatic land recovery and eustatic rise in sea level. The shoreline succession indicates the pattern of land recovery since the Flandrian, gradually slowing down to the present situation of near-stability. On the gently shelving coastline, offshore bars form and become progressively dune-capped. The barrier increases until salting formation begins landward of the bar utilising the shelter provided by the bar. Continued land uplift shallows the offshore zone and a second seaward bar is formed, repeating the process described above. The 'stranded bars' become land ridges, the saltings become slacks, and characteristic pioneer vegetation associations change as saline immersion becomes less and eventually ceases. A seaward to landward sequence of vegetation thus results, which is broadly described later in the report. The almost exclusively sand substrate of the frontal marshes means that there is a very fine balance between slack and dune-ridge formation. As the rate of land uplift decreases, the distance between individual ridges, ie shoreline positions, increases, and this may explain the greater size and height of the ridges nearer the sea, and their considerably greater spacing.

Sand supply is of course another essential factor in shoreline progradation, but charts of the Firth and observation of current accretion indicate that continued sand supply is assured. On the other hand, continued growth of the seaward side of the Morrich will progressively reduce supplies to Inver beach, and this may be causally correlated with current undercutting of the western part of the Inver-Arboll dune system. Material removed from the Inver-Arboll system is carried eastward by the ebbing tide through the Inver channel.

The most striking feature of the eastern margin of the Morrich More is the exceptionally high parabolic sand ridges which have a relief amplitude in excess of 14m. The dunes, almost entirely Marram clothed on the

ridges, run in a series orientated north-eastwards, and sub-parallel to the western shore of the Morrich. As the dunes travelled eastwards, they left behind deflation areas scoured almost to the water table. The most easterly dunes are still mobile with sand faces spilling forward, but the major part of the system has been stabilised by a decrease in sand supply, assisted by afforestation. The technique of afforestation is substantially similar to that used in the Culbin Sands of Morayshire with brushwood on the steep faces and railway sleepers across the major sand blow corridors.

As described previously, the beach fringing the western shore of the Morrich is very narrow and is backed by an almost continuous erosion scarp running from Tain, along the edge of the golf course, and beyond the planted area. Signs of coastal edge erosion extend almost to the tip of the strandplain. The parabolic dunes now receive no nourishment from the shore or the sandflat. Indeed, the deflation area of one of the afforestated dunes is truncated by the current backshore erosion. In fact, the dunes rest on, and are partially blown out of, postglacial marine sand deposits sitting on top of the exposed peat bed previously mentioned as outcropping on the beach. It seems probable that the dunes were created by severe blow out of a westerly foredune system now completely eroded away. Indeed, the initiation of backshore erosion may well have been the motivating force. At this time, or at least in the period of formation of the initial foredune system, offshore gradients in the Dornoch Firth must have been steeper, allowing sand to be thrown up on the beach, and thence blown on to a foredune system. As the Dornoch Firth silted up, so sand sedimentation reduced the offshore gradient until no further sand could feed the original foredune system. This accretional phase was then replaced by an erosive phase which created blow outs and the parabolic dune system began to migrate. With the lack of continuing sand supply from offshore, the distance of migration was short, and thus the dunes were partially stabilised by natural means.

The parabolic dunes exhibit exceptionally steep and often knife-edged slopes in excess of 30°, and excessive trampling or grazing could re-activate movement.

On the most easterly dunes, which are still relatively mobile, the advancing sand faces carry Marram, which thrives on the continuing sand supply (Plate 7.1.12). Previous positions of the advancing crest are visible in the form of small arcuate Marram-covered ridges within the deflation areas. Old soil horizons are visible just behind the main face. A clear vegetation sequence can be traced behind the bare sand with *Festuca rubra-Carex-Empetrum* giving way to an *Empetrum-Erica tetralix* community, with some Calluna on the old soil horizon within the deflation area. On days with westerly winds, sand blow is considerable at the proximal end of the dune, being channelled through the cols between *Ammophila* hummocks in the advancing face. A detailed topographic map of the most mobile dune was made by Aberdeen University Geography Department in 1972, together with a belt vegetation transect.

The parabolic dunes form exceptionally clearly marked ridges, but are replaced eastwards by an amorphous system of *Ammophila*-dominant dune hummocks which slope eastwards at an angle of 10°. These partially cover a machair area which recurs consistently, right to the strandplain point. The machair plain is truncated in places by backshore erosion, but the shore scarp is less than 1m high, enabling the limited beach sand available on the fringing beach to be blown up on to the machair. The machair turf carries *Agrostis tenuis-Festuca ovina* and *Trifolium repens* and is being locally stripped by wind scour exacerbated by sheep. Small Marram dunes are forming at the down-wind ends of machair erosion scars where fresh sand is accumulating (Plate 7.1.10).

North and east of the machair areas, the dominant backshore erosion characteristic of this western shore is replaced by relatively strong backshore accretion with Marram colonising a sand ramp down onto the fringing beach. The Marram cover continues inland as a dune capped ridge swinging round to the characteristic NW–SE orientation of the Morrich system. This accreting part of the western shore is partially protected from wave attack by the westerly continuation of the dunecapped Innis More. The fringing beach remains narrow, and rests on top of the saltmarsh. Sand capped ridges are characteristic of the more recent parts of the strandplain. At least six of the more recent shoreline ridges carry Marram cover but the relief amplitude is less than 4m, and the system is cut off from any fresh sand supplies. Sand is thus gradually stripped off and infills the intervening hollows. The Marram-dominant ridges are thus gradually colonised by more advanced types of vegetation as distance from the present shoreline increases and mosses bring more humus into the originally skeletal soils. The ridges themselves are characteristically asymmetric, with a 12° seaward slope and a 4° landward slope.

Occasional patches of dunes with Marram recur throughout the strandplain system, often far from the present shoreline. Frequently they occur in association with extensive scarring through rabbits or sheep, and always on the higher ridges. In general, the Marram can be regarded as in retreat, and is being gradually replaced by *Calluna-Juniper* associations which are extensive in the inland parts of the system.

On the offshore islands, major dunes are localised with *Elymus* fringes and *Ammophila* in the central older parts of the island dune system. Here the dune systems are high, exceeded only by the easterly parabolic dunes, with crests 8 or 9m high. These dune islands carry high rabbit populations and there are a number of non-representative plant species brought in either by the high gull population or by the tides. The islands are building up fast and can be expected to extend both west and east along the bare sand bar thrown up by wave action. Apart from these, only parts of the machair area of the strandplain windblown situations can be said to be evolving, and even here the process is very slow. Like the parabolic dunes, the machair plain has been more active in the past – witness the deposition of now vegetated windblown sand over the ridges beyond the immediate backshore ridge as they curve round towards the east. Most of the other windblown areas are either in a state of natural degradation or at least closely balanced between erosion and deposition. Bombing is not generally carried out on the dunes except near the point, and small bomb craters (see Plate 7.1.11) pockmark the saltings and low dune ridges. It is important to stress that the salting substrate is highly sandy, and only partially fixed with *Puccinellia maritima*. Most of the young saltings on the western and northern margins of the Morrich thus undergo cycles of erosion-deposition which are annual in duration, indicating a very delicate balance between wave, wind and the ability of vegetation to colonise such sand surfaces satisfactorily.

The machair pasture is clearly localised on the Morrich More to the western shore and its landward environs. Its situation at the back of the beach is unusual and it is likely that the front part of the typical foredune has been removed by erosion. The characteristic erosional coastal edge carries a Marram-clad rim, though on occasions the backshore passes directly into machair. The machair has a gradient of 2–3°, sloping inland from its highest point, and a slope of 5° seaward. The coastal edge is less than 2m high. A number of erosion scarps dissect the machair turf, taking the form of small linear cuts orientated due east and north-east (Plate 7.1.10). The sand scarps are about 1m high and have small areas of sand accumulation at the down-wind end of the scars, which are progressively being colonised by Marram. There are signs that in the past a blow out, similar in process to the parabolic system, has occurred within the machair. The motivating forces of backshore erosion and turf stripping by wind were responsible. No clear deflation hollow exists

and the low is occupied by irregular Marram-clad hummocks. The machair interdigitates with *Ammophila* and *Calluna* which occupy the higher rim of back margins of the gently sloping plain. A certain amount of old military machinery and dumped cars indicates that part of the machair area has been used in the past for bombing but there are very few fresh scars. Northwards towards Rubh'na h Innse Moire, the machair is replaced by a low foredune ridge leading off older ridges, and eventually one passes to the most recent shore ridge, excluding the Innis More offshore island. Here the machair is replaced by a narrow Marram-clad ridge fronted by recent salting, with a narrow fringing sand beach resting at the back of the salting.

The present Morrich More strandplain has been built up during a succession of changing land-sea relationships. The plain has been built up north-eastwards in the form of a succession of shore bars of which Innis More is the most recent member. The system is built up at right angles to the direction of maximum wave exposure, and evolved when a ready sand supply from the inter-tidal zone was available on both north-east and north-west shores. The process has decelerated as isostatic recovery slowed down, and accretion on the west side has been replaced by shore erosion, probably as a result of the trapping of inter-tidal silt and sand in the inner Dornoch Firth. Mobile sand suitable for beach and dune formation now only occurs on the north-eastern side of the strandplain. The current stable land-sea relationship has created a relatively stable situation on the seaward side, enabling offshore bars capped with dunes to extend both eastwards and westwards, on a scale greater than at any time in the earlier post-glacial period.

Recent backshore erosion on the western shore has almost entirely removed an original foredune system of substantial proportions, during the removal of which a system of mobile parabolic dunes was formed from initial backshore blow outs. With the removal of an inter-tidal sand supply, the parabolic dunes have stabilised themselves, partially due to afforestation, but more basically due to depletion and eventual cessation of a continuing sand supply. Erosion has truncated a machair area north of the major dune system, although parts of it are still receiving limited accretion from the narrow fringing beach. Some degradation and stripping of the machair is being achieved by a combination of backshore erosion and grazing. With the exception of the most northerly set, the parabolic dune system is now stabilised. Present movement is slow even in the mobile dunes, although more rapid movement could easily be induced by increasing anthropic pressures.

On the prograding north-eastern shore, accretion is very rapid by sand trapping induced by Marram and sea lyme grass. The sandflats themselves between the offshore bar and the mainland are probably accreting fast as a result of sand trapping by the algae which form a seasonal coating to the area. No sand now reaches the inland dune-capped ridges which are therefore gradually 'running down' and being colonised by less maritime types of species. The sand-based substrate of the frontal saltings is subject to windblow following a strong wave action during spring tide submergence and small ephemeral *Ammophila* and *Elymus* dunes are being created at the salting level. At other times, the sand is concentrated by wave and current into bars resting on top of the *Puccinellia* salting. These can be regarded as ephemeral unless, as has happened in one case, the sand bars become colonised by *Ammophila*.

Broadly, beach sand is freely available at the north-east shore and therefore accretion, sand trapping by vegetation, and progradation continue, whereas on the western shore, onshore sand supply conditions have changed and backshore erosion has supervened. In contrast to the natural factors of wind and wave, the strandplain usage for grazing and military purposes has had minor effects in accelerating natural processes. Their effects are very small in comparison with the rates of the natural processes. Sheep grazing may well

have maintained the diversity of flora rather than, as is more usual, reduced it, by keeping in check the luxuriant growth of *Calluna* and *Juniper* which appears to be the climax community on the strandplain. Bomb craters pit the salting and slacks but have formed micro-habitats where concentration of moisture has permitted an even greater local floristic variety. Military utilisation has also reduced the number of visitors to a tolerable level in the fragile dune areas.

The vegetation pattern of the Morrich More is dominated by the pattern of ridges and slacks described in the previous sections. A representative cross-section of the vegetation is shown on Figure 7.1.4, simplified from an important piece of fieldwork completed by Miss Patricia Rae as part of her undergraduate degree in the Department of Botany, University of Aberdeen (1973). In addition to the slack and ridge system, the sandflats carry pioneer inter-tidal species, and the migration of the parabolic dune system has added a sequence of vegetation change within the deflation hollows behind the main ridges. Additional complicating factors to the vegetation pattern include the age of the ridges, their variable shell content and degree of leaching, and altitude, which governs fluctuations in both internal water table and degree of salt water penetration. The system is clearly worthy of detailed research as a unique record of prolonged shoreline progradation. Bearing in mind the difficulties of generalisation in an area carrying a rich flora of over 200 flowering species (Nature Conservancy, collected observations 18/10/71), there follows a discussion of the vegetation characteristics in terms of process and succession.

The extensive expanse of tidal sandflat fringing the strandplain provides surfaces which vary in stability according to currents and silt content. The western sandflat from Tain to Innis More carries an extensive *Enteromorpha* and *Zostera* growth, particularly on the lows between the megaripples which run parallel to the coastline. Between Innis More and the mainland, on the north-eastern sandflat, extensive fields of microscopic green algae occur (possibly Lyngbya spp) which probably stabilise the surface. Certainly the area is notably easier to traverse than the sandflats further east, and is frequently crossed by military personnel in Land Rovers when recovering offtarget bombs. The *Zostera* and *Enteromorpha* form part of the food supply of the large wader and wildfowl populations. More limited *Zostera* beds occur west of Inver. Here, because of the greater fresh water inflow from the Inver channel, *Ruppia* becomes locally significant in pools of inter-tidal standing water. *Salicornia* also occurs locally nearer the shore and extends on to the low marsh, particularly where mud accretion is abundant as around the mouths of tidal creeks. Only a small proportion of the total sandflat area carries plant cover. Large parts of Inver Bay, for example, carry no green growth.

The dune vegetation which is created on the offshore islands such as Innis More starts off with *Elymus arenarius* and *Agropyron junceiforme* forming blown sand fixation on the offshore bars. After the dunes have reached a height of 2–3m, *Ammophila arenaria* takes over, and eventually becomes dominant. On the largest offshore island of Innis More typical land species such as Tansy and Thistle are present. These land species, which add variety to the dune species, are probably brought in by tide and gulls. The islands carry heavy gull populations, and terns and whimbrel nest here. Extension of the dunes takes place outwards by successive *Elymus* ridges (see Plate 7.1.5) in a longshore manner (see Plate 7.1.4). Considerable sand accretion also takes place around old fishing nets deposited in the environs of the salmon bothy. *Elymus*, although a common pioneer species in the Moray Firth, is very localised in the Morrich and occurs only on the offshore islands and very spasmodically along the eroded western backshore near the parabolic dunes.

The seaward salting on the north-eastern shore is unusual in terms of the amount of free sand available on its surface. While *Puccinellia maritima* is dominant and forms the pioneer species, *Plantago* and *Armeria* are

also present. The surface is hummocky and has been activated by wave erosion followed by sand blow at low-tide. Further inland within the same association, the dune species like *Agropyron* come in and small dunes are formed (see Plate 7.1.7). At this stage, it is possible that an *Ammophila* ridge will eventually develop on top of the salting or that the salting will eventually stabilise and more typical saltmarsh species become dominant. Part of the loose sand apparent on the salting surface is derived from offshore and brought by tidal currents in suspended form.

The low ridges backing the saltings appear to develop from initial *Ammophila*-clad bars followed by *Carex arenaria* and *Festuca rubra*. Subsequently the variables of moisture and leaching rates supervene, and ground cover is completed by mosses and dune pasture species. As distance from the sea and possibilities of salt spray or submergence recede, so the ridge progressively changes into a low turf grassland with a *Juniper* upper storey over *Festuca ovina*, *Thymus* and *Trifolium repens*. Progressively a heathland type of vegetation becomes dominant, with *Calluna*, *Agrostis* and *Juncus squarrosus* and occasional *Juniper*. The *Calluna vulgaris* is the variant *hirsuta*, and frequently *Erica tetralix* can also be picked out although it is more characteristically found in lows further inland. The immense variation here makes generalisation dangerous, particularly as the rate of moisture replenishment and rates of leaching are presumably governed in part by water table fluctuations, themselves governed by the complex network of creeks and imperceptible gradients.

The slacks which separate the low ridges are equally complex in their vegetation association. Species fade out and shade in with no apparent relationship to topography or distance from sea and here degree of leaching may be the dominant factor. In addition, the slacks have probably been infilled, after being left by the tide, by variable quantities of blown sand from the intervening ridges. The outer slacks carry a low turf with occasional tussocks, often containing species also found on the intervening ridges. Characteristic of the seaward slacks are *Carex*, *Festuca rubra*, *Euphrasia* spp, and *Armeria maritima*. In the older slack systems, the appearance of the slack surface is characteristically more hummocky with *Erica tetralix*, *Salix repens*, *Carex*, *Potentilla* and *Juniper*. *Empetrum* and *Juncus balticus* are also present.

Further inland, *Calluna* is dominant on many ridges, being accompanied in places by *Juniper* and *Ulex*. In between the ridges, standing water occurs in the form of elongated lochans, some of which are base-rich. Loch nan Tunnag and Loch na Muic are most permanent standing lochans and they carry thriving colonies of *Chara* and *Potamogeton* spp associated with *Eleocharis palustris*. The bottoms are floored with clay over sand and the species are indicative of free lime in the water.

The last zone within the largely undisturbed vegetation zonation is an association of low *Juniper* scrub, carrying interesting lichen cover, with *Ulex europaeus* on sand ridges, a very rare association in dune topography. Clearly certain features are unique in Scottish dune systems and up to the present, human interference has been sufficient to maintain a balance between grazing and the persistence of the flora. Range activities appear to have very limited effects, if any, on the roosting feeding and wading bird populations. In addition, older relict habitats, not described in this report, extend back to the limit of improved ground beyond the secondary road from Tain to Portmahomack.

Three major land uses are found within the strandplain. The westerly part of the system is under forestry, including a substantial part of the parabolic dune complex. At the moment a considerable relict flora survives, under the trees, in dune pasture and deflation areas behind the dune faces. The remaining part of

the system is open range grazing for a thousand Cheviot sheep from adjoining farmers who hold common grazing rights. The level of grazing is only locally high, for example on the machair areas, and in general the intensity of stocking appears to be just sufficient to prevent the rapid expansion of *Juniper* and *Calluna*, but not sufficiently high to damage the extremely rich flora described above. In addition there are regionally important wildfowl and wading bird populations. The major land use is the range activities which involves bombing of targets from the air. An old airfield and various old military huts are scattered over the system but at least one third of the total strandplain system remains undisturbed.

More recently, Army proposals to shift their shelling range from Shoeburyness to the Morrich More have met considerable local opposition on several counts, including noise levels and general interference with established tourist interests, notably at Inver. The establishment of such a range would involve considerable modification to the existing drainage pattern and might interfere with the existing vegetation pattern. Under the existing range operation, it is unlikely that the forestry area will be extended eastwards as it would interfere with one of the target areas.

At present the recreational use of the Morrich More is very low, a result of the discipline of distance and range activities. Most people approach towards the dune islands by walking along the west shore from Tain, but rarely penetrate beyond the range boundary flag opposite the most northerly parabolic dunes. Few people penetrate beyond this point, even at weekends when there are no range activities. Clearly both bombing activities and the proposed shelling activities cannot be reconciled with any development of recreational facilities. Nor indeed is the area suited for it, as it is very open, exposed and inaccessible. The Nature Conservancy proposals for the Moray Firth (1972) envisage the Morrich More as a National Nature Reserve and believe that the present range land uses are compatible with this status. The Nature Conservancy published the following description of the Morrich More in 1972, when designating it as Grade 1 in status.

'This area is one of the most important dune systems in Europe and is considered to be of international importance. It carries a wealth of species, many of them rare or local. The full extent of the system reaches inland as far as the 50 foot contour near Loch Eye and encompasses a clearly defined transition from inter-tidal flats and saltmarsh to sand dune and grassy pasture, damp dune slacks and acid peats and finally to arable land inland.

The dune and slack system is one of the most distinctive in Europe. It consists of a large, and remarkably level, vegetated sandy plain extending from Innis More inland for about three miles. It does so in an irregular series of alternating low-lying dune ridges and wide damp or flooded dune slacks. The system is still extending at the seaward end. To the west is another quite different system of parabolic dunes (Cnocan Mealbhain) superimposed on the main system. The outer dune islands are colonised by Marram grass and lyme grass. The main area of the dune system is extremely rich in species, with over 200 species of flowering plants recorded. In the older parts, heather of local hairy variety and crowberry occur, and there are distinctive areas of grazed juniper not known on any other British dune system. They carry a varied lichen flora and both lichens and mosses form an important element in the habitat.'

Clearly the site is Grade 1 in status, and conservation of the existing diversity of flora and fauna could not be reconciled with any recreational development. Fortunately a substantially more attractive area nearby offers an alternative for recreational development.

As the recreational potential of the Morrich More is very limited, it is recommended that the Grade 1 designation of the Nature Conservancy be accepted (as Ross and Cromarty County Council has already done), and that steps be taken to manage the area as a National Nature Reserve with the continuation of the existing level of military use. The use of the area as a shelling range as proposed by the Army might involve the tilting of the delicate though fortunate balance of circumstances which has enabled the survival of this interesting system. Monitoring of the effects of different levels of grazing might well be initiated and clearly there is scope for a detailed botanical and geomorphological study of the whole system at post-graduate level. There is a need to extend the wire-mesh cages on the western shore the whole length of the shore, except where peat outcrops on to the beach.

The Morrich More is a raised strandplain which continues to prograde at its north-eastern end. It consists of an alternating system of dune ridges and dune slacks, with an exceptionally well developed parabolic dune system on its western shore. Despite the existing military and grazing land uses, the botanical interest of the area is exceptionally high. It is designated Grade 1 status by the Nature Conservancy. The Morrich More has no recreational potential other than its existing casual usage when there are no military activities. It is recommended that existing uses continue and that steps are taken to monitor grazing intensities as well as to initiate an exhaustive geomorphological and botanical study of the whole system.

Figure 7.1 Morrich More

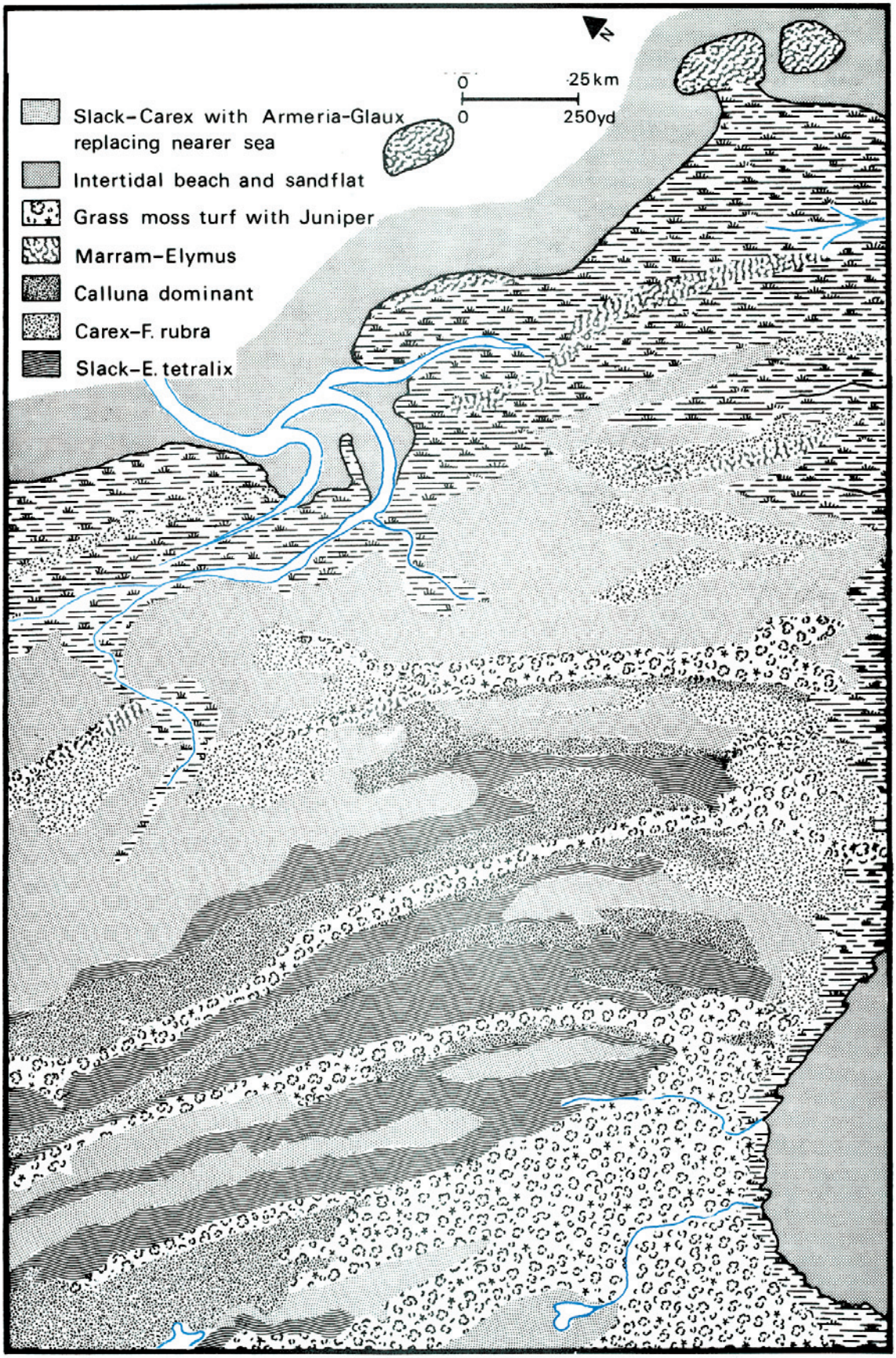


Figure 7.1a Morrich More

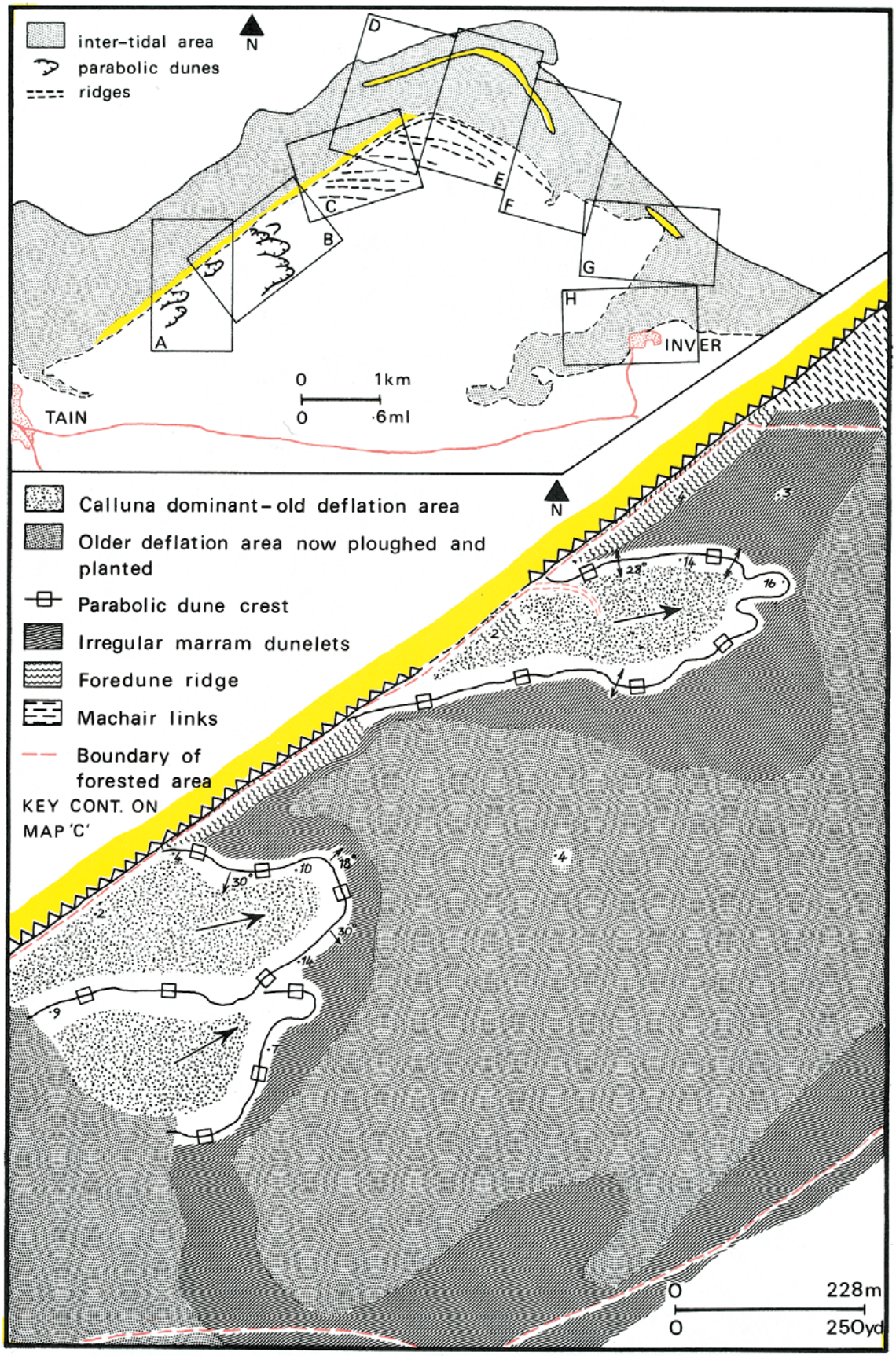


Figure 7.1b Morrich More

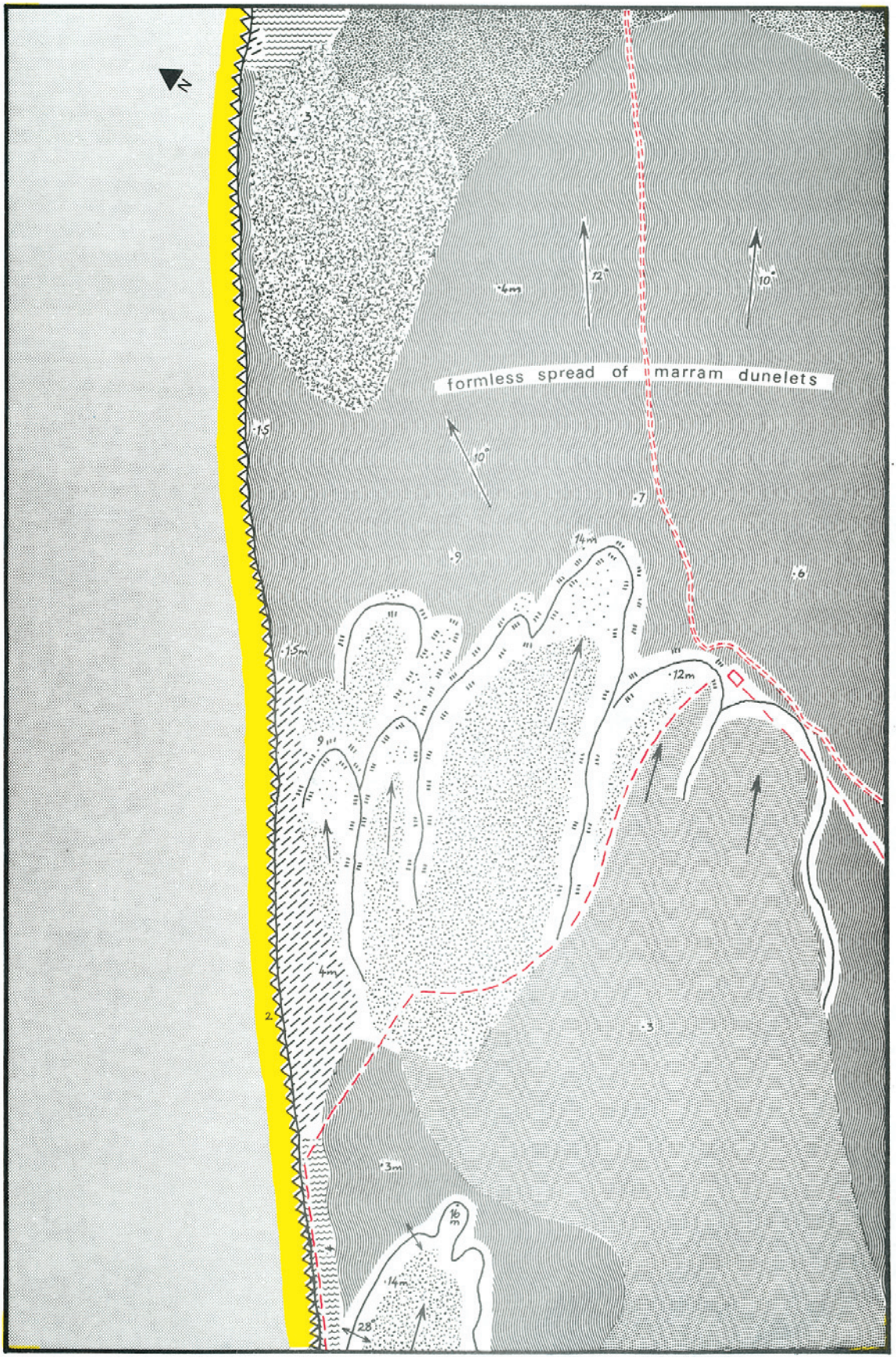


Figure 7.1c Morrich More

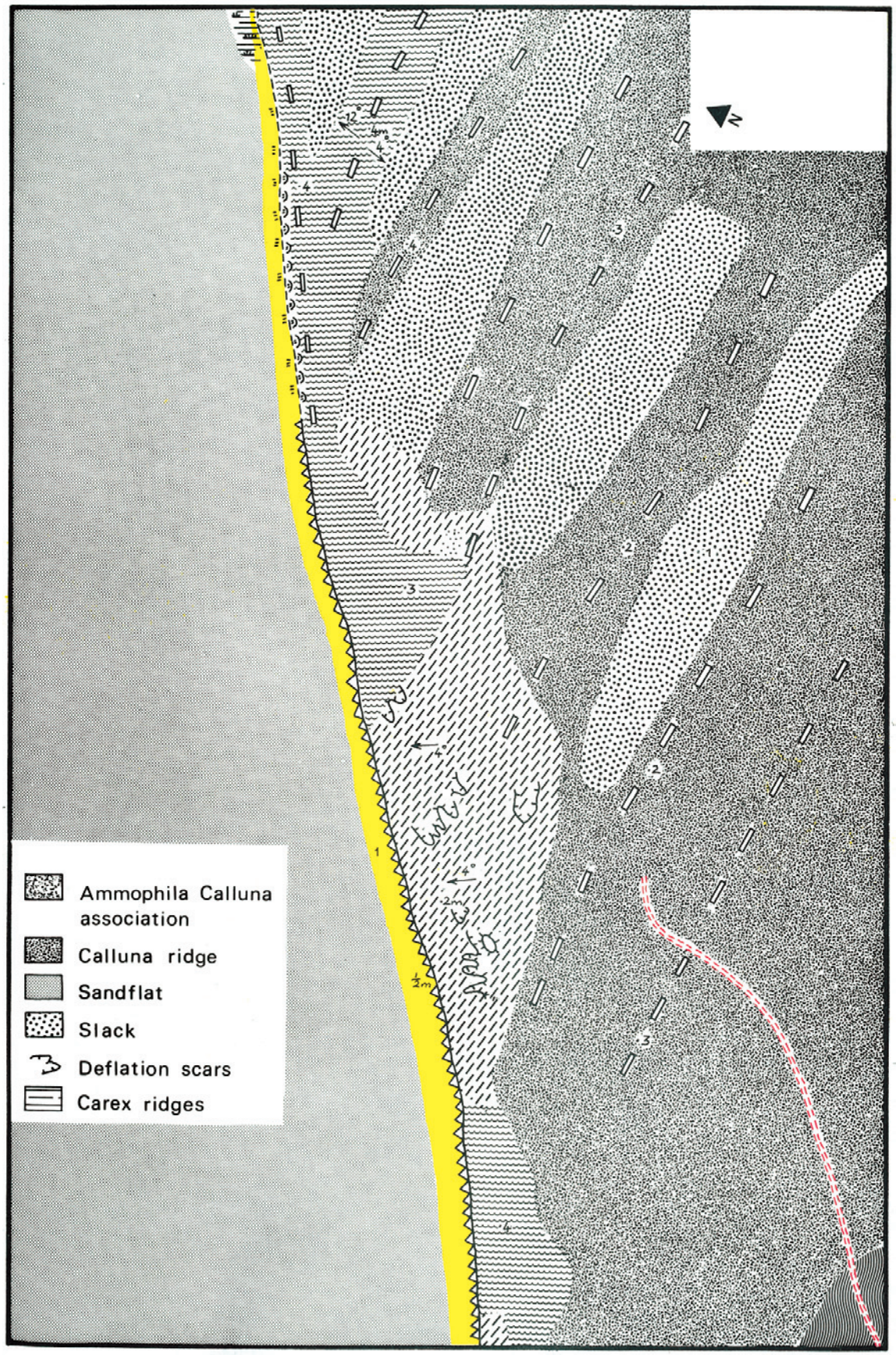


Figure 7.1d Morrich More

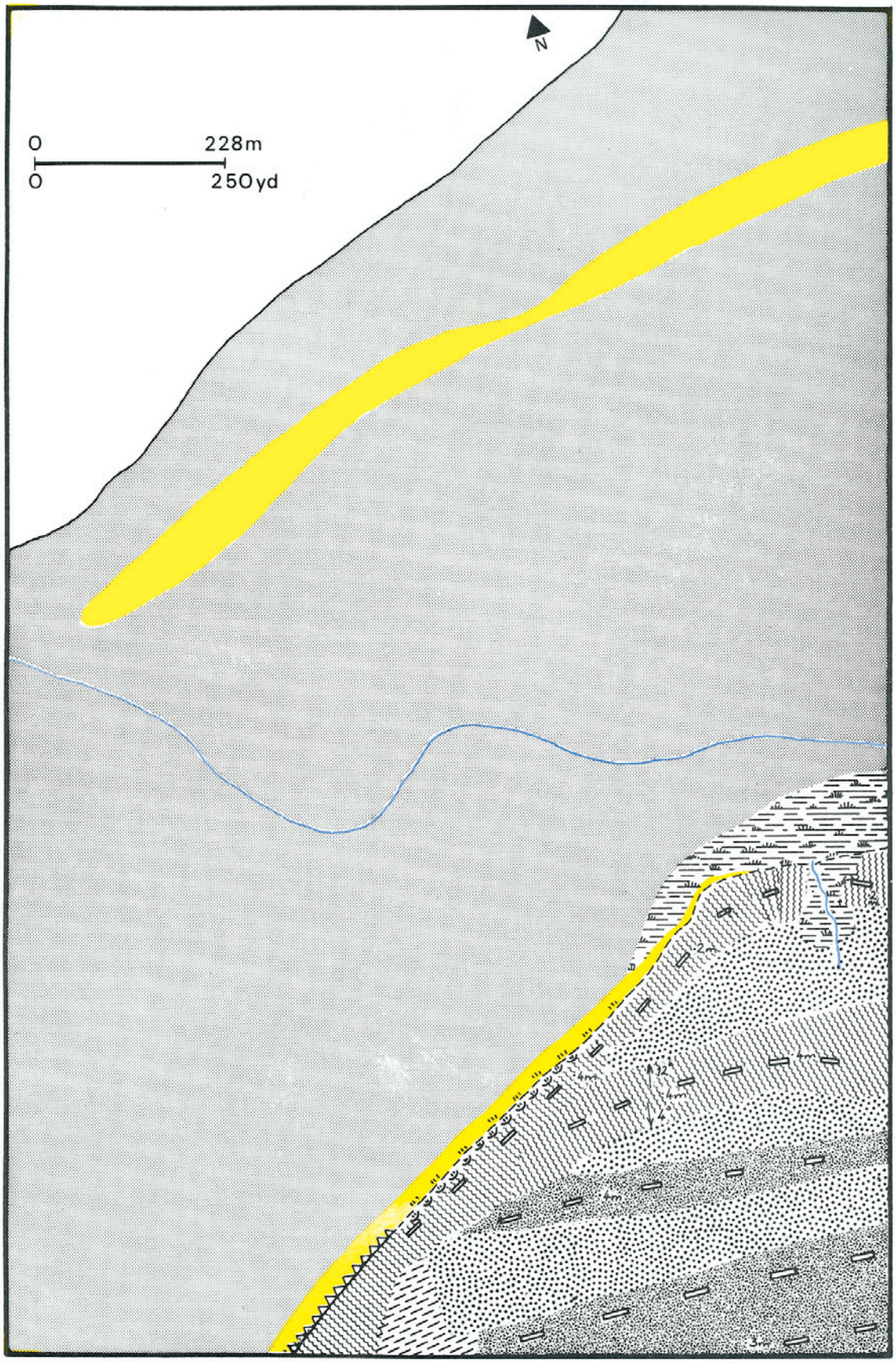


Figure 7.1e Morrich More

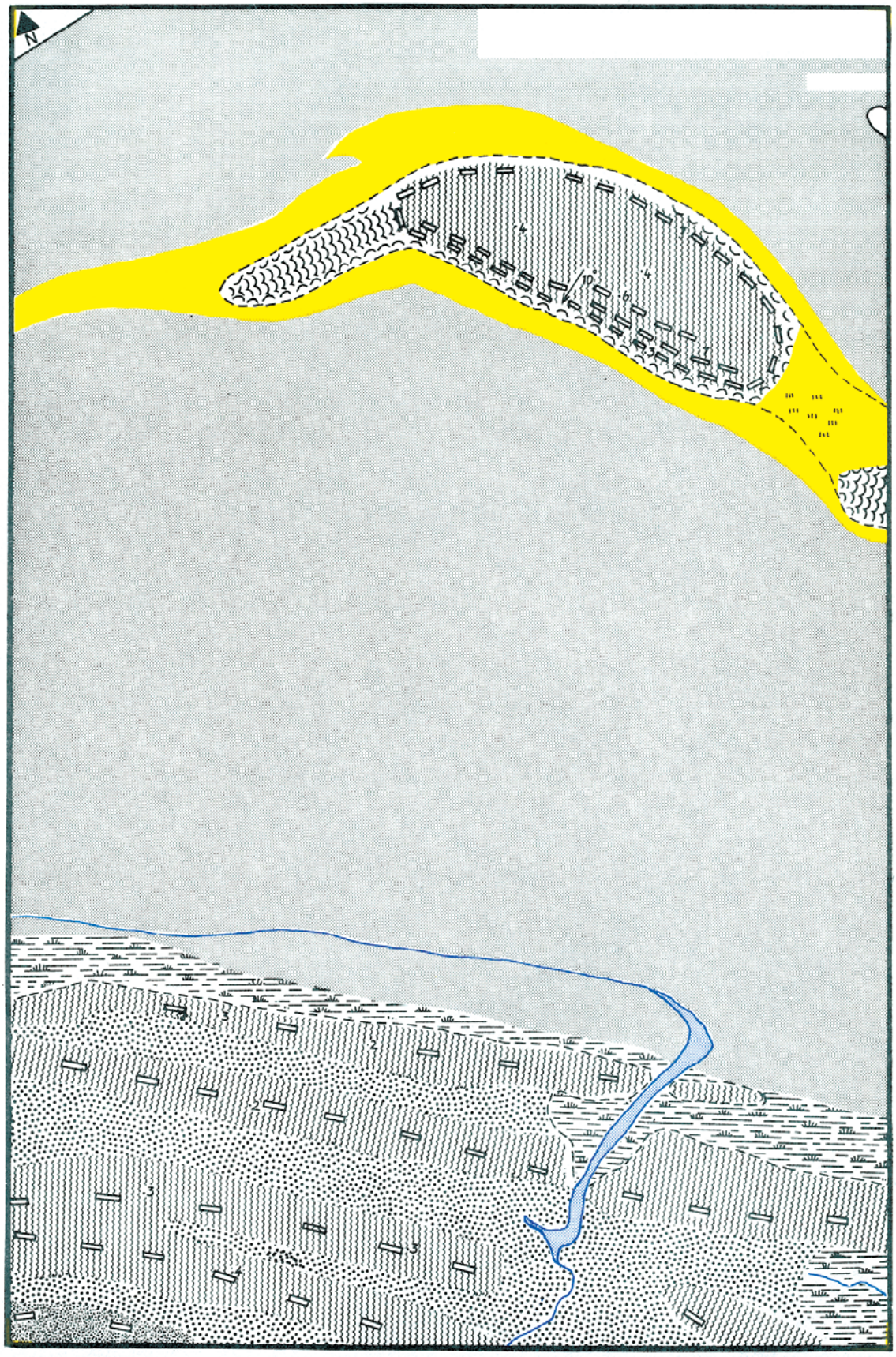


Figure 7.1f Morrich More

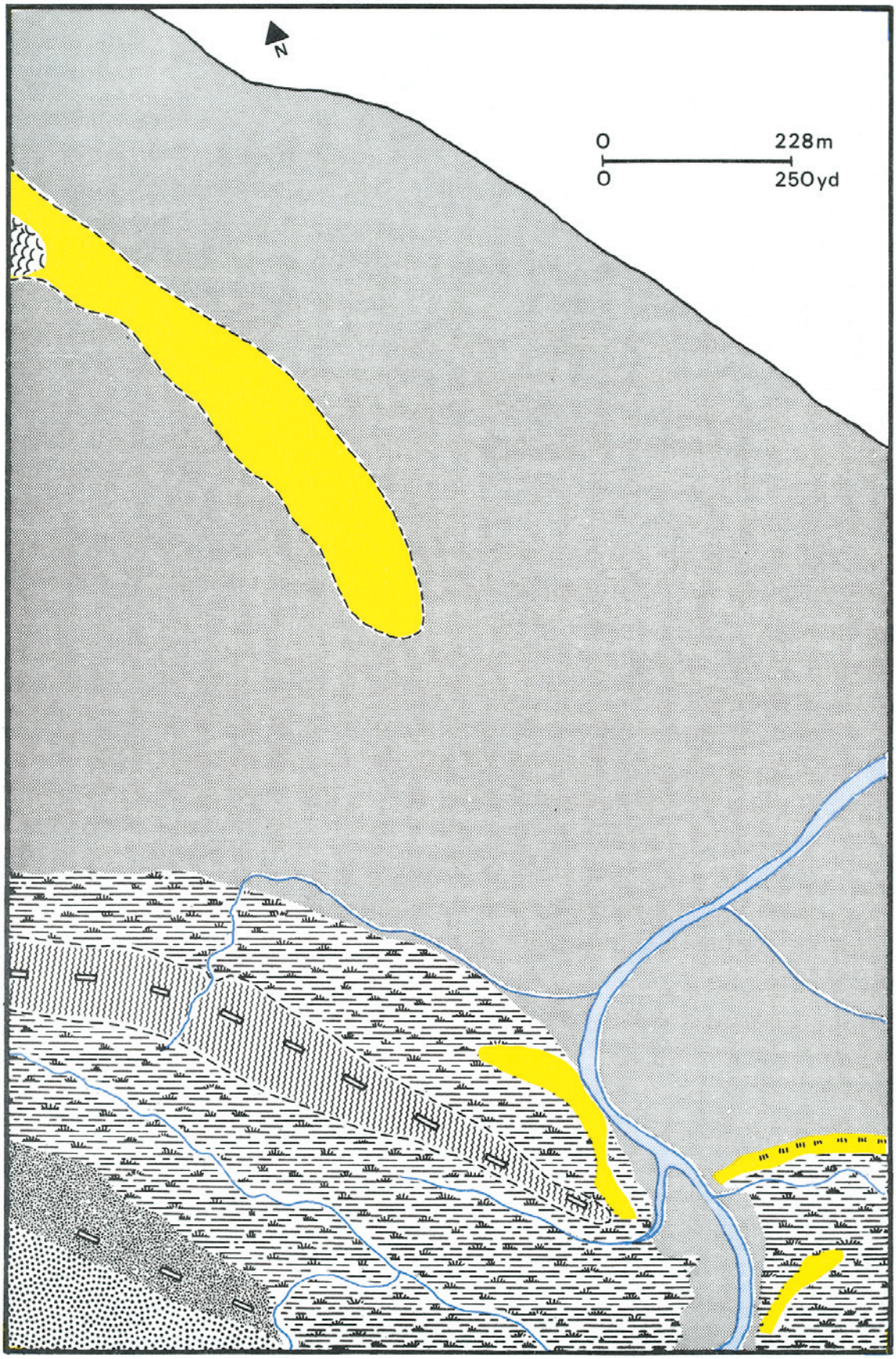


Figure 7.1g Morrich More

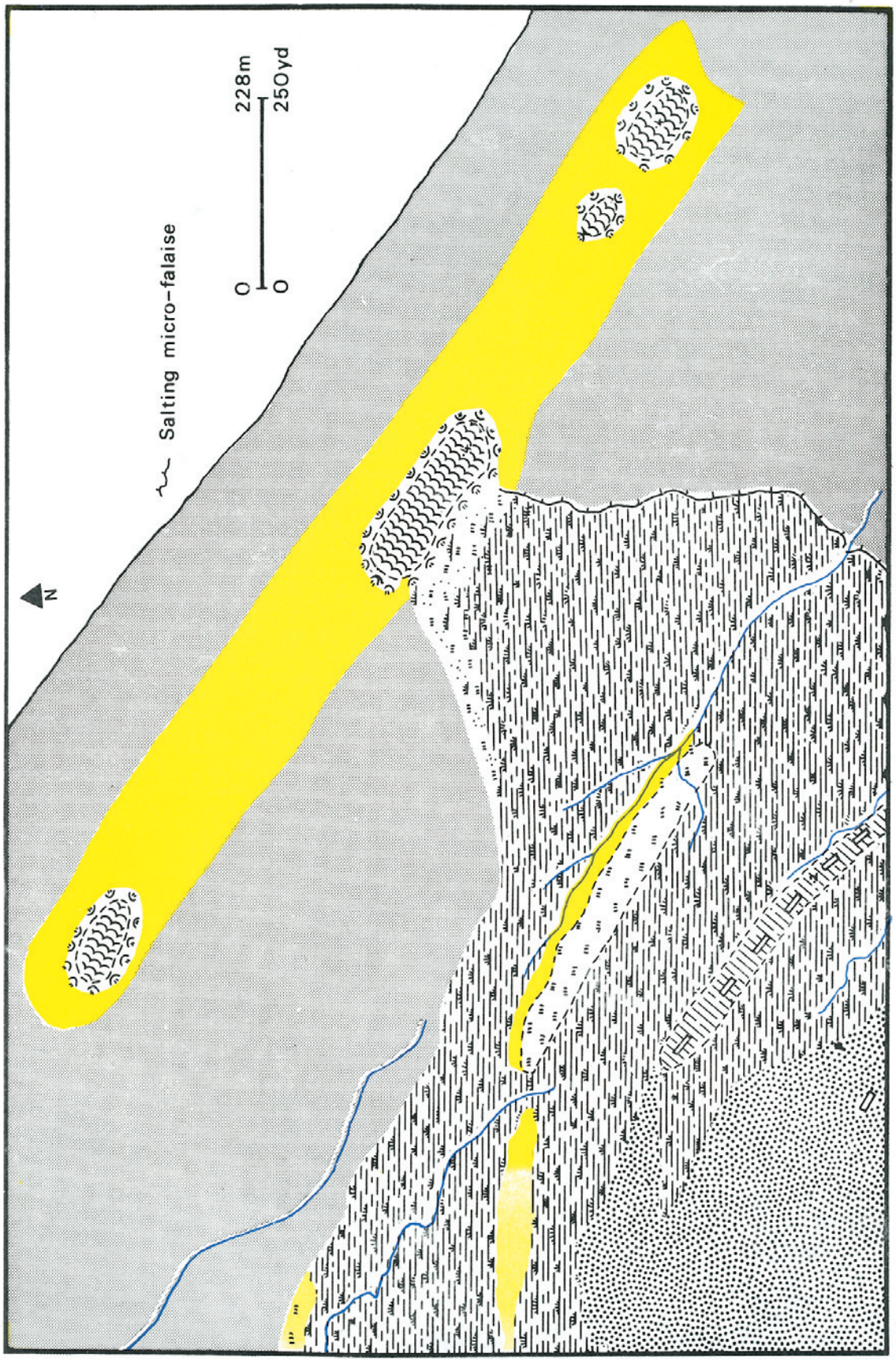


Figure 7.1h Morrich More

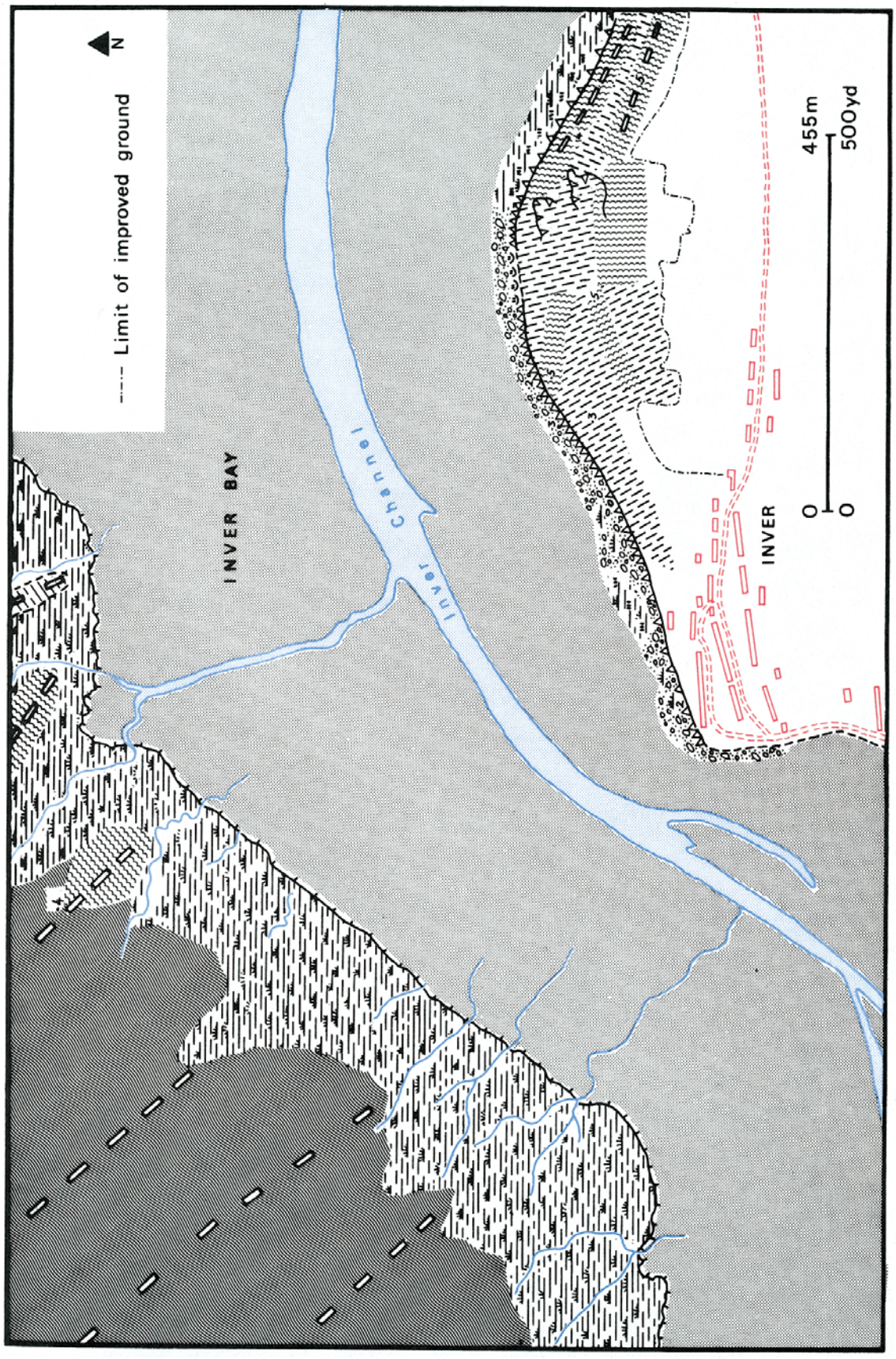


Plate 7.1.1 The Morrich More – the complexity of the ridge and slack sequence is apparent together with the prograding nature of the dune islands. Aerial Survey, 1966.

Plate 7.1.2 The Morrich More – the characteristically undercut western shore with narrow fringing shell rich beach.

Plate 7.1.3 The Morrich More – the machair edge on the western shore with sand spilling over the backshore via the backshore sand ramp.

Plate 7.1.4 The Morrich More – the rapidly prograding outer dune islands.

Plate 7.1.5 The Morrich More – Elymus dunes at the western end of Innis More.

Plate 7.1.6 The Morrich More – the offshore bars at the eastern front of the strandplain.

Plate 7.1.7 The Morrich More – the Puccinellia salting-slack. Note the sandy substrate and delicate balance between salting and dune formation.

Plate 7.1.8 The Morrich More – characteristic sand ridge in foreground with slack beyond.

Plate 7.1.9 The Morrich More – one of the two-storied tidal creeks which dissect the slacks.

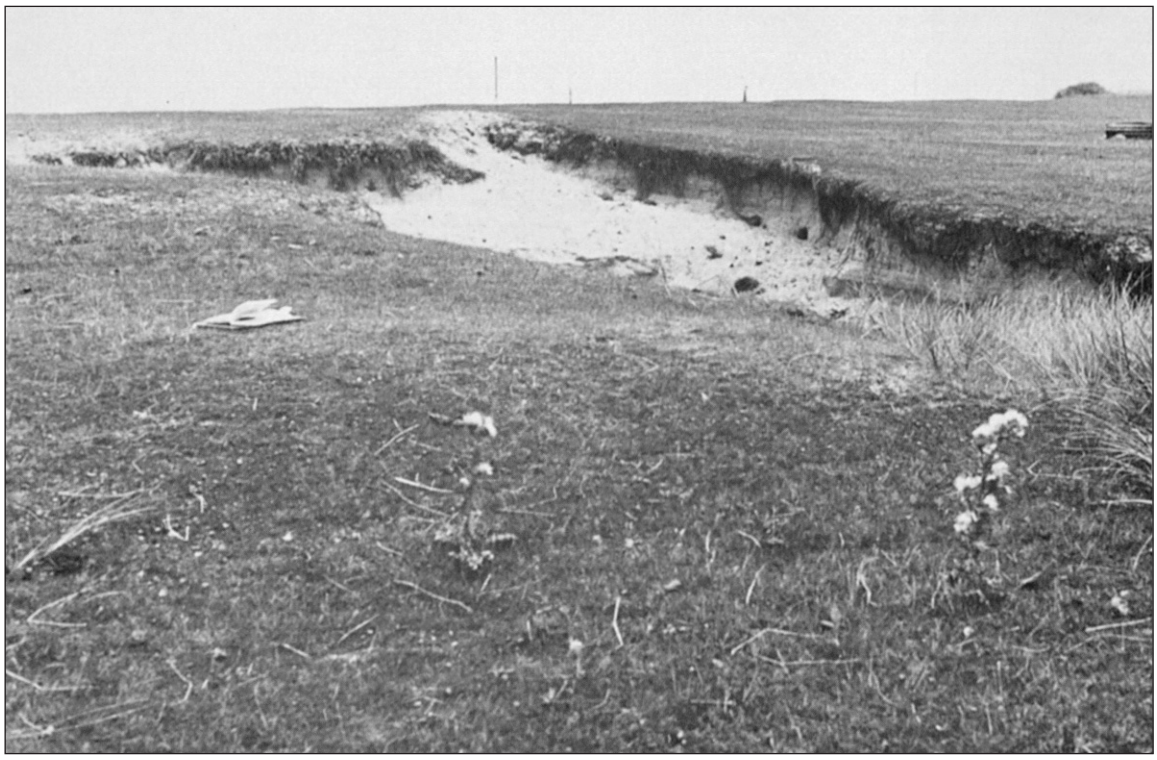


Plate 7.1.10 The Morrich More – small erosion scars in the westerly machair.

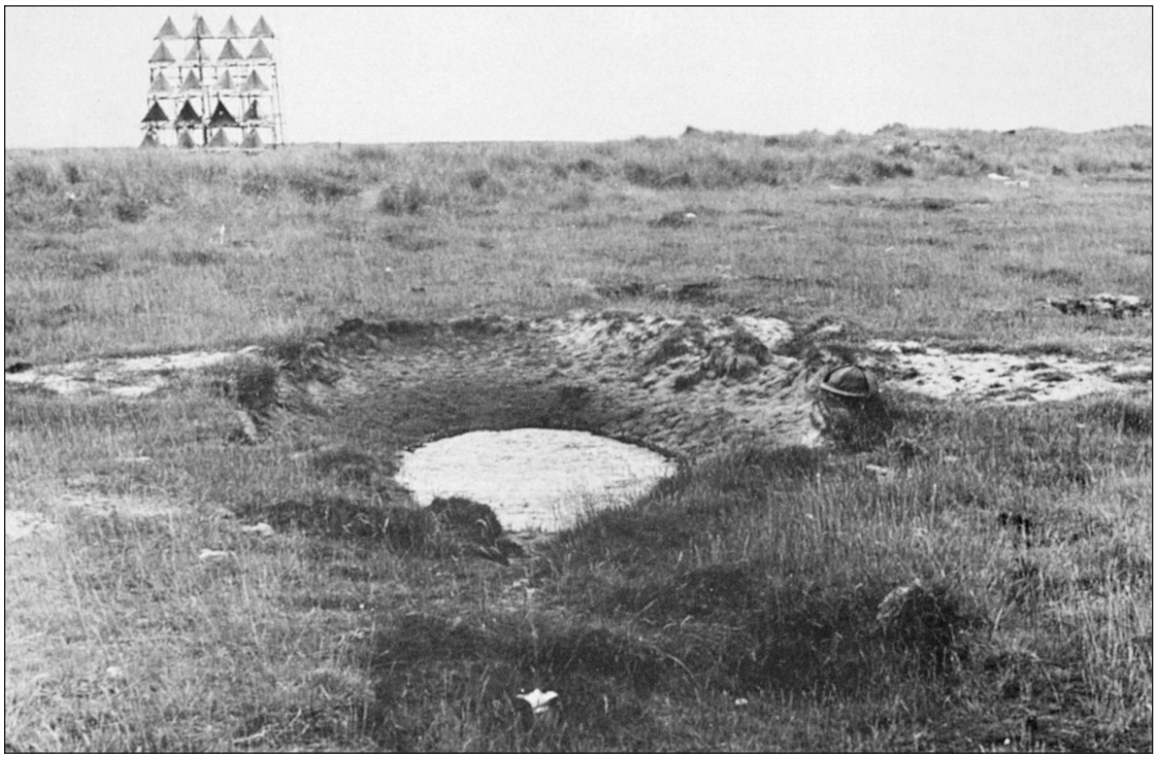


Plate 7.1.11 The Morrich More – bomb craters around one of the main target areas.

Plate 7.1.12 The Morrich More – an aerial view of the most active parabolic dunes near the western shore. Note narrow fringing beach and extensive sandflat.

7.2 Inver-Arboll

The beach and dune system streches from just east of Inver village Arboll, a total distance of 3km. The beach, which is very variable in its constituent materials and shore morphology, overlooks the eastern part of the Morrich More which lies less than 1km away across the Inver channel. A wide expanse of sandflat with a dune fringed island fronts the Inver beach. The beach faces almost due north but is sheltered by a gentle offshore gradient from strong wave attack. Extensive saltings occur in the more sheltered conditions west of Inver.

The dune system is mainly old grey dunes backed by improved agricultural land. Sand accretion increases eastwards as the shelter afforded to the beach by the Morrich More decreases. The dunes and limited machair have accumulated on the post-glacial level but are only 350m broad at their widest point. The beach and dune system is hinged on a sandstone rock platform at the east end, and bedrock occurs on the beach at the mouth of the Arboll burn. The characteristics of the beach and dune complex differ markedly east and west of the burn.

Access to the system is by track through farm fields from the Inver end. There is no vehicular access to the Arboll beach which is therefore seldom visited. The track is signposted in Inver village.

As mentioned above, both beach and coastal edge have highly variable characteristics. Broadly the Inver-Arboll beach unit can be divided into two stretches with the Arboll burn the dividing line. Eastwards of the burn, the dunes are more vigorous in form, with especially marked sand accretion around a yellow dune just east of the burn. Westwards, the dunes are less steep and largely immobile, with a coastal edge characterised by undercutting. The low dunes are seperated by lows and patches of dune pasture.

a) Inver section

Where present, the fringing beach is narrow, being seldom more than 6m wide, passing into sandflat (Plate 7.2.1). The beach material is highly variable but is predominantly lag shingle and gravel with only patches of sand. A small area of made ground beside Inver village is succeeded by eroding saltmarsh resting on top of gravel. As the saltmarsh gradually disappears, coastal edge erosion begins with scarps 2m high cut into the low irregular blown sand deposits beyond the backshore. As the shore trends eastwards in a concave arc, coastal edge erosion ceases and is replaced by an eroding saltmarsh with small *Elymus* dunes at its landward edge backed by a stable coastal edge 2m high. From the morphology of the first foredune ridge behind the backshore, it is clear that this *Elymus* accretion is recent, and has replaced a period of erosion in the recent past which has reduced the foredune ridge in places to almost its crestline. This delicate balance between erosion and deposition continues eastwards, with the backshore features diminishing in height and being characteristically fronted by backshore shingle and cobbles. The fringing sand beach re-appears as the shoreplan trends convex, but remains less than 6m in width. Lag gravels and glacial erratic blocks are strewn on the sandflat. The last few hundred metres before the Arboll burn has a stable backshore fronted by a 3m young dune carrying Marram and sea lyme grass resting on top of backshore shingle (Plate 7.2.2).

Examination of the pattern of foredune ridges beyond the backshore indicates that parts of the system have been removed by shore erosion in the past. While the spasmodically occurring shore saltmarsh is generally

eroding, in general current shore erosion is slowing down, probably as a result of the continued eastwards extension of the offshore sand bar of the Morrich More system which, as it extends east, will increasingly protect the Inver shore. The shore is prograding in places *via* an *Elymus* apron built up in front of an old shore scarp now wholly fixed by *Ammophila* (Plate 7.2.2). Frequently the crestline of the original foredune forms the top of the old shore scarp, testifying to a former predominance of shore erosion. The narrow and discontinuous fringing sand beach has a gradient of 5°. The general situation is similar to the western shore of the Morrich but the erosion problem here is less severe.

b) Arboll section

The characteristics of beach and backshore change radically east of the Arboll burn. The beach gradient steepens to 6°, is five times as wide, and is characterised by almost continuous backshore accretion of blown sand. The shoreline is actively prograding (Plate 7.2.3). This situation fits in with the pattern of dune, ridges which are higher and steeper and would appear to represent parts of a more complete dune system which once extended westwards towards Inver (Plate 7.2.5). East of the saltmarsh at the mouth of the burn, a steep 8m yellow dune backs the shore. This dune is strongly prograding westwards on top of a sand spit. Eastwards, the dune edge takes the form of a neutral backshore, with seasonal erosion and accretion (Plate 7.2.3). The face, 30° in gradient, is in the form of a sand ramp with irregularly dispersed tussocks of *Ammophila*. In places, the dune ridge is very narrow, with a predominance of bare sand. Change is rapidly occurring here, but in general, accretion of sand is dominant. Extensive backshore sand ramps indicate sand blow along the beach from east to west. Clearly this yellow foredune ridge has been breached on several occasions in the very recent past, but sand supply has been sufficient from the wider beach here to allow the scars to be rapidly healed. The dune height decreases eastwards and the backshore becomes increasingly stable. The top of the beach is flat or slightly convex, and there is an extensive wrack sand accumulation area. In the extreme eastern part of the beach, a new line of *Elymus* dunes over 2m high has built up in front of an old erosion scarp cut into the first foredune, now healed with *Ammophila*, a situation similar to areas of the Inver, although on a far grander scale (Plate 7.2.4). Both beach sand and dune forms stop east of the appearance of the inter-tidal sandstone abrasion platform.

There is undoubtedly a relationship between the accreting eastern arc of the Arboll-Inver beach and dune system and the continued build-out and extension eastwards of the Morrich More shore bars. Sand continues to be brought inshore across the narrow Inver channel to Arboll, but has been effectively cut off from the Inver shore. In addition the morphology of the westerly end of the Arboll section indicates that sand is moved along the shore in a westerly direction as far as the Arboll burn. In the distant future, the Arboll sand supply is likely to be reduced as the Morrich offshore sand bar grows, but even at the present rate, this is likely to be several generations distant.

The dune system between Inver and Arboll can be treated as a single unit, bearing in mind the current differences in rates of sand supply. At the time when the parallel foredune ridges were constructed, sand accretion was regular in a shallowing shore. The resultant complex is relatively simple, consisting of foredunes with a predominantly *Ammophila* cover separated by narrow sand floored lows also with a predominance of *Ammophila* (*Ammophila* is replaced landwards by herbs and dune pasture species). The foredunes are higher and steeper east of the burn, but clearly the whole system, with the exception of the Arboll yellow dune, evolved as a single unit. Variety to the general pattern can be observed at Arboll where a damp dune slack exists between the second and third old grey dunes. There is a relatively narrow strech of machair behind the dune ridges which have been partially improved as grassland. A deserted sand pit occurs in the

second foredune near the western end of the system, with small erosion scars nearby caused by the sheep which graze the dunes. In general, however, the system is stable and grazing pressures are low.

The stabilised old grey dunes east of the Arboll burn are remarkably steep with 30° seaward slopes and 18° landward slopes. Heights are frequently in excess of 10m. At the extreme eastern end, the dune system tapers off and disappears. In contrast to the vigorous dune morphology in the east, the Inver component of the system is rather low and poorly developed. Slopes are seldom in excess of 10° and two of the more recent foredunes appear to have been removed by recent shore erosion. Some farm refuse has been dumped in an old sandpit just east of Inver. The dune system passes inland to a narrow machair area, and then into fenced agricultural land.

The machair areas behind the dune ridges are narrow and discontinuous, reaching their widest development just east of the burn. Blown sand probably extends as a thin sheet landward of this, but it has been encroached upon by improved grassland and cultivation. There is no true dune pasture.

The Inver shore is suffering limited erosion in places due to progressive decrease in sand supply as the Morrich bar grows eastwards. There are signs that more severe erosion in the past of the dune backshore has been replaced by a new equilibrium with limited backshore accretion around Elymus.

East of the burn accretion, while suffering winter downcombing, is dominant from both offshore and longshore sources, and a yellow dune is extending westwards. Old backshore scarps on the extreme eastern shore have been healed by a new foredune line. In contrast to the early stage of dune development exhibited by the yellow dune, the old ridges have stabilised themselves and retained relatively steep asymmetric cross sections. The shore system can thus be regarded as largely stable in the west, and vigorously extending in the east. The dune and links area are stable, with very localised exceptions.

The residual saltmarsh contains representative halophytic flora, while on the dunes, backshore *Elymus* pioneer colonies are rapidly replaced by *Ammophila*. At one point on the backshore, the succession is reversed with *Ammophila* colonising the beach and *Elymus* on the backshore behind. No reason can be advanced to explain this. Only one dune slack occurs. The system appears to lie within the Grade 1 site described under Morrich More in the Nature Conservancy proposals for the Moray Firth, but it is not described in their text.

The land backing the shore is used as rough grazing for sheep and cattle. Access is available by vehicles as far east as the burn, where the land ownership changes. A right of way is alleged to exist between Inver and Portmahomack. The shore is fenced off as far east as the burn where the fence line swings inland to exclude grazing on the shoreward dunes. There is a very limited amount of sand blow around sheep scars.

Recreational use at present is very low. There is no caravan site at Inver but caravanning is apparently permitted within the western part of the dune system. There is little sign that many people avail themselves of this opportunity. On the other hand, the beach is clearly signposted in the village but the access track degenerates quickly making, vehicular access somewhat hazardous. The most attractive stretches of beach and dune occur east of the burn, which is unbridged and fenced off. Clearly there is scope for development of organised recreational facilities to take advantage of the Arboll beach, although care should be exercised to prevent undue pressures on the evolving yellow dune.

There is scope for the development of caravan facilities in the vicinity of Inver. The links are dry, the topography subdued, the dune system stable, and the area is not visible from the main road. While the most attractive beach lies east of the burn, there the environment is fragile, and the dunes could not withstand high densities of tourists. However, in the Easter Ross context, most visitors are touring from overnight sites, and lack of a wide beach need be no drawback. It is recommended that the track running east from the village be improved for a distance of 1500m, and that a caravan site with about 30 stances capacity be established behind the second foredune ridge. This should be a holiday caravan site subject to the standards approved under the Caravan Sites and Control of Development Act, 1960. No encouragement should be given to facilitate access to the Arboll beach, but on the other hand, no restrictions are necessary at the moment, other than the consent of the owner. An opportunity exists here to layout a model site in an area well suited for holiday caravans, and usefully situated for touring westwards by car.

The Inver-Arboll system of beach and dunes is variable along its length. The widest beach and most vigorous dunes lie east of the Arboll burn. The low foredunes east of Inver have suffered backshore erosion in the past, but there are signs that accretion is beginning to remedy the situation naturally. The Arboll section is somewhat fragile and cannot stand heavy tourist pressures. It is also included within the Grade 1 Nature Conservancy proposals for the Morrich. It is recommended that a caravan site be established on the links some 1500m due east of Inver with stances restricted to holiday caravans.

Figure 7.2a Inver-Arboll

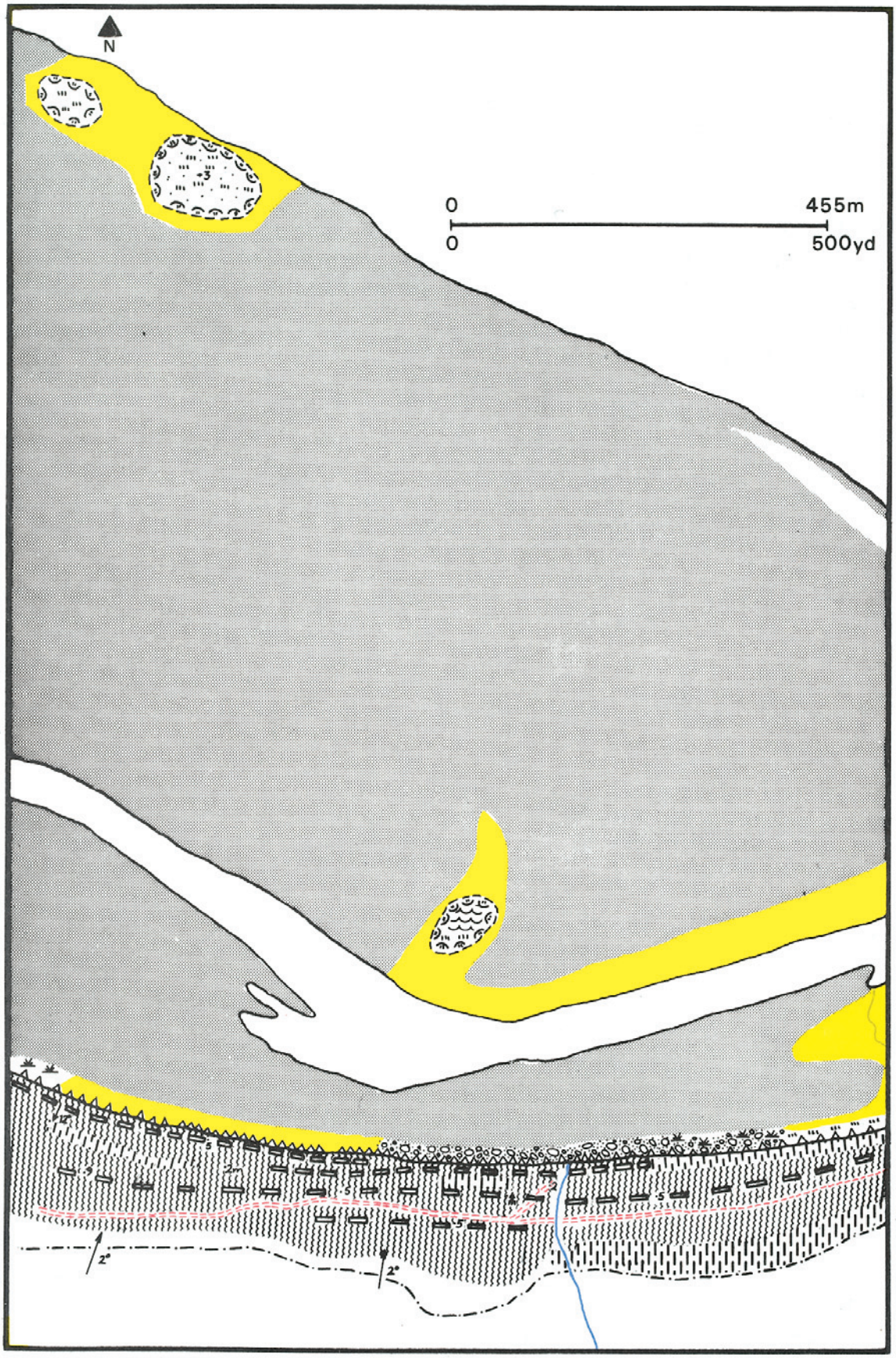


Figure 7.2b Inver-Arboll

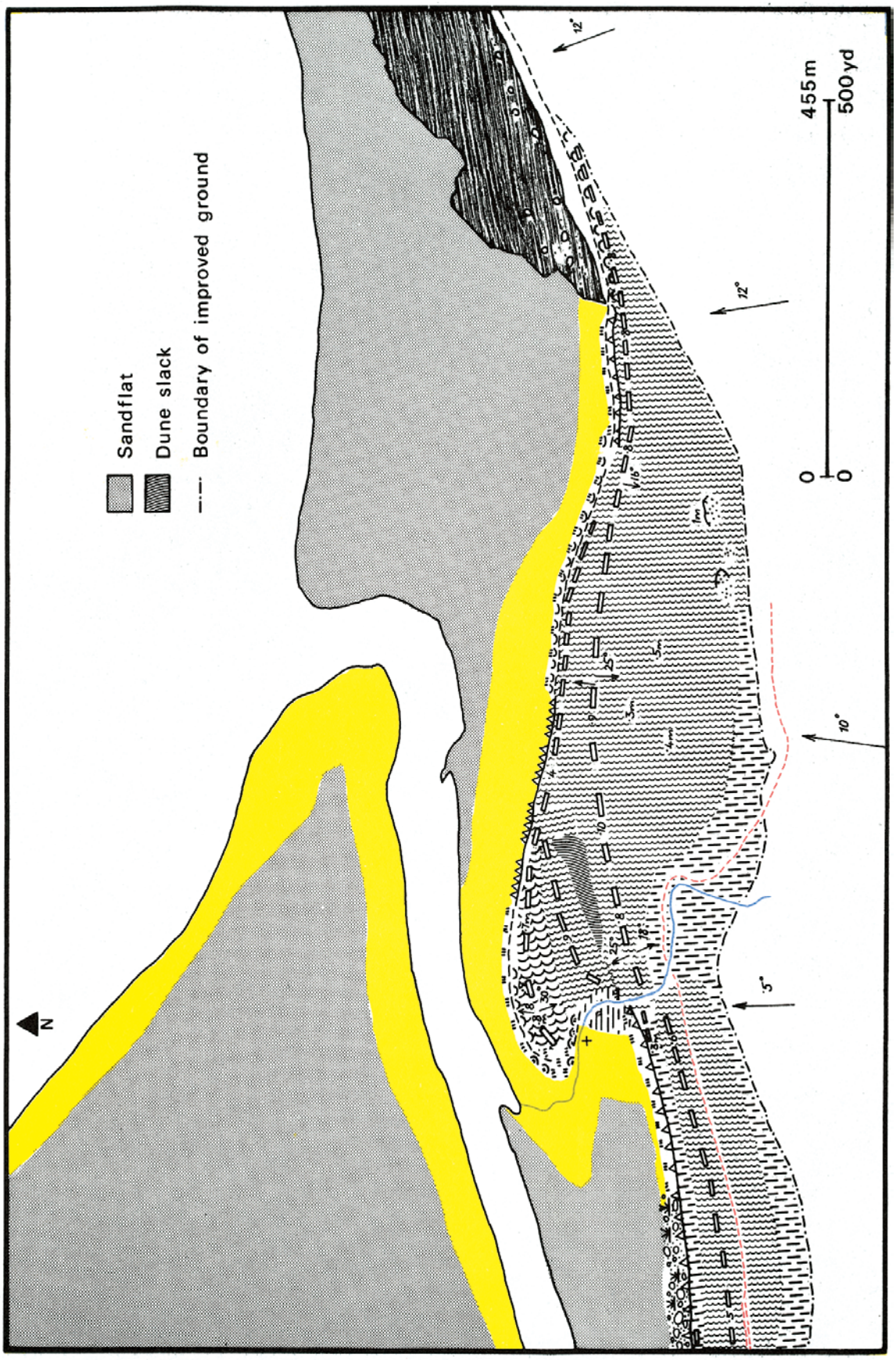


Plate 7.2.1 Inver-Arboll – the discontinuous fringing sand beach east of Inver, with low backshore edge and shingle.

Plate 7.2.2 Inver-Arboll – looking eastwards towards the Arboll burn, and the more vigorous dune topography characteristic of this part of the system.

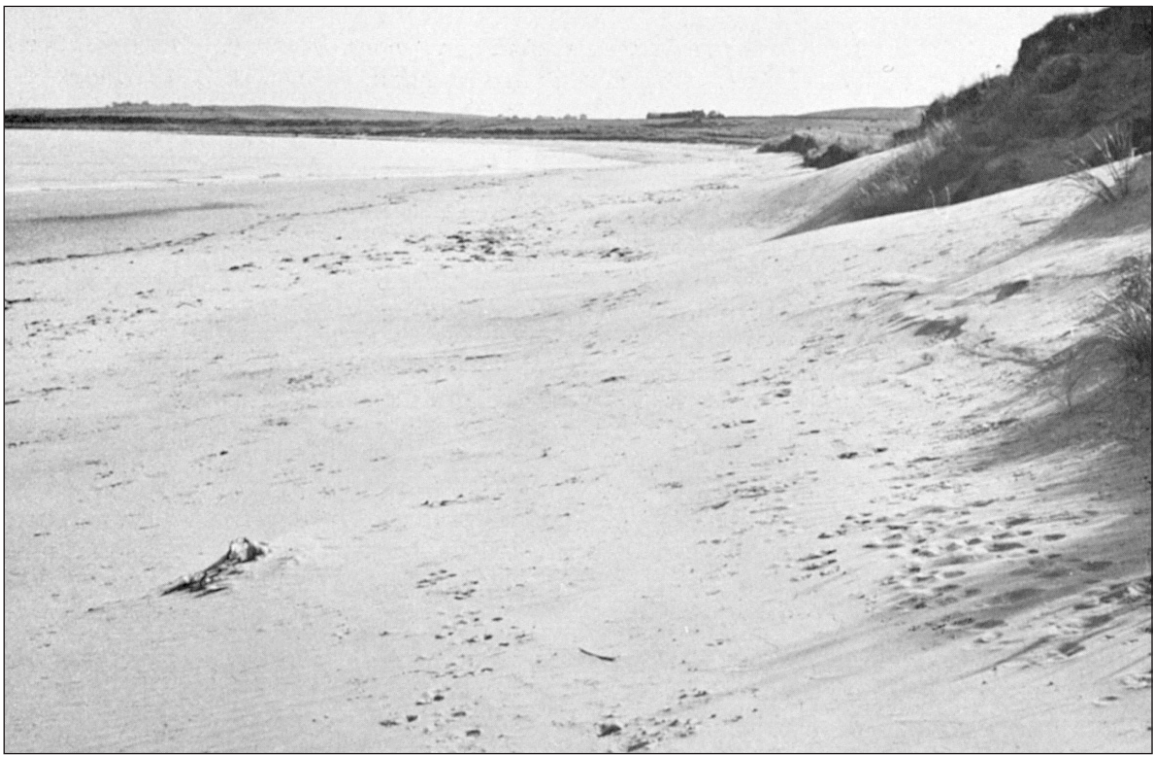


Plate 7.2.3 Inver-Arboll – the seasonally changing backshore of the Arboll 'yellow dune' with characteristic Ammophila hummocks and sand ramp. Note the relatively wide sand beach.

Plate 7.2.4 Inver-Arboll – the eastern part of the Arboll section, where notable sand accretion along the backshore has healed an old dune scarp.

Plate 7.2.5 Inver-Arboll – the beach and dune system from the air.

7.3 Wilkhaven

Wilkhaven is a small fringing beach near the tip of the rock bounded coast of Tarbat Ness peninsula, within 3km of Portmahomack (Plate 7.3.1). The narrow fringing sand beach some 10m broad passes seaward into shingle and patchy sand resting on an even sandstone abrasion platform. Landwards, the sand continues as a vegetated veneer running up the flank of the old cliff line, here over 20m high. The cliffs, which are entirely vegetated behind the beach, are formed of Old Red Sandstone but carry a capping of till, topped with late-glacial marine shingle. The vegetated sand above the high water mark has a low rim about three quarters of a metre high, then slopes inland at 8° gradient and extends part of the way up the degraded cliff where its upper limit can be discerned by changes in the pattern of soil creep. The beach is approached by a single-track tarmac road leading to the small pier at Wilkhaven. There is however no parking space and visitors leave their cars in the carpark on the cliff-top near the lighthouse at Tarbat Ness.

The sand beach is small – about 400m long and less than 10m broad. The sand component has a steep gradient of 8°, but flattens out at mid-tide level into a shingle fringed abrasion platform with a veneer of rippled sand. The machair behind is banked up against the old cliff line, and its gradient is controlled by the angle of rest of the old colluvium washed down from the cliff in the past. The edge of the machair has a small rim about three quarters of a metre high which is very degraded, primarily as a result of intense grazing and trampling by sheep. This has resulted in small-scale wind blow extending back from the machair edge and total removal of the edge at one point (Plate 7.3.1). There is no dune ridge other than the typical slightly raised rim characteristic of many machair areas. Blown sand has advanced a considerable distance up the cliff but is almost wholly vegetated, and less than 1m thick. A small till-plugged stack at the post-glacial level carries a pocket of blown sand banked up against it. The superimposition of shingle over till over sandstone has proved to be an unstable combination and the degraded cliff is typified by numerous till slumps, both recent and fossil. The machair carries patchy *Ammophila* on its edge but it is clearly heavily grazed and short of sand supply from the beach and is quickly replaced by dune pasture grasses, where not improved (Plate 7.3.2).

The main factor in an otherwise completely stable situation, if one excepts occasional slumping associated with the cliff slope, is the heavy sheep grazing which the blown sand area experiences. The turf is very closely grazed, as indeed is the Marram, while a close pattern of sheep tracks lead along the edge of the machair just behind the backshore margin. The sand layer on the beach itself is generally thin, and it is probable that only limited supplies are available for renewal offshore (see Table 2). This is supported by the general thinness of the sand mantle behind the beach. The main resource of the site is the machair which at present is being gradually degraded by overgrazing. Bearing in mind the impossibility of replenishment, serious thought should be given to reducing the stocking rate, or possibly, fencing off of the beach and sand spread area from grazing.

The favourable local climate experienced by Wilkhaven and the relative ease of access suggests that casual recreational pressures may increase in the future as the area becomes better known. Although it has no potential for caravans, the views of cliff and beach are pleasant, with the additional attraction of rock pools and sandstone sedimentary structures including taffoni weathered out by the salt spray on the abrasion platform. While the beach and machair can only support a dozen people at a time, it forms an additional dimension to a peninsula which is generally devoid of local scenic attraction. Should the present pattern of grazing continue, however, its recreational attraction will correspondingly diminish.

Wilkhaven is not well known and therefore is only visited by either local people or visitors staying for several days and exploring the peninsula. A resource, however small, should be carefully managed and it seems possible to merge the grazing requirements of the owner and the recreational requirements of a small number of visitors. It is therefore recommended that grazing pressure be reduced and the area of even sand spread and beach from the pier to the cliff-foot be stock fenced and grazing controlled to allow healing of the erosion scars and some regrowth of the vegetation. No effort should be made to direct visitors to Wilkhaven as its carrying capacity is low. The type of management suggested is in sympathy with the scientific interest of this stretch of coastline.

Wilkhaven is a small cliff girt beach with a small sand component comprising fringing beach and a thin, vegetated sand spread extending to the foot of the old degraded cliff. There are limited car parking facilities nearby on the top of the cliff. The machair is showing the effect of over-grazing by sheep and recommendations are made to reconcile a limited amount of public recreation with the established land use.

Figure 7.3 Wilkhaven

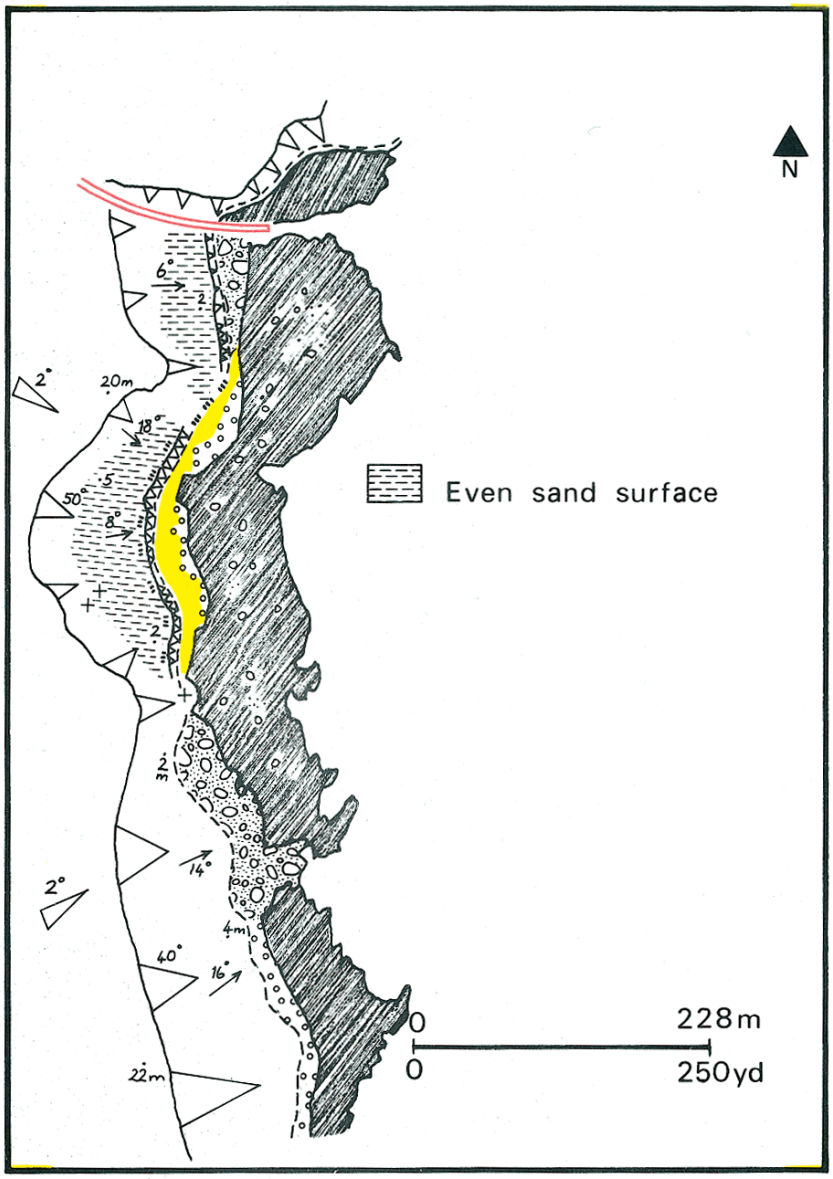


Plate 7.3.1 Wilkhaven – a general view of this small fringing sand beach with machair accumulated at the old cliff base. Note erosion scars.

Plate 7.3.2 Wilkhaven – the machair edge has a rim with Ammophila, but heavy grazing is tending to prevent successful regeneration, and so accelerate the limited erosion at the machair front.

7.4 Portmahomack

Portmahomack beach and dune system is located on the western side of the Tarbat Ness peninsula overlooking the Dornoch Firth and the east coast of Sutherland. The village is 16km from Tain, and set amidst prosperous agricultural countryside. The dune system rests on the series of well marked raised beaches which fringe the low peninsula. The village itself, formerly a fishing village during the herring boom of the 19th century, is largely residental and tourist-orientated. Very similar to Cromarty in appearance and function, it caters for residential tourists in its hotels and caravan site. Recent plans have been approved for a composite tourist development involving chalets, disco and other ventures, rather in contradiction to the established Portmahomack tourist pattern. The peninsula competes with the Nairnshire coast for the highest sunshine incidence and lowest rainfall figures in the North of Scotland. Within recent years, considerable renovation of the older houses has been taking place both as holiday cottages and permanent residences. Portmahomack's eccentric position has encouraged an emphasis on a loyal clientele of visitors returning each year, and repeating their established pattern of recreation.

The beach is about 1000m long, has an average mid-tide gradient of 5°, and is hinged on Old Red Sandstone platforms at north and south ends. This latter feature is evidently an old feature underlying at least the post-glacial raised beach, as it can be traced intermittently below the sea wall which protects the backshore south of the harbour. The sea wall, some 2m high and vertically set, divides the beach from the road and a series of small garden plots. Southwards, in the vicinity of the church, the backshore is of unconsolidated materials comprising the irregular edge of a small sand dune system, a large part of which is utilised as a caravan site (Plate 7.4.2). The beach is predominantly formed of sand with a prominent seepage line at about the mid-tide level. Gravel and cobbles occur intermittently at northern and southern ends, and are also localised in certain parts of the backshore zone. All backshore margins, where not protected by a sea wall, suffer occasional wave undercutting. However, the dune system in the south is a curious mixture of erosion and accretion, repeating, in part, the situation at Nigg Ferry. An undercut sand face 3m high just behind the high water mark consists of part sand ramp, part embryonic dunes with *Elymus* (Plate 7.4.1). The sand ramp is partly made unstable by movement from the caravan site to the beach and back. In the extreme southern edge of the dune front, an old scar completely vegetated but with a 20° gradient has been completely healed by sand accretion around *Elymus*. The backshore slope is lowest at the point where the caravan site fronts the beach, but rises northwards in sympathy with the increase in the relief amplitude of the dune system. Limited progradation can be seen at the central part of the backshore.

Coastal edge erosion by wave action at Portmahomack is extremely limited except in the central arc of the beach where the sea wall requires extension southwards. While the dune system is periodically undercut, there is sufficient sand available at the beach back to prevent this reaching serious proportions. On the other hand, the dune edge could be better conserved through the provision of additional ingress by steps to the beach, which might reduce casual sliding and running down the sand ramp from the caravan site.

A large proportion of Portmahomack village is covered with an irregular veneer of sand extending over the raised beaches and forming the nucleus of the nine hole golf course on the level of the late-glacial beach. The whole dune system, including the portion around the caravan site, is in the form of old grey dunes, which, apart from localised baring by rabbits, public pressure or public works, can be regarded as stable and fossilised. No fresh sand is reaching the dunes from the beach due to the steepness of the coastal edge and the apparent lack of ample fresh supplies from offshore. There is thus no possibility of natural processes healing

progressive shore erosion, and the resource should thus be treated carefully. The highest dunes attaining heights of 10m and 8m occur in the vicinity of the Free Church, with slopes on average about 15°. The steepest gradient occurs where the main road skirts the edge of the 8m dune, and a very limited amount of sand blow can usually be seen on the road verge. It is the periodic undercutting of the seaward edge of these dunes which has created the sand ramp already described. The other dune forms are very amorphous and have an amplitude of less than 2m, east of the road. The caravan site occupies a low within the higher dune system and is comparatively sheltered, and unobtrusive (Plate 7.4.2). With the exception of the coastal edge portion, the Portmahomack dune system is stable and rather uninteresting. Recreational interest centres on the beach and coastal edge, the latter being the most fragile area in the whole system. Excepting the golf course, the dune system is very restricted in area, and forms a small part of an originally more complete complex.

The dune system and beach at Portmahomack is very restricted in size. The system is largely a fossil one created at a time when offshore sand supplies were more readily available within wave base. The pattern of wave attack under certain conditions has been to focus wave energy on coastal edge erosion, and the end result has been the small residual dune area remaining. At present, *Elymus* and the present level of human pressures are keeping backshore erosion to reasonable proportions, although the partially eroded dune face is proving the most attractive part of the beach for visitors. There is clearly a threshold of capacity for both caravan site and dune edge, and the evidence suggests that this has been reached. It is highly likely that the blown sand at backshore position is partially the result of dune backshore erosion in very recent times. This is supported by the old scar now healed, at the extreme southern end of the bay. The *Elymus* dunes formed in front of it, which have allowed the scar to heal, have probably derived their sand supply from erosion of the high dunes to the north. In other words, virtually no supplies of fresh sand are entering the system from offshore. Healing at the dune edge is relying purely on the dune system for material, a situation which is equivalent in human terms to spending money from capital rather than interest. If this is the situation, the current periodic erosion of the dune front, which is attractive to the visitor, requires some remedial action and careful monitoring.

The dunes carry *Elymus* tussocks along the seaward front edge, and in the form of small dunes at the back of the beach. The high dunes carry a surprising amount of Marram which is a result of adjacency to the sea. There is a reduction of Marram density on the inner faces of the higher dunes. The dunes are not grazed and are unfenced.

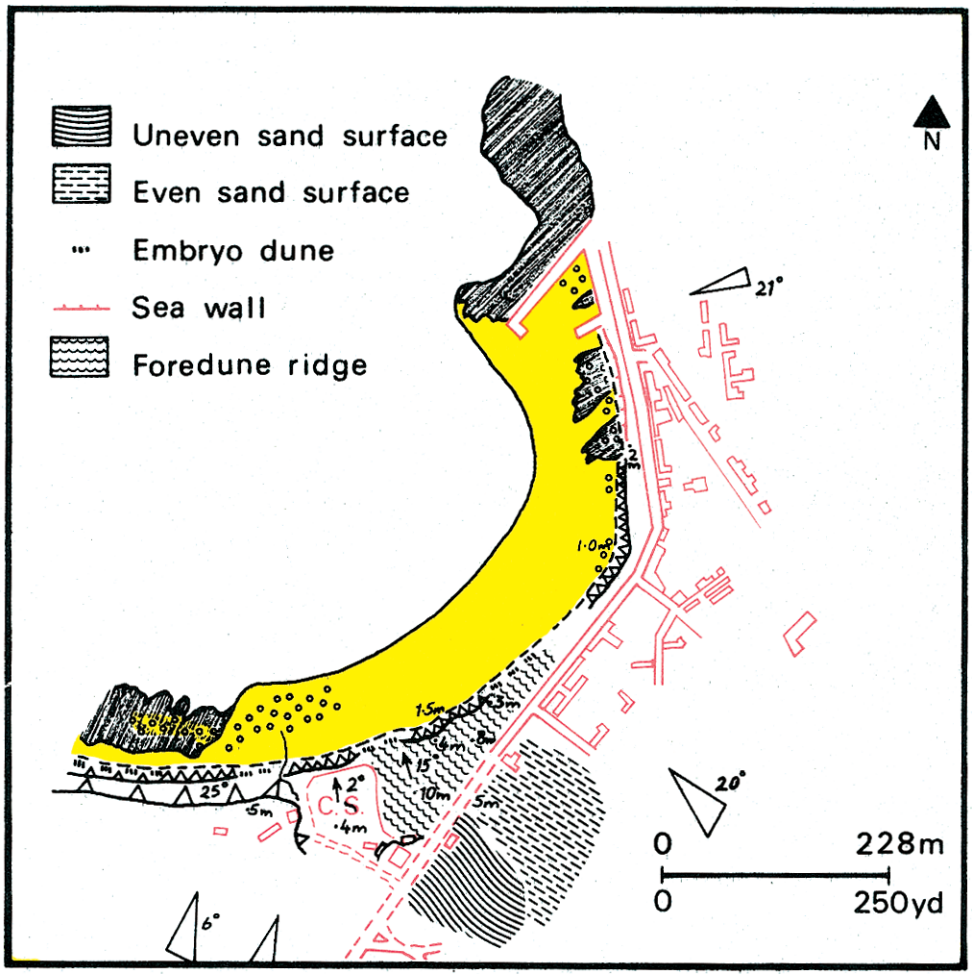
The village is surrounded by farmland in owner-occupied units. The nine hole golf course above the village on the late-glacial beach is laid out on old grey dunes and is used for grazing. The caravan site itself carried 20 caravans in the day of visit in September. The caravans are laid out randomly with a preference for parking adjacent and at right angles to the backshore edge. The site is served by a track and is adjacent to the main road. The bay is used for bathing and boating.

The recreational use comprises the beach, dune edge, the bay itself and the golf course. Attractive walks are readily made to the cliff-girt village of Rockfield and the Tarbat Ness headland. Unlike Cromarty, the beach carries considerable sandy areas and is frequently walked over. The dune system is so modified by the village itself that it cannot be classed on the whole as a recreational resource. It is largely used up by the caravan site itself. There is ample car parking space along the beach above the sea wall, and access to the beach is easy. There is no possibility of increasing the size of the caravan site, and it has reached its optimum in terms of the number the dune edge can support.

Clearly the most fragile feature is the dune edge in the vicinity of the site and immediately north of it. With the limited amount of fresh sand available from offshore, care should be taken to minimise and decelerate current erosion of the backshore edge. It is recommended that the caravans are resited within the park so that they do not sit next to each other along the top of the backshore edge. It would be possible to set the site capacity of 30 caravans in a semicircle concave to the shore, and to encourage ingress to the beach along one or two carefully constructed stepways. This would cut down on casual sliding down to the beach which is undoubtedly an important factor in preventing healing of the sand ramp by vegetation. Sea lyme grass or Marram transplants could be attempted to speed the rate of healing. North of the site, because the dune face is much higher, current erosion, which is visible on 1946 aerial photographs, is less damaging, and no action is required there. It must be stressed that the beach and dune resource at Portmahomack is very small in comparison with other systems in Easter Ross, but is very important to the village itself. Expansion of the caravan site numbers is not possible but attention might be given to expanding water sports facilities.

The existing dune system at Portmahomack forms a small part of a once more active and extensive system which spread up to over 30m O.D. onto the late-glacial beach. At some stage after the formation of the post-glacial beach, the original foredune system blew out, creating the irregular grey dune arc now the site of the golf course, and leaving a residual foredune system near the Free Church, now the caravan site. Other parts of the system have been levelled and built over by the village itself. The system is wholly fossilised and cut off from any fresh sand arrival. There are indications that the rate of replenishment has fallen dramatically since dune formation as a result of sea level stabilisation. The result is continuing backshore erosion accelerated by public pressure. Certain remedial actions are suggested to conserve the very limited resource still available for recreation.

Figure 7.4 Portmahomack



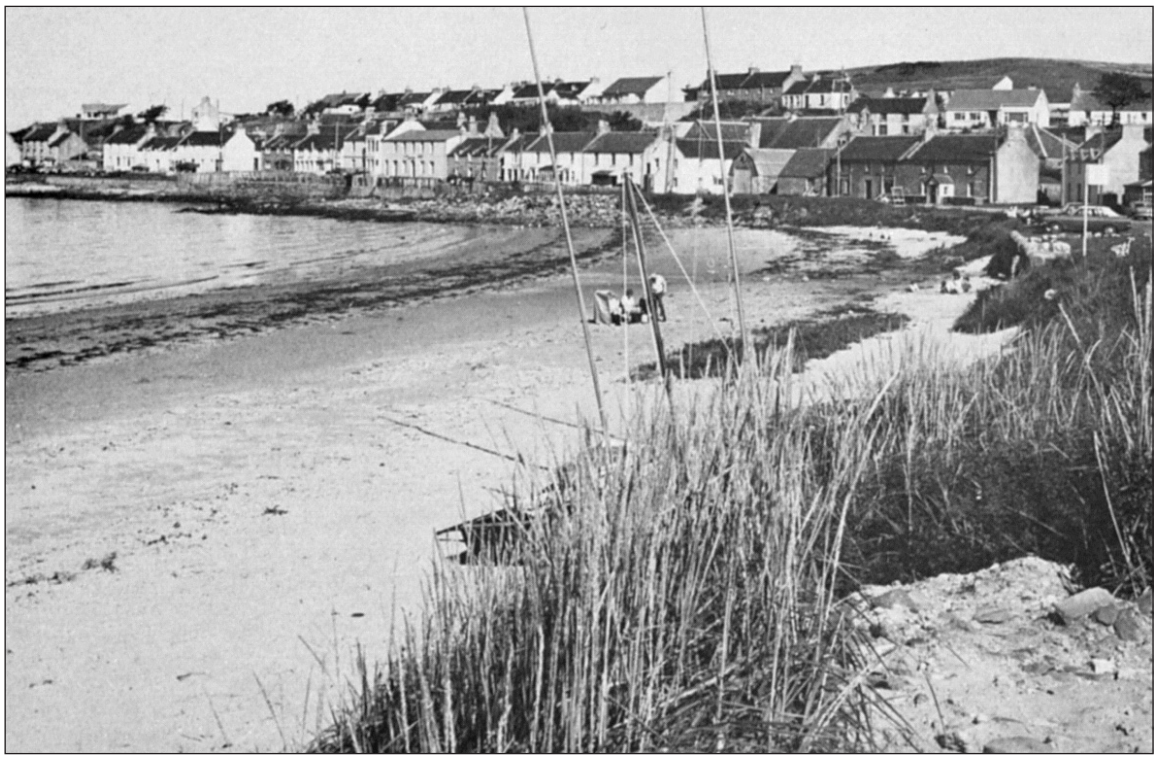


Plate 7.4.1 Portmahomack – the beach from the dunes beside the caravan site. The village sits right at the back of the beach.

Plate 7.4.2 Portmahomack – looking south-west towards the dune edge which is being eroded by passage from the caravan site to the beach. (See also the photograph on the cover of this report).

7.5 Balintore

Balintore beach and dune complex occupies part of the only embayment in the largely cliff-girt eastern coastline of the Tarbat Ness peninsula. The village is situated on the post-glacial level, backed by an old cliff line at a point where a low col leads over from the Fearn-Nigg lowland. The col is covered with a complex of shingle bars deposited during the highest late-glacial transgression. Sandstone cliffs fronted by a narrow post-glacial beach and rock platform extend to north and south of Shandwick Bay. The village forms part of a now continuous former linear fishing settlement incorporating the smaller settlements of Cadboll and Shandwick, both of which were originally laid out in a narrow linear form below the old cliff line. The built up area is almost 3km long, but the beach and dune extends for less than half of the total length of the embayment and backs Shandwick Bay. North of the harbour, the shore consists of shingle beach and abrasion platform. Beach and dune recreational interest therefore centres on Shandwick Bay. The beach is 9km from Nigg and 22km from Tain.

The beach is widest in the north central part of the embayment and narrows southwards, being replaced there by a block-strewn abrasion platform with sporadic sand patches. The beach has a mid-tide gradient of 5° and is hinged at the north end by the sandstone abrasion platform into which the old harbour has been excavated. The sand beach is about 1800m long and 100m wide at low-tide at its widest point. It narrows notably to the south, becoming a narrow upper fringing beach at Shandwick, sitting at the back of the abrasion platform. Shingle occurs as a backshore feature of the beach wherever the abrasion platform occurs, but only very sporadic shingle is visible at the back of the main sand beach. The backshore is consistently formed of a foredune edge which varies in height, being highest and widest beside the caravan site (which is partially built on top of it) (Plate 7.5.1) and narrowest and lowest to the south where the dunes are much less in amplitude and narrower. Limited undercutting at several points shows blown sand resting on cobbles and this may be taken to indicate that the dune system rests on a series of shingle bars, similar to those already mentioned as having being constructed at the late-glacial level. Undercutting occurs notably at the shoreward edge of the high dune (6m O.D.) where sand faces with patches of Marram over 5m high occur (Plate 7.5.2). The areas of bare sand extend on top of the dune itself which is very heavily trampled, presumably by the inhabitants of the *residential* caravan site adjacent. Limited backshore undercutting also occurs north of the caravan site and in the central part of the beach but the scars are only 1m high and there is very limited public pressure to exacerbate them. Backshore undercutting extends for a total length of 500m, and is replaced by definite accretion of sand at the southern end of the bay. There, small Marram based dunes are accumulating on top of cobbles, in addition to some temporary sand fixation around the strandline vegetation. There is a limited amount of made ground at backshore just south of the harbour. Some attempt has been made to decelerate dune-edge erosion by the tipping of sundry concrete and stone material in the vicinity of the caravan site at Balintore. A path runs along the top of the foredune ridge from the caravan site to the southern end of the beach.

The coastal edge of the high dune beside the caravan site is a serious problem (Plate 7.5.1 and 7.5.2). This has reached an advanced state and will accelerate due to the exceptionally large number of permanent caravans associated with the Nigg Development (36 at time of visit). While the winter situation remains unknown, it is clear that the backshore sand ramp, the blowing of sand from it to the dune top, and the many paths across and down the dune, are all causally related to site pressure. A tendency towards degradation of the dune edge is visible on 1966 aerial photography and thus the process is by no means catastrophic in rate. Nonetheless some remedial action is required as soon as possible to prevent the situation becoming progressively worse.

The dune system extends to the base of the post-glacial cliff at 8m O.D. The blown sand area takes the form of a continuous vegetated foredune ridge, with traces of parallel ridges inland of it separated by discontinuous lows. The inner ridges have been heavily modified and levelled by housing development and gardens associated with the growth of the villages, and only survive as remnants. The ridge form of the system decreases south of Old Shandwick and becomes a featureless, though slightly irregular sand spread lapping up to the foot of the old cliff line. Around Old Shandwick, the dune area and the sand spread have been partially improved for grazing. The predominant vegetation on the shore face of the dunes is *Ammophila*, with *Elymus* occurring spasmodically nearest the high water mark. Inland a wide variety of grasses and herbs occur, many of them unrepresentative of dune pasture. The continuous foredune ridge, where present, varies in height from 6–7m to 4 or even 2m. It is clear that greatest accretion during dune building phase took place in the central arc of the bay. The system is almost totally stable despite the network of tracks and paths which run across it, many of them leading to gardens and houses (Plate 7.5.3). Because the houses are built right behind the dune edge and often near to the shore, isolation and seclusion are not qualities found in Balintore beach, and direct access from road to beach is not always possible. The most attractive part of the beach from this point of view is that portion south of Old Shandwick, where the foredune ridge narrows and eventually is replaced by a machair-like ramp of 14° gradient running up to the old cliff base. This takes the form of an improved dune pasture. The old cliff line behind is almost wholly vegetated and carries a substantial cover of bracken. A temporary quarry exists and the machair is fenced for grazing.

The total beach-dune system at Balintore is stable at present with almost totally vegetated dunes, often partially improved, and largely concealed or modified by buildings and gardens. The relatively steep post-glacial cliff nearby, together with the orientation of the beach, has prevented the formation of a machair. Only the backshore foredune remains relatively unaltered and it is now in a neutral phase, receiving very restricted sand supply, and suffering little backshore erosion, except beside the caravan site. The relative lack of erosion is at least in part related to the presence of backshore shingle, not always visible, but underlying the whole of the dune system. Only the highest point in the dune ridge is suffering intense shore-face erosion through trampling pressures acting on an already eroded face (Plate 7.5.2). The trampling is spreading to the top and is intensified by permanent caravans becoming predominant in the site. Remedial action is required. Otherwise the stable condition is typical of many East Highland beaches.

A major part of the dune system is taken up by land uses related to the permanent inhabitants of the villages (ie houses, gardens, storage space). The remaining foredune is used as a walkway, while the harbour shelters a large number of small sailing boats. Development of the dune system for traditional land uses has inevitably taken place in a haphazard way, and the area is generally cluttered and untidy. The tipping of rubbish on the shore is an established custom. The area immediately south of the harbour is particularly in need of remedial action as it could well be the entrance point to the beach for visitors.

Most of the factors mentioned above under land use mitigate against Balintore further developing its recreational facilities based on the beach and dune system. On the other hand, there is scope for further development of sailing and boating. Old Shandwick has limited potential for a small caravan park at the south end of the village.

It is recommended that an effort be made to restrict the number of permanently occupied caravans on the Balintore site (there were 36 there at time of visit). Human pressures on the dune edges adjacent to the site

are too heavy and are creating erosion and sand-blow problems. Efforts should be made to divert access to the beach by the direct route, possibly by fencing, and time given to the healing of the eroded face, with assistance through Marram transplant. The area of ground between the harbour and the caravan site is virtually derelict and might be imaginatively utilised as a caravan site or a car park, thus removing pressure from the overworked site on the high foredune. The dumping of odd pieces of concrete in a hopeful attempt to slow backshore erosion should stop, and efforts be made to construct a stone faced sea wall from the south arm of the harbour to the edge of the dune. Some planning decisions are required to prevent Balintore becoming a caravan dormitory for Nigg.

The beach at Balintore is long and wide, though narrowing out to the south. The dune system is largely fossilised and partially built over by the village itself. The main foredune ridge remains in a semi-natural state but the remainder of the blown sand deposits have been much altered. Severe pressures are occurring on a restricted part of the shore face of the foredune system in the vicinity of the existing caravan site. The present situation is the combined result of backshore erosion and pressures from the public. Some remedial action is required and suggested above. The existing caravan site is overcrowded and could be relieved by use of the largely made ground between it and the harbour. Seasonal tourists might well be diverted to a new caravan site established in the vicinity of Old Shandwick.

Figure 7.5 Balintore

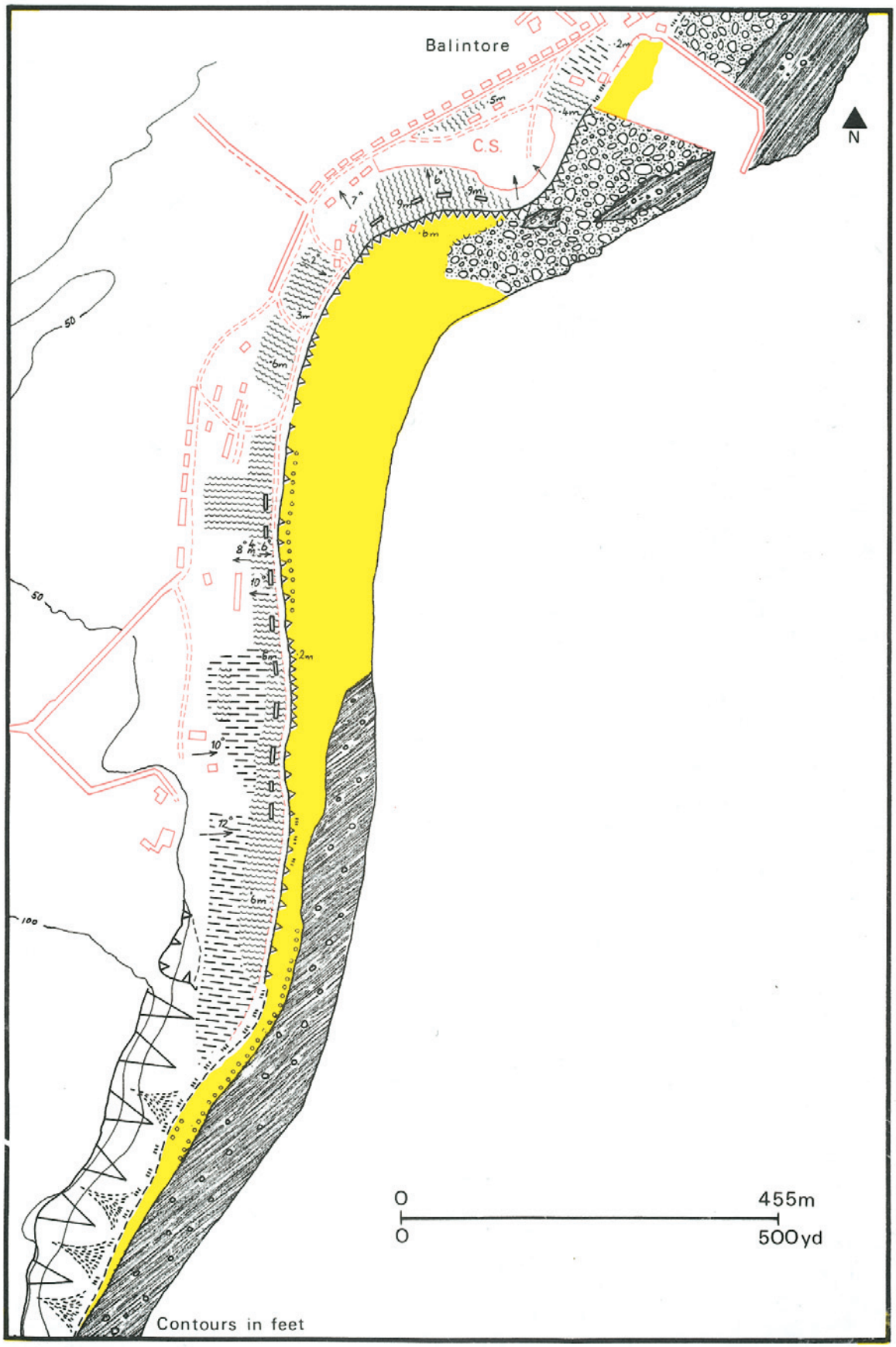


Plate 7.5.1 Balintore – the beach at Balintore south of the harbour and caravan site. The unstable state of the highest backshore dune can be seen in the middle distance.

Plate 7.5.2 Balintore – extreme erosion of the dune edge just south of the caravan site.

Plate 7.5.3 Balintore – the beach south of the caravan site. Note the proximity of houses and gardens to the beach edge.

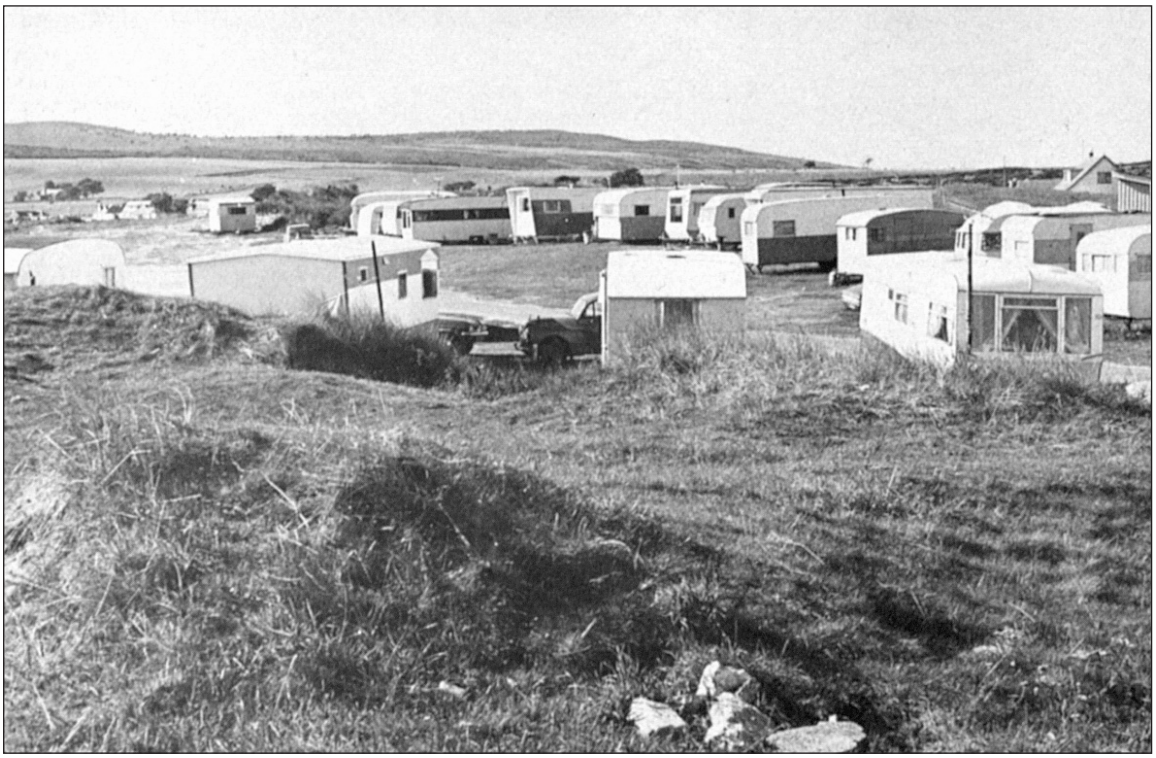


Plate 7.5.4 Balintore – the largely residential caravan site.

7.6 Nigg Ferry

Nigg Ferry is a cuspate foreland built out at present and post-glacial level in the shelter of the cliffed headland of the North Sutor. Westwards lies the 21sq km embayment of Nigg Bay, a sandflat area which dries out at low-tide. Eastwards lies the cliffed headland of the Sutors cut in Moine rock series. To the south, Nigg Ferry faces the 10 fathom deep water channel of the Cromarty Firth, and beyond, Cromarty and the Black Isle. Sand deposited by wave action at Dunskaith in the lee of the Sutors has in the past been blown up the westerly face of the Hill of Nigg, partly concealing the raised beaches, and almost obscuring the contact between Old Red Sandstone and Moine basement. At the post-glacial and recent level, a complex of gravel spits and saltmarsh low surmounted by dunes developed at Dunskaith, with a hooked spit swinging round into the eastern edge of Nigg Bay. Within the last two years, the Dunskaith component of this complex has been totally removed by the construction of an oil fabrication yard (Plate 7.6.1), and the dunes running up the Hill of Nigg now form part of land zoned for industry in the late 1960's, although not yet developed. Only a small area of links and beach lying due east of the pier remains open to recreation. This area carries a haphazard scatter of residential caravans associated with the Nigg Developments. The nearby hotel and a few dwelling houses at Nigg, together with the welding school, and assorted fences and tracks form an unattractive background to what remains of the Nigg beach.

The Nigg Ferry beach extends for 1400m along the edge of the remaining dune links and is hinged on the rock cliffs of the North Sutor. The beach is convex in plan and consists of a rapidly accreting sand beach in the east with the proportion of gravel and shingle increasing markedly westwards, although the backshore shingle west of the pier carries a thin cover of blown sand. The flanks of the beach arc are undergoing seasonal wave attack with undercutting of the dune links and consequent slumping of Marram bound blocks, despite the wrack accumulation of sand at the top of the beach (Plate 7.6.3). The undercut faces are between 3–4m high, and wartime gun emplacements are now collapsing onto the beach. Erosion is most marked at the eastern end of the beach. The erosion faces have an angle of 15–20° and are usually being re-colonised by fresh Marram profiting from the amount of sand blow thus created. Human trampling and sliding down the coastal edge are undoubtedly a factor in accelerating its erosion, but the initial impetus comes from wave attack.

The beach is relatively steep with a gradient of 6°, flattening off in the upper part of the profile with a characteristic upper sand accumulation zone some 8m wide (Plate 7.6.4). From time to time, Marram regeneration and colonisation of the links areas has occurred. The beach on the eastern side is fed from a nearshore bar which has decreased markedly in size since 1970. This is presumably the main source for the whole beach system, and unless this bar builds up again, it is possible that beach starvation may occur, leading to acceleration of backshore erosion. Offshore dredging continues intermittently west of the pier, and it is impossible to predict the final outcome of the sand situation until it ceases. As the source of sand lies east of the dredging operation, it is unlikely that there will be any deleterious effects on the beach under review. On the other hand, there is considerable evidence to indicate fresh sand accretion is occurring within the sandflats of Nigg Bay. The most stable part of the beach lies in the centre and due east of the Hotel, where the backshore margin is 4m high, stable and at an angle of 20°.

The dune and links comprises an amorphous vegetated sand spread, with slope angles seldom in excess of 12°. The general altitude is 6–7m O.D., with a shallow low running parallel to the links rim, midway between the backshore and the tarmac road to the Castlecraig quarry. Nearly half of the surviving links

system has been modified by hotel grounds, car parks and houses. The remaining half now functions as a temporary residential caravan site, associated with the Nigg Development. The effects of this recent, more intensive use of the links are now becoming apparent. A number of gravel tracks have been laid across the more accessible parts of the system to individual caravans, and the lows are rapidly becoming sites for dumping of domestic debris, and abandoned cars. While there are few signs of excessive trampling and wind scour, the system is at the stage when a decision has to be made as to its long term future. Continuation of the present unorganised caravanning will soon make the links system opprobrious to visitors. This would be unfortunate as the beach itself is small but attractive, with wide views across to Cromarty and the Black Isle. It seems to be only a matter of time before the lows are full of domestic debris and dumping starts on the beach, which is remarkably free of debris at present.

The present backshore erosion is seasonally severe and continues a process of shoreline adjustment. The dune links themselves do not now receive any substantial quantities of sand from the beach, being separated from it by the coastal edge. Yet excepting the shore erosion, the dune system is potentially stable. If the dune system should begin to degrade through excessive usage, it cannot rehabilitate itself because it is cut off from its beach source. The coastwise drift of sand westward is now partially interrupted by the dredging operation and ultimately by the drydock channel. It is therefore likely that more sand will arrive on Nigg beach and remain there, eventually slowing down the current backshore erosion. It would therefore be useful to attempt an experimental scheme of backshore-face thatching on the eastern part of the beach with the aim of stabilising the eroding face. The viability of attempting this depends on the future of the 29 residential caravans at present on the site, and also on the type of development likely to take up the zoned ground on the flanks of the Hill of Nigg.

The beach backshore carries strandline vegetation of *Cakile* and *Atriplex*, while the backshore face carries *Ammophila*, with occasional *Elymus* where sand accretion is exceptionally rapid. The dune pasture consists of the usual grasses and herbs. There are no signs of grazing in the recent past, although it is likely that it has occurred within the last hundred years.

The main land uses represented at Nigg at the moment are residential caravans and dumping. Entrance to the links area has been made more complicated by a network of temporary construction vehicle tracks between the yard and the quarry. While the total number of visitors to Nigg has dramatically increased, the number coming for recreation has dropped. Previous to the yard construction, some 15 or 20 cars were common during weekends at Dunskaith. The beach and links are dominated by the massive scale of the development and the floating dormitory of the 'Highland Queen' housing 300 Nigg workers (Plate 7.6.3).

The physical assets of the remaining beach and links system are still capable of supporting recreation, assuming that public tolerance of the proximity of the yard and other projected developments to their recreational areas exists or can be fostered. Bearing in mind the shortage of sandy coastlines, it is desirable to conserve this recreational asset. Steps should be taken to put an end to the scatter of residential caravans, and to congregate them at the western end of the links or preferably on the north side of the quarry road. A firm effort could then be made to clean up the links system and slow down backshore erosion in an unobtrusive way. The advantages of this can be seen in the light of the restricted number of beaches suitable for recreation within reasonable distance of developing Easter Ross (see Chapters 2 and 3).

It is suggested that Nigg beach and links have a limited but important role in the future for local recreation. Accepting that the residential liner is temporary, it may be possible to foster recreation adjacent to large-scale developments. In this case, the temporary residential caravans should be shifted to the north side of the tarmac road, and efforts made to remove existing domestic debris and dumped cars. Some thatching of the dune edge would then be attempted, with appropriate advice, and the system managed by the County Council.

Nigg beach and links form the residual part of the much larger Dunskaith system now either totally removed or scheduled for future large-scale development. The system is currently stable apart from localised coastal edge erosion. The present caravan situation is unsatisfactory. Attempts should be made to rehabilitate the system through resiting or total removal of caravans and a modest amount of experimental coastal edge stabilisation should be undertaken. This could appropriately be achieved through the good offices of the County Council, with the advice of the Countryside Commission.

Figure 7.6 Nigg Ferry

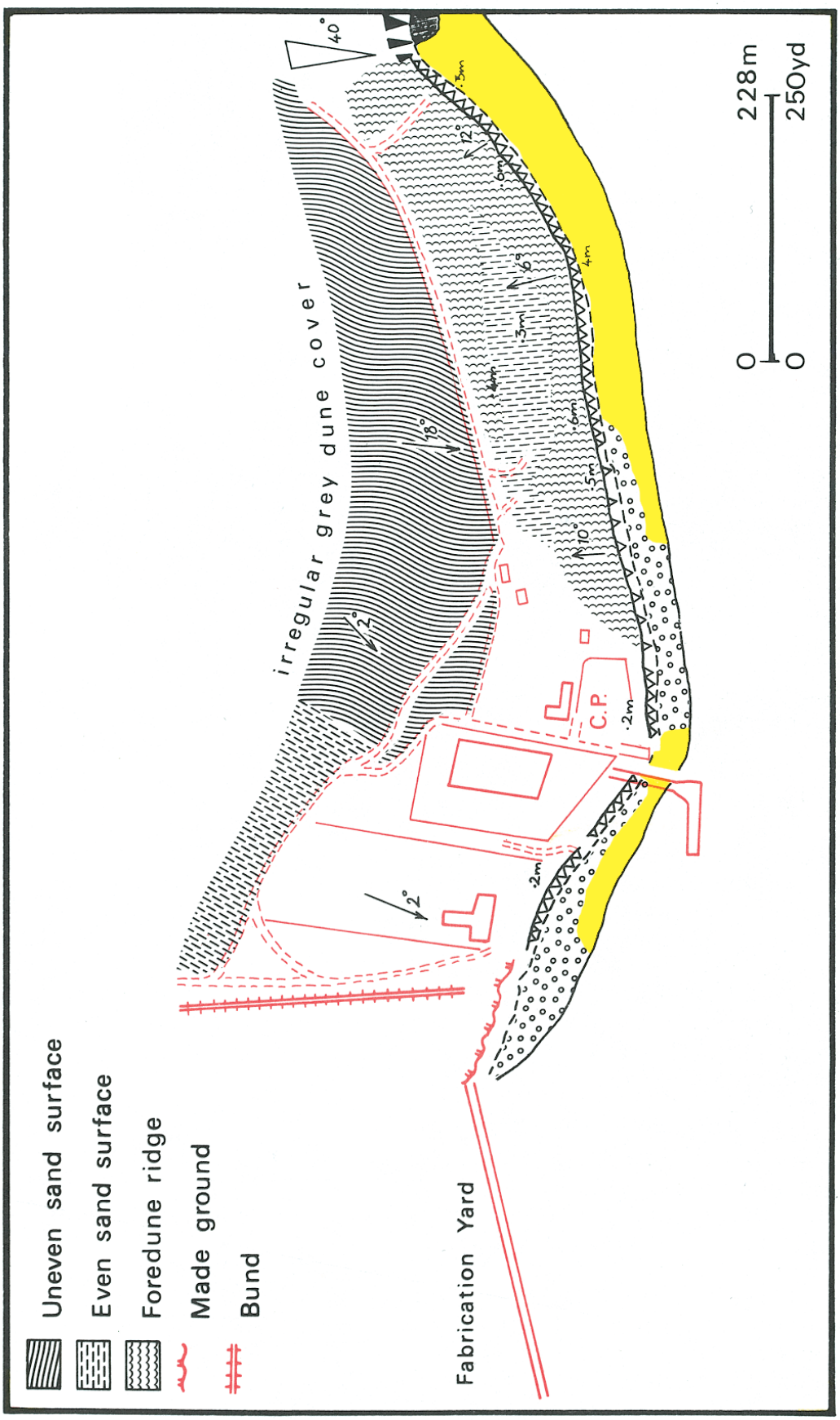


Plate 7.6.1 Nigg Ferry – the pre-development situation at Nigg in 1966. Note the Dunskaith foreland now totally levelled, and also the extensive old grey dune field stretching up the Hill of Nigg.

Plate 7.6.2 Aerial view of Highland Fabricators Yard in 1973. (Copyright John Dewar Studios.)

Plate 7.6.3 Nigg Ferry – the eroded backshore edge in the foreground, with the floating dormitory in the background.

Plate 7.6.4 Nigg Ferry – the most easterly part of Nigg beach where wrack accumulation is vigorous.

7.7 Cromarty

Cromarty beach lies on the western flank of a cuspate foreland built out during late- and post-glacial times on the inland margin of the Southern Sutors headland. Eastwards, the Old Red Sandstone series outcrop along the inter-tidal zone of the east beach, and pass eventually into the Moine cliffs of the headland. The beach overlooks the Cromarty Firth and the Easter Ross lowlands. The foreland is almost entirely covered with the settlement of Cromarty, although the individual beaches and cliffs of the raised beach sequence are clearly apparent. Cromarty itself lies behind the beach and includes an impressive range of Scottish vernacular architecture. A recent addition to the settlement's outlook has been the Highland Fabricators production platform yard at Dunskaith (Plate 7.6.2). The lower raised beach is backed by a major degraded cliff line which extends from Jemimaville as far as the cliff coast east of Cromarty. The view to the west is very extensive towards Invergordon and Nigg Bay with a pleasant foreground of water. Although it does not enjoy a central location, Cromarty remains a very popular tourist resort, and local unemployment has decreased since the fabrication yard began.

The beach consists in the main of fine gravel with a backshore fringe of shingle. Beach sand occurs only at the mid-tide level in a narrow continuous layer, and part of this was derived from the recent dredging operations carried out by Highlands Fabricators in connection with their dry dock at Nigg Ferry. Sand was put into motion in very large quantities, succeeded in crossing the deep water channel and was deposited on the west beach at Cromarty. There has been a subsequent loss of part of this recent sand accretion and it is unlikely to be renewed. The backshore is entirely encased in concrete and stone, with the backshore wall 1.5m high continuing some distance south-westwards. The necessity for this wall is acknowledged by continual historical references to land loss in Cromarty, and the village and road rest hardby on the back of the beach. Access to the beach is facilitated by ramps and steps. The backshore shingle is completely barren apart from a small patch of backshore *Atriplex* just south of the harbour. The mid-tide beach gradient is 4°, steepening at the low-tide level to 6°, where it flattens off and consists of lag cobbles. A small sand berm occurs at the high-tide level but this is not a permanent feature. A small area of made ground occurs just north of the harbour and is used as a carpark.

The beach is largely a lag beach with an enclosed fetch within the Cromarty Firth. Nonetheless considerable wave action can occur when the westerly prevailing winds are channelled up the Firth. There are no dunes or sand-built features, in distinct contrast to Nigg Ferry, which indicates that there has been virtually no sand supply since glaciation. A large and unsightly effluent pipe enters the beach just west of centre (Plate 7.7.1). There is considerable dumping of household debris on the beach (generally dumped in the inter-tidal zone in the hope that it may disappear), together with a collection of old hawsers at the low-tide mark.

Access to the beach is made by ramps from the road which runs behind the sea wall. There is ample space for car parking along the roadside. The observed dynamic relationships are few in number. The historic backshore erosion has been satisfactorily halted by coastal protection works, and the beach itself carries only a small quantity of sand, usually concentrated at mid-tide and high-tide levels. The beach itself cannot be described as sandy beach, and seaside recreation is orientated towards water sports and sunbathing. It is notable that most visitors tend to congregate beside their cars on top of the sea wall and few venture onto the beach. It is possible that sand might be introduced to the beach and stabilised by beach groynes but the success of such a scheme is improbable. The gradual removal of the dredging accretion suggests that it would be difficult to hold sand on the shore.

Appropriate advice should be sought into the viability of beach sand introduction onto Cromarty beach, but a more pressing need is the provision of a modern toilet near the harbour.

Figure 7.7 Cromarty

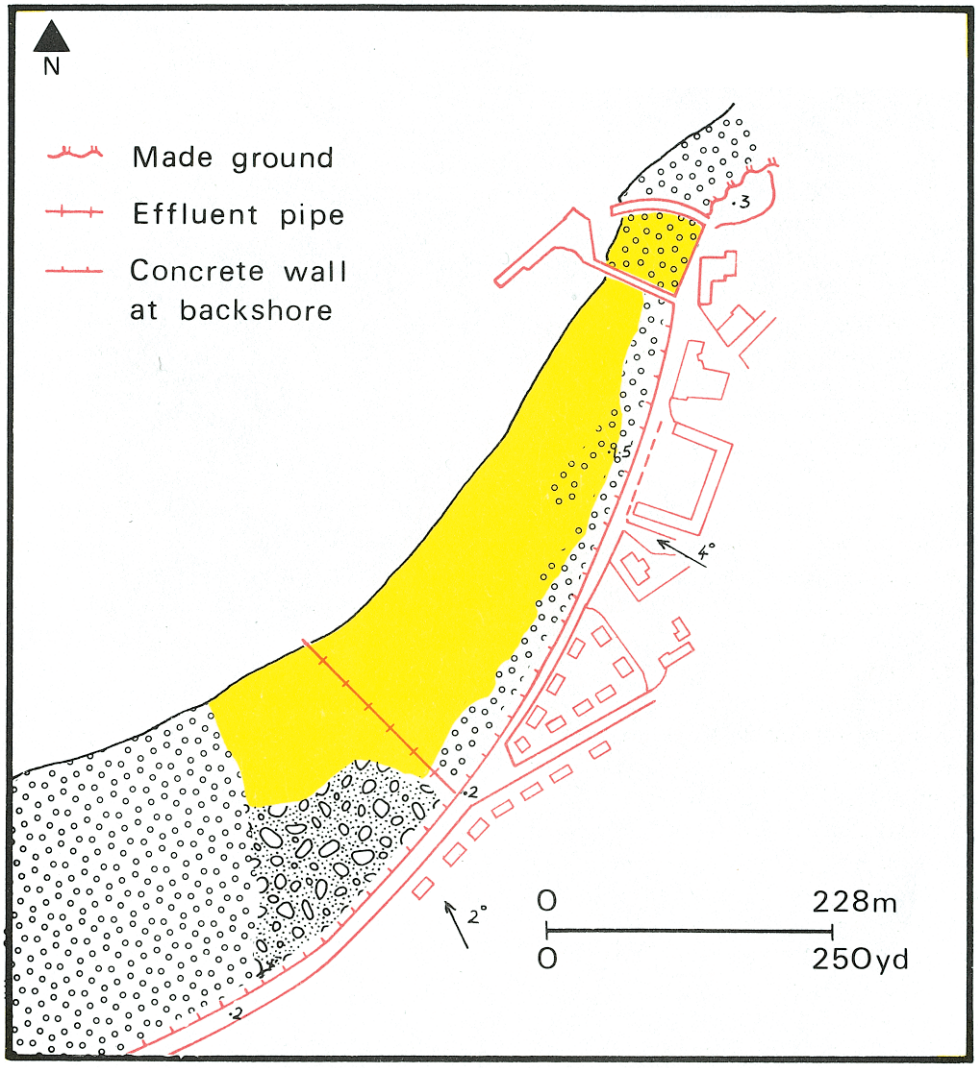


Plate 7.7.1 Cromarty – the largely gravel beach, with Highland Fabricators, Nigg on the skyline.

7.8 Rosemarkie – Scart Craig

Rosemarkie beach is a fringing sand, gravel and shingle beach on the north-eastern flank of the Chanonry Ness cuspate foreland. The triangular foreland consists of a series of shingle bars and marine terraces resting on glacial deposits. The glacial deposits can be seen in backshore section just east of Fortrose harbour. The south and west shore of the foreland is relatively sheltered and consists of lag shingle and gravel. It is seldom walked over by visitors. The discontinuous fringing sand beach on the northern shore faces the Moray Firth, and continues due north-east along the fault-scarp cliff coast of the Black Isle, where the highest dune form occurs at Scart Craig. The foreland forms a natural recreational area for the settlements of Fortrose and Rosemarkie which rely substantially on tourism. Important features of the beach complex are its easy accessibility from the tarmac road (Plate 7.8.1), its relatively large size, its continuity, and the scenic and habitat diversity nearby offered by Rosemarkie Glen and the cliff coastline. These relative advantages are balanced by seasonal fluctuations of sand supply, the paucity of fringing dunes, the 'barrier' effect of the golf course, and the thinness of the beach sand cover, which rests on gravel.

The beach unit stretching from Chanonry Ness to Scart Craig is just over 5km long with an average width at low-tide of 40m. A complete range of beach material is represented, with the medium and fine sand localised at the north end on the cliff-backed beach, and fronting Rosemarkie itself. Patchy and ephemeral sand occurs over fine gravel at the south-eastern end. Backshore shingle, mainly of Moine derivation but with a limited sandstone content, occurs in the central part of the beach arc, notably fronting the main municipal caravan site. Here the whole beach consists of heavily cusped coarse and medium shingle. The shingle calibre decreases south-eastwards towards the tip of the foreland, eventually becoming gravel with a very thin and ephemeral veneer of sand. The shingle is strongly cusped with a 22° gradient and forms a natural backshore protection, absorbing wave energy through gradient and percolation. North of Rosemarkie the fringing beach is fronted by an irregular abrasion platform on which are littered glacial erratics derived from the Inchbae augen-gneiss outcrop. Coarser material occurs in the form of a coarse lag deposit of shingle and boulders carrying algae and seaweed at the burn mouth. A sewage pipe enters the sea just south of the burn outlet.

The mid-beach gradient where sand occurs is 5° and observation indicates that the beach is building up north of Rosemarkie and south-east of the golf course. Backshore erosion has occurred in the past at Rosemarkie but this has been halted by the construction of a vertical concrete sea wall 2.5m high at Rosemarkie which continues south-eastward in the form of a 35° stone and concrete facing to the caravan site. Work on the eastern section of the sea wall is still in progress. The section of the beach east of the caravan site is well protected by shingle berms, while nearer the lighthouse, where the backshore shingle is no longer visible, backshore sand accretion is occurring with the formation of small *Elymus* dunes 0.5–1km high. Backshore erosion is therefore confined to the central part of the beach arc fronting Rosemarkie where wave trains converge. Completion of the present pattern of backshore stabilisation will end current erosion. Access to the beach has been facilitated by steps through the concrete sea wall, and car parks are usefully situated at the east and western ends of the beach (ie convenient to the areas of main beach sand accumulation). Access to the cliff-foot beach of Scart Craig is facilitated by a well constructed path starting north-east of the tennis court beside the newly constructed public convenience.

The coastal edge can be conveniently divided into four sections – namely:

1) the cliff-foot beach north of Rosemarkie;
2) the sea wall section from the Rosemarkie burn to the caravan site;
3) the berm protected section from the caravan site south-eastwards;
4) the dune fringed section at the tip of the foreland.

Recreational pressures are unequally distributed over the 5000m long beach complex partly because of the attraction of the localised beach sand pattern, partly because of access from established car parks, and partly because of the sea bathing potential which is limited to that portion of the beach fronting Rosemarkie. As shown on the Map 7.8, a poorly developed path extends the whole length of the coastal edge from the caravan site to the Lighthouse, but foot ingress to the foreland tip is generally made by an extraction track leading from the car park near the Lighthouse.

The Scart Craig section is backed by a regular foredune ridge 3m in height which is prograding actively through sand blowing north-eastwards along the coast (Plate 7.8.2). The foredune ridge is wholly stable with *Ammophila* dominant, and occasional *Elymus* on its seaward margin, and strandline vegetation of *Cakile* and *Atriplex*. There are no signs here of trampling, and stability and accretion of sand prevail. The beach and dune complex is backed by a degraded cliff line of fault scarp origin some 60m high (Plate 7.8.3). The Scart Craig dune complex is notified as a Site of Scientific Interest on botanical grounds. The picture of general stability and lack of high recreational pressures is very satisfactory.

The Rosemarkie section is stabilised by the concrete backshore wall previously described, and the tarmac road runs along behind. There is ample room for parking and the situation is stable.

The golf course section with its predominantly shingle beach is backed by a series of low raised beach ridges and notches forming the fairways of the course. At several points shingle has been washed over turf during spring tides, but the shingle accretion continuing here can only increase shoreline stability. The nature of the substrate makes the coastal edge immune to human trampling.

The dune complex at the foreland edge has been heavily modified by the construction of the golf course and true dune forms only occur in a narrow band backing the beach. Backshore accretion via *Elymus* dunes is occurring, although the increased human pressures due to easier access from the road have resulted in areas of bare sand and small sand scarps. Occasional sand is extracted from a pit in one of the dunes, and also from the foreland tip itself. Sand blow is not yet a problem but care should be taken to curtail sand extraction from the dune to a tolerable quantity, particularly as regards the extent of bare sand faces. The litter and trampling noted here must be regarded as an inevitable concomitant of beach recreation. Overall the beach and coastal edge situation at Rosemarkie is stable and satisfactory, despite the unequal distribution of pressures. There is no way of counteracting the inequality without diverting tourists to the Scart Craig beach, which would be undesirable because of the botanic interest of the site.

Although modified dune forms occur near the Lighthouse, the main dune system occurs at Scart Craig. Here sand from an accreting beach has blown up onto the low post-glacial beach which lies at the base of the degraded cliff. A continuous foredune ridge 3m high with *Ammophila* is backed by a convex 15m dune built up in the cliff re-entrant at Scart Craig (Plate 7.8.4). The landward part of the convex dune is built

over scree and fans and is surrounded by bracken. Northwards from Rosemarkie, the foredune ridge increases in height to 8m and is fronted by a steep backshore sand ramp, of 13° gradient. The dune system is wholly stable, although, in company with a large stretch of the cliff slope north of Scart Craig, it had been burnt early on in the season for no apparent reason. There is no machair because the beach sand areas are either backed by steeply rising ground or occur at the narrow foreland tip.

The complex is extremely stable, despite the changing nature of the beach material in certain parts of the inter-tidal zone. While the offshore sand supply is probably limited, with very little landward supply, gravel and shingle occur offshore and fresh quantities are brought by the ebb and flow pattern of currents in the Moray Firth. The whole cuspate foreland has been shaped by a variety of changing land-sea relationships to an equilibrium form where very limited backshore modification occurs. This situation is greatly aided by (and in part is the result of) the ample supplies of backshore shingle which have a protective function. With the exception of the Scart Craig dune complex, where backshore accretion is still considerable, the dunes on Chanonry Ness are largely fossilised, and the dune ecosystem has been replaced by typical golf course links turf. At the tip of the foreland, limited embryonic *Elymus* dunes continue to form. There is an obvious correlation between the areas of beach sand and the existing dune forms, whether active or fossilised. With the exception of the Rosemarkie section which has an artificial backshore, the system will repair itself as and when necessary.

The major part of Chanonry Ness foreland is either under cultivation or golf course turf. Marram dunes or spasmodic Marram cover occurs near the Lighthouse in a heavily modified form, and in a natural form at Scart Craig. Sea lyme grass occurs as a fringe in all prograding backshores where sand is freely available, and is fronted by *Atriplex*, *Cakile* and *Honkeyna*, the latter locally at Scart Craig. "These strandline plants form the first stage in sand accretion." The Scart Craig dunes carry Purple Milk Vetch and the rare wild Liquorice. The degraded cliff backing the Scart Craig dune complex carries a very varied range of plant associations from trees down to bracken and primrose. It forms a very varied backcloth to the dune complex. The cliffs and dunes are ungrazed.

The recreational use of the whole beach complex is relatively high by regional standards. The caravan site at Rosemarkie has a capacity of 70, and is supplemented by a second site near Fortrose also with a capacity of 70. Both sites are full in the months of July and August, and together form the largest caravan complex in Easter Ross. The visitors from both sites tend to gravitate to Rosemarkie beach. There is an active sailing club at Fortrose and water skiing has recently been introduced. In terms of usage of the beach itself for recreation, with the limited physical assets of sand, there is no scope for an increase in tourist numbers. There is a need for an additional public convenience near the Lighthouse which could well be sited within the old ice house, provided the restoration and modification were sympathetically planned. The golf course and shingle beach in the central part of the foreland forms an effective break and divides the main fringing beach into two parts of tourist focus. The attractiveness of the coast is reinforced by the nearby hill walk to Raddery overlooking the foreland, and there is great scope for continuing and extending the 'tidying up' of the Rosemarkie Glen, part of which is scheduled as a Site of Scientific Interest on physiographic grounds. The area is thus fortunate in the range of pleasing habitats within walking distance, which could, if developed further in terms of access and signposting, divert visitors for part of the day away from the beach, particularly when the tide is above mid-tide level. At such times, the amount of available beach is much reduced in area.

There is no scope for the expansion of casual use of the beach. The limit to the numbers is set by the relative openness and exposed nature of much of the beach and by the relative paucity of sand. In the height of summer, the most attractive part of the whole complex is just north of the burn where rock outcrops with intervening sand pockets allow partial seclusion within easy walking distance of car park and convenience. The botanically interesting area of Scart Craig remains by sheer distance infrequently visited. It would be unfortunate if active steps were taken to divert visitor interest here and it would be preferable to open up parts of the Rosemarkie Glen by walkways, possibly making the hillwalk a circular one from Fortrose to Rosemarkie via the glen. This would involve the construction of a path with some steps down the steep western side of the gorge, avoiding the immediate area of the earth pillars. Although the foreland tip near the Lighthouse is unsafe for bathing, the dunes do offer some semi-natural attraction for visitors and a public convenience near the point, together with signposting of the track to the beach, could increase the usage of this part of the beach. It should however be pointed out that active 'promotion' of this part of the beach would have to be carefully monitored for damage by trampling and resultant sand blow. The foreshore protection work should be extended as far as the caravan site. The periodic extraction from beach and dune system at its present level creates few problems but should not be permitted to expand.

The beach and dune complex is stable, but relatively full use is already being made of the relatively limited space and resources of sand. Expansion of the recreational value of the site should be through the provision of additional access into the attractive Rosemarkie Glen rather than to the limited area of natural and botanically interesting dune and beach system at Scart Craig. An additional public convenience is required in the vicinity of the Lighthouse, and care should be taken to monitor the sand and gravel exploitation on the coastal edge. The most attractive beach area to tourists just north of the burn is limited in extent but the situation is stable and the numbers of visitors will adjust themselves naturally to a tolerable level.

Figure 7.8a Rosemarkie

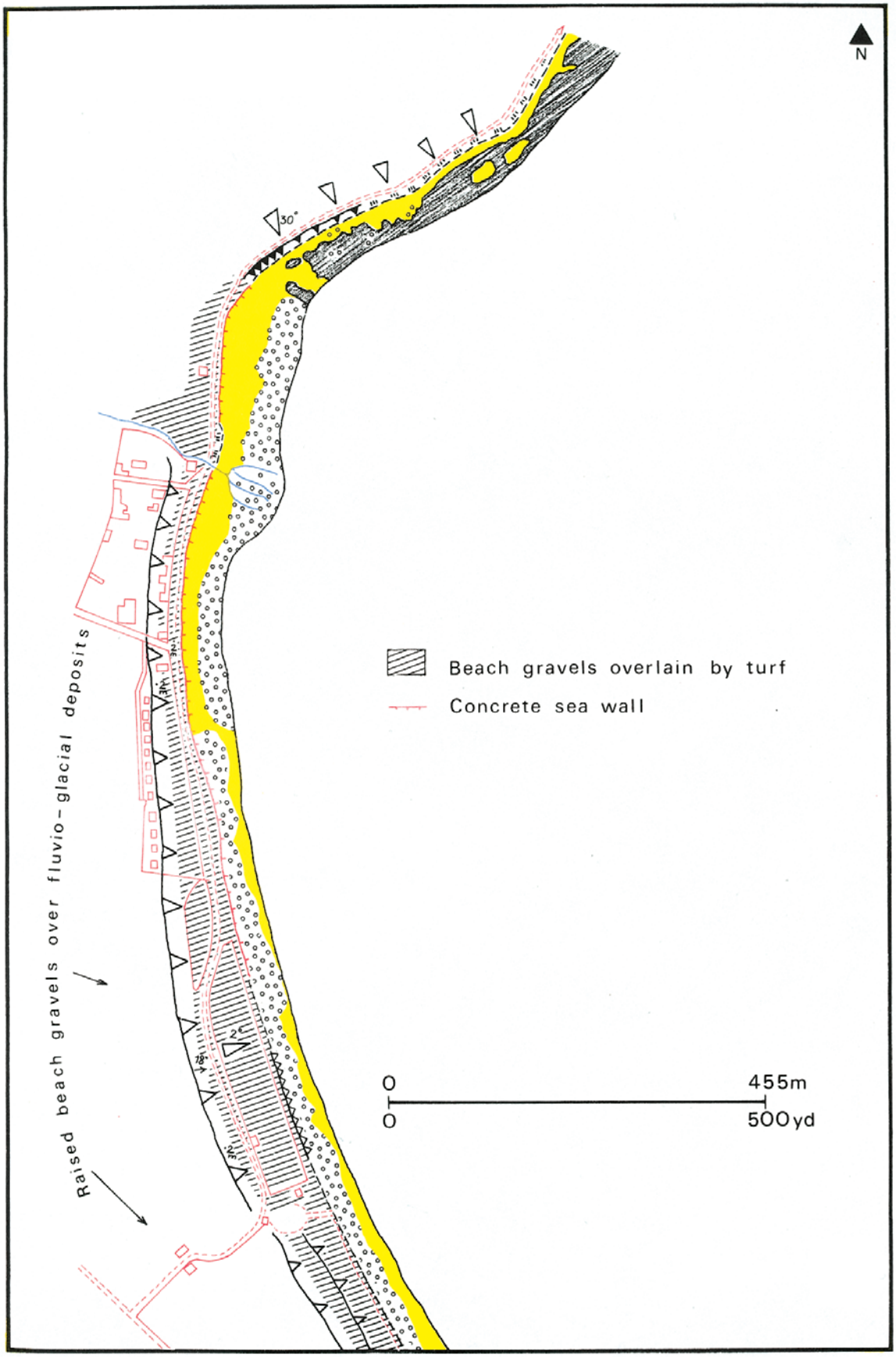


Figure 7.8b Rosemarkie

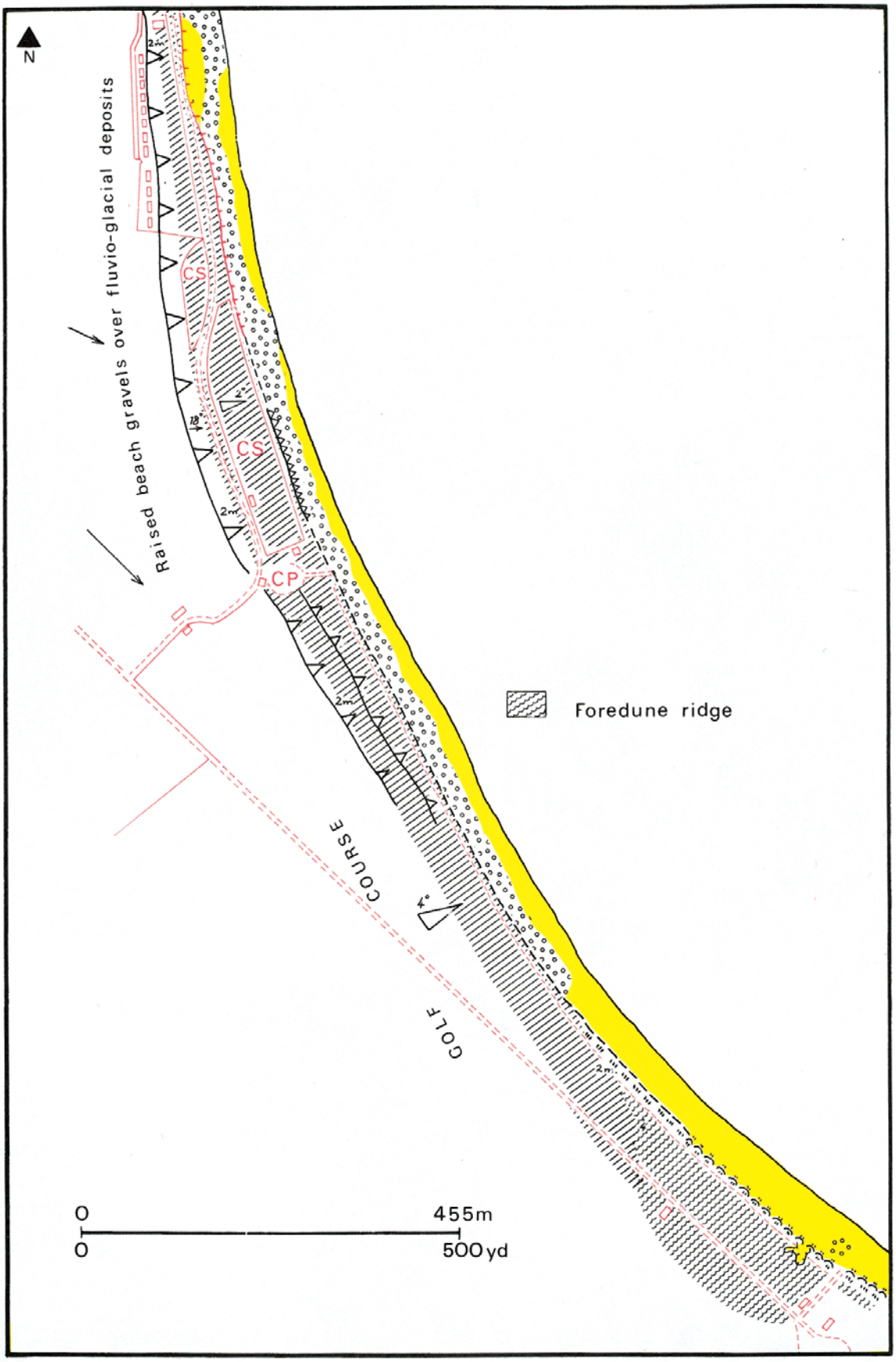


Plate 7.8.1 Rosemarkie – the sand beach is widest in the area adjacent to the village. Car parking is available at several points.

Plate 7.8.2 Part of the wider, although less visited portion of the beach, extending north-eastward along the fault-scarp coastline of the Black Isle.

Plate 7.8.3 Scart Craig, Rosemarkie – the narrow dune and machair fringing the old degraded cliff-line.

Plate 7.8.4 Scart Craig, Rosemarkie – the high dune at Scart Craig. Its comparatively 'yellow' appearance at time of photograph is a result of an early season fire.

8. Conclusions and Recommendations

The nature of the coastline and its beaches

A high proportion of the coastline of the East Highlands is in the form of sandy beaches, but the size of the individual beaches varies greatly, and they have an irregular distribution. Some of the largest and most complex beach units in the Highlands occur along this stretch of coastline; the Morrich More in Easter Ross extends to 2000ha, while Coul Links near the mouth of Loch Fleet has an area of 300ha. Most of the beaches are relatively well sheltered from both wind and wave action, and they are, with certain exceptions, lower energy forms than the units of the north and west coasts. The bayhead type of beach common on the west and north is rare in the East Highlands, and instead the beaches are usually either long, straight sandy fringes, or alternatively convex-seawards accumulations of sand and shingle. Both these types of beach are possibly more susceptible to occasional lateral shifts than the bayhead type of beach.

In many of the beach units, dune morphology is subdued. Very few of the dune zones display large blow outs symptomatic of strong instability. Large proportions of most of the dune zones are in the old grey form, where a relatively mature vegetation cover has successfully fixed the sand surface. In the smaller proportions of yellow dunes, sometimes occurring in the seaward parts of the dune zones, surface fixation has proceeded less far, and instability is greater. This is, however, a form of positive instability, since although the dune surface remains unfixed, the general tendency is for sand to be deposited on the dune rather than for blow outs to be eroded. Furthermore, some of the dune ridges appear to be cored with shingle ridges, which offer effective basements to any blow outs which might develop. Thus in general terms, many of the dune zones along the East Highland coastline are relatively stable, at least in the Highland context, but in more absolute terms it should be remembered that the dune is an inherently fragile landform. The links or machair zones typically consist of a thin veneer of blown sand overlying raised-beach gravels. Extensive development of blow outs is rare, and again the gravel or shingle foundation would prevent the excavation of deep deflation hollows.

The intensity of recreational use is highly variable. The largest concentration of caravanning in the Northern Highlands is centred around Dornoch, but just a few kilometres away, at Coul, the beach is seldom visited by tourists. Similarly, Rosemarkie beach is intensively used during summer, but Scart Craig, about 3km north, is rarely visited. Accessibility is an important control on intensity of recreational use, and slight variations in ease of accessibility are reflected in sharp contrasts in amount of use. Yet relative to many other parts of the Highlands, the beaches are not inaccessible.

Locally-based recreational pressures are likely to increase on these east coast beaches as growth in Easter Ross continues. The re-routing of the A9 trunk road across the Black Isle, with the bridging of the Beauly Firth at Kessock, together with the proposed Meikle Ferry crossing of the Dornoch Firth, will mean that all the beaches described in this report will ultimately be within approximately one hour's car journey from the main population clusters in the Moray Firth growth zone. Rosemarkie, in particular, is likely to experience greater pressures for coastal recreation. With pressures unevenly distributed at the moment, an opportunity exists to manipulate growth of recreational pressures, and funnel them towards those beaches which can support a greater number of visitors. As development proceeds in the Cromarty Firth, some of the tourist traffic may well by-pass the area for the magnet of the north and west. The more development spreads out into the west, however, the less the probability is that this will occur. Therefore, since the beaches in the East Highlands have relatively high recreational capacities because of their physical nature, their full recreational potential should be utilised.

Further loss of beach units with recreation potential should be kept to a minimum. With some beach units already given over to industrial use and others designated as conservation areas, the number of coastal areas which can be used for recreation is limited, especially in Easter Ross. Yet the genial climate and the established infrastructure of services and communications suggest that the area could be well suited for tourism. In the short term, problems of accommodation will be difficult as the provision of new jobs outstrips housing construction, but over the longer term the East Highlands have a high potential for tourism. It would be unfortunate if visitors were forced to seek their beach recreation on the more fragile beach units outwith the Moray Firth, when the East Highland beaches are more suitable, in physical terms, to sustain the pressures of recreational use. On a regional scale, the optimal use of the beach resource can be made not by dispersing recreational activity evenly across all the beach units, but rather by encouraging it to concentrate on those units best able to sustain the resultant pressures. The local recommendations set out in Table 5 have been drawn up with this principle in mind.

Conservation and the coastline

Although the beaches of the East Highlands are relatively stable and relatively numerous, they should not be used haphazardly with no regard to the maintenance of physical stability or to the efficient allocation of land to the various land-use interests. In the long term, optimal efficiency in utilisation will be achieved if each beach unit is allocated to the purpose for which it is most suited. Wrong types and intensities of use will deplete the resource and thus prevent optimal utilisation. Conservation can best be regarded as the best use of the limited set of resources which the beach units represent. In the example of a large and scientifically important beach unit such as the Morrich More, public access and the maintenance of exceptional physiographic and botanical interest are irreconcilable, and the present levels of dual land use as proposed national nature reserve and military range could be argued to form the optimal solution.

Utilisation of the beaches

All the beach units on the East Highland coastline are used in some way, but intensities and types of use vary greatly. In general terms, present use is resulting in relatively little damage or resource depletion. At present, however, demands are increasing from various sources. Apart from recent growth in recreational demand, agricultural use of the links and dunes as outwintering areas is also increasing, although it is still at a limited intensity. Industry, usually in the form of oil-related engineering, has also recently become a strong competitor for land along parts of the low soft Moray Firth coastline. As demand for land grows, competition will increase. Friction between different interests will become more severe, and there may thus be a greater danger of non-optimisation of use of the beach resource. It is thus vital that beach land be allocated in a rational manner, with each beach unit given over to the use, or combination of uses, for which it is best suited. In making such decisions, a regional rather than local perspective should be employed, and cognisance should be taken of spin-off effects such as those described in Chapter 2.

Identification of general principles for the allocation of beach land is not easy, but high on the list of priorities should be 'rarity value' and 'least impact' on the physical environment. Other things being equal, it seems logical to guide a specific type of land use towards the beach unit where it will have the least effect on the physical environment. Similarly, if land use A can take place only on beach a, but land use B is feasible on beaches a, b, c and d, it would seem reasonable to use beach a for land use A, leaving B with a choice from b, c and d. Unfortunately, however, it rarely happens that "other things are equal", and both the land

specifications for a given use, and environmental impacts resulting from a particular use, are often clouded with uncertainty and imprecision.

It is suggested that an impact matrix, along the lines of Table 6, be used to assist in the evaluation of environmental impacts of proposed developments on the coastline. In the table, proposed developmental actions are set against possible impacts, and the matrix could be used as a preliminary checklist against which changes in land use might be considered. The development actions refer not to specific land uses, but rather to techniques or practices resulting from a change in type or intensity of land use. Value judgements on the desirability or undesirability of the possible impacts are not given, nor is the probability or magnitude of an impact indicated quantitatively. The matrix is intended to assist in the identification of possible impacts rather than in the quantification of their magnitudes.

The distinction between direct and indirect effects in the matrix is arbitrary, and it could be argued that most of the possible impacts are indirect rather than direct effects since they are frequently unintentional rather than deliberate. Indirect effects, however, have been employed to describe the possible impacts of offshore actions on the links and dunes. These landward parts of the beach complex are at the end of the chain of transmitted effects rather than near its beginning.

The probability and magnitude of the impacts will vary from beach to beach, depending on its physical composition. Some dune zones, for example, will respond much more quickly and more acutely to trampling pressures than others. It is difficult, however, to quantify these variations in likely responses over a whole set of beach complexes, but the comparative value of the matrix might be greater if only two or three beach units were being considered. Nevertheless it is suggested that the main use of the matrix would be in the preliminary identification of possible impacts at particular beach units, rather than as a tool for the comparison of impacts over a large number of beaches.

Scientific or ecological conservation

Beach complexes are frequently of scientific or ecological interest since they consist largely of natural or semi-natural vegetation, and because they are composed of dynamic landforms. Two of the beach complexes in the East Highlands are of outstanding physiographic and ecological interest. The larger, the Morrich More, carries one of the major parabolic dune systems in Western Europe, together with a rich and unique set of vegetation associations. Grade 1 site of international importance (Nature Conservancy, nd). The Morrich More has a very high rarity value, and has an unequalled combination of scale, range of processes and richness of habitats. As yet, relatively little is known about the wildlife of the links, and neither landforms nor vegetation have been subjected to intensive scientific analysis. It is therefore suggested that not only should the beach unit be retained in its existing uses, but also that its physiography and ecology should be thoroughly investigated.

The other beach complex of outstanding interest is Coul Links, together with the adjacent area of Ferry Links at the north side of the entrance to Loch Fleet. The interplay of aeolian, marine and estuarine processes, operating during a changing sea level, has produced a rich variety of landforms and habitats. Coul Links is one of the very few beach complexes in the north of Scotland with multiple dune ridges, and therefore also has a strong rarity value. The links offer a high diversity of habitats, and there is a well developed sequence of vegetation from embyro dunes to heath and scrub, but the main interest lies in its physiography. Coul lies

to the south-east of Loch Fleet, which is a "fine wildfowl and wader feeding and nesting area" (Nature Conservancy, nd). It is also listed as a Grade 1 site by the Nature Conservancy, equivalent to a National Nature Reserve in nature conservation value, and indeed an area at the head of the loch has already been designated as an N.N.R. The whole area around Loch Fleet is one of high interest, and it is suggested that the beaches lying on either side of the mouth of the loch should be rigorously conserved.

Both the Morrich More and Coul Links have already been proposed as conservation areas in the Nature Conservancy Prospectus (Figure 8), but it must be emphasised that their physiographic interest is as great as their ecological interest, and would in itself merit their rigorous conservation.

Although these two units are the most outstanding, it does not follow that the other beach complexes are of no scientific interest. Indeed most units are inherently interesting, because of the relatively natural habitats which they offer and because of the intricate relationships between landform, vegetation and wildlife. Of the other beaches, those of greatest interest are probably Dornoch South and Cuthill Links. The former is the north shore counterpart of the Morrich More, and its southern tip, at Dornoch Point, is highly dynamic, and has a relatively fragile foredune ridge. Thus it is recommended that access should not be improved, and that the caravan site at the north end of the beach should not be expanded southwards. The main interest in Cuthill Links is in the complex series of raised shingle ridges, covered in gorse and heath. The links contain large quantities of gravel, but it is recommended that extraction should not be permitted since scientific interest would be greatly impaired.

A recently published Discussion Paper (North Sea Oil and Gas – Interim Coastal Planning Framework – Scottish Development Department) has indicated 'preferred conservation zones' on the east coast of Scotland. This document indicates those areas where the developer might encounter difficulty in re-zoning of land. Such preliminary zoning on a national scale is an interesting development of forward planning acknowledging the pressures currently exerted on coastal resources. It forms the first step in the evolution of a broad forward-looking plan set out within an agreed conservation framework, incorporating an essential measure of flexibility.

The coastal planning framework set out in the Discussion Paper designates the Dornoch Firth west of Dornoch and Tain as conservation zones. In the light of the physiographic and ecological interest of the Morrich More and Coul Links, it is strongly recommended that the Dornoch Firth conservation zones be extended to Tarbat Ness and the entrance to Loch Fleet.

Recreational use

The coastline of the East Highlands is well favoured for further development of tourism. The climate is dry and comparatively warm and sunny, and many of the beaches are relatively stable and have spare recreational capacity. They are therefore more suitable for recreation, especially that involving caravanning, than most other parts of the Highland coastline. If large-scale facilities for caravans are to be provided in coastal sites in the Highlands, then the East Highland coastline is probably the most suitable location. An adequate basic infrastructure and road pattern already exist, and much of the coastline is well screened from the landward by relict cliffs or raised shingle bars. The beaches also have higher damage thresholds than most of the beaches in the north and west.

Dornoch and Embo beaches are already intensively used for caravanning, and it is recommended that site

capacities should not be further increased at these centres. Further north, however, the central part of the Golspie-Littleferry unit could be used more intensively. In terms of physical suitability and resistance to damage, the area is almost ideal. A vegetated shingle platform offers hard standing for caravans, and there is little possibility of vehicle or pedestrian tracks being exploited by wind erosion. Thus on physical grounds, there would be no objections to an expansion of the Golspie site, provided that satisfactory arrangements could be made for sanitary drainage. Potential capacity could even exceed that presently existing at Dornoch or Embo. Physical suitability is also relatively high at Brora (Dalchalm), Crakaig, Kintradwell, Kilmote and Inver-Arboll, but accessibility and other problems probably rule out the possibility of establishment or expansion of caravan sites at most of these beach units in the near future.

Informal day recreation could be improved and increased at many of the beaches in East Sutherland. Intensity of use is closely related to accessibility, and can thus to a large extent be controlled. Dornoch South beach is already highly accessible, and is intensively used. Although there are some signs of trampling damage, further deterioration could probably be controlled by measures such as the fencing of the dune edge. If such measures were undertaken, there would not be objections on physical grounds to increases in car-parking capacity, but it is emphasised that vehicular access should not be permitted to the more vulnerable south and central parts of the beach. The north and central parts of Golspie-Littleferry beach have a large amount of spare capacity for day recreation; the main limitations on use at present are probably a lack of knowledge of the existence of the beach and partly the dereliction around the north end of the beach at Golspie village. Similarly, the beaches at Brora (Dalchalm) (except for the extreme south end), Kintradwell, Crakaig and Kilmote could all withstand higher intensities of use, with the provisos that management measures might be required in some instances.

The beaches in Easter Ross, however, are almost fully utilised for recreation. Most of the small beaches backed by existing settlements have absorbed their full complement of pressures. Others, like the Morrich More, are inaccessible and their optimal use lies in land uses other than recreation. Fortunately Inver-Arboll beach is largely untapped, and is capable of development. As yet this beach receives few visitors, and an opportunity exists for the careful planning of a high standard caravan site and the improvement of access for day-visitors in a generally resilient links area. The remaining beaches will undoubtedly come under increasing pressure as the local population increases, and as their catchment is widened through the crossing of the two Firths. Spare capacity to absorb further pressures is very much lower in Easter Ross than in East Sutherland. It is suggested that every effort should be made to anticipate the pressures by providing facilities at those beaches which are best suited to accommodate recreational demands. It is this local shortage of sand beaches which suggests the remedial action proposed for Nigg Ferry. In the longer term the bridging of the Dornoch Firth may enable the channelling of pressures to the presently untapped beach units in East Sutherland.

Industrial use

The coastal zone along either shore of the Moray Firth is undergoing increasing pressures from industrialisation, and frequently sandy beach sections of the coastline offer attractive sites for engineering projects associated with oil exploration or production. The establishment of an industrial facility can influence a beach complex in a number of ways. In addition to the replacement of an area of natural or semi-natural vegetation by a paved or built surface, the relief may be greatly modified by earth-moving or dredging. Effects such as the triggering of accelerated erosion along the site margins may also result, while the

introduction of large structures into the coastal zone may impair its visual quality. The visual effect will be least where there is effective screening, and in this respect the beaches at Brora South and Golspie-Littleferry (central part only) would be the least unsuitable for industrial use. Trigger effects along the site margins are more probable in sand dunes than on links, since the sand dune is usually a more fragile landform. Therefore beach units in which sand dunes are poorly represented are likely to suffer lesser impacts from industrial development than those units where the dune component is more highly developed. Both the Brora beaches, and the central section of the Golspie-Littleferry beach are thus likely to be the most suitable units from the viewpoint of minimising environmental impact.

Beyond these broad generalisations, it is difficult to formulate specific recommendations since there is such a wide range of possible developments, each involving a specific set of land and offshore requirements and site preparation actions.

Agricultural use

At present the amount and intensity of agricultural use varies from unit to unit, and seems to depend more on ownership than on physical nature of the beach complex. Agricultural use is mainly confined to rough grazing, and in particular a number of beach units are used for the wintering of stock. There is no evidence that definite physical deterioration has resulted from this grazing or wintering, but it should be borne in mind that the agricultural use is frequently in addition to a recreational use. If an area is grazed in winter, there is less chance that the vegetation can recover from any trampling damage caused by visitors in summer. Therefore an increase in recreation, or an increase in grazing intensity, could upset the present balance between grazing and the environment of the beach unit. The exposure of bare surfaces during cultivation or the burning of dune heath or scrub in the hope of improving the grazing are undesirable practices from the viewpoint of maintaining stability, since there is always a danger that wind erosion is triggered off on the exposed surfaces. There is also a danger in some beach complexes that the scientific interest of the dunes or links is reduced by surface reseeding or other methods of pasture improvement. Such a danger is clearly greatest in the Morrich More and Coul Links, where scientific interest is greatest, as indicated in section 8.4.

Summary of conclusions and recommendations

Beaches are distributed irregularly along the 'outer' coastline of the East Highland region. They vary in size, physical composition and resilience to recreational pressures. The Morrich More and Coul Links are of outstanding scientific interest and should be rigorously conserved. Within the remainder, intensity of use varies, with a number of the smaller units, notably in Easter Ross, already used to their optimum. The greatest potential for expansion of recreation occurs in East Sutherland, notably at Littleferry and the cliff-foot beaches north of Brora. In Easter Ross, only Inver-Arboll and Nigg Ferry are capable of sustaining additional pressures. The characteristic stability of the beach units in the area suggests that full development of recreational opportunities should take place, not only to absorb locally generated recreation demands, but with a view to relieving pressures already evident on the more fragile beaches of the north and west parts of the mainland. Viewed in this light, the loss of potential recreational links to industry is undesirable. The projected crossing of the Dornoch Firth offers the possibility of relieving pressures in Easter Ross, and it is suggested that future recreational planning should take account of this. It is suggested that a regional rather than a local perspective be taken in the planning of both recreational and industrial land uses, and that the beaches of East Sutherland and Easter Ross be viewed not just individually, or even in comparison with each other, but in comparison with the beaches on the north and west coasts of the Highlands.

Figure 8 Proposals for Coastal Statutory Safeguards – East Sutherland and Easter Ross

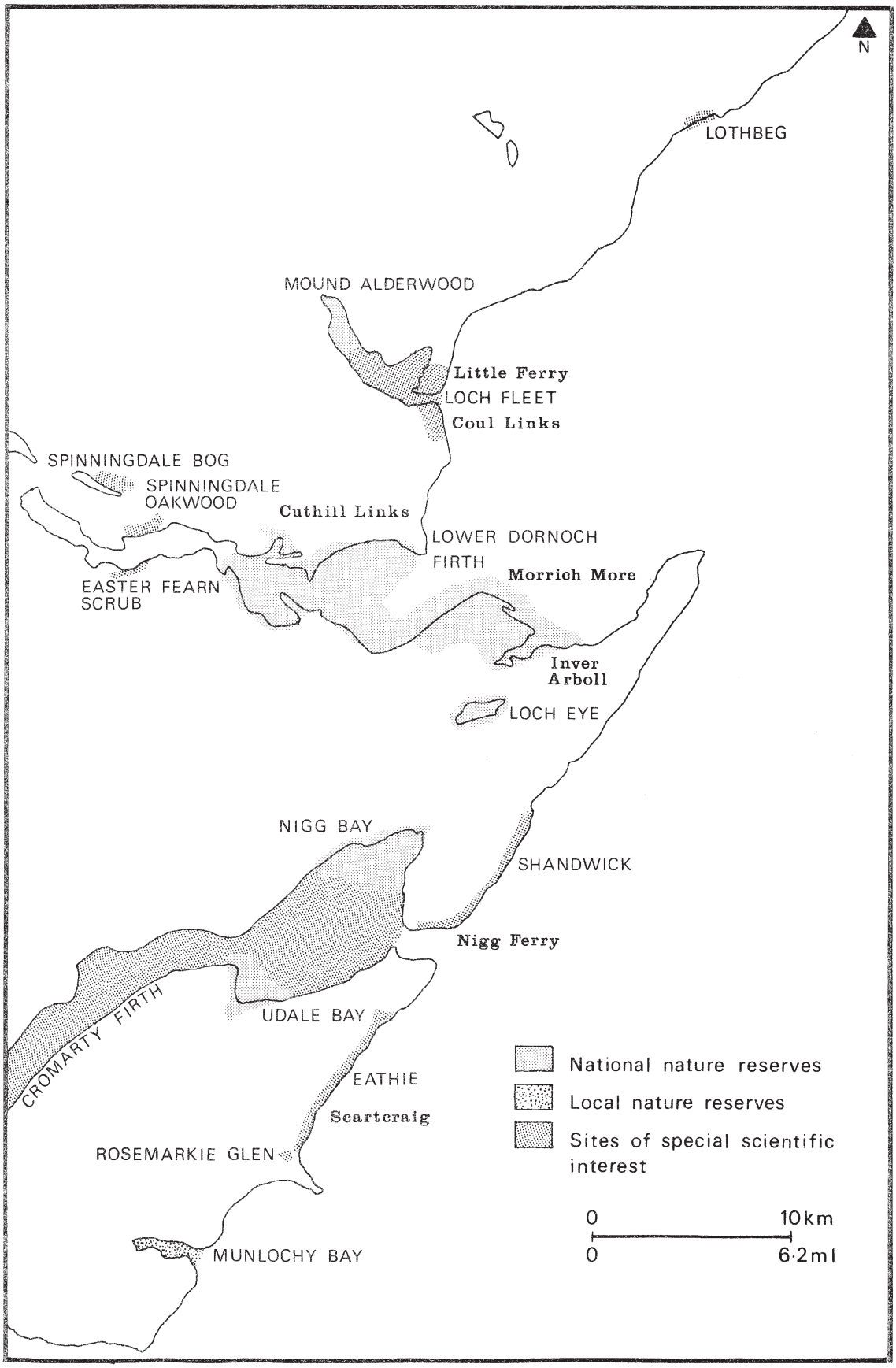


Table 5 Local Recommendations

BEACH UNIT	HIGH NATURAL STABILITY	SCENIC QUALITY LOCAL REGIONAL			PRESENT RECREATIONAL USE		PREFERRED USE RECREATION OR CONSERVATION	RECOMMENDATIONS						
CUSPATE FORELAND TYPE		HIGH	MEDIUM	LOW	CARAVANS	DAY-VISITOR		INCREASED CARAVAN STANCES POSSIBLE	ACCESS IMPROVED	CONSERVATION PRIORITY	NO FURTHER DEVELOPMENT POSSIBLE	REMEDIAL ACTION SUGGESTED	CASUAL VISITOR USAGE ONLY	MAXIMUM UTILISATION ATTAINED
Cromarty	✔			✔	✔	✔	Recreation							✔
Nigg				✔	✔		Recreation					✔		
Portmahomack			✔		✔	✔	Recreation					✔		✔
Rosemarkie	✔		✔		✔	✔	Recreation							✔
STRANDPLAIN TYPE														
Brora Dalchalm	✔		✔		✔	✔	Recreation		✔					
Coul		✔					Conservation			✔				
Cuthill Links	✔			✔			Recr./Conserv.						✔	
Dornoch South			✔		✔	✔	Recreation				✔	✔		✔
Embo	✔		✔		✔	✔	Recreation				✔	✔		✔
Golspie-Littleferry	✔		✔		✔	✔	Recr./Conserv.	✔						
Inver-Arboll	✔	✔					Recreation	✔	✔					
Morrich More				✔			Conservation			✔				
CLIFF-GIRT TYPE														
Balintore	✔			✔	✔	✔	Recreation					✔		✔
Brora South	✔			✔		✔	Recreation						✔	
Crakaig	✔		✔		✔		Recreation	✔	✔	✔				
Dornoch North	✔		✔			✔	Recreation						✔	
Kilmote	✔			✔			Recreation	✔	✔					
Kintradwell	✔			✔			Recreation		✔				✔	
Scart Craig	✔	✔	✔				Recr./Conserv.						✔	
Wilkhaven	✔	✔	✔				Recreation					✔	✔	

Table 6 Impact Matrix

Possible impact	Proposed Development	Grazing	Cultivation	Burning	Alteration of vegetation	Afforestation	Earth-moving	Road building	Drainage	Waste discharge	Offshore dredging	Groyne/pier construction	Partial coast defences	River control	Sand/gravel extraction	Trampling	Tracking
Beach	Combing down						✶				✶	✶	✶	✶	✶		
	Building up						✶				✶	✶	✶	✶			
	Physical pollution						✚			✶				✚			
	Visual pollution						✶			✶	✶	✶	✶	✚	✶		
Dunes	Coastal edge erosion						✶				❍	❍	❍	❍	✶		
	Coastal edge accretion						✶				❍	❍	❍	❍			
	Increase in wind erosion	✚	✶	✶	✚		✶	✚	✚		❍	❍	❍	❍	✶	✚	✶
	Reduction in wind erosion				✚	✚											
	Vegetation modification	✚	✶	✶	✚	✚	✶	✚	✚	✶	❍	❍	❍	❍	✶	✚	✶
	Wildlife modification		✶	✶	✚	✚	✶	✚	✚	✶	❍	❍	❍	❍	✶	✚	✶
	Physical pollution	✚					✚			✶						✚	✚
	Visual pollution		✚	✚			✶	✚		✶					✶	✚	✚
Machair	Increase in wind erosion	✚	✶	✶	✚		✶	✚	✚		❍	❍	❍	❍	✶	✚	✶
	Reduction in wind erosion				✚	✚											
	Vegetation modification	✚	✶	✶	✚	✚	✶	✚	✚	✶	❍	❍	❍	❍	✶	✚	✚
	Wildlife modification		✶	✶	✚	✚	✶	✚	✚	✶	❍	❍	❍	❍	✶	✚	✚
	Physical pollution	✚								✶					✶	✚	✚
	Visual pollution		✚	✚			✶	✚		✶						✚	✚

✶ Major effect

✚ Minor effect

❍ Indirect effect

Appendix I Glossary

ABRASION PLATFORM	Surface cut by wave action, forming flat rock platform in inter-tidal zone.
ACCRETION	Process of accumulation of sand or other sediment.
AEOLIAN	Pertaining to the wind.
BACKSHORE	Zone of beach or other shore lying between high water mark and coastal edge.
BEACH	Inter-tidal sand accumulation thrown up by wave action, with a gradient in excess of 3°.
BEACH COMPLEX, beach unit	Assemblage of beach, dunes and links.
BERM	Small ridge of sand built up at or near high water mark.
BLOW OUT	Erosional hollow or depression in dune or machair surface, created by wind action.
COASTAL EDGE	Feature marking landward limit of wave activity, and frequently dividing vegetated from unvegetated surfaces.
CONGLOMERATE	Type of rock in which pebbles are cemented together in a matrix of finer materials.
CUSPATE FORELAND	Triangular-shaped plain of accumulation of marine sediments.
DEFLATION	Process of removal of sand by wind action.
DRIFT	Unconsolidated sediments.
DRIFTLINE	Backshore zone of accumulation of debris such as vegetation and seaweed.
DUNE-EMBRYO	Small, often ephemeral, depositional mound of sand on backshore.
DUNE-GREY	Dune fixed under grasses and herbs, with complete vegetation cover over sand.
DUNE-SLACK	Inter-dune hollow with high water table.
DUNE-YELLOW	Dune with incomplete vegetation cover – bare sand exposed between plant stems.
EUSTATIC	World wide (changes in sea level).
FETCH	Amount and direction of open water in front of any specified point along the coast.
FLUVIO-GLACIAL	Pertaining to water action in conjunction with bodies of ice.
FLANDRIAN TRANSGRESSION	Rise in sea level about 5000–3000 BC.
FORESHORE	Zone of beach between low and high water marks.
HEAD	Soliflucted rock debris.
HIGHLANDS	Seven crofting counties of Argyll, Inverness, Ross and Cromarty, Sutherland, Caithness, Orkney and Shetland.

ISOSTATIC	Pertaining to relative movements of land and sea levels, resulting from loading and unloading by glacial ice.
LAG DEPOSIT	Residual coarse particles from which finer material has been removed.
LINKS	Wind-built sand surface, stabilised under sward of short grasses and herbs (also machair).
LOW	An elongated hollow between dunes.
MACHAIR	Wind-built sand surface, stabilised by sward of short grasses and herbs (see also links).
MARRAM	*Ammophila arenaria.*
METAMORPHIC ROCK	Rock whose original characteristics have been modified by heat and/or pressure.
MOINE	Group of metamorphic rocks of which much of Highland land-mass is constructed.
PARABOLIC DUNE	Crescent-shaped dune where advancing face is orientated convex downwind.
RAISED BEACH	Accumulation of marine sediments built up by a sea level different from that of the present.
RELICT CLIFF LINE	Cliff line cut by the sea at a higher level than at present.
SANDFLAT	Inter-tidal sand plain with high water table and exceptionally low gradient.
SCHISTS	Crystalline, metamorphic rock.
SEA LYME GRASS	*Elymus arenarius.*
SPIT	Marine-built linear landform, frequently with hook on end.
STRANDPLAIN	Low relief landfrom constructed by processes of marine deposition.
SUB-LITTORAL ZONE	Offshore zone lying just below low water mark.
TAFFONI	Small weathering pits caused by the evaporation of salt spray near the inter-tidal zone.
TILL	Unsorted sediments laid down by glacial ice.
TRANSGRESSION	Relatively rapid sea level rise causing land submergence.
WAVE BASE	The depth of water below which wave action is negligible.
WRACK	Dead or decaying seaweed and flotsam left on the upper beach – forms base for sand accumulation.

Appendix II Sedimentary Characteristics

Beach	Median Diameter (mm)	Sorting Coefficient	Carbonate %	Colour
Arboll	0.20	0.350	12.27	10YR 6/3 pale brown
Balintore	0.24	0.424	10.58	10YR 6/3 pale brown
Brora (Dalchalm)	0.25	0.417	27.53	10YR 6/4 yellowish brown
Brora (South)	0.29	0.789	41.50	10YR 6/4 yellowish brown
Coul	0.38	–	8.89	10YR 6/3 pale brown
Crakaig	0.65	0.515	29.56	10YR 6/3 pale brown
Cromarty	highly varilable	highly varilable	0.19	10YR 5/4 yellowish brown
Dornoch (North)	0.22	0.419	17.49	10YR 6/4 light yellowish brown
Dornoch (South)	0.24	0.523	14.56	10YR 6/3 pale brown
Embo	0.33	0.376	16.74	7.5YR 6/6 reddish yellow
Golspie-Littleferry	0.29	0.414	20.11	10YR 6/3 pale brown
Kilmote	0.39	0.538	40.32	10YR 5/4 yellowish brown
Kintradwell	0.30	0.437	39.87	10YR 6/4 light yellowish brown
Morrich More				
West beach (Tain)	0.17	0.307	0.17	10YR 6/4 light yellowish brown
West beach (F.C.)	0.85	–	95.66	10YR 7/4 very pale brown
Innes More beach	0.25	0.384	11.98	10YR 6/4 yellowish brown
Bar beach	0.19	0.373	13.89	10YR 6/3 pale brown
Nigg Ferry	0.33	0.209	5.71	10YR 6/3 pale brown
Portmahomack	0.25	0.464	12.83	10YR 6/4 yellowish brown
Rosemarkie	0.21	0.348	1.72	10YR 6/4 yellowish brown
Rosemarkie-Scart Craig	0.20	0.494	2.44	10YR 6/3 pale brown
Wilkhaven Beach	0.45	0.355	32.43	10YR 6/4 yellowish brown

Notes:

1. Samples were taken from mid point of inter-tidal zone at centre of beach.

2. Sorting coefficient is a measure of the deviation of grain sizes around the mean.

<0.35 very well sorted
0.35-0.50 well sorted
0.50-1.00 moderately sorted
1.00-2.00 poorly sorted
>2.00 very poorly sorted

3. Carbonate content is expressed as a percentage of calcium carbonate in the sand sample, and was measured by means of a Collins' Calcimeter.

4. Colour notation relates to classification employed in the Munsell Soil Colour Chart, and refers to oven-dried sand samples.

Appendix III Habitat Diversity

Habitats →	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	*Total*
Kilmote	✔			✔	✔	✔					✔	✔				✔				✔	✔	9
Crakaig	✔			✔	✔	✔					✔	✔			✔				✔	✔		9
Kintradwell	✔			✔	✔	✔					✔	✔			✔					✔	✔	9
Brora (Dalchalm)	✔			✔	✔	✔					✔	✔		✔		✔				✔		9
Brora (South)				✔	✔	✔			✔		✔	✔	✔						✔	✔		9
Golspie-Littleferry	✔			✔	✔	✔		✔	✔		✔	✔		✔			✔	✔	✔	✔	✔	14
Coul	✔		✔	✔	✔	✔	✔		✔		✔	✔		✔	✔	✔	✔	✔		✔		15
Embo	✔			✔	✔	✔			✔		✔									✔		7
Dornoch (North)				✔		✔					✔		✔									4
Dornoch (South)	✔			✔	✔		✔				✔									✔		6
Cuthill Links	✔		✔	✔	✔		✔	✔							✔	✔	✔			✔		10
Morrich More	✔	✔	✔	✔			✔		✔		✔			✔	✔		✔	✔		✔	✔	13
Inver-Arboll	✔			✔	✔	✔	✔		✔		✔					✔				✔		9
Wilkhaven	✔			✔	✔	✔						✔	✔							✔		7
Portmahomack	✔			✔		✔					✔											4
Balintore	✔			✔		✔					✔		✔			✔				✔		7
Nigg Ferry	✔			✔	✔	✔					✔		✔							✔		7
Cromarty				✔								✔										2
Rosemarkie-Scart Craig	✔			✔	✔	✔					✔	✔	✔		✔				✔	✔		10
Totals	16	1	3	19	14	15	5	2	6	0	16	10	6	4	6	6	4	3	4	16	4	*Total*

Notes:

Permanently Flooded

1 Creeks and drainage channels
2 Lagoons

Intermittently Flooded

3 Foreshore mud
4 Foreshore sand
5 Foreshore shingle
6 Foreshore rock
7 Saltmarsh and brackish marsh
8 Shingle beach lows
9 Sand dune slacks

Terrestrial

10 Earth and cliff embankment
11 Sand dune and sandy beach
12 Shingle beach
13 Rock-cliff and sea-wall
14 Coniferous plantation
15 Deciduous woodland/scrub
16 Cultivated land
17 Dry heather moor
18 Wet moor (including mir, blanket bog).
19 Grass heath (*not* sand)
20 Machair
21 Freshwater marsh or swamp

(Based on "*Nature Conservation at the Coast*", Countryside Commission Special Study Report, Vol.2 HMSO).

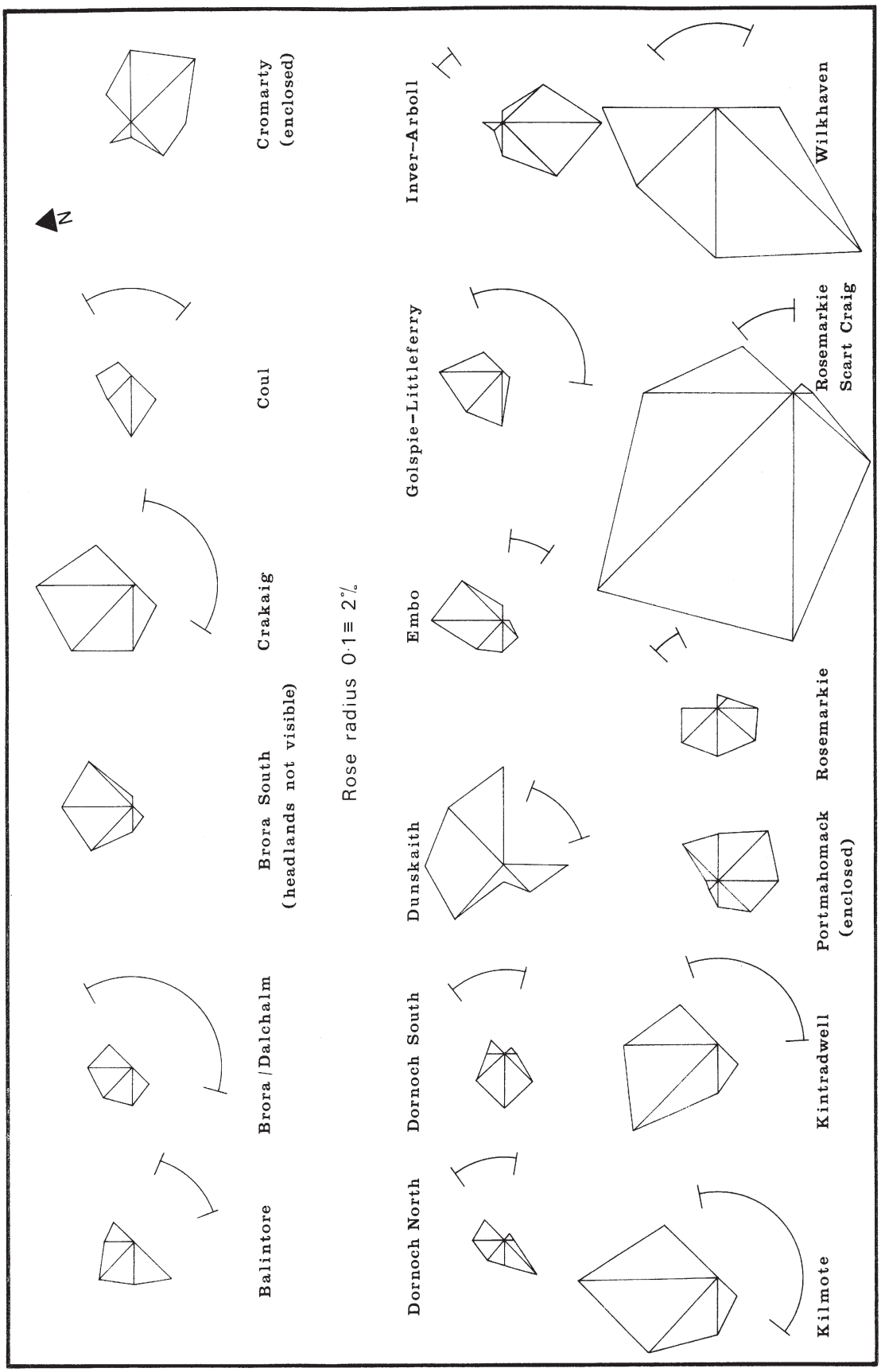
Appendix IV Exposure Indices

The amount of shelter afforded to each beach by the surrounding terrain was estimated by measuring the slope to the skyline at eight compass points. The slope was expressed in percentage form, and the percentages for each beach unit were then represented in rose diagrams drawn to scale (Figure 9). The size of a rose is proportional to the amount of shelter, and its area in comparative square units is given in brackets. It must be emphasised that the areas are meaningful in comparative rather than absolute terms.

Marine orientation and exposure are represented by arcs of circles centred in each beach unit (Figure 9). Many of the beaches have strong easterly or southerly components in their orientation, but width of exposure arc is variable, and is, as might be expected, much greater for beaches on the outer coastline than for those in the firths.

In general terms, beaches with small exposure roses and wide exposure arcs receive higher energy inputs from wind and waves than beaches with large roses and narrow arcs.

Figure 9 Shelter Indicies and Marine Exposure Areas



References

Carter, M. R . 1971.	A method of analysing patterns of tourist activity in a large rural area: The Highlands and Islands of Scotland. *Reg. Studies* 5., 29-37.
Meteorological Office	Averages of Temperatures for Great Britain and N. Ireland. 1921–50.
" "	Averages of Bright Sunshine for Great Britain and N. Ireland. 1931–60.
" "	Averages of Rainfall for Great Britain and N. Ireland. 1916–50.
" "	Monthly Weather Reports, Annual Summary.
" "	Tables of surface wind speed and direction over the United Kingdom.
Nature Conservancy (n.d.)	A prospectus for Nature Conservation within the Moray Firth.
Plant, J.A. (nd)	The climate of the coastal region of the Moray Firth. *Met. Office Climatological Memorandum 62.*
Rae, P.A.S. 1973.	The soils and vegetation of the Morrich More, Easter Ross. Unpublished Thesis, Department of Botany, University of Aberdeen.
Scottish Development Department. 1973.	Discussion Paper on Oil Production Platform sites in Scotland.
"	Report on Dunnet Bay Public Inquiry.
"	North Sea Oil and Gas – Interim Coastal Planning Framework. Discussion Paper.
Zenkovitch, V.P. 1967.	Processes of coastal development. Edinburgh.

Key


Major slopes

Slope angle and direction

Ridge crest


Rock platform

\+ Rock outcrop

High water mark

Low water mark

Active cliff

Inactive cliff

Neutral coastal edge

Prograding coastal edge

Terrace edge


Blow out margin


Links or machair (where other tone has not been employed – see map legends)

△ Glacial till


Pebbles, cobbles or boulders


Gravel


Mixed sediments


Saltmarsh


Yellow dune


Grey dune

Q Quarry

CP Car park

CS Caravan site

TT Made ground

.5 Spot height (metres)

5 Height difference (between top and bottom of coastal edge, terrace edge, blow out edge)

Railway

Roads

Houses


Built-up area

Man-made features in red
Bare sand surfaces in yellow – except for


Inter-tidal sandflat