Department of Geography, University of Liverpool

Research Papers

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COASTAL CHANGES ON WALNEY ISLAND, NORTH LANCASHIRE

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Computer Typeset by Cheshire Typesetters, Chester.
Printed by Bemrose Press (Michael Bemrose) Ltd., Ellesmere Port, Cheshire.

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"This country in divers places suffereth the forces of many flowing tides of the sea, by which (after a sort) it doth violently rend assunder one part of the shire from the other: as in Fournes, where the Ocean being displeased that the shore should hence shoot a main way into the west, hath not obstinately ceased from time to time to slash and mangle it, and with his fell irruptions and boistrous tides to devour it."

John Speed
The Theatre of the Empire of Great Britain 1611

PREFACE

The coastline of North Lancashire has previously received only superficial geomorphological and historical investigation. In comparison with the Fylde coast and that of South West Lancashire, where the late R. Kay Gresswell did much of his work, the North Lancashire coasts have remained neglected. Although many local historians and naturalists recorded their valuable observations in the transactions of field clubs and natural history societies, the attentions of professional scientists were only rarely turned to these northern coasts.

At a time when the conservation of natural resources is regarded as of increasing importance a need exists for studies of particular sections of coast from both the historical and contemporary viewpoints. The importance of considering a coast as an eco-system, in which a delicate balance exists between the edge of the land area and its flora and fauna on the one hand, and the varying wind, wave and tidal conditions on the other, cannot be overstressed. Only when the changes producing the evolution of the coastline are known in detail over as long a period as possible, and the processes bringing about these changes are understood as well as possible, can the most suitable action be taken to conserve the coast. This memoir is intended as a contribution in this field, using the research methods of the historical geographer and the geomorphologist to study the coasts of Walney Island. It was originally intended to include the coast of the mainland of Furness also, but the untimely death of Dr. R. Kay Gresswell did not allow this.

The field work was financed by the Department of Scientific and Industrial Research from 1963 to 1965 and the University of Liverpool. Without the generous and willing help given by our students and friends this work could never have been completed. We would particularly like to thank the following: Mr. J. Melville, Mr. F. Barnes, Mr. W. Shepherd, Mr. A. Wheeler and the late Mrs. Wheeler and Mrs. P. Braithwaite. The maps and diagrams were drawn by Mr. A. G. Hodgkiss and his colleagues in the Drawing Office of the Department of Geography, University of Liverpool.

Ada W. Phillips
W. Rollinson
January, 1971

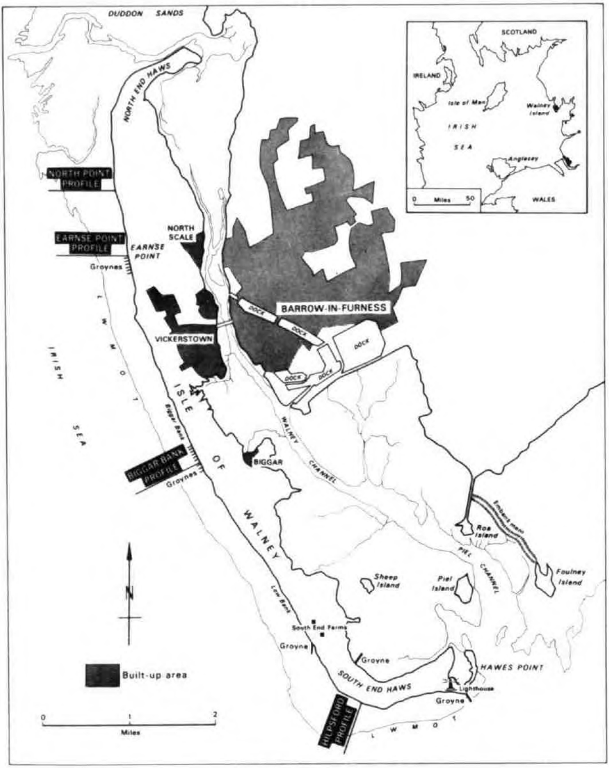

Fig. 1. Walney Island.
(Locations of the profiles in Fig. 7 are shown).

COASTAL CHANGES ON WALNEY ISLAND
AN HISTORICAL APPRAISAL

EROSION ON THE WESTERN COAST

Coastal changes on Walney Island [Fig. 1] have interested local historians, antiquarians, and scientists for centuries and therefore it is not surprising to find that such changes have been documented and mapped at least since the eighteenth century. However, active interest in coast erosion and defence dates from the medieval period; the Cistercian monks of Furness Abbey constructed the great dike on the eastern side of the island to prevent inundation at high tide of an area of pasture near to their grange at Biggar. There is evidence to suppose that the monks not only built dikes on the eastern side of the island but also constructed and maintained similar embankments on the western coasts which have subsequently been destroyed by marine erosion.[1]. These sea defences were kept in repair by the monastic tenants throughout Furness, and although there is little evidence in the Furness Abbey records[2] to suggest that there was serious flooding or erosion on Walney Island during the monastic period, after the dissolution of the monastery in 1537 a period of neglect ensued with predictable consequences.[3] Seventeen years after the dissolution the Chancellor of the Duchy of Lancaster heard a complaint from the inhabitants of "the Isle of Walney, Ramsed, Salthouse, Marchgrange and Sowerby Loge all in the Parish of Dalton, and of Angerton Moss in Kirkby Ireleth" that on December 6th, 1553, "a great part of the said (lands) adjoining the sea by great tempestuous rages, surges, and higher springes of the sea was surrounded and overflown either by sea or sand. . ." There are records of similar inundations in 1546, 1552, 1561, and 1564 and there are several pleas to the Court of the Duchy of Lancaster for assistance. In 1564 an agreement was finally reached between the Walney tenants and the Duchy Court; the tenants took upon themselves full responsibility for the maintenance of the sea defences on condition that their rents were reduced permanently by £6. 11s. 2d. per year. In addition they somewhat rashly guaranteed the whole of the rent irrespective of any future erosion of the land. Yet the tenants' attempts to control coast erosion can have met with limited success for in 1586 it was claimed that even three thousand days labour per year was not sufficient to keep the dikes and sluices in good repair, a figure which dramatically indicates the magnitude of the problem at that time.[4]

Clearly then, the problem of coast erosion was giving rise to some concern even in the sixteenth century; it was still a cause for anxiety in the eighteenth century for in 1774 Thomas West, a local observer wrote

> "When a high tide shall concur with the heavenly bodies to swell the equinoxial tides to a certain height, as may be expected, the island will probably be cut in two if not timely prevented."[5]

Considerable damage resulted from storms in 1771 and 1796, and in 1805 another local writer, Dr. William Close recorded that

> ". . . the encroachment of the sea has of late been so rapid near to the houses called Southend, and for two miles to the northward, that the dwellings of the present inhabitants seem destined to the fate of those of their predecessors; and that in the course of a few centuries, the sea will break through the island in one or more places. (Footnote: In January, 1796 and two or three times since, the tide broke over the western shore of the island in several places and did a great deal of damage)." [6]

Interest in the erosion of the west coast of Walney continued in the nineteenth century. In 1833 R.A. Peacock, C.E., surveyed the South End of the island on a scale of 26⅔ inches to a mile, and later transfered his measurements, and those of an earlier survey undertaken in 1797, onto the 1847 edition of the Six-Inch Ordnance Survey map.[7] This map may be justly described as the first accurate record of coastal changes for although there were earlier surveys of this North Lancashire coast such as the Fearon and Eyes chart (1737) and the Laurie and Whittle map (1794), these were intended as sailing charts and as such must be used with caution. Dr. A. P. Carr has rightly pointed out that evidence provided by maps prior to the end of the eighteenth century "must be treated with the greatest reserve, both from a qualitative and especially a quantitative point of view."[8] Adopting the Cragg – Peacock outlines as a basis on which to work, it is possible to add further outlines of the coast surveyed at various times in the nineteenth and twentieth centuries.[Fig. 2]. The coastline in 1847 has been taken from the first edition of the Ordnance Survey map, that of 1879 from a detailed manuscript survey undertaken by W. B. Kendall,[9] while the 1951 coastline has been plotted from the detailed observations of Mr. James Melville.[10]

The maps clearly show the extent of marine erosion along this western coast since the end of the eighteenth century. Fig. 2 shows the losses along the central section of the coast between the boulder clay cliffs of Middle Hill and Hillock Whins. Within this area losses have varied widely; Kendall[11] reports that between 1879 and 1882 more than 20 feet was lost in the vicinity of Lamity Syke but such a figure is rather exceptional. Between 1889 and 1904 almost 73 feet of land was lost at this point and since then a further 70 feet has been eroded, on average, along this section of the coast. At Hillock Whins between 1842 and 1879 an average loss of some 70 feet was recorded, but in the period between 1879 and 1904 the rate of erosion appears to have accelerated and 140 feet of land was lost at this point, an average of more than five feet each year. Since then erosion loss has decreased and the average loss between 1951 and 1965 was less than ten feet.

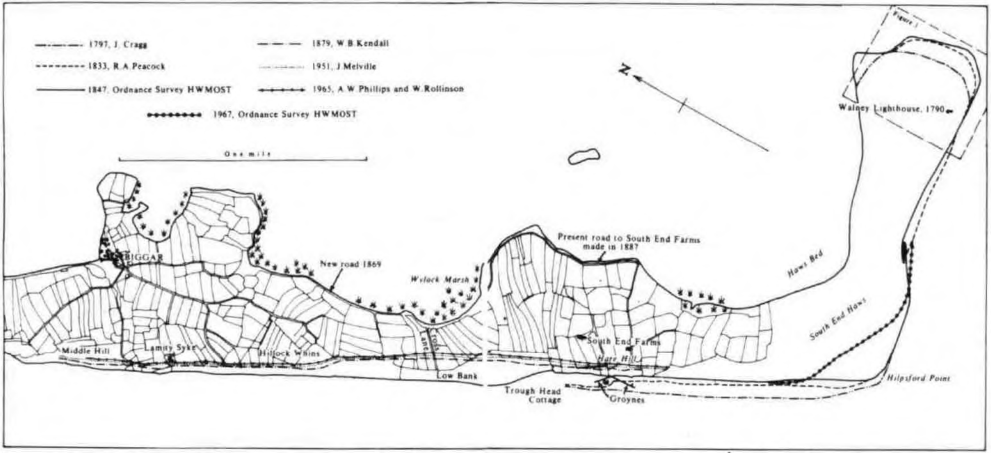

Fig. 2. Surveyrs of the coast of Walney Island in the late 18th, 19th and 20th centuries.

Between Hillock Whins cliff and Hare Hill is the area of coast most seriously affected by marine erosion. Here is the narrowest part of the island, less than 650 feet from east to west, and here the unconsolidated storm ridges offer little resistance to the advancing high-water-mark (H.W.M.). On occasions when low barometric pressure and on-shore gale force winds coincide with high spring tides, waves have washed over the island from west to east at this point. In January 1796 William Close [13] records the inundation of this area, and on 27th December 1852 the **Ulverston Advertiser** reported that during a severe gale the sea breached the island in several places to such an extent that it would have been possible to sail a boat from one side to the other. Since then erosion has reduced the distance between the east and west coasts even further; between 1842 and 1879 an average width of 286 feet was lost and between 1879 and 1904 an average of 125 feet was wasted, but thereafter the rate declined to 80 feet between 1904 and 1951. The average loss in the period 1951 to 1965 was 20 feet but between 1847 and 1965 the width of the island at Cross Lane has been reduced by almost half. The erosion here seems to have been most serious during the nineteenth century; an index of the loss is afforded by the position of a small cottage at Trough Head [Fig. 2] relative to the H.W.M. In 1833 the cottage was some 250 feet from H.W.M. but by 1840 the H.W.M. came within 140 feet of the building, a figure which was further reduced to 90 feet in 1879. In 1902 [14] the cottage was partly washed away and now the site of the building is almost 100 feet seawards of H.W.M.

Erosion at Hare Hill is similarly dramatically underlined by the history of the farms which comprise the Township of South End. The farms at South End are first mentioned in monastic documents in 1247 but it seems probable that the settlement has been rebuilt on more than one occasion as erosion threatened the site.

In 1810 William Close mentions that erosion had "demolished the paternal habitation of some of the present inhabitants and consumed a part of their heritage." [15] Peacock's map [Fig. 2] indicates the position of farm buildings in 1833 which were destroyed by erosion between that date and the surveying of the first edition of the Ordnance Survey map in 1847. James Melville has drawn attention to the several dated stones contained in the walls of both the farms. The most northerly farm has stones dated 1641, 1691, 1757 and 1764 while the second farm has stones dating from 1699 and 1755. It may be argued that these successive rebuildings were, in part, a response to coast erosion.

As well as necessitating the re-siting of the South End farms, coast erosion has meant the re-routing of the road to the township. In 1842 the road from Biggar to the South End farms ran for the most part along the western coast of the island, but by February 1851 it had to be re-routed eastwards of its original position. Continued erosion made further re-siting imperative; in

1869 the road was taken along the eastern side of the island as far as Cross Lane where it rejoined the western coast road, but by 1886 this western route had been destroyed and a new road to the farms along the eastern coast of the island was substituted in 1887.[16] [Fig. 2].

Between 1833 and 1879 W. B. Kendall claims that an average width of 200 feet was lost from the cliff face at Hare Hill but between 1879 and 1904 the loss was reduced to 60 feet, perhaps a response to the groynes erected in 1885 by the landowner, the Duke of Buccleuch. [Fig. 2]. Between 1951 and 1965 an average of 11 feet has been lost along this cliff-line.

South of Hare Hill, at Hilpsford Point, erosion has considerably modified the coastline since 1847. The blown sand and gravel deposits offer little resistance and the Hilpsford Point shown on the first edition of the Ordnance Survey map has been entirely destroyed by marine erosion. [Fig. 2].

Although the erosion problem on Walney Island has been recognised for centuries, from time to time suggestions have been advanced to combat the destruction. Dr. William Close in 1810 observed that where "scars", or pebble beds, occurred on the foreshore the erosion was less pronounced. He therefore suggested that the most effective way to fortify the shore was to "intersect the flat and broadest plains of sand by flats or collections of large, loose stones, in imitation of the natural scars which afford sure protection", for, he mistakenly concluded, "there is little doubt that if the declevity of the beach were rendered more gradual in certain places than it is at present the intermediate tracts of sand would rise, and the devastating fury of the waves, when urged by storms, would be dismissed". At the same time, Close was the first observer to indicate the dangers of the removal of beach material from the shore in the vicinity of the South End farms. The shipping of great quantities of pebbles from the beach to pave the roads of the rapidly growing industrial towns of South Lancashire was common. In spite of Close's warning and his statement that the practice ceased after 1788, it is known that the export of beach material continued well into the nineteenth century. As late as 1848 pebbles were removed in shiploads from this vulnerable sector of the Walney coast and a letter to the **Ulverston Advertiser** in March,[18] 1849, claimed that

> ". . . during the last year no fewer than 50 vessels were thus freighted for Fleetwood, Liverpool etc."

In 1885 attempts were made to stabilise the beach by groyning but within twenty years much of the timber-work had been destroyed. More recently the Barrow-in-Furness Corporation have attempted to counteract the effects of erosion by tipping refuse on the low-lying land at Low Bank. [Fig. 2]

COASTAL ACCRETION

The accretion at the south-eastern end of the island is not as well documented as the erosion of the western coast, nevertheless, this process was noted by Close in 1805:

> "The southern part of the Isle of Walney, for the length of two miles, is an immense ridge of pebbles, which the ocean has amassed and is daily increasing. The stones and gravel, for five or six miles, along the western shore of the island, after repeated agitation, are impelled forwards by the impetuosity of the ocean, and there left in repose. The progress of this neptunian process is very curious. Every high tide, as a monument of its power, amasses a long convex ridge or bar of pebbles to those that were there before; and so rapid is the increase that it is said the Haws-end had lengthened two hundred yards, in the period of sixty years."

The Walney lighthouse was built by the Port of Lancaster Authority in 1790 near to the then H.W.M., but fifty-seven years later it was 1,350 feet from the south-east tip of the island. The question of the eastward extension of the island interested R. A. Peacock and his measurements between 1833 and 1847 indicate that during this period the island was growing at a rate of 12 feet per year, and W. B. Kendall's observations suggest that between 1737 and 1889 the island had been extended by 2,200 feet.[19] Further extension of the island was prevented after 1878 by commercial gravel exploitation. Some indication of the quantity of sand and gravel shipped from the small pier at South End Haws is given by the Royal Commission on Coast Erosion (1907); it was claimed that between 1895 and 1905 some 1,156,206 tons of gravel and 107,132 tons of cobbles (round stones) were removed from this area.[20] Clearly, the removal of such a large amount of beach material considerably altered the position of H.W.M. and the various changes which resulted from the working of gravel between 1878 and 1907 were recorded by W. B. Kendall [Fig. 3]. With the transfer of the gravel workings inland away from the shore, a recurved spit has established itself at South End Point and the area formerly exploited for gravel has reverted to a salt marsh.

The connection between the growth of the southern end of Walney and the rate of erosion on neighbouring Piel Island is worthy of some comment. Piel Island is composed mainly of boulder clay with a shingle extension northwards; it was chosen by Furness Abbey as a stronghold protecting the entrance to the medieval port of Furness and here in the fourteenth century a castle or pele was built on the highest point. The unconsolidated boulder clay offered little resistance to marine erosion and consequently the southern part of the island suffered considerable encroachment and the castle was partly

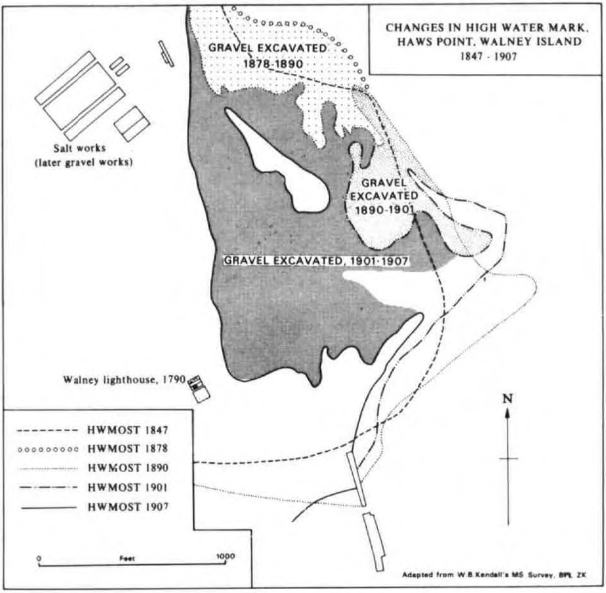

Fig. 3. Haws Point, Walney Island.

destroyed. In 1790 most of the keep was still intact, but by 1820 much of the eastern wall of the keep had collapsed, to be followed soon after by most of the remaining portions of the wall. Erosion continued unabated until 1856 when the Duke of Buccleuch began the construction of sea defences; since then the rate of erosion has been reduced. It is interesting to speculate whether this decreased rate of erosion has been a response to the duke's defences or a result of the extension eastward of Walney Island, thereby protecting Piel Island from the effects of southerly waves. The hypothesis that the accretion of Walney Island provided natural protection for Piel Island was advanced by William Close in 1805:

> ". . . the island of Fouldrey (Piel Island) has certainly been much larger at the erection of the castle than it is at present; but the sea, having reduced it to its present small compass, has abated the rapid career of its destruction: it now wastes the western shore of Walney, and forms a new tract out of the ruins, which proves a barrier to its progress upon the Pile of Fouldrey, and, at some future period, may be an accession to this island, in place of the land which it has lost."[21]

At the northern end of Walney Island there has been some accretion of sand and shingle but no marked extension of the island has been recorded. A comparison of the first edition of the Six-Inch Ordnance Survey map with later editions shows only slight changes. Similarly, the western coast of the island north of Middle Hill [Fig. 2] has suffered some erosion but this is nowhere as serious as the waste of land south of this point.

In summary, it may be observed that the erosion of parts of the western coast of Walney has given rise to considerable concern in the past, and there is no reason to believe that the erosion of this coast is any less serious today. Attempts to slow down the rate of marine erosion by the construction of wooden and concrete groynes has met with limited success, mainly because of the neglect of these defence works. The more recent measure of tipping urban refuse onto the H.W.M. is open to question; in other areas of the island not actively being eroded this policy has been employed with success, but at Low Bank where erosion is serious the consequences could be far-reaching.

NOTES AND REFERENCES

1. West, T., **The Antiquities of Furness,** 1805 edn., 368.

2. Richardson, J., **Furness Past and Present,** 1880, Vol. 2, 221.

3. In 1775 West wrote "since the suppression of the abbey the sea has ravaged a great part of it, and threatens to waste it entirely." West, T., **op. cit.** 18.

4. West, T., **op. cit.,** 196.

5. West, T., **op. cit.,** (1775 edn.), 19.

6. Close, William, in West, T., **op. cit.** 1805 edn., 375.

7. Both Peacock's large scale survey, and that made by J. Cragg in 1797 have been lost. However, the composite Six-Inch map with Peacock's manuscript notes is preserved in the British Museum, No. P53/11539. Peacock presented a paper to the Geological Section of the British Association in 1866 entitled "On a gradual change of form and position of land at the South End of the Isle of Walney."

8. Carr, A. P., "Cartographic and Historical Accuracy", **Geography**, 47,215, 1962, 135 - 144.

9. Barrow Public Library ZK 27, 55, and 56. See also Kendall, W. B., "Waste of Coastline, Furness and Walney, in 1000 years", **Barrow Naturalists' Field Club Annual Reports, 18,** 1906, 75 - 84.

10. The authors are indebted to Mr. Melville for loan of his field maps and observations. See also Melville, J., "How Long Will Walney Remain One Island?", **Barrow Naturalists' Field Club Proceedings, 8,** New Series, 1956, 25 - 34.

11. Kendall, W. B., **op. cit.,** 79.

12. **ibid.**

13. Close, William, **loc. cit.**

14. Figures from Kendall, W. B. **op. cit.**

15. Close, W., "An Itinerary of Furness and the Environs", 1810, (transcript by T. A. Beck), Manchester Central Reference Library, B. R. 942.72. F4).

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17. Close, W., manuscript **op. cit.**

18. **Ulverston Advertiser,** 22nd March 1849.

19. Kendall, W. B., "Waste of Coastline", **Barrow Naturalists' Field Club Annual Report, 18,** 1906, 83.

20. Walker Smith, J., in **The Royal Commission on Coast Erosion and the Reclamation of Tidal Land from the Sea in the United Kingdom**. Cd. 3684, 1907, 347.

21. Close, W., in West, T., **op. cit.** 374.

PRESENT COASTAL CHANGES ON WALNEY ISLAND

A study of the present coastal changes was undertaken to gain an understanding of the processes affecting them. The knowledge so gained could then help to explain the changes in historical time which have been examined in the preceeding section. The beaches are usually the part of any coast where changes occur most frequently and the trend of these changes, whether it be towards erosion or accretion, will become reflected in the development of the whole coast. With this in mind, a research programme was drawn up to investigate both the tranverse and longshore movements of beach material.

The steady erosion of the till cliffs along the western side of Walney Island provides the beaches at their foot with a continous supply of material. These beaches are divisible into two main units. The upper unit varies in width from one part of the coast to another, and also with different wind, wave and tidal conditions, but it is generally between 100 and 200 feet. It is composed of material ranging from coarse sand to shingle up to about 8 inches long axis with occasional erratics up to several feet long axis. As may be seen in the profiles of the beach, this upper division lies at a relatively steep angle.

From the lower edge of the upper unit, which may be defined by a sharp line or a broader transition zone, the lower unit extends down to low water mark (L.W.M.) and is approximately half a mile in width. It is composed predominantly of fine sand of median grain size 2.40ϕ and lies at a relatively low angle. North of Earnse Point this sand is characteristically formed into ridges and runnels which leave the upper beach at a small angle opening northwards towards the Duddon Estuary. On this lower division of the beach there are extensive "scars". These are areas of relatively coarse shingle which is moved only slightly during storm conditions and which at other times appears to form a stable foundation to the beach. On the scar at Biggar Bank the median size of the shingle is 5 inches, but on the Earnse Point scar the average size of the large erratics is 3 feet. The fine sand moves about freely over the scars. Whilst these are found along the whole of the west coast of the island their greatest extent and concentration is adjacent to the till cliffs between Earnse Point and Hare Hill. This suggests that they may be formed from the coarsest fraction of material in the boulder clay which fell to the beach as the cliffs were eroded, but was too large to be carried away by marine forces. The individual scars may approximately delimit the extent of drumlins which lay seaward of the present coastline.

The eastern side of the island contrasts markedly with the west. This coast lies adjacent to Walney Channel which divides the island from the mainland of Furness. In places a narrow beach of fine shingle of median size 1.1 inches, exists, but elsewhere the island is edged by salt marsh. To the south of Vickerstown the salt marsh has developed at two distinct levels. A cliff about 3.7 feet high divides the two sections and is actively retreating due to wave attack in storm conditions. It is thought that the cliff may have originated when dredging commenced in the southern half of Walney Channel and lowered the local base-level.

THE TRANSVERSE MOVEMENT OF BEACH MATERIAL

The changes in the transverse profile of the beach on the western side of the island were measured over a two-year period from October 1963 to October 1965, and were related to varying wind, wave and tidal conditions.

Beach Profiles

Four datum points were established on the edge of the dunes or cliffs, in positions such that when the profile of the beach was surveyed along a fixed bearing, each profile would cross a different type of beach [Fig. 1].

1. North Point datum was fixed where a narrow upper beach of shingle is usually present, and where the lower beach has developed into a marked series of ridges and runnels, which are interrupted by a scar about half a mile from the edge of the dunes.

2. Earnse Point datum was established where a slightly wider sand and shingle upper beach is found, with usually a smooth sandy lower beach below it.

3. Biggar Bank datum was beside a shingle upper beach which is occasionally removed to reveal the boulder clay beach platform beneath it. The lower beach is composed almost entirely of an extensive scar which only towards low water mark is occasionally partly covered in fine sand.

4. Hilpsford datum was established where a sand and shingle upper beach exists, and where the lower beach is composed of fine sand in its highest and lowest sections with an extensive scar in the middle section.

Profiles were surveyed at approximately monthly intervals from each of these datum points over the two-year period.

Wind, Wave and Tide Data

In order to be understood the beach changes must be examined in the light of prevailing wind, wave and tidal conditions. Wind records have been obtained since October 1963 from Barrow Docks. These are continuous trace recordings from which direction and velocity were abstracted at 6-hourly intervals. Tidal predictions for Barrow were obtained from the Admiralty Tide Tables and tidal records were obtained from Barrow Docks. It was not possible to insert a wave recorder along this coast nor to make wave observations at frequent intervals during the two-year period. For the whole of 1966, however, daily observations of wave height and period were made at the southern end of Walney Island and these have been related to daily wind conditions during the same period.

Wind

While the wind may play an important transporting role on the sand beaches leading to the extensive development of dunes where the coast is low, mainly at the northern and southern ends of the island, the most important role of the wind lies in the development of waves which are considered below. Also, by exerting a frictional drag over the water surface the wind indirectly sets up reverse compensatory movements of water close to the sea bed in shallow water. Whilst these are usually only weak drifts unable to lift sediment from the bed, they may play an important transporting role with fine sediment already in suspension. The frictional drag which the wind sets up also has an important effect on the tides. The level of the tide may be raised by several feet with a strong onshore wind, or it may be depressed by an offshore wind.

Waves

The waves are the dominant force effecting beach change, the size to which they develop being governed broadly by the wind velocity and the fetch.

The observations taken at the southern end of Walney Island were of wave height at break point and wave period. The wave period data was used to calculate deep water wave lengths according to the formula:

$$L_O = 5.12\ T^2$$

where L_O is deep water wave length in feet

and T is wave period in seconds.

As waves interact with the sea bed only in shallow water, that is water of a depth less than half the wave length, the measurements thus obtained are of importance in assessing the width of the zone being directly affected by wave action at any one time.

The data on wave height at break point was used to calculate deep water wave height according to the formula:

$$\frac{H_b}{H_o} = \frac{1}{3.3\sqrt[3]{H_o L_o}} \times K_b$$

where H_b is wave height at break point in feet

where $H_o$is deep water wave height in feet

and $K_b = \sqrt[3]{\frac{S_o}{S_b}}$

where $\frac{S_o}{S_b}$ is the ratio of the spacing between wave rays or orthogonals in deep water and near break point, the effect of wave refraction being thus taken into account.

Wave energy was then calculated according to the formula:

$$E = 41H_o^2 \ T^2$$

where E is wave energy in foot lbs/foot of wave crest/wave length

Wave refraction diagrams were constructed according to the method proposed by Pierson, Neumann and James [1] [Fig. 4]. All directions from which waves may approach Walney Island directly were examined.

Only to the west-south-west is the Irish Sea of sufficient depth to allow waves of up to 8 second wave period to develop. The refraction diagram for 4, 5 and 8 second waves formed from this direction shows that they are hardly refracted at all before breaking on the coast. The wave energy expended on the coast will therefore be evenly distributed along it. Waves of up to 6 second wave period may develop from the south-west and west and the refraction diagram for 4 and 6 second waves shows that they are only slightly refracted.

Waves of up to 6 seconds approaching from the west-north-west and north-west suffer an increasing degree of refraction with the longest waves from the north-west being most affected. The refraction diagram shows that energy is being concentrated more on the northern half of the island under these wave conditions than on the southern half. The reverse occurs with waves approaching from the south-south-west. Only waves up to 4 second period are able to develop in the shallower depths to the south-south-west and they are so refracted that energy is concentrated on the southern half of the island.

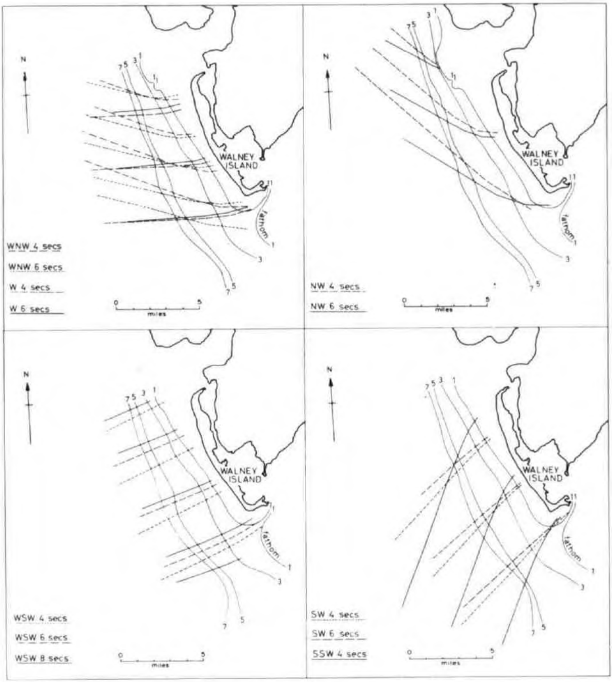

Fig. 4. Wave orthognals, Walney Island.

The Relationship between Wave Energy and Wind Conditions.

Using the daily wave data and wind data for 1966 the relationship between wave energy and wind conditions was examined. The complexity of this relationship cannot be overstressed. Waves may be formed in the open sea or ocean under wind conditions which differ markedly from those affecting the coast, maybe hundreds of miles away, on which the waves ultimately break. Nevertheless because of the configuration of the coast between West Cumberland and Anglesey and the proximity of the Isle of Man [Fig. 1] only relatively limited fetches are available from Walney Island except towards the west-south-west where the fetch is the width of the Irish Sea. It was hoped therefore that a useful and valid relationship between wind and wave data might be found.

The wind directions were divided into 5 segments thus:

Segment A $3\overset{3}{\cancel{0}}5^{\circ} - 055^{\circ}$	Winds blowing from the land.
Segment B $055^{\circ} - 095^{\circ}$	Winds blowing over intertidal sand banks in Morecambe Bay.
Segment C $095^{\circ} - 185^{\circ}$	Winds blowing over Morecambe Bay below L.W.M.
Segment D $185^{\circ} - 265^{\circ}$	Winds blowing over the maximum fetch across the Irish Sea.
Segment E $265^{\circ} - 33\overset{5}{\cancel{0}}^{\circ}$	Winds blowing over the Irish Sea east of the Isle of Man.

For each of these direction segments the wind velocity was plotted against the log. of wave energy. The correlation coefficient was calculated and the regression line plotted [Fig. 5].

Table 1 shows the range of wind velocities and logs. of wave energy, together with the average values for each segment and the correlation coefficient.

Table 1

Direction Segment	Wind Velocity (mph)			Log. Wave Energy			Correlation Co-efficient	% variance unaccounted for
	Max.	Min.	Average	Max.	Min.	Average	r	
A	28	8	15.00	11.04	5.66	7.45	0.623	61.21
B	32	6	19.55	10.49	3.58	7.57	0.434	81.19
C	32	4	18.11	11.04	5.66	8.18	0.612	62.59
D	46	4	21.69	11.54	3.49	8.44	0.750	43.72
E	44	2	20.19	13.14	3.58	8.77	0.787	38.08

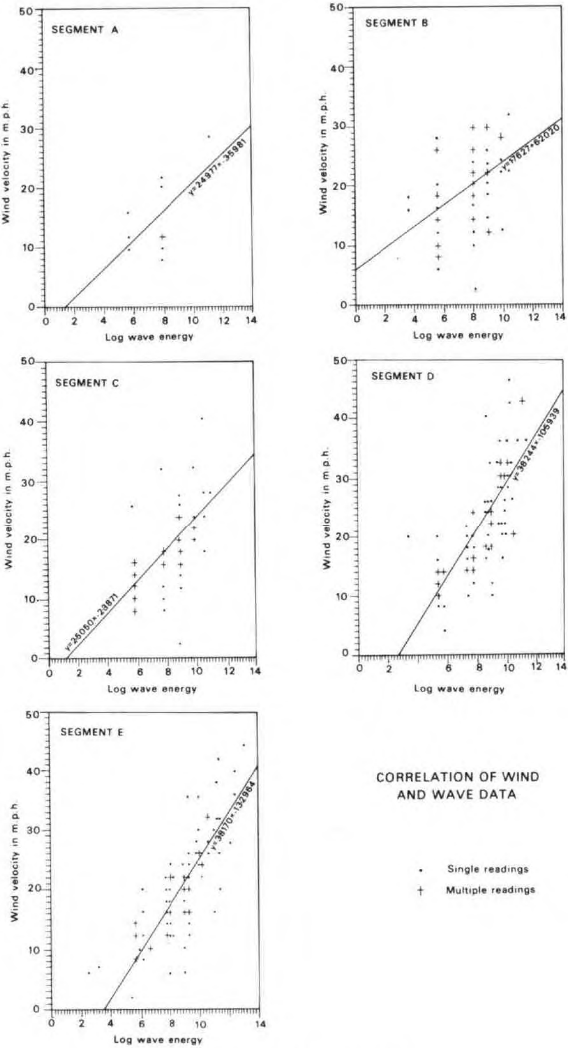

Fig. 5. Wind velocity and wave direction.

The wind velocity data show clearly that the strongest winds are those in segments D and E, and the fact that they blow over the maximum fetch means that thev can produce waves of a considerable energy content. From the correlation coefficients it can be seen that the strongest relationships between wind velocity and wave energy occur when the wind is blowing in these two segments, that is from the Irish Sea. When the wind is blowing from any other direction the relationship is much weaker as there is strong probability that the waves breaking on the coast will have been produced at a distance from that coast under different wind conditions. Such swell may mask local sea produced in the severely limited fetch of Morecambe Bay.

The wind data for the two-year period October 1963 to October 1965 was divided into the same segments and plotted in wind roses [see Figure 6a and b].

Tides

The tidal range at Barrow is approximately 10 feet at minimum neaps and 30 feet at maximum spring tides. With the low gradient of the beach on the western side of Walney Island this means that the intertidal zone is approximately half-a-mile wide there, and in Morecambe Bay where the bed is of a lower gradient the inter-tidal zone is up to 7 miles in width.

The height of both high and low water are raised when a strong wind blows from between south and west. This occurred on 15 occasions lasting from one to four days during the two-year period October 1963 to October 1965 and caused the level to be raised between 1 and 3.5 feet above the predicted level. During these occasions wind velocities of up to 68 m.p.h. were recorded. The raising of H.W.M. especially at spring tides enables wave energy to be expended on a part of the shore normally above its influence. The fact that the largest waves are produced by winds blowing from between south and west means that maximum wave energy may thus be expended at this height.

Strong winds blowing from an easterly quarter tend to lower the height of high and low water. On three occasions, ranging from one to five days, during the two-year period winds of up to 28 m.p.h. depressed the level by between 1 and 2 feet. At times of spring tides such a lowering may mean that wave energy is expended at an unusually low level on the coast.

Except when confined to narrow channels, tidal streams do not usually reach sufficiently high velocities to enable sediment to be lifted from the sea bed, although they may be important in transporting material already in suspension.

In the Irish Sea [1] 12 miles west of the entrance to the Lune Deep the flood stream runs eastwards at a speed of 1.9 knots at spring tides, and the

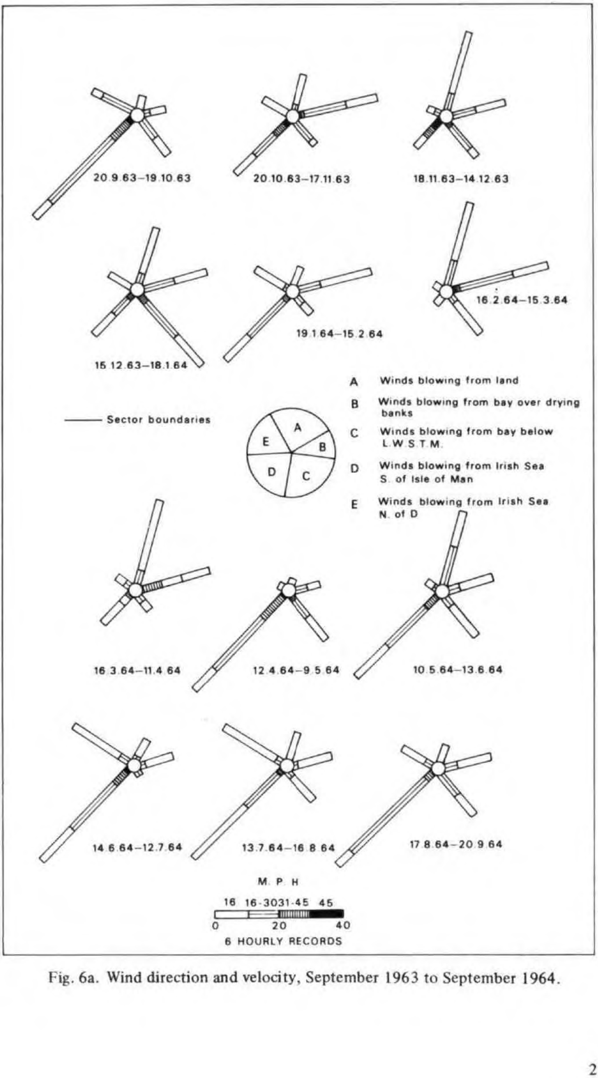

Fig. 6a. Wind direction and velocity, September 1963 to September 1964.

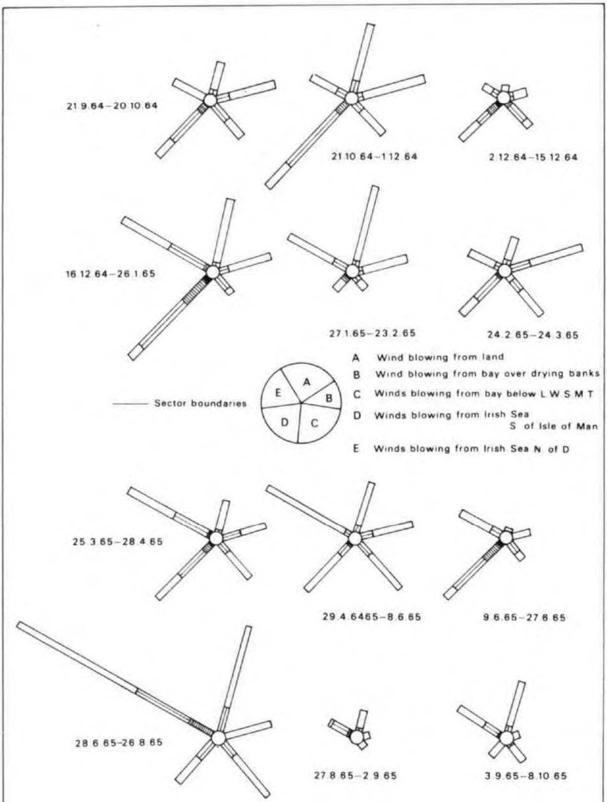

Fig. 6b. Wind direction and velocity, September 1964 to October, 1965.

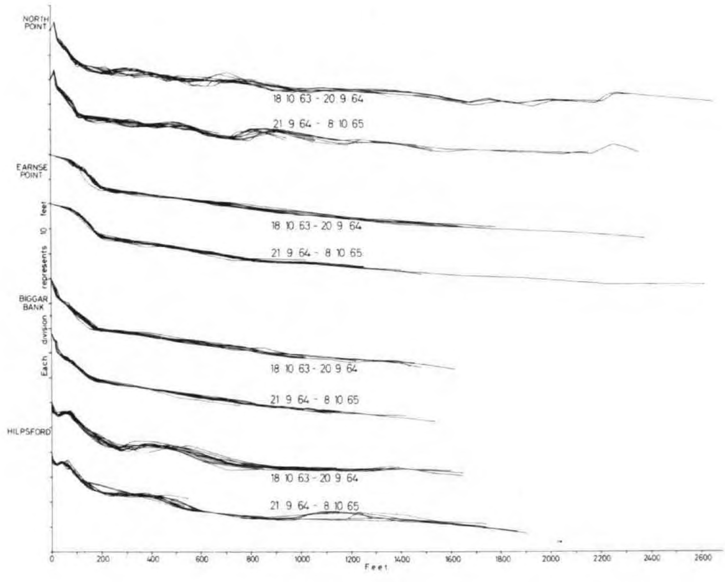

Fig. 7. Sweep zone profiles, Walney Island.
(For the location of these profiles see Fig. 1.)

ebb stream runs westwards at 2 knots. In the area 3½ miles south-west of the entrance the flood stream has an anti-clockwise rotary movement which swings from south-east to north-east attaining a maximum velocity at springs of 1.9 knots when flowing south-eastwards. By contrast the ebb stream is almost rectilinear flowing at about 1.8 knots towards the west-south-west and finally turning to the south-west.

Near Lightning Knoll to the south of Walney Island a more fully developed anti-clockwise rotary movement occurs. The flood begins with a weak south-south-easterly stream which turns eastwards to reach a maximum velocity at springs of 1.5 knots in a south-east and east-south-easterly direction. The rate finally decreases as the stream turns northwards. The ebb begins with a weak north-westward flowing stream which turns west-north-west and west and there reaches a velocity of 2 knots at springs. As the rate decreases the direction swings southwards. In Morecambe Bay itself the tidal streams run in the direction of the main channels when the banks are dry, but when the tide covers them the tidal streams tend to flow across the banks. The ebb and flood rates both reach about 3 knots at springs.

Observed Changes in the Cross Profiles of the Beach.

From the repetitive surveying of the beach profile from the four datum points during the period October 1963 to October 1965 the sweep zone diagrams [Fig. 7] were drawn. The changes which these reveal will now be examined in the light of the varying wind and tidal data.

Changes on the Upper Part of the Beach.

The changes on the upper part of the beach profile, from 0 to 200 feet from the datum points were of three types. Swash bars were built on the rising tide and left as a feature up to about 2 feet in height close to H.W.M. They were formed from material eroded from the lower part of this zone and pushed up the slope to give a steeper profile of equilibrium. Swash bars were most frequently present as single features although at Earnse Point in particular they were sometimes present in pairs.

At other times a smooth profile was found, either sloping at an even gradient or convex in form. More rarely the profile was cliffed to between 1 and 2 feet in height giving a change in the equilibrium profile above and below the cliff. Material eroded from immediately below the cliff was combed down the lower part of the profile.

Table 2

Changes on upper part of beach, related to different wind directions.

The first figure in each column refers to dominant wind direction during preceeding inter-survey period. The second figure relates to dominant direction during preceeding 5 days. Where the wind during the 5 days was variable the second dominant direction was used to calculate the third figure.

Direction	North Point	Earnse Point	Biggar Bank	Hilpsford	Profile Features
Sector A	4 1 –	4 2 –	2 1 –	4 1 2	Swash Bars
$335^{o} - 055^{o}$	1 1 2	1 – 3	3 1 1	1 1 1	Smooth
	– – 1	– – –	– – 2	– – –	Cliffing
Sector B	– 3 4	– 7 6	– 3 4	1 5 5	Swash Bars
$055^{o} - 095^{o}$	1 6 3	1 2 1	1 5 3	– 4 2	Smooth
	– – –	– – –	– 1 –	– – –	Cliffing
Sector C	1 – –	1 4 4	– 1 –	1 2 –	Swash Bars
$095^{o} - 185^{o}$	– 2 4	– – –	1 1 1	– 2 4	Smooth
	– 1 –	– – –	– 2 3	– – –	Cliffing
Sector D	1 1 1	11 3 6	3 – 1	3 1 3	Swash Bars
$185^{o} - 265^{o}$	10 3 4	2 1 1	5 3 4	9 3 4	Smooth
	1 – 1	– – –	5 1 2	– – –	Cliffing
Sector E	– – –	– – –	1 1 1	3 2 –	Swash Bars
$265^{o} - 335^{o}$	2 2 1	4 4 2	1 1 1	2 2 2	Smooth
	2 2 1	– – –	2 2 –	– – –	Cliffing

Table 2 shows the number of changes of each of the three types related to winds blowing from the different segments. At North Point there was the greatest tendency for the building of swash bars when winds were blowing from Sector B, for the smoothening of the profile with winds from Sector D, and for cliffing with winds from Sector E.

At Earnse Point swash bars tended to be formed when winds were blowing from Sector D, and to a lesser extent from Sectors C and B. Smoothening occurred most frequently with winds blowing from Sector E. Cliffing was not observed on this profile.

At Biggar Bank there was a slight tendency towards swash bar building with winds from Sector B, and a marked tendency towards smoothening and cliffing with winds from Sector D.

At Hilpsford swash bars tended to be constructed with winds blowing from Sectors A and B, and the profile tended to be smoothened when winds were from Sector D. No cliffing was observed on this profile.

There is an overall tendency therefore for constructive wave action to lead to the building of swash bars when off-shore winds are blowing. Such winds decrease the steepness of the waves and in setting up surface drifts of water in an off-shore direction produce compensatory shoreward drifts close to the sea bed in shallow water. Sediment tends to be moved towards the shore and the profile of equilibrium steepened.

Cliffing occurs mainly with onshore winds which tend to steepen the waves and produce seaward drifts of water close to the sea bed. Material tends to be moved down the beach profile under these conditions. The smooth profile was also found most commonly with onshore winds and reflects a state of equilibrium. Strong onshore winds raise the water level as has already been stated and especially at times of spring tides. This enables the wave action to be spread over the whole of the upper part of the beach allowing a profile of equilibrium to be fully established.

Changes on the Lower Part of the Beach

At North Point as stated previously the lower part of the beach, below 200 feet from the datum point, is characterised by the presence of a well developed series of sand ridges and runnels. The sweep zone profiles show that the ridge crests appeared most consistantly at between 300 and 350 feet from the datum, and at about 700 feet and 1200 feet on the profiles for the period October 1963 to September 1964. The profiles for the second year show the ridge crests concentrated at 300 feet, 500 feet, 800 - 900 feet and 1300 feet. The height of the profile at some points varied by up to 6 feet with the movement of the ridges and troughs.

When the monthly profiles were examined in sequence the main changes were found to be associated with a steady landward migration of the ridges. Only one of the profiles, that for 15th February 1964, showed a complete smoothening of the profile with the obliteration of the ridges and runnels. A partial smoothening occurred on three occasions, 13th June 1964, 20th October 1964 and 15th December 1964. During the inter-survey period preceding each of these dates winds had been blowing predominantly from Sector D, although as the wind rose diagrams show these were not the only periods when such conditions prevailed. By the surveys following those on the dates above, the ridges and runnels had been re-established. After the marked smoothening in February 1964 winds blew predominantly from Sector A, and after the partial smoothenings, from Sector D, at similar velocities to those in the preceding inter-survey periods.

The lower beach at Earnse Point throughout the two year period sloped at an even gradient to L.W.M. and was almost completely featurless. Only during one inter-survey period, between 8th and 27th June, 1965, did the height of the profile change by more than 1 foot. Then it was lowered by up to 1.5 feet and the eveness of the gradient was interrupted by the building of a sand ridge with its crest at 560 feet from the datum and a trough at 370 feet. During this period the wind had been blowing predominantly from Sector D at velocities between 16 and 45 m.p.h. By the time of the following survey on 28th August, 1965, the ridge, centred on 425 feet, had become very subdued and the profile generally had regained most of its previously eroded sediment. Winds during this period had been variable but were predominantly from Sector E at velocities below 30 m.p.h. The next survey on 2nd September, 1965 showed that the smooth evenly sloping profile had been fully restored, during a period when strong winds from Sector E were experienced.

As at Earnse Point, the generally even gradient of the lower beach at Biggar Bank showed very little change during the two years. Only three of the surveys showed a change in height of over 1 foot. Between 11th July and 16th August 1964 the surface was lowered by about 2 feet and the boulder clay on which the scar rests was extensively exposed. Winds blew predominantly from Sector D during the period at velocities up to 30 m.p.h. This loss was not subsequently regained.

Between 15th December 1964 and 26th January 1965 a further loss of up to 1.5 feet occurred. Winds blew predominantly from Sector D during the period at velocities up to 45 m.p.h. This loss also was not regained. During a third period, from 24th March to 28th April, a loss of up to 1.5 feet was recorded between 400 and 750 feet from the datum. Winds were predominantly from Sectors D and E, up to velocities of 30 m.p.h. This loss was restored by 8th June 1965 during a period of light and variable winds.

The lower beach at Hilpsford was characterised by the development of two large ridges with a scar between them. During the first year, from October 1963 to September 1964 the landward ridge moved steadily landwards by about 200 feet, occasionally suffering slight lowering and at other times being more accentuated. The height variation in the profile did not exceed 1 foot between surveys except over very short distances. On a number of occasions during this period a slight rise was noted on the profile at about 1400 feet from the datum, but it was often not possible to survey the profile to this distance.

Between 20th October and 1st December 1964 the crest of the landward ridge, which on the former date had been at 375 feet, divided into two to produce crests at 265 feet and 440 feet on the later date. By 15th December the two crests had become reunited and flattened to join the upper part of the beach. Little further change took place up to 26th January 1965. Throughout the whole of this period winds blew predominantly from Sector D.

By 23rd February when winds were mainly from Sectors A and E the ridge was almost completely absorbed into the beach, but by 24th March it had become re-established with a crest at 385 feet, during a period of light variable winds. Before 28th April the ridge had again been flattened and pushed up the beach to be attached with a small crest at 150 feet from the datum. Winds up to 30 m.p.h. blew predominantly from Sectors D and E during this period. By 8th June a ridge had been re-established with a crest at 375 feet and although it subsequently degenerated into a gentle convexity it was clearly recognizable until October.

Between October 1964 and October 1965, whenever it was possible to survey a long profile, a second ridge with its crest varying in position from 1235 to 1025 feet was clearly recognizable.

Whilst the greatest changes, which affected the lower beach along each of the four survey sections, occurred at different times during the two-year period and in different ways, all occurred after a period when the winds had been blowing predominantly from Sector D, that is the open Irish Sea. Here, in the maximum fetch and the maximum water depths, the largest waves can develop and subsequently they can be driven onshore without being refracted except possibly to a very slight degree. It must be noted however that a period of winds blowing from Sector D did not necessarily bring about a major change at any point and it has not been possible to detect a relationship between wind velocity and degree of change.

The fact that the type of major change at North Point and Hilpsford was the same, was to be expected in the light of the similarity of the beach material. The relatively small changes found at Biggar Bank were anticipated in the light of the size of the shingle making up the scar and the proximity of the boulder clay beach platform beneath it. The small changes at Earnse Point, despite the fine sand composing the beach, are probably due to its nearness to a scar to the south. To the north of the profile a fine sand beach is present extending up to North Point and beyond, but it is only about half way between Earnse Point and North Point that the ridges and runnels begin to develop.

THE LONGSHORE MOVEMENT OF BEACH MATERIAL

The way in which the northern and southern ends of Walney Island curve eastwards suggests that beach material from the west coast is being carried in towards the Duddon Estuary in the north and the entrance to Walney Channel in the south. It is at these two ends that sand dune development is most extensive.

The most rapidly growing feature of accummulation lies at the south-east tip of the island. Here a sand and shingle spit has developed to a length of

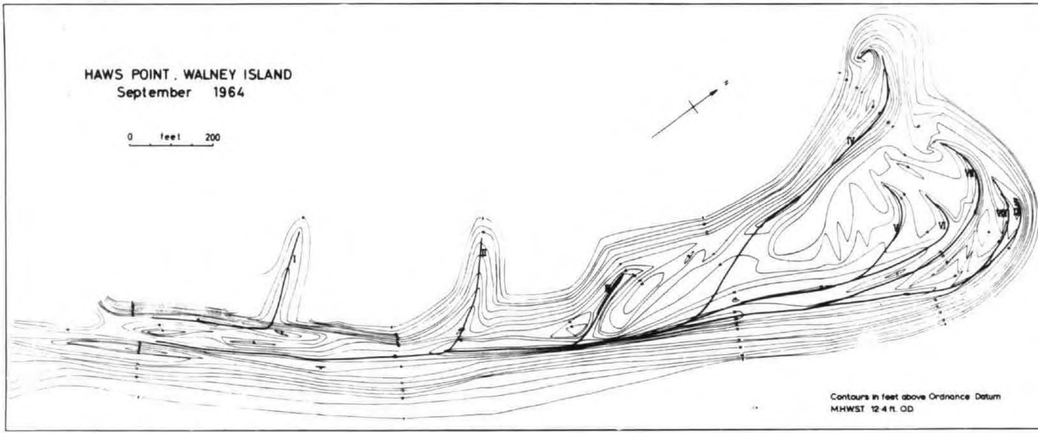

Fig. 8. Haws Point, Walney Island.

about 1,600 feet in 70 years. During the later part of the 19th century gravel was extracted from the south-eastern part of the island which previously had had a smoothly rounded south-eastern end. When the foundations of the lighthouse became endangered through the gravel extraction this was stopped by Act of Parliament in 1900 and it is since this time that Haws Point has developed.

The spit was surveyed in detail to produce the map shown in Figure 8. Like many similar features it is composed of a high seaward ridge of shingle which forms the backbone of the spit. The seaward side of this is generally smooth and steeply sloping. From the landward side of the main ridge a series of slightly lower subsidiary ridges curve in towards the main south-eastern end of the island. These appear to represent earlier ends of the spit, and the most likely sequence of development of these is indicated in Figure 8. This reveals not only that the spit is growing in length but that the end of the main ridge is extending north-eastwards. Despite the fact that the main part of the most north-westerly ridge appears to have developed early, its curved extremity is still actively growing by the addition of material carried completely round the end of the spit.

Material is added to the spit in the form of large tongues of shingle which are swept round the south eastern tip of the island and are carried northwards along the seaward side of the spit for a considerable distance before being absorbed. Such a feature is clearly visible on the map in the south-eastern part of the spit. Marked wave refraction occurs around the south-east of the island and this is particularly so with waves from the west and south-west. These may break at a high angle to the beach and are capable of producing a considerable amount of longshore drift.

A Tracer Pebble Investigation

In an attempt to test the theory that shingle is being carried by longshore drift completely round the southern end of the island from the west coast, a tracer pebble investigation was designed. 5,000 tracer pebbles, previously taken from the beach and coated with marine enamel, were placed on an injection line, the profile line at Hilpsford extending from H.W.M. to L.W.M. on 1st September, 1963. Three different colours of enamel were used to distinguish between a third of the tracers which were placed on the upper part of the beach, a third which were placed on the upper half of the lower beach, and a third placed on the lower half of the lower beach. At the time of the injection the upper part of the beach was composed primarily of shingle, the upper half of the lower beach of sand, and the lower division of sand with a scar extensively exposed in places. Each batch of the tracers was itself divided into thirds according to size. One third were under 2 inches diameter, one third 2 to 4 inches, and one third over 4 inches. Each size was distributed equally along the injection line.

The main problem which has been encountered in work with tracers, whether they be radio-active, fluorescent or coated, lies in the rapid rate of mixing of the sediment of all sizes on a beach and in the off-shore zone. This normally results in the rate of location of the tracers on the surface falling rapidly after the first few days, to a level which statistically is unsatisfactory.

The way in which the tracers behaved in this investigation was no exception. During the first 12 days when the tracers were tracked at one-or two-day intervals the percentage located ranged from almost 100% on all parts of the beach on the third day to as follows on the twelfth day; 76% on the upper beach, 7% on the middle section and 38% on the lower section. The marked drop in the latter two percentages resulted from extensive burying of the tracers by the sand. The percentage did not fall regularly but oscillated with the amount of sand deposited on a particular tide.

Only on the upper beach did the location rate tail off relatively smoothly and tracking was discontinued in May 1964.

Upper beach	15%	on	19.10.63	to	1%	on	9. 5.64
Middle beach	7%	on	9. 5.64	to	0%	on	14.12.63
Lower beach	14%	on	10. 4.64	to	1%	on	14.12.63

After the first 12 days, tracking of the tracers was carried out at monthly intervals until September 1964. The location rates again oscillated markedly between the following extremes:–

Details of the average rates of movement and maximum distance travelled by the tracers of different sizes on each sector of the beach are given in Tables 3 and 4. Table 3, which gives the results between 1st and 12th September 1963, shows that the maximum distance travelled by a tracer on the upper beach was 1213 feet, on the middle beach 40 feet and on the lower beach 145 feet, and the movement was entirely in a south-easterly direction. From both the average and the maximum distances it can be shown that there is a tendency for the largest tracers to move most rapidly on all parts of the beach, followed by those of medium size and finally the smallest tracers.

Table 4, which gives the results between October 1963 and September 1964, shows that the maximum distance travelled in this longer period by a tracer on the upper beach was 1965 feet (by December 1963); on the middle beach it was 650 feet and on the lower beach it was 660 feet. The medium and largest size tracers however travelled the greater average distances. As in the initial period of the investigation the movement of tracers was solely in a south-easterly direction.

Whilst it is not possible to draw conclusions as to the rate of movement of volumes of beach material the evidence clearly indicates a marked movement from the west coast of Walney Island around the southern end. Whilst none of the tracers travelled as far as the spit there is no reason why there should be any interruption to this south-easterly movement before the spit is reached.

TABLE 3

The Movement of Tracer Pebbles at Hilpsford, Walney Island, from 1st to 12th September 1963

Date	Beach Section	Small Tracers		Medium Tracers		Large Tracers	
		Maximum Distance	Average Distance	Maximum Distance	Average Distance	Maximum Distance	Average Distance
3.9.63	Upper	425 ft.	27.8 ft.	425 ft.	39.6 ft.	475 ft.	41.4 ft.
	Middle	Nil	Nil	Nil	Nil	Nil	Nil
	Lower	Nil	Nil	Nil	Nil	Nil	Nil
4.9.63	Upper	500	48.6	560	55.7	500	79.3
	Middle	Nil	Nil	Nil	Nil	Nil	Nil
	Lower	Nil	Nil	Nil	Nil	Nil	Nil
5.9.63	Upper	400	28.6	575	28.6	525	59.1
	Middle	Nil	Nil	Nil	Nil	15	3.8
	Lower	50	38.3	50	19.2	45	27.1
6.9.63	Upper	575	75.6	725	48.2	825	102.1
	Middle	25	15.0	Nil	Nil	25	14.2
	Lower	60	35.7	55	25.0	70	47.0
7.9.63	Upper	575	56.6	1015	82.4	700	114.6
	Middle	35	13.2	Nil	Nil	30	12.8
	Lower	45	29.5	50	28.9	55	47.1
8.9.63	Upper	750	87.1	1213	56.3	800	108.4
	Middle	25	14.4	20	9.4	30	7.9
	Lower	Nil	Nil	10	10.0	20	20.0
10.9.63	Upper	675	94.4	750	81.6	1175	143.3
	Middle	Nil	Nil	15	3.8	25	10.0
	Lower	100	34.0	115	69.1	140	46.3
12.9.63	Upper	Nil	Nil	875	96.5	1160	115.6
	Middle	25	10.8	Nil	Nil	40	15.4
	Lower	145	59.7	115	33.5	140	52.5

TABLE 4

The Movement of Tracer Pebbles at Hilpsford, Walney Island, from October 1963 to September 1964.

Date	Beach Section	Small Tracers		Medium Tracers		Large Tracers	
		Max. Distance	Average Distance	Max. Distance	Average Distance	Max. Distance	Average Distance
19.10.63	Upper	1115	658.3	1140	734.1	1240	612.0
	Middle	15	15.0	35	25.0	105	20.7
	Lower	25	77.5	170	36.0	165	47.5
16.11.63	Upper	360	360.0	1503	589.3	1000	473.0
	Middle	Nil	Nil	Nil	Nil	100	38.0
	Lower	190	131.3	220	98.6	385	68.4
14.12.63	Upper	620	474.0	1985	734.4	1045	478.5
	Middle	Nil	Nil	Nil	Nil	45	45.0
	Lower	250	153.3	235	128.6	210	71.5
18.1.64	Upper	1445	1070.0	1924	772.4	815	568.8
	Middle	140	106.7	165	106.1	195	102.4
	Lower	350	188.1	305	134.7	145	75.0
15.2.64	Upper	1425	815.0	1000	477.0	1830	576.2
	Middle	360	233.8	245	203.3	330	182.2
	Lower	405	233.8	295	134.7	270	116.4
14.3.64	Upper	790	707.5	1305	720.0	1425	584.7
	Middle	Nil	Nil	Nil	Nil	175	71.3
	Lower	500	225.4	380	167.9	290	134.0
10.4.64	Upper	1000	642.0	1140	631.3	920	528.1
	Middle	260	195.0	290	170.8	280	76.9
	Lower	380	140.9	310	106.7	265	69.6
9.5.64	Upper	570	570.0	1045	750.0	1350	695.7
	Middle	435	227.7	650	264.7	530	76.3
	Lower	505	179.6	660	161.4	630	118.1
12.6.64	Middle	455	282.0	285	140.6	220	53.0
	Lower	345	147.0	510	132.5	150	76.7
12.7.64	Middle	410	225.0	325	193.5	360	109.2
	Lower	305	210.3	475	209.4	495	105.8
15.8.64	Middle	255	169.3	255	154.0	320	90.2
	Lower	215	156.9	505	122.6	280	85.9
17.9.64	Middle	135	95.0	210	50.9	155	51.1
	Lower	390	210.0	315	128.4	265	103.9

THE CONTRIBUTION OF THE OFF–SHORE ZONE TO THE BEACHES

It has long been known that Morecambe Bay is choked with vast quantities of sand, probably of glacial origin. Borings carried out recently in connection with the feasibility study of the Morecambe Bay Barrage Scheme have proved that in places glacial sands and clays reach thicknesses of 240 feet. Whereas the frequent shifting of the tidal channels cut in the sand is well appreciated little is known about the overall movement of sediment over the bed of the Bay.

Whilst it appears that the shingle on the beaches of Walney Island has its source in the boulder clay cliffs which are being actively eroded on the west coast it seems possible that much of the sand present in such vast quantities on the beaches might have its origin off-shore.

Two sea-bed drifter investigations (fully discussed elsewhere [3, 4]) were carried out to study the net drift of water close to the sea-bed in Morecambe Bay. It is this drift, which is produced by tidal currents, waves and the wind, which affects sediment movement. Two distinctly different patterns of drift were revealed and it was concluded that there is an anti-clockwise movement in the outer part of the Bay directed towards the southern end of Walney Island and the south Furness coast, whereas there is a north-eastward movement in the inner part directed towards the head of the Bay. Both these sea-bed water movements appear to be governed mainly by tidal currents which may be reinforced by wind induced drifts under specific wind conditions.

It seems highly probable that the anti-clockwise drift in the outer part of the Bay may be carrying sand from the off-shore zone to supply the beaches around the southern end of Walney Island.

The processes at present producing changes around the coast of Walney Island are probably little different from those which have been acting since prehistoric times. Strong winds blowing over the maximum fetch across the diagonal width of the Irish Sea are capable of producing waves of an energy content up to 103.194 foot lbs/foot of wave crest/wave length which are driven onshore without refraction. Such winds are capable of raising the height of the tide by up to 3.5 feet, and producing a marked seaward drift of water close to the sea-bed. On the western side of the island maximum erosion of the cliffs and the greatest changes on the beach result from these conditions. Some of the eroded material is carried laterally along the beaches and is deposited in shingle ridges around the southern and northern ends of the island which thus become recurved in form. The heights of these ridges become raised as dunes develop upon them. At least in the case of the southern part of the island the source of the beach sand is probably in part the offshore zone of Morecambe Bay and adjacent parts of the Irish Sea.

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CONCLUSION

This study has important implications not only for Walney Island itself, but also for the neighbouring coasts and Morecambe Bay where intensive scientific and economic investigations into the feasibility of constructing a barrage or barrages are nearing completion. It is essential to understand the natural regime causing coastal evolution, before it is possible to predict the likely changes which would be brought about by extensive engineering works. Walney Island acts as a natural breakwater, protecting the docks, harbours and slipways of the shipbuilding town of Barrow-in-Furness and changes in the island due to erosion, whether natural or induced by man could have important repercussions there. The danger of the pollution of our coasts is being increasingly recognised and already the findings of this research project have been used in planning action in the event of this section being endangered by oil pollution. They need to be taken into account before the tipping of town waste causes another serious form of pollution along the seaward coast of the island, which is at present amongst the least spoilt in Lancashire.