

I.O.S.

CHESIL BEACH AND ADJACENT AREA:

OUTLINE OF EXISTING DATA AND SUGGESTIONS
FOR FUTURE RESEARCH

Report to the Dorset County Council and
Wessex Water Authority

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Wessex Water Authority

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CONTENTS

	Page
SUMMARY	1
1. INTRODUCTION	2
2. EXISTING PUBLISHED DATA	2
3. OTHER SOURCES OF DATA	4
3.1 Offshore	4
3.2 Wave data: computed and observed	5
3.3 Beach Sections	6
3.4 Gravel extraction	7
3.5 Tracer experiments and littoral drift	8
3.6 Additional sources	8
4. VALIDITY OF DATA	9
5. THE BEACH AS A FINITE RESOURCE	11
5.1 Introduction	11
5.2 Mechanism of replacement	11
5.3 Conclusions	12
5.4 Further research	12
6. IMPLICATIONS OF DATA ON SEA DEFENCES, COAST PROTECTION WORK AND GRAVEL EXTRACTION	14
7. CONCLUSIONS	16
ACKNOWLEDGEMENTS	19
REFERENCES	
TABLES	
APPENDICES	
FIGURES	

TABLES

1. Nature Conservancy beach sections availability: 1965-68
2. Dorset County Council " " " : 1955-59
3. " " " " " " : 1974-78
4. Chesil Beach: maximum crest height : 1955-79
- 5.a Extraction of beach material (c1935-1977): specific sites
- b " " " " overall (tonnes)

APPENDICES

1. Air photography (vertical) for area between Chiswell and Abbotsbury Beach/West Bay
2. Dorset County Council/Nature Conservancy Council Proposal for Research Contract, July 1974. Outline of research required.
3. C H Dobbie and Partners. Preliminary Report on Flooding at Portland, March 1979. Proposed research investigations
4. Sources examined for this Report
5. Data unobtainable during period of this Report

FIGURES

1. Site map to show Nature Conservancy section lines and place names referred to in text
- 2.a-c Site maps to show Dorset County Council section lines: (a) 1955-59; (b) 1974-77; (c) West Bay, 1977-78
- 3.a-i Comparison of selected Nature Conservancy/Nature Conservancy Council sections: 1965-1979
4. Comparison of part of beach crest traverse: 1955-1979

SUMMARY

This Report gives a brief outline of the evidence available in relation to sea defences, coast protection and gravel extraction in the area of coast extending NW from the Isle of Portland to approximately West Bay. It goes on to indicate lines of research which need to be undertaken to clarify the existing situation and resolve outstanding problems.

Section 2. summarises the existing published data about which there is either undisputed agreement or adequate documentation. The following section indicates other sources of information relevant to the seabed; computed and observed wave data; beach profiles; gravel extraction; and tracer experiments. In addition certain further topics are considered mainly in respect to the December 1978 and February 1979 flooding events at Chiswell and to seepage through the beach.

Section 4. assesses the validity of existing data. It is noted that there has been no recent bathymetric survey of the whole offshore area. Much of the other data, whether boreholes, beach sections or tracer studies, have shortcomings of one sort or another while the figures for gravel-winning provided for the 1966 Public Inquiry must be qualified.

Parts of Sections 5. and 6. suggest subjects where additional research is necessary, for example to provide sufficient information for a future Public Inquiry on gravel extraction. These include: an offshore sampling programme with related geophysical survey off West Bay; tracer experiments; calculations of chert reaching the foreshore in the Charmouth area; additional boreholes through the beach to confirm the volume of pebbles and cobbles present; well-documented beach sections; the rates of loss of material through attrition, and the nature and magnitude of percolation through the beach. There is a need for long-term acquisition of wave data.

Section 7 'Conclusions' provides a résumé of the previous part of the report and indicates other lines of research and data collection which could be of value. Long-term trends are frequently obscured by substantial fluctuations in the short-term. There is a need for greater emphasis on qualitative results.

Research needs to be coordinated better and investigations broadened to obtain maximum value for time, effort, and cost expended. Short-term goals must be set in the context of a longer term research programme, covering a representative range of environmental conditions.

1. INTRODUCTION

This Report is compiled in response to an approach to the Institute of Oceanographic Sciences by the Dorset County Council and the Wessex Water Authority.

The following terms of reference were specified.

Objectives:

To ascertain from existing data:

(a) whether the beach is a finite resource and what if any are the mechanics of replenishment.

(b) the implication of (a) on

(i) sea defence and coast protection work

(ii) gravel extraction

Extent of study area:

The coastline between Portland Bill and Golden Cap and such relevant landward and seaward areas.

Work programme:

Stage 1:

1. Identify all the available published and unpublished research work
2. Comment upon the validity of the data

Stage 2:

1. Appraise the data relevant to objective (a)
2. Prepare conclusions on replenishment
3. Indicate areas of further research that would be required to achieve objective (a)

Stage 3:

1. Appraise the data relevant to objective (b)
2. Indicate areas of further research that would be required to achieve objective (b)

It was subsequently agreed that while the whole field would be covered the staging would be modified and the present Report takes account of that decision.

2. EXISTING PUBLISHED DATA

Much of the literature concerning Chesil Beach has been summarised in Carr and Blackley (1974). Although written primarily from a geological and historical standpoint a lot of this information has a direct bearing on the remit for the present Report and will be outlined below in this Section.

- 2.1. There is evidence to suggest that there have been various changes in the crest height of Chesil Beach over the last 300-400 years and that at one time the crest may have been lower over most of the length between Abbotsbury and Portland. Between 1852 and 1968-9 the beach between Abbotsbury and Wyke Regis increased in height, by the order of 2 m, while that at Chiswell (Chesilton) has fallen. (See Fig 4 of this report. Most place names are indicated in Fig 1.)
- 2.2. Apart from the area opposite Portland Harbour recession landward of the beach crest was less than the potential scale error over the period 1852-1968.
- 2.3. The western limit of the beach is arbitrary depending upon the criteria used to define it (ie beach pebble grading; continuity of crest). It may be changing with time.
- 2.4. There were various potential sources of material; ie marine, fluvial etc and the relative significance of these sources is likely to have also varied with time in the long-term. Although the bulk of the material, chert and flint, could have been derived from a number of primary (and secondary) sources the diagnostic rocks (eg Triassic quartzites) are all derived from the SW. In general, there is little appropriate material now available to the beach from offshore.
- 2.5. Pebbles in boreholes become more angular with depth and are there derived from more local, less resistant, geological strata. (This implies that attrition is of some importance as a cause of loss of volume of the beach, at any rate in the long-term.)
- 2.6. There has been considerable disagreement about the nature and cause of longshore grading of beach pebbles and cobbles. However, recent work at Chesil confirms that, providing wave energy is high enough to move coarse material, the largest fraction on the exposed beach will move faster. Longshore transport is also dependent upon the angle of wave approach relative to the shoreline.
- 2.7. In tracer experiments near Wyke Regis, approximately Section 4. in Fig 1, longshore movement was predominantly towards the SE, ie in the direction of coarsening of particle size of the natural beach material, although coarsening of tracer pebbles towards the NW was recorded at one time. At Portland (where

waves approach approximately normal to the beach) lateral transport was much more random in its nature.

2.8. Grading alongshore is restricted to the zone above low water mark. It is not true that the direction of grading is reversed below low water; rather that there is no grading there.

2.9. The massive pebble and cobble deposits occur in the exposed, ie sub-aerial, part of Chesil Beach. Although shingle is present below low water mark it is as limited, discontinuous, horizons. (This explains why estimates for shingle volume range between 25 and 100 million tonnes; the volume of deposits below mean sea level is not adequately known from existing borehole coverage.)

Most of the published literature up until 1973 is included in Carr and Blackley (1974) and sources are appended to this Report in the References section. For other, often restricted documents and reports see Appendices 4 and 5.

3. OTHER SOURCES OF DATA

There are two groups of data. These are:

- (a) Information and surveys dating mainly from about 1955 which have not previously been analysed or have only been reported upon in brief.
- (b) Recent reports and surveys which post-date the 1974 paper summarised above and which are, in part, confidential. These relate largely to:
 - (i) Mains drainage/sewage disposal schemes
 - (ii) Flooding/^{at}Chiswell following the December 1978 and February 1979 events
 - (iii) West Bay sea defences. It is convenient to include reports relating to the earlier outfall schemes in this group.

For the present Report these sources will be grouped under:

- 1. Offshore
- 2. Wave data: computed and observed
- 3. Beach sections
- 4. Gravel extraction
- 5. Tracer experiments and littoral drift

3.1 Offshore

The principal early sources are from the former Physiographic Section of the Nature Conservancy. They include 2 surveys of the surface deposits on the seabed between West Bay and Chesil Cove. Twelve sections were examined in 1960 and 1961. While the location and transect lengths are available unfortunately the description of the samples and other relevant details are at present mislaid by NCC.

In April 1970 the Physiographic Section used a modified Kelvin Hughes MS-26A echo-sounder to examine the bedrock over the same general area. These data indicated that there was very little recent unconsolidated material above the 'solid' geology.

Three seabed profiles from conventional echo-sounding opposite West Bexington, Langton Herring and Portland Harbour were made in October 1966 as an extension of land surveys and boreholes, while a limited bathymetric and sidescan survey has been undertaken on behalf of C H Dobbie and Partners (WWA) by Mobell Marine in October 1979 off Chiswell.

Boreholes have been undertaken offshore in the Portland area by consulting engineers for the CEGB and, more recently, by Dredging Investigations Ltd for John Taylor and Sons, consulting engineers to WWA. Although it is difficult to specifically identify bedrock in the CEGB boreholes, all records suggest only limited quantities of coarse grained sediment.

This view has been confirmed in the vicinity of the Wyke sewage outfall by diving (report to John Taylor and Sons by Dr C Wooldridge) and an offshore geophysics (sidescan) survey of the same area by Dr C R Price in April 1978, again for John Taylor and Sons. The picture appears less clear cut in the West Bay area where more active interchange of sediments from the beach and nearshore may occur.

Tidal current observations have been carried out in relation to the Wyke sewage outfall scheme and it is understood further investigations will be made for CEGB in respect of the Herbury Point power station proposals. However, neither of these sets of data are likely to be germane to the terms of reference of this Report.

3.2 Wave data

3.2.1 Computed

Wave refraction computations by Professor P Holmes exist for the following offshore approach directions: 90° , 135° , 180° , 225° , 240° (direction of maximum fetch from the Atlantic) and 270° . A water level height of 5' above Chart Datum was assumed.

For each direction wave periods of 6, 8, 10, 12, 14 seconds have been analysed with the exception of 270° which is severely fetch limited. Here, only 6 and 8 seconds periods have been used. With both of the latter refraction is minimal; least energy is found at the W end of the beach.

For offshore wave approach directions of 240° , 225° and 180° the computations are complicated by caustics near to, or at, the shoreline. These offset some of the rays for 10, 12 and 14 second periods from 240° ; 12 and 14 seconds from 225° ; and 14 seconds from 180° .

For 240° , refraction of 6 s waves is negligible but 8 s ones show slight, although irregular, focussing especially near Section 8 (See Fig 1). The 10 s analysis suggests a substantial increase in energy SE of Section 9 and high levels continue for both 12 s and 14 s waves SE of Section 13 with a probable maximum near Section 7 (approximately Langton Herring). The picture for waves from 225° suggests relatively uniform energy levels along the whole beach although for 10, 12 and 14 s wave periods there appears to be slight focussing around Section 13 and a more definite one concentrated on Section 5 and adjacent areas.

Wave approach from 180° (ie due S) produces negligible refraction at 6 s and 8 s and leaves Portland unaffected. For 10 s and 12 s there are slight peaks around Sections 14 and 10 while for 14 s (an atypically long period for this direction) wave energy would be very low SE of Section 8.

Waves approaching from 135° have little effect on the Chesil Beach area. Even those of 10 s period and above which tend to be refracted reach the beach with low energy values. Waves from due E (90°) allow virtually no energy to reach the shore in the stretch of coastline between West Bay and Portland.

Further wave refraction studies have been undertaken by the Hydraulics Research Station at the instigation of C H Dobbie and Partners. These data concentrate on the Chiswell area.

3.2.2 Observed

A summary of waves recorded during 1968-70 at West Bexington and Chickerell has been published (Hardcastle and King (1972)). This shows that the median wave period for both sites was between 10 s and 10.5 s, although longer period waves were more prevalent at Chickerell. Mean wave heights were 0.23 and 0.26 m respectively. The greatest wave height (as H_s) at West Bexington was approximately 4 m.

Total data run for the West Bexington site covers the period 23 November 1968 to 7 May 1971; 2 March 1973 to 26 September 1977; 25 October 1977 to 30 August 1978 and 2 March to 5 April 1979. Records between March 1973 and September 1977 are especially good. Records from Chickerell were restricted to the periods 23 June 1969 to 12 February 1970 and 29 April to 7 November 1970. The methods of recording and analysis have varied over time. Unfortunately no data cover the period of the 2 major flooding events during the winter 1978-79 and the Meteorological Office wind data for Portland are also fragmentary for this time.

It is the intention of C H Dobbie and Partners to maintain a self-contained NBA pressure wave recorder approximately 480 m offshore of the tank farm in a depth of water of 20 m for a period of 1 year.

3.3 Beach Sections

In 1968-69 the Physiographic Section of N C, attempted to repeat John Coode's 1852-3 profiles and traverse along the crest of Chesil Beach. This project was largely successful aided by access to Coode's original field data and is reported in Carr and Gleason (1972) as well as summarised above. Additionally however, N C had surveyed 23 sections between Chiswell and West Bay (mainly) in 1965-66. (See Fig 1 and Table 1.) During 1977-78 Nature Conservancy Council in association with IOS, attempted to recapture many of these lines and those used in the Coode/NC comparison. A number of difficulties occurred in this attempt but examples are shown in Figs 3 a-i. The data suggest little change between Abbotsbury Beach and Langton Herring; an actual increase in crest height (typically 0.7 m but up to 1.2 m on Section 7) between Langton Herring and Tidmoor Point ie E of Section 5, and somewhat varied results further towards Portland eg a fall of 0.7 m on Section 1a but little consistent change on Section 1.

Other beach sections were undertaken by Dorset County Council (Tables 2,3) at various times. These fell into 3 periods: 1955-59 (mainly Chiswell to West Beach, Bridport, but including limited surveys at Chideock and Charmouth); 1977 (Lyme Regis to West Bay - 3 of these sections had also been done in 1974); and late 1977 to 1978 (West Bay). It is unfortunate that most of the latter 2 groups lack absolute height references while a major criticism of many of the sections, both DCC and NC, has been the lack of adequate documentation to enable long-term comparative studies to be attained.

This stricture applies to another cross-section, this time by the Portland UDC, dated March 1948. While it runs from Victoria Square, Chiswell, across Chesil Beach its precise position is not documented.

C H Dobbie and Partners carried out a number of sections related to the 1979-80 piezometer studies but while clearly of value for this particular project they do not afford comparisons with any earlier information.

It has been possible to use a number of surveys (see Table 4) to examine the crest height of the Beach in the area between Wyke Regis and Chiswell, especially between the tank farm and Chiswell. These records suggest (Fig 4) that there were no real changes between October 1955 and September 1978 in the latter area but dramatic variations between then and March 1979. The results lend substance to the view that alterations are almost unique and that the substantial changes between 1852 and 1968-69 may be due to only a single, or at any rate extremely isolated, occurrence(s).

3.4 Gravel extraction

According to HRS (1979) sand and gravel has been extracted from East Beach, West Bay for about 700 years. More recently shingle has been removed from the Chiswell area ^{by} 'pebble-picking', Cogden; Burton Bradstock; West Bay; and various localised locations farther W, eg Eype Mouth and Seatown. Tables 5a, b give some

indication of extraction rates from the mid-1930's to about 1977. The information is largely based on Jolliffe (1979) although the units have been standardised. The data suggest that 1.1 m tonnes have been known to be removed from the coastal stretch between Chiswell and West Bay. In a similar analysis at Swansea Bay, IOS found that actual extraction appeared to be about 40% greater than that recorded. Additionally, as far as Chesil is concerned, material was moved prior to the 1930's and may well have been extracted from other locations than those itemised in the table both then and subsequently.

Using the estimated volume of pebbles and cobbles from Chesil Beach given in Section 2.9 ie between 25 and 100 million tonnes, it suggests that from mid-1930 between 1.1 and 6.4% of the beach has been removed, apart from any losses attributed to attrition.

3.5 Tracer experiments and littoral drift

Jolliffe (1979) describes qualitative experiments extending over 18 months using simulated pebbles incorporating fluorescent particles. This study was undertaken in West Bay. The results suggest that while labelled material travels from E to W, ie the opposite shown as the general trend in the Wyke Regis area, it does not move in the opposite direction. The Hydraulics Research Station (1969; 1979) also expressed this view in part because shingle extended further seaward along the E jetty of the West Bay harbour approach than along the W jetty. It had been formulated in the 1955 and 1966 Public Inquiries.

It is the present writer's view that the results obtained at West Bay may be an artefact (see Sections 4.5 and 5.4). Further investigations are needed.

3.6 Additional sources

Some aspects of the mains drainage, sewage disposal and Chiswell flooding reports have been referred to earlier. One aspects which is important from a number of standpoints is the permeability of the beach. Kolbuszewski (1977) wrote 'very little information exists on the actual behaviour of water and the hydraulic properties of Chesil Bank'. To this end C H Dobbie and Partners installed 17 piezometers along 5 lines in the Chiswell area during the 1979-80 winter together with several water level tubes. Earlier analyses had been restricted to that part of Chesil Beach backed by the Fleet lagoon. There the initial investigation was carried out in 1967-68 by George Wimpey Ltd for the CEGB and the data analysed by J Whitaker (1972 and in press) and P A Poulter (1979). Both authors supplemented the CEGB data. Poulter considered that while salinity may be somewhat greater near the beach relative volumes are small and under normal conditions seepage is unimportant. This view is the opposite of that taken by Bird (1971) and Bownass (1979).

The description of the meteorological conditions which caused the February 1979 flooding at Chiswell has been described by Draper (1979), Bowmass (1979) and C H Dobbie and Partners (1979). It is concluded that the conditions giving rise to the February flooding occur very infrequently. The last similar set of conditions appears to have been in 1904. Lewis (1979) discussed the flooding mainly from a socio-economic standpoint.

Some reference to borehole data has been made under earlier headings. (See especially 2.5 and 3.1.) Borehole information is important for calculating volume of material; potential sources offshore; permeability of the beach, susceptibility to attrition etc. Principal sources are the various site investigations carried out by different firms on behalf of the CEGB; further boreholes are likely to be carried out in respect of Herbury Point and offshore of that area. Apart from boreholes undertaken for John Taylor and Co, Norwest Holst made 2 series, the first for Weymouth and Portland Borough Council in respect of the sewage and mains drainage scheme and the second for C H Dobbie and Partners related to the piezometer studies. Most of the earlier series are shallow; the later ones lack detailed records. A few boreholes were also carried out for the (then) Nature Conservancy and, like certain CEGB data, have already been reported. As in the case of the levelling information the maximum value has not been realised for most of these bores since they were designed to achieve a specific, and limited, purpose rather than provide wider benefit.

Dr D Brunsden (King's College, London) has carried out extensive research into the mudflows and landslips in the Charmouth area. As a result of preliminary calculations he estimates (personal communication) that sufficient chert and other solid material is supplied to the shore to make this an important potential source of beach supply. Further studies are required. Additionally, if proved significant, then work is required to determine where the rock and pebbles go to once they reach the beach. Although Hoyle and King wrote: 'It is emphasised that the beaches on the farside (W) of the (Bridport) Harbour wall are not part of the Chesil Beach and are not connected with it in any way' there appears to be no real proof of this view.

4. VALIDITY OF DATA

In general, the data incorporated under Sections 1. to 3. are likely to be of high reliability as far as they go. However, the following reservations should be made.

- 4.1. Borehole data are only representative of the actual site. Fines may be washed out in using shell and auger techniques above the water table. Most analyses only relate to specific aspects (see 3.6).
- 4.2. Offshore surveys. There has been no detailed published Admiralty hydrographic survey offshore of Chesil Beach and Lyme Bay since 1855. As noted above (Section 3.1) some hydrographic and geophysical work has been undertaken over the last decade or so but, while almost entirely corroborative of the view that there is little coarse sediment over bedrock, the area covered is rather restricted. The rediscovery of the NC Physiographical Section's records for 1960 and 1961 would be of value in this context.
- 4.3. Observed wave data. There is a considerable body of information for the West Bexington site but in spite of this wave data coinciding with critical flooding events are not covered. It seems unlikely that a 1-year deployment by C H Dobbie and Partners will prove any more satisfactory than the similar duration one by NC at Chickerell.
- 4.4. Wave refraction computations. The report by Professor Holmes indicates the critical nature of direction of wave approach, ie the difference between waves with an offshore approach direction of 240° as compared with those from 225° and 270° . However the refraction plots are not very detailed. This should be remedied for the Chiswell area by HRS's study.
- 4.5. Tracer studies. The data from investigations at Wyke Regis, Portland and West Bay give totally different results. It is suggested here that the Portland ones are a fair representation of the processes occurring but the Wyke results are somewhat biased by the grades of pebbles and cobbles employed. The West Bay tracer programme was complicated by susceptibility of the particles to wear, atypical particle size and initial angularity of the tracer. Other complications attributable to availability of, or lack of, beach material; infilling of extraction areas and to the localised hydraulic conditions at the harbour entrance are possible.
- 4.6. Beach sections. Dorset County Council inaugurated a programme of profile measurements in 1955. Surveys were fairly frequent until the end of 1957. A new programme began in 1974 but with different lines even when the same general area was being surveyed. Furthermore many of the later series lack absolute datums. The (then) NC's Physiographic Section undertook beach sections as an

adjunct to its research programme in 1965-66. It was not considered that these (or other surveys in 1968-69) would be remeasured subsequently and this accounts for the difficulty in reoccupying the precise lines in 1977-78 when NCC attempted to repeat some of the profiles. Other profiles are of a 'one-off' nature, such as those by Land and Marine Contractors at West Bay in 1969.

4.7 Gravel winning from beach. The records submitted to the 1966 Public Inquiry are not complete and the units of measurement vary. The figures listed (Table 5a, b) must be regarded as very approximate (as indeed is the calculation of the volume of beach material available). The order of magnitude should be about right however.

It can be seen from the above list that a coordinated overall research programme could, by now, have been in the position to answer many of the questions still only partly resolved. What is more this could have been achieved at relatively little cost in, say, permanent marking of beach sections or more comprehensive sampling of boreholes. Such a programme would need to be multi-purpose and multi-disciplinary eg a wider interchange between engineering and geologically orientated projects.

5. THE BEACH AS A FINITE RESOURCE

5.1 Introduction

Carr and Blackley, (1974) considered that all the evidence indicated that Chesil Beach, defined by them as running between Portland and West Bexington, was a relict feature. This evidence took the form of:

- (a) known deposits of pebbles and cobbles offshore were very limited,
- (b) pebbles were more angular and contained a higher percentage of local material at depth, ie the present beach has reworked and rounded the shingle. New material would be expected to be more angular,
- (c) no substantial changes in plan outline had occurred over the past century.

New data, mainly from the Chiswell area and offshore of it, merely helps confirm the original views.

5.2 Mechanism of replacement

However, it is not certain that there is no 'new' material further W. Indeed, recession of the coastline in the Charmouth area provides considerable but so far unquantified chert (as well as 'mud') which might be regarded as a

potential source. Additionally, there appears to be some interchange of sand-grade sediment in the area of West Bay at least as far as 250 m offshore, (HRS 1969).

Small quantities of Portland quarry waste reach the beach from time to time. The limestone component is relatively soft and soon worn away. Very slow landward retreat of Chesil Beach results in rock fragments eventually being exposed on the seaward face eg/^{the} Forest Marble 'debris slope' at West Bexington. But this, the mudflow source further W, and the occasional cliff falls between Burton Bradstock and West Bay are all the consequences of recession and cannot really be regarded as 'new' material. It is just possible that some of the sand grade sediment off West Bay may be.

Present-day criteria, based on experiments off Worthing, Sussex, allow extraction of gravel at depths exceeding 18 m on the grounds that pebbles do not move beyond these depths. These criteria are subject to review but suggest that, even were it present, shingle would be unlikely to reach Chesil Beach from offshore SE of East Fleet (Section 6) with its depths of the order of 27 m or more less than 1.5 km of the shoreline.

Kelp rafting (transport of pebbles because of increased buoyancy due to attached seaweed) does not appear to be an important mechanism here (Jolliffe 1979).

5.3 Conclusions

It is apparent that nearshore sources of single supply are limited and mainly result from erosion of the existing coastline. While some gravel occurs well offshore in Lyme Bay this is likely to be immobile because of its depth below sea level. Some sand or coarser material may reach the coast from closer inshore at West Bay. Although this seems improbable it needs to be proven or disproved.

5.4 Further research

The available evidence goes far to demonstrate that there is no offshore, or indeed any substantial, source of single to replenish that extracted from the foreshore or wasted by attrition, at least over the coastline SE of West Bexington. Some additional data would be welcome and the site investigation offshore of Herbury Point may help provide this.

Elsewhere, the picture is less clear and it is suggested there is need for:

(a) A sampling programme in the West Bay area to determine the size of sediment offshore. If there are suitable 'pea-sized' or coarser pebbles then their lateral distribution needs to be mapped and the depth of the deposit determined by geophysical methods. The 1969 report by Land and Marine Contractors Ltd gives sand with some boulders offshore but does not cover a sufficiently large area to answer the question.

(b) Quantitative tracer experiments are required to confirm the results reported by Jolliffe (1979), using more representative labelled material and examining the fate of sediment placed W of the West Bay harbour entrance. It may prove worthwhile to examine longshore particle movement in one of the small embayments along the stretch of coast between West Bay and West Bexington particularly in relation to shingle extraction at Cogden Beach. Transport of sediment from E to W recorded by Jolliffe may be an attempt by the beach to make good excavations at West Bay. Similar tracer work needs to determine what happens to coarse material reaching the shoreline at, say, Black Ven (Charmouth).

(c) Calculations need to be made as to the quantities of rock/pebbles arriving on the beach at Black Ven near Charmouth, and elsewhere.

(d) A number of additional boreholes should be made through the beach at various sites to complement those already in existence. The principle (but by no means the sole aim) of these would be to gain a better knowledge of the volume of cobbles and pebbles present in Chesil Beach, and further W, and hence to have a better feel for the proportion being removed.

(e) A series of well-documented and clearly identifiable beach sections should be undertaken. It is less important for these to be done frequently than to be rapidly surveyed after extreme conditions. Although while gravel extraction continues the beach should be monitored from time to time in any event.

Partly because of problems of accurate ground control and short-term beach variability, it is not advocated that air photographs be taken on a routine basis as has been done by Southern Water Authority along the coast of Sussex since 1973. Accurate photogrammetry would be needed to obtain meaningful data. Neither photogrammetry nor beach sections provide any useful data about volume of sediment below low water mark. It would be useful, but difficult, to extend profiles to cover this zone.

(f) Research needs to be carried out to assess the effect of wear on flint and chert pebbles. Some of this work already exists and has been reported in papers by Humbert, Kuenen and Sames, but needs to be applied to the specific Chesil problem. If attrition really is an important process, which is unlikely, and the order of wear was comparable with that of commercial extraction, then the situation would become doubly serious.

It will be noted that Section 5.4 emphasises the need for quantitative results. Most work until now has been qualitative in character.

6. IMPLICATIONS OF DATA ON SEA DEFENCES, COAST PROTECTION WORK AND GRAVEL EXTRACTION

Many of the points raised in Section 5. as a whole, and the research proposals formulated in 5.4 in particular, have a direct bearing on sea defence, coast protection and gravel extraction.

6.1 If no new material is added to the coastline to make good that removed for commercial purposes (and any that may be worn away through beach processes) then it follows that some readjustment of the foreshore will take place. It is unlikely that this adjustment will be restricted to the point of extraction, especially in a beach with minimal lateral obstruction between West Bay and the Isle of Portland even although the longshore grading does imply an equilibrium portion for any specific particle size.

Geological, historical, and present-day evidence suggests that coastal recession W of Abbotsbury (and probably as far E as Portland) has occurred for centuries. There seems every reason to expect it to accelerate if commercial extraction takes place but the relative rates are unknown. For the section of Chesil Beach, SE of Abbotsbury, recession between 1852 and 1969 did not exceed 17 m opposite Portland Harbour while, over much of the beaches' length, retreat either did not occur or was not measurable. The natural rate of recession should not result in serious short or medium term coast protection problems but extraction, coupled with man-made sea defences and harbour works, appear to have resulted in more serious difficulties. These include:

(a) The sea wall at Chiswell seems to have been designed without adequate height and so is unable to withstand overtopping; it is also subject to scour at its base. Furthermore there is some doubt as to the alignment between the wall and the unconsolidated natural defence of Chesil Beach. Certainly evidence suggests much more rapid changes in the crest of Chesil Beach since the sea wall was built than in the century previously; changes which are concentrated in the immediate junction area. It may be that the volume of material remaining in the beach is becoming critical to its stability but, judging from the historical record, occasional overtopping occurred in the past although evidence of breaching is more suspect.

C H Dobbie and Partners have suggested that the increased incidence of flooding may be due to a loss of fines from the lower layers of the beach. This hypothesis is an interesting one but is particularly hard to measure since 'undisturbed' samples are difficult to obtain and percussion shell and auger techniques result in loss of fine material above the water table. As

Dobbie's have observed the piezometer study between Chesil Cove and the tank farm has not yielded the hoped-for results largely due to the localised nature of seepage points through the beach.

(b) Sea defences at West Bay. These have been the subject of a recent report (HRS 1979). The long-term recession of the cliffs, especially W of the harbour may have been aggravated by the harbour jetties. The latter were originally open lattice-work and so enabled longshore transport of shingle (as well as causing obstruction of the harbour entrance). With retreat of the beach on the W side, and deterioration of the groyne system there, scouring has become more evident at the junction of the promenade and the harbour approach wall and sea defences have been severely damaged on several occasions resulting in substantial emergency works.

(c) Gravel extraction. Data given in Table 1a, b indicate that extraction along the W end of Chesil Beach represents a perceptible, and possibly a sizeable, proportion of the available material. Although quantities extracted at the Chiswell end were small by comparison they represented specific grades of pebbles. Because of the well-known longshore grading, this would have resulted in a shortage at specific locations as well as damaging the scientific importance of the site.

As noted above extraction at localised sites is likely to have more widespread implications because of draw-down of material into the former from peripheral areas.

6.2 Many of the research requirements needed to clarify the effect of existing sea defences and coastal structures, together with gravel extraction, have been listed in Section 5.4. In addition:

(a) Research needs to be carried out to evaluate the way in which water percolates through the beach especially if the present studies by C H Dobbie and Partners prove inconclusive. This problem has a major bearing on the primary causes of flooding (as distinct from flood alleviation) at Chiswell. Such research should not be restricted to that immediate area, however, but include the stretch of Chesil Beach backed by the Fleet where contradictory views on seepage have been expressed previously.

(b) West Bay: It has already been suggested (Section 5.4b) that sampling and tracer studies should be made in this area to examine longshore transport and possible offshore sources. The problem of erosion along West Beach and scouring at the junction of the sea wall with the harbour jetty has been discussed by HRS (1979) who have suggested a scheme for remedial action. Their

proposal of rubble-stone mound groynes, beach nourishment and additional armouring will probably not require any related research or modelling programmes.

Long-term wave data acquisition is also important (see 7.2 viii).

7. CONCLUSIONS

7.1 Hoyle and King, in their 1978 Coastal Plan to the WWA wrote: 'The most vulnerable stretch of coastline in the British Isles today is that of Dorset, particularly the Chesil Bank (which) is not a source of raw material to be exploited but an enormous asset to be protected and preserved'. 'Sooner or later some ill-advised construction will initiate a chain of erosion problems which will irreversibly damage the bank and cost immense sums of money'.

This present Report has focussed attention on a number of fields where existing data are inconclusive and where further research is required to help determine future policy.

(i) At present the actual volume of shingle constituting Chesil Beach and the coastline from Golden Cap eastwards is not known.

(ii) While it is clear that there is no substantial source of new material reaching the beach E of West Bexington it is less certain that fine grades do not do so in the environs of West Bay harbour. Quantities of pebbles or coarser particles from landslips in the Charmouth area need to be assessed as do their ultimate fate.

(iii) The effect of extraction at West Bay and Cogden Beach on other areas alongshore and hence the peripheral areas' susceptibility to erosion, is not adequately known. Nor is the actual mechanism of transport around the harbour jetties at West Bay.

(iv) Rates of wear of flint and chert pebbles under conditions comparable with those occurring on Chesil Beach are not sufficiently well documented.

(v) Beach porosity and permeability are important in respect of flooding especially under extreme conditions. Current investigations in the Chiswell area may need to be extended both there and to other sites.

7.2 To meet these problems it is suggested that research is undertaken into the following (not in any order of priority):

(i) Offshore sampling programme in West Bay area possible supplemented by geophysical surveys.

(ii) Calculations as to quantities of pebbles/cobbles/rock reaching the beach from Charmouth area.

(iii) Tracer experiments to determine:

- (a) longshore transport at West Bay
- (b) effect of shingle extraction at Cogden Beach
- (c) fate of coarse material reaching foreshore from mudflows and landslips in Charmouth area.

(iv) Additional boreholes through Chesil beach and possibly areas to W, to determine total quantity of pebbles and cobbles more adequately. Samples should be analysed for geological composition; angularity etc.

(v) Research needs to be undertaken to resolve questions as to rates of wear of flint and chert pebbles which form the vast majority of the beach pebbles.

(vi) A comprehensive, systematic, well-documented series of beach sections should be surveyed from time to time. In order to gain long-term perspectives it is suggested an attempt be made to reoccupy and then permanently mark some of the profile lines surveyed in the past.

(vii) Studies need to be made as to the permeability of Chesil Beach and especially its variability both vertically and laterally.

(viii) Wave data needs to be acquired on a long-term basis. It might prove best to remobilise the West Bexington site and establish correlations between this and a Waverider buoy deployed for a shorter timespan offshore of the tank farm at Portland.

It is to be noted that the most acute gaps in the information available until recently relate to the Chiswell area and to the coastline to the W of West Bexington. The recent site investigation at Chiswell by C H Dobbie and Partners will have gone a considerable way to resolve problems there. Thus the future emphasis needs to be directed mainly to the western area of Chesil Beach and the coastline as far as Golden Cap.

7.3 Other areas where further data would be useful but probably not essential are:

(i) Over most of the offshore area there is no recent bathymetric survey although small areas have been resurveyed in respect of specific problems or projects eg on behalf of C H Dobbie and Partners and John Taylor and Sons, both acting as agents of WWA. Dobbie's note recession of deep water contours off Chiswell since the 1855 survey. Wimpey Laboratories are carrying out a bathymetric survey during summer 1980 for CEEGB, extending from approximately Sections 4 to 10 (Fig 1) over a zone up to 2 km offshore. This, coupled with the other 2 surveys, will mean that there should be reasonable bathymetric coverage along the beach offshore to the SE of Abbotsbury Beach.

(ii) Additional boreholes and geophysical surveys would also prove of value in helping confirm existing information. Sidescan sonar surveys, seabed

sampling, and recording current meter investigations by Wimpey's for CEEB again should help to achieve these objectives over their particular area of investigation.

(iii) Additional data on tidal heights, and hence tidal constituents, in the area between Isle of Portland and Lyme Regis. It may be possible to link this work with the long-term acquisition of wave data or the CEEB's current meter analyses.

Supplementary research, such as that by the Department of Oceanography, University of Southampton, into numerical modelling of the tidal regime of the Fleet lagoon, should in general be welcomed.

There is a considerable agreement between the research indicated herein and that proposed by NCC/DCC in 1974 and by C H Dobbie and Partners in 1979. However, some aspects suggested here are new while other proposals, notably a study of the slopes of the hills landward of the Fleet, have been omitted as irrelevant.

7.4 General considerations

(i) Because short-term variability eg the loss of large volumes of material from the beach face during storm conditions, is so great the long-term trends are difficult to determine.

(ii) Much of the earlier work on Chesil Beach has been geologically orientated and qualitative, rather than quantitative. Steps should be taken to obtain more precise figures.

(iii) The value of site investigations, surveys, and research has not been maximised. With prior knowledge and coordination it should have been possible for cores to have been examined on a more comprehensive basis while bathymetric, geophysical and topographic surveys could have been rendered compatible and extended with only marginally increased cost. Similarly, beach profiles and traverses could have afforded long-term comparisons instead of being on different section lines spread intermittently over time. Some form of coordinated action is required to ensure that future studies result in maximum value for the time and effort expended.

Since most of the site investigations have been carried out by, or on behalf of statutory organisations this should prove possible without undue additional expense. DCC might feel it was appropriate to assume this role of administrative coordinator and also to provide limited financial support to supplement these, or other, research projects. Technical advice should be sought outside where appropriate and some monetary provision again needs to be made to meet such contingencies.

(iv) As noted by the Hydraulics Research Station (1979) research needs to be long-term. HRS suggested a 5 to 10 years study of the area between Charmouth

and Portland. Although in certain respects even this span must be regarded as a minimum, short-term objectives for specific aspects of the research programme should be attainable over a much briefer period. But short-term investigations of permeability, wave climate and beach profile changes are liable to produce unrepresentative results; even longer-term ones may do so. For example, if the February 1979 flooding event has a return period of about 70 years then neither a medium-term programme which encounters, nor one that does not encounter, such a phenomenon is typical of the overall scene.

7.5 It has proved impossible during the period of this report to obtain all the documents and reports desirable although it is believed that most relevant data are discussed. Appendix 4 lists the various sources examined; Appendix 5 itemises those unobtainable. It was not considered appropriate to recommend studies relating to the structural characteristics of the Chiswell sea wall.

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J Taylor and Sons

Weymouth and Portland Borough Council

- Airy, G. (1853). In discussion, Coode.
- Airy, G. (1865). In discussion, Redman.
- Airy, G. (1875). In discussion, Prestwich (1875a).
- Arkell, W. J. (1947). 'The geology of the country around Weymouth, Swanage, Corfe and Lulworth'. *Mem. Geol. Surv. Gt. Br.*
- Arkell, W. J. (1956). 'The effects of storms on Chesil Beach'. *Proc. Dorset Nat. Hist. Archaeol. Soc.*, 76, 141-145. (Volume for 1954).
- Atkinson, E. H. T. (1927). 'Some Abbotsbury records'. *Proc. Dorset Nat. Hist. Antiq. Fld. Club*, 48, 70-85.
- Baden-Powell, D. F. W. (1930a). 'On the geological evolution of Chesil Bank'. *Geol. Mag.*, 67, 499-513.
- Baden-Powell, D. F. W. (1930b). 'Notes on the Raised Beach mollusca from the Isle of Portland'. *Proc. Malacological Soc.*, 19, 67-76.
- Beche, H. T. de la (1830). 'Notes on the formation of extensive conglomerate and gravel deposits'. *Phil. Mag.*, Series 2; 7, 161-171.
- Bidder, G. P. (1853). In discussion, Coode.
- Bird, E. F. C. (1972). 'The Physiography of the Fleet'. *Proc. Dorset Nat. Hist. Arch. Soc.* 93, 119-124. (Volume for 1971).
- Black, W. J. (1879). 'Remarks on the Chessil Bank'. *Trans. Manchester Geol. Soc.*, 15, 43-50.
- Bond, W. R. G. (1951). 'Theories as to the origin of the Chesil Beach'. *Proc. Dorset Nat. Hist. Archaeol. Soc.*, 73, 163-170.
- Bristow, H. W., and W. Whitaker (1869). 'On the formation of the Chesil Bank, Dorset'. *Geol. Mag.*, 6, 433-440.
- Buckland, W. (1860). Cited in Damon.
- Camden, W. (1586). *Britannia*, 1st English ed. 1610 (originally in Latin).
- Carr, A. P. (1969). 'Size grading along a pebble beach: Chesil Beach, England'. *J. Sedim. Petrol.*, 39, 297-311.
- Carr, A. P. (1971). 'Experiments on longshore transport and sorting of pebbles: Chesil Beach, England'. *J. Sedim. Petrol.*, 41, 1084-1104.
- Carr, A. P. and M. W. L. Blackley (1969). 'Geological composition of the pebbles of Chesil Beach, Dorset'. *Proc. Dorset Nat. Hist. Archaeol. Soc.*, 90, 133-140. (Volume for 1968).
- Carr, A. P. and M. W. L. Blackley (1973). 'Investigations bearing on the age and development of Chesil Beach, Dorset and the associated area'. *Trans. Inst. Br. Geogr.*, 58, 99-111.
- Carr, A. P. and R. Gleason. (1972). 'Chesil Beach, Dorset and the cartographic evidence of Sir John Coode'. *Proc. Dorset Nat. Hist. Archaeol. Soc.*, 93, 125-131. (Volume for 1971).
- Carr, A. P., Gleason, R., and A. C. King. (1970). 'Significance of pebble size and shape in sorting by waves'. *Sediment. Geol.*, 4, 89-101.
- Carreck, J. N. (1960). 'Whitsun field meeting to Weymouth, Abbotsbury and Dorchester, Dorset'. *Proc. Geol. Ass.*, 71, 341-347.
- Clarke, R. H. (1970). 'Quaternary sediments off south-east Devon'. *Q. Jl. Geol. Soc. Lond.*, 125, 277-318.
- Codrington, T. (1870). 'Some remarks on the formation of Chesil Bank'. *Geol. Mag.*, 7, 23-25.
- Coode, J. (1853). 'Description of the Chesil Bank, with remarks upon its origin, the causes which have contributed to its formation and upon the movement of shingle generally'. *Minut. Proc. Instn. Civ. Engrs.*, 12, 520-546.
- Corbyn, P. R. (1967). 'The size and shape of pebbles on Chesil Beach'. *Geogr. J.*, 135, 54-5.
- Cornish, V. (1898a). 'On sea beaches and sandbanks'. *Geogr. J.*, 11, 528-543.
- Cornish, V. (1898b). 'On sea beaches and sandbanks'. *Geogr. J.*, 11, 628-651.
- Cornish, V. (1898c). 'On the grading of the Chesil Beach shingle'. *Proc. Dorset Nat. Hist. Antiq. Fld. Club*, 19, 113-121.
- Damon, R. (1860). *The geology of Weymouth and the Isle of Portland*. London. (Some copies dated 1864; 2nd ed. 1884).
- Davies, G. M. (1935). *The Dorset Coast*. London. (2nd ed. 1956).
- Donovan, D. T. and A. H. Stride. (1961). 'An acoustic survey of the sea floor south of Dorset and its geological interpretation'. *Phil. Trans. R. Soc. B.*, 244, 299-330.
- Doornkamp, J. C. (1964). 'Subaerial landform development in relation to past sea levels in a part of South Dorset'. *Proc. Dorset Nat. Hist. Archaeol. Soc.*, 85, 71-77. (Volume for 1963).
- Fisher, O. (1873). 'On the origin of the estuary of the Fleet in Dorsetshire'. *Geol. Mag.*, 10, 481-482.
- Fitzroy, R. (1853). In discussion, Coode.
- Gibbs, J. (1853). In discussion, Coode.
- Gleason, R. and P. J. Hardcastle. (1973). 'The significance of wave parameters in the sorting of beach pebbles'. *Estuarine and Coastal Science*, 1, 11-18.
- Godwin-Austen, R. (1857). 'On the newer Tertiary deposits of the Sussex coast'. *Q. Jl. Geol. Soc. Lond.*, 13, 40-72.
- Greenwood, G. (1874a). 'Why are the largest stones found at the east end of the Chesil Bank?'. *Geol. Mag.*, dec. II, 1, 576.
- Greenwood, G. (1874b). 'Origin of the Fleet'. *Geol. Mag.*, dec. II, 1, 143.
- Greenwood, G. (1875). 'Origin of the Chesil Bank'. *Nature*, 11, 386.
- Groves, T. B. (1875). 'The Chesil Bank'. *Nature*, 11, 506-7.
- Hardcastle, P. J. and A. C. King. (1972). 'Sea wave records from Chesil Beach, Dorset'. *Civil Engineering*, 67, 299-300.
- Hardy, J. R. (1964). 'Sources of some beach shingles in England'. 20th Inter. Geogr. Congress, London. (Duplic. mss.).
- Harrison, J. R. (1848). 'Observation on the causes that are in constant operation to alter the outline of the English coast, to affect the entrances of the rivers and harbours, and to form shoals and deeps in the bed of the sea'. *Minut. Proc. Instn. Civ. Engrs.*, 7, 327-365.
- Harrison, J. T. (1875). In discussion, Prestwich (1875a).
- Hawkshaw, J. C. (1853). In discussion, Coode.
- *From Carr A P and M W L Blackley (1974). 'Ideas on the origin and development of Chesil Beach, Dorset'. *Proc Dorset Nat Hist Archaeol Soc*, 95, 9-17.
- Hutchins, J. (1774). *History and antiquities of the County of Dorset*. 2 vols. 1st ed.
- Hutchins, J. (1803). *History and antiquities of the County of Dorset*. 4 vols. 2nd ed. Revised by R. Gough and J. B. Nichols. Vol. 3 (1803) refers to Chesil and quotes Smeaton.
- Jolliffe, I. P. (1964). 'An experiment designed to compare the relative rates of movement of different sizes of beach pebbles'. *Proc. Geol. Ass.*, 75, 67-86.
- Kemp, P. H. (1960). 'The relation between wave action and beach profile characteristics'. 7th Conference in Coastal Engineering, Hague. *Proceedings*, 1, 262-277.
- Kemp, P. H. (1963). 'A field study of wave action on natural beaches'. *Inter. Assoc. of Hydraulic Research*. London. 1, 131-138.
- Kidson, C., and A. P. Carr. (1961). 'Beach drift experiments at Bridgewater Bay, Somerset'. *Proc. Bristol Nat. Soc.*, 30, 163-180.
- Kinahan, G. H. (1877). 'On the Chesil Beach, Dorsetshire and Cahore shingle beach, County Wexford'. *Q. Jl. Geol. Soc. Lond.*, 33, 29-41.
- Leland, J. (1710-12). *The Itinerary of John Leland the Antiquary published from the original mss. by T. Hearne*. Oxford. 9 vols.
- Lewis, W. V. (1931). 'The effect of wave incidence on the configuration of a shingle beach'. *Geogr. J.*, 78, 129-148.
- Lewis, W. V. (1938). 'The evolution of shoreline curves'. *Proc. Geol. Ass.*, 49, 107-127.
- Lilly, C. (1715). 'A report of the fortifications and artillery at Portland'. [B. M. Kings Geo. III Mss. 45 f 57].
- Luc, J. A. de (1811). *Geological travels*. London. Vol. II deals with Chesil. de Luc's tour dates from 1804.
- MacFadyen, W. A. (1970). *Geological highlights of the West Country*. London.
- Mansell-Pleydell, J. C. (1873). *A brief memoir of the geology of Dorset*. Blandford.
- Miller, R. L. (1958). 'A study of the relation between dynamics and sediment pattern in the zone of shoaling wave, breaker and foreshore'. *Eclogae Geol. Helv.*, 51, 542-551.
- Moss, A. J. (1962). 'The physical nature of common sandy and pebbly deposits'. 1. *Am. J. Sci.*, 260, 337-373.
- Moss, A. J. (1963). 'The physical nature of common sandy and pebbly deposits'. 2. *Am. J. Sci.*, 261, 297-343.
- Murray, J. (1853). In discussion, Coode.
- Neate, D. J. M. (1967). 'Underwater pebble grading of Chesil Bank'. *Proc. Geol. Ass.*, 78, 419-426.
- Palmer, H. R. (1834). 'Observations on the motions of shingle beaches'. *Phil. Trans. R. Soc.*, 124, 567-576.
- Pengelly, W. (1870). 'Modern and ancient beaches of Portland'. *Rep. Trans. Devon Ass. Advmt. Sci.*, 4, 195-205.
- Prestwich, J. (1875a). 'On the origin of Chesil Bank, and on the relation of the existing beaches to past geological changes independent of the present coast action'. *Minut. Proc. Instn. Civ. Engrs.*, 40, 61-114.
- Prestwich, J. (1875b). 'Notes on the phenomena of the Quaternary period in the Isle of Portland and around Weymouth'. *Q. Jl. Geol. Soc. Lond.*, 31, 29-54.
- Prior, E. S. (1919). 'The Bridport shingle. A discussion of pebbles'. *Proc. Dorset Nat. Hist. Antiq. Fld. Club*, 40, 52-65.
- Reade, T. M. (1873). 'The Chesil Bank'. *Geol. Mag.*, 10, 573-574.
- Reade, T. M. (1875). In discussion, Prestwich (1875a).
- Reade, T. M. (1876). 'Pebble ridges'. *Geol. Mag.*, dec II, 3, 360.
- Redman, J. B. (1852). 'On the alluvial formations, and the local changes, of the south coast of England'. *Minut. Proc. Instn. Civ. Engrs.*, 11, 162-223.
- Redman, J. B. (1865). 'The East Coast between the Thames and the Wash estuaries'. *Minut. Proc. Instn. Civ. Engrs.*, 23, 186-256. (Volume for 1863-64).
- Redman, J. B. (1875). In discussion, Prestwich (1875a).
- Reid, C. (1898). In discussion, Cornish (1898b).
- Rennie, J. (1853). In discussion, Coode.
- Richardson, N. M. (1902). 'An experiment on the movements of a load of brickbats deposited on the Chesil Beach'. *Proc. Dorset Nat. Hist. Antiq. Fld. Club*, 23, 123-133.
- Russell, J. S. (1852). In discussion, Redman.
- Russell, J. S. (1865). In discussion, Redman.
- Sames, C. (1966). 'Morphometric data of some recent pebble associations and their application to ancient deposits'. *J. Sedim. Petrol.*, 36, 126-142.
- Smeaton, J. (1803). Cited in Hutchins.
- Sparks, B. W. (1952). 'Stages in the physical evolution of the Weymouth lowland'. *Trans. Inst. Br. Geogr.*, 19, 17-29.
- Steers, J. A. (1946). *The coastline of England and Wales*. 1st ed.
- Strahan, A. (1898). 'The geology of the Isle of Purbeck and Weymouth'. *Mem. Geol. Surv. Gt. Br.*
- Taylor, I. (1765). *Dorsetshire*. Surveyed and engraved by Isaac Taylor. [B.M.: 2153(3)].
- Tucker, M. J. (1963). 'Analysis of records of sea waves'. *Minut. Proc. Instn. Civ. Engrs.*, 26, 305-316.
- West, R. G. and B. W. Sparks. (1960). 'Coastal interglacial deposits of the English Channel'. *Phil. Trans. R. Soc. B.*, 243, 95-133.
- Weston, C. H. (1852). 'On the sub-escarpments of the Ridgway Range and their contemporaneous deposits in the Isle of Portland'. *Q. Jl. Geol. Soc. Lond.*, 8, 110-120.
- Wilson, E. (1870). 'Notes on the Fleet and Chesil Bank'. *Geol. Mag.*, 7, 140-141.
- Winterbotham, H. S. L. (1926). Editor. *Survey Computations to be used in conjunction with the Text Book of Topographical and Geographical Surveying*, 3rd ed. London.

Additional References:

- Avebury, Lord (= Lubbock, J) 1902. 'The Coast', Chap 4 of The Scenery of England and the causes to which it is due. London 534 pp.
- Belderson, R H, Kenyon, N H and Stride, A H 1971. Holocene sediments on the continental shelf west of the British Isles. ICSO/SCOR Working Party 31 Symposium, Cambridge 1970. The Geology of the East Atlantic Continental Margin, ed Delany, F M, 1971. I.G.S. Report No 70/14, 157-170.
- Bird, E C E 1971a. A 17th Century attempt to drain the Fleet, Dorset: the County Magazine, pt 17, 8-10.
- Bird, E C E 1971b. The lost wall, Dorset: the County Magazine, pt 21, 25.
- Draper, L. 1977. Waves at Shambles Light Vessel, Portland Bill, during 1968 in A voyage of Discovery, ed Angel M.V. Pergamon Press, 696 pp
- Kenyon, N H and Stride, A H 1970. The tide-swept continental shelf sediments between the Shetland Isles and France. Sedimentology, 14, 159-173.
- Matthews, E R 1922. Coast Erosion and its prevention. J.Roy.Soc.Arts, 70, 477-89 and 491-505.
- Pingree, R D, 1978. The formation of the Shambles and other banks by tidal stirring of the seas, J.Mar.Biol.Ass.UK, 58, 211-26.
- Terzaghi, K and Peck, R B, 1967. 'Soil Mechanics in Engineering Practice', 2nd edition. Wiley, New York. 729 pp.

Table 1. Nature Conservancy (Physiographic Section) beach sections: 1965-66

<u>Section No</u>	<u>Survey date</u>			
	7 : 65	2 : 66	6 : 66	3 : 68
1	✓	✓	✓	✓
1a	✓			✓
2	✓	✓	✓	
2a	✓			
3	✓			
3a	✓			
4	✓		✓	
4a	✓			
5	✓			
5a	✓			
6	✓			
6a	✓			
7	✓	✓	✓	
8	✓			
9	✓			
10	✓	✓	✓	
11	✓			
12	✓			
13	✓	✓	✓	
14	✓			
15	✓			
16	✓	✓	✓	
17	✓			

For location, see Figure 1

Sections also taken through Wimpey (CEGB) boreholes opposite Portland Harbour; at Langton Herring and West Bexington. These extend offshore for between 700 and 1000m (October 1966).

TABLE 2

CHESIL : DCC Sections 1955-59

Sections	Dates surveyed												1959												
	1955						1956								1958										
	J	F	M	A	M	J	J	A	S	O	N	D			J	F	M	A	M	J	J	A	S	O	N
'A' (from BM near farm wall)	✓			✓		✓								✓				✓							
'Va' 'As shown Coode 1852' Portland Rly Stn										✓															Survey undated
'V' Chesil Cove										✓															
'W' Near Va									✓																
'Z' Ad 1855: Abbotsbury Swan.						✓		✓																	Conflicting dates for survey. Also one undated survey
" " (may be same)										✓															Site map included in file
'B' Old CG stn Abbotsbury			✓*		✓*					✓				✓					✓						*Liverpool datum
'C' East Beach Bridport				✓				✓					✓					✓						✓	
'D' West Beach Bridport				✓				✓					✓					✓						✓	
'A' Chideock																			✓			✓			
'B' "																			✓			✓			
'C' "																			✓			✓			
'E' "					✓			✓					✓					✓							
'F' Charmouth					✓			✓					✓												
Admiralty 'B'								✓																	

No surveys in 1957

(There seems to be various duplicate copies of Admiralty 1855 survey line: not clear re boundaries etc)

Some subsidiary traverses to and from BM's: crest heights on Chesil Beach in tank farm - Chiswell area but difficult to plot; dated 13.10.55.

All OD NEWLYN except where shown.

TABLE 3

CHESIL: DCC Sections 1974-78

Sections		Survey dates										
		5/74	4/77	7/77	11/77	1/78	3/78	5/78	7/78	9/78	11/78	
F	} Charmouth		✓									} No absolute heights
E			✓									
H	} Westhay Water		✓									
G			✓									
J	} (nr Golden Cap)											
I												
D2	} Seatown		✓									} No absolute heights
D3			✓									
D1			✓									
A	} Eype Mouth	✓	✓									} 5/74 absolute heights on A, B, C. 4/77 absolute heights on B & C only. Recession on B between surveys but not clear how much; possible plotting error also.
B		✓	✓									
C		✓	✓									
I	} Wear Cliff			✓								} No absolute heights. National Grid coordinates provided
J				✓								
K				✓								
L				✓								
M				✓								
N	} West Bay						✓	✓	✓	✓	✓	} Absolute height 11/77 only Poss. absolute height on manhole cover but not c Absolute height 11/77, 1/78, 3/78, 5/78, 7/78, 9/78 <u>not</u> 11/78
O							✓	✓	✓	✓	✓	
P							✓	✓	✓	✓	✓	
Q							✓	✓	✓	✓	✓	
R							✓	✓	✓	✓	✓	
S							✓	✓	✓	✓	✓	
T							✓	✓	✓	✓	✓	
U							✓	✓	✓	✓	✓	

Table 4

Chesil Beach : maximum crest height

<u>Date</u>	<u>Height (m)</u>	<u>Notes</u>
1955	14.73 (48.32')	DCC traverse
1968	14.67 (48.11')	NC
1972	14.51 (47.58')	UCS After gale
1977-8	14.10 (46.25')	WPBC, etc. But highest position excluded in survey (see Fig 4).
1979	13.58 (44.54')	IOS. Highest undisturbed point.

All outlines between October 1955 and September 1978 are very similar.

However that for March 1979 shows substantial changes reflecting the damage to the beach in December 1978 and February 1979.

Table 5a. Extraction of beach material from Chesil Beach between circa 1935 and 1977: specific sites.

			Notes
West Bay	1935-39	13,900 tons/yr (13,564 in 1939)	
	1945-55	7,600	10,000 tons/yr assumed for 1940-44 (8-9,000 during 1952-54)
East Beach	1955-6	9,108	} HRS gives 1956-66 as 123,420 tons
	56-7	7,463	
	57-8	9,604	
	58-9	5,165	
	59-60	9,596	
	60-61	8,659	
	61-62	7,191	
	62-63	8,290	
	63-64	21,805	
	64-65	26,738	
	65-66	18,910	} 8months only
	66-67	10,000	
	1969	5,620 yds ³	17,000 tons assumed for 1966-67; 7,500 for 67-8; /rest of 1968 = 4,200 yds ³
	70	4,747	
	71	6,648	
	72	5,823	
	73	7,385	
	74	7,322	
	75	6,426 = 8,500 tons	
	76	5,705 = 6,000	
	77	5,800	
Burton (Hive) Beach	1938-46	Total: 13,535 tons	
	1947-56	34,590	
	1957-66	19,878	1965=3,500 yds ³ ; 1966=3,500 yds ³ .
	1967-72	11,000	Estimated. Extraction ceased 1973
Cogden Beach	1932-42	19,500	
	43-44	202,469	Military use
	44-45	41,250	
	1956	1,517	} Total = 41,442 tons
	57	2,602	
	58	2,873	
	59	3,946	
	60	4,014	
	61	5,016	
	62	4,806	
	63	4,117	
	64	5,160	
	65	4,678	
	66	2,712	} 1st half
			Estimated 4,000 tons/yr for 1967-77
Chesil Cove area	1944-72	8,000 yds ³	Wraxall 'pebble-picking'. Latterly / 350 tons/yr.

Table 5b. Overall extraction

<u>Mid-1930's to 1977</u>	tons	tonnes
West Bay/East Beach	435,644	624,614
Burton Bradstock	79,003	80,267
Cogden Beach	348,660	354,238
Chesil Cove	8,679	8,818
		<hr/>
		= 1,085,937 tonnes
		<hr/>

The values given here are based on those in Jolliffe (1979). Extraction W of West Bay is omitted. So, too, is that pre-1930's. There may be other extraction which has gone unrecorded. The 1966 Public Inquiry indicates that planning permission then existed for: Seatown 2,500 tons/yr; Bridport and Burton Bradstock, 20,000 t/yr; Cogden, 4,000 t/yr; Burton, 3,000 t/yr.

The following conversion factors have been used: 90 lbs = 1ft³*; 1.43 tonnes = m³*; 1 Imperial ton = 1.016 tonnes.

*Terzaghi, K and Peck, R.B. (1967). Values for unconsolidated material.

APPENDIX 1List of vertical air photographs

<u>Area</u>	<u>Date</u>	<u>Source</u>	<u>Print Nos</u>	<u>Nominal scale</u>	<u>Notes</u>
Swyre-Cogden Beach	4.11.46.	RAF	3311-15	1:10000	
Abbotsbury castle-West Bexington	22. 1.48.	"	3282-85	1:10000	} Good definition. Tilt not recorded.
Abbotsbury swannery - Abbotsbury castle	22. 1.48.	"	4284-88	1:10000	
Cogden Beach-West Bay	7. 5.48.	"	3095-3101	1:10000	" " "
West Bay	7. 5.48.	"	4099-4101	1:10000	" " "
Portland tank farm - nr West Bexington	29. 7.63.	"	0011-33	1:10000	" " "
Abbotsbury Beach - Portland tank farm	5. 6.70.	St. Joseph Camb. Univ	RC8 S134-155	1:10000	Good definition. Some tilt at times.
E side of Isle of Portland	Undated	Fairey	1:406-415	1:6500	Good quality. Tilt not recorded
W " " "	"	"	1:432-439	1:6500	" " "
E coast of Portland - nr Wyke bridging camp	1. 6.77.	J A Story	086-116	1:3000	Other runs include Weymouth, Wyke Regis & I of Portland
Wyke Regis seawards across Chesil Beach	18. 5.79.	"	104-118	1:3000	
Portland to nr Wyke Bridging Camp	24. 2.79.	Fairey	7900/ 1:327-47	1:3000	Good photography: oblique shadows
Abbotsbury beach- Chiswell seawall	15. 9.79.	Cartogr. Services Soton	860:437-93	1:3000	Photo quality very good. Tile not recorded.

APPENDIX 2

Dorset County Council/Nature Conservancy Council: Outline of proposed research July 1974

The main areas of study can be summarised as follows:-

1. Land boreholes: possibly four to six boreholes drilled through the full thickness of the Beach. These would be drilled for the purpose of sampling the gravels forming the Beach and the foundations to gravel bank. The borehole casing, or an alternative arrangement would be left to form a permanent reference point for long-term monitoring purposes.
2. Submarine inspection: arrangements would be made, if considered feasible and safe, for appropriate sub-aqua inspection and sampling in the zone immediately offshore.
3. Longshore drift studies: extensive studies have previously been carried out by the then Nature Conservancy into drift of artificially introduced gravels. Similar tests, involving larger samples distributed in strips normal to the beach and stretching from the offshore zone onto the beach itself, could be considered. Alternatives exist and it is in this area that cooperation in the provision of transportation services might be encouraged from the gravel working companies.
4. Surveys of the Beach: both longitudinal and localised cross-profiling of the Beach would be required to supplement previous studies and support the new investigations.
5. Characteristics of beach gravels: possibly adequate work has been already published in this field but, inevitably, some supplementary studies will be required.
6. Maturity of inland slopes: geomorphological studies of these slopes, combined with the excavation of trial pits, limited boreholes, sampling and laboratory testing could provide background information to the relative maturity of these slopes in relation to similar slopes elsewhere in southern England.

It would appear desirable to concentrate these essentially shore-based studies at specific localities such as Chesilton, mid-way along the Fleet, Abbotsbury Beach, Cogden Beach and West Bay. Such localisation of detailed investigations could have greater long-term value in relation to the need for an eventual monitoring scheme.

Laboratory investigations would be required to support and supplement the field studies. These investigations would include an appropriate review of all previously available information (whether published or not), soil mechanics tests on the foundations of Chesil Beach, C₁₄ dating of peats or buried organic deposits and experimental attrition tests on gravels, quarry-run stone and other appropriate materials.

APPENDIX 3

C H Dobbie and Partners: Proposed investigations: March 1979

6.4 We would, therefore, recommend that the following investigations be undertaken as soon as possible.

6.4.1 A hydrographic survey be carried out in the West Bay (Portland) area. This survey should include:

- (a) An echo sounding survey
- (b) A sidescan sonar survey
- (c) Bed sampling (preferably by diver to accurately assess the sidescan results)
- (d) The installation of wave and tide recorders. Because of the severe exposure of this area, we consider at present that both these functions should be satisfied by a pressure type wave recorder with a suitable interrogation rate. The actual type to be adopted would need to be carefully studied (eg land line recording, or self contained record diver retrieved) but it is important that a full year's records should be obtained.

4.2 The installation of automatic recording piezometers across the landward slope of the Chesil Beach, the results of which will be to be correlated with the wave and tidal data recorded under the hydrographic survey. (An estimate for this work has been requested by the Weymouth and Portland Borough Council from Norwest Holst.)

4.3 A preliminary site investigation consisting of two boreholes through the Beach taken down to clay level. Grading analyses and SPT results will be required. (An estimate for this work has been requested by the Weymouth and Portland Borough Council from Norwest Holst.)

4.4 In order to establish the following:

- (a) The pattern of waves attacking the beach
- (b) The effects of the sea wall on the wave pattern
- (c) The effects of the proximity of Portland Bill
- (d) The location of any points of concentration of energy

A mathematical model analysis is recommended for which the Hydraulic Research Station at Wallingford has a capability.

In general data is listed under the commissioning body (eg photogrammetry by Fairey Surveys is found under C H Dobbie and Partners) but this is not invariable.

APPENDIX 4: Sources examined for this Report (Page 2)

<u>Originator</u>	<u>Title or Description</u>	<u>Notes</u>
Humbert F L	Selection and wear of pebbles on gravel beaches 1968	Geol Institut, Groningen, Netherlands. (Also related papers by Ph H Keunen same address)
Hydraulics Research Station	Bridport sewage outfall: a study of the security — May 1969 West Bay, Bridport, Dorset: a sea defence and coast protection study January 1979	Report No Ex 441. On behalf of Land and Marine Contractors Ltd Report No Ex 863. On behalf of Wessex Water Authority
Institute of Oceanographic Sciences	Chesil Beach: Computer refraction analysis: July 1973 and March 1974 Geophysics, hydrographic sections etc Basis for answers to parliamentary questions 22 Feb 1979 Traverse between Portland Bounds and Chiswell March 1979 Wave data	2 volumes of printout plus plots by Prof P Holmes, Dept Civil Engrg. L'pool Univ Undertaken by NC in 1966 and 1968 For sites and coverage both by NC and IOS see Section 3.2.2.
Jolliffe I P	West Bay and the Chesil Bank, Dorset — July 1979	Report to WDDC and DCC
Prof Kolbuszewski; Birmingham Univ	Chesil Beach drain channel study, 1977	
Land and Marine Contractors Ltd	Report on investigations relating to Bridport outfall, West Bay, 1969	
Lewis J	Storm and flood at Chiswell, Dorset June 1979	
MAFF	A survey of the sewage sludge disposal area in Lyme Bay, 1978	By Eagle R A et al. Fisheries Research Technical Report No 49
Meteorological Office	Wind data at Portland. December 1978 to February 1979	
Morris S	Notes on past major flooding events, Chiswell, Portland	And accompanying letter
Nature Conservancy Council	Beach sections 1977-78	
Southampton University Department of Oceanography, M Sc theses:	(a) High wave activity and flooding at Portland on 13 February 1979 (b) The Fleet: physical properties	By Bownass T M By Poulter P A. Uses G Wimpey Ltd data with some update

APPENDIX 4: Sources examined for this Report (Page 3)

<u>Originator</u>	<u>Title or Description</u>	<u>Notes</u>
Taylor, J and Sons	Weymouth and Portland long sea outfall: sidescan sonar survey. April 1978 Diving inspection of sea bed along line of proposed outfall. Feb 1978 Borehole logs by Foundation Engineering Ltd and Dredging Investigations Ltd	By Price, C R. All reports and data from John Taylor and Sons was for WWA.
Weymouth and Portland BO	1 section at Chiswell by Portland UDC, 1948 Aerial survey of Chiswell area. 1977 Ground survey of Chiswell to Smallmouth. 1978 Borehole logs and sample analyses by Norwest Holst Ltd	Based on photograph by J A Story Relates to main drainage scheme " " " "
Whitaker, J.	Taxonomy, ecology and distribution --- Dorset 1972	PhD thesis. Univ.Coll.of Wales, Aberystwyth. Subject of forthcoming paper in Proc. Dorset Nat. Hist. Arch. Soc.

All air photographs are listed in Appendix 1.

APPENDIX 5: Data unobtainable during the course of this Report

<u>Originator</u>	<u>Title of Description</u>	<u>Notes</u>
Dorset County Council	File relating to the 1966 Public Inquiry	Probably largely covered by Jolliffe 1979
Nature Conservancy Physiographic Section	Field notes relating to seabed surveys in 1960 and 1961 off Chesil Beach	Loaned by IOS to NCC in August 1978 and not subsequently located
Wooldridge C F	Underwater survey of the sea bed mobility off Chesil Beach 1977	Report for J Taylor and Sons re outfall

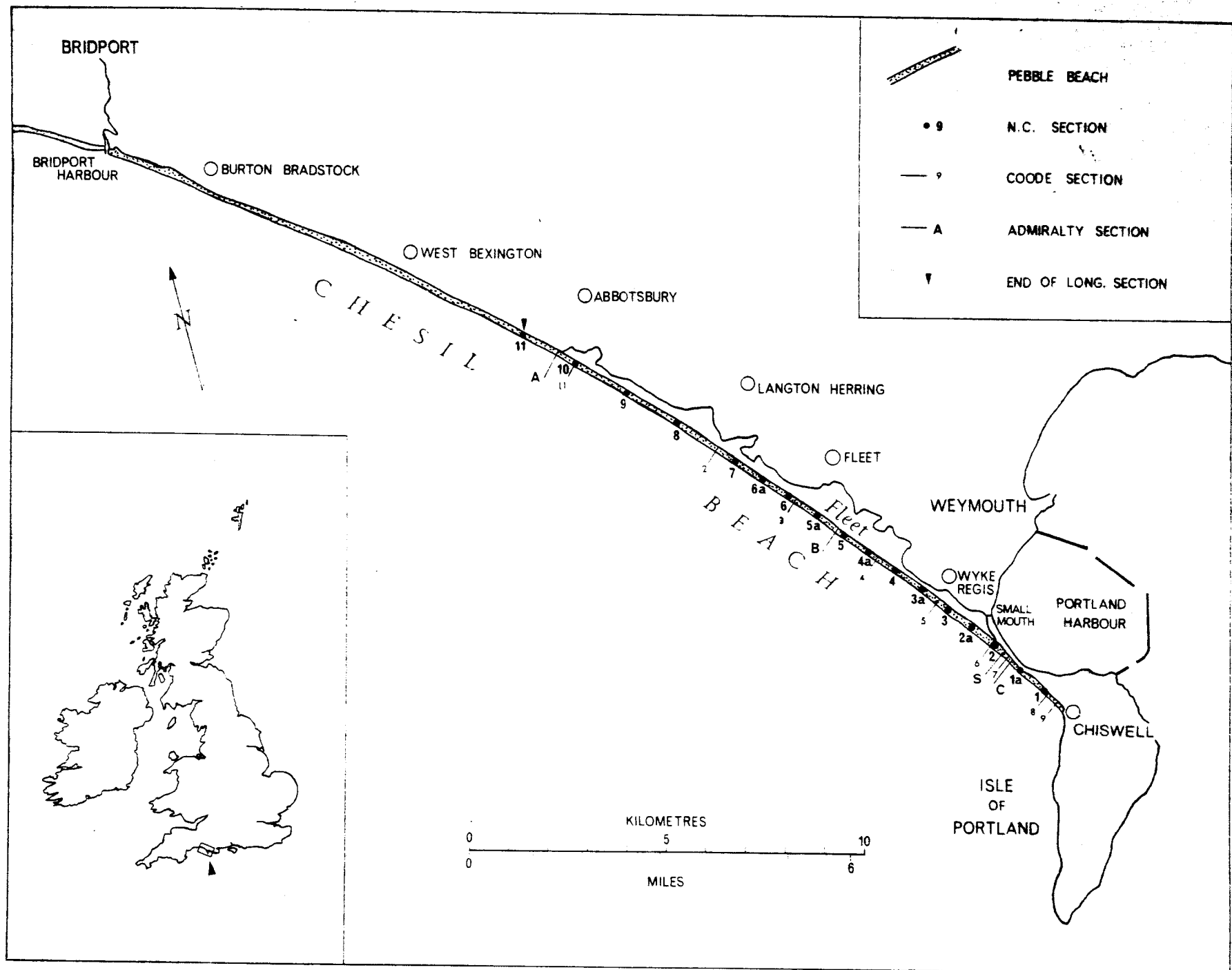
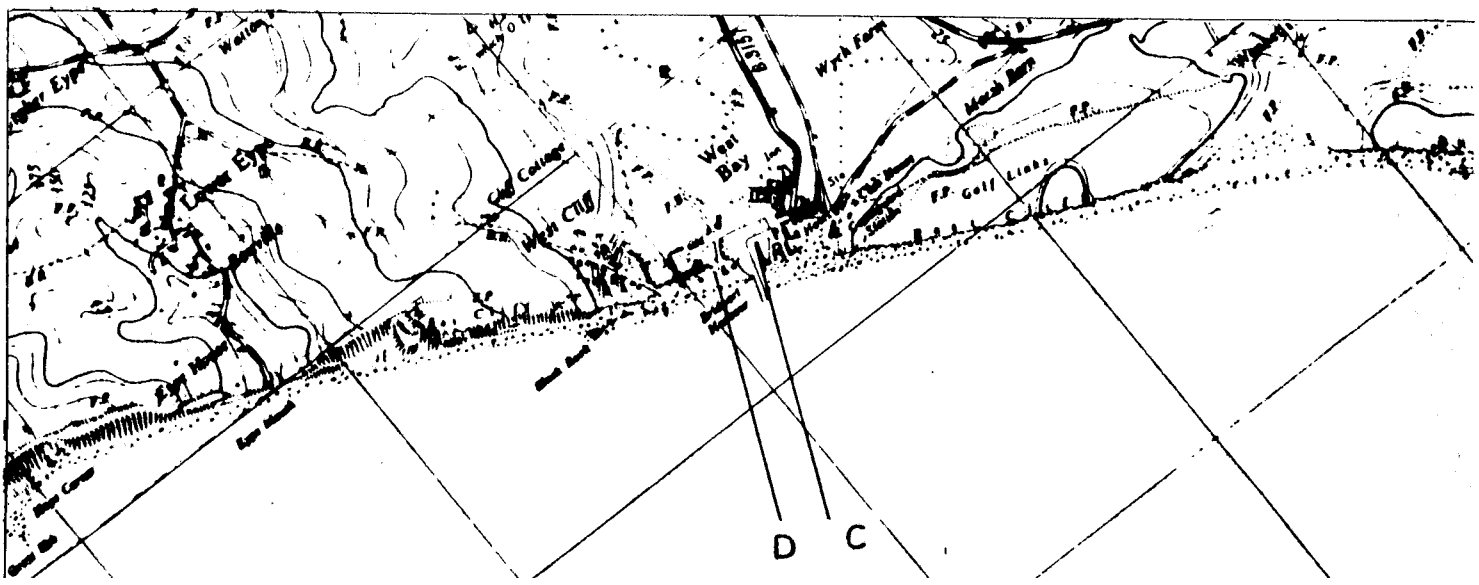
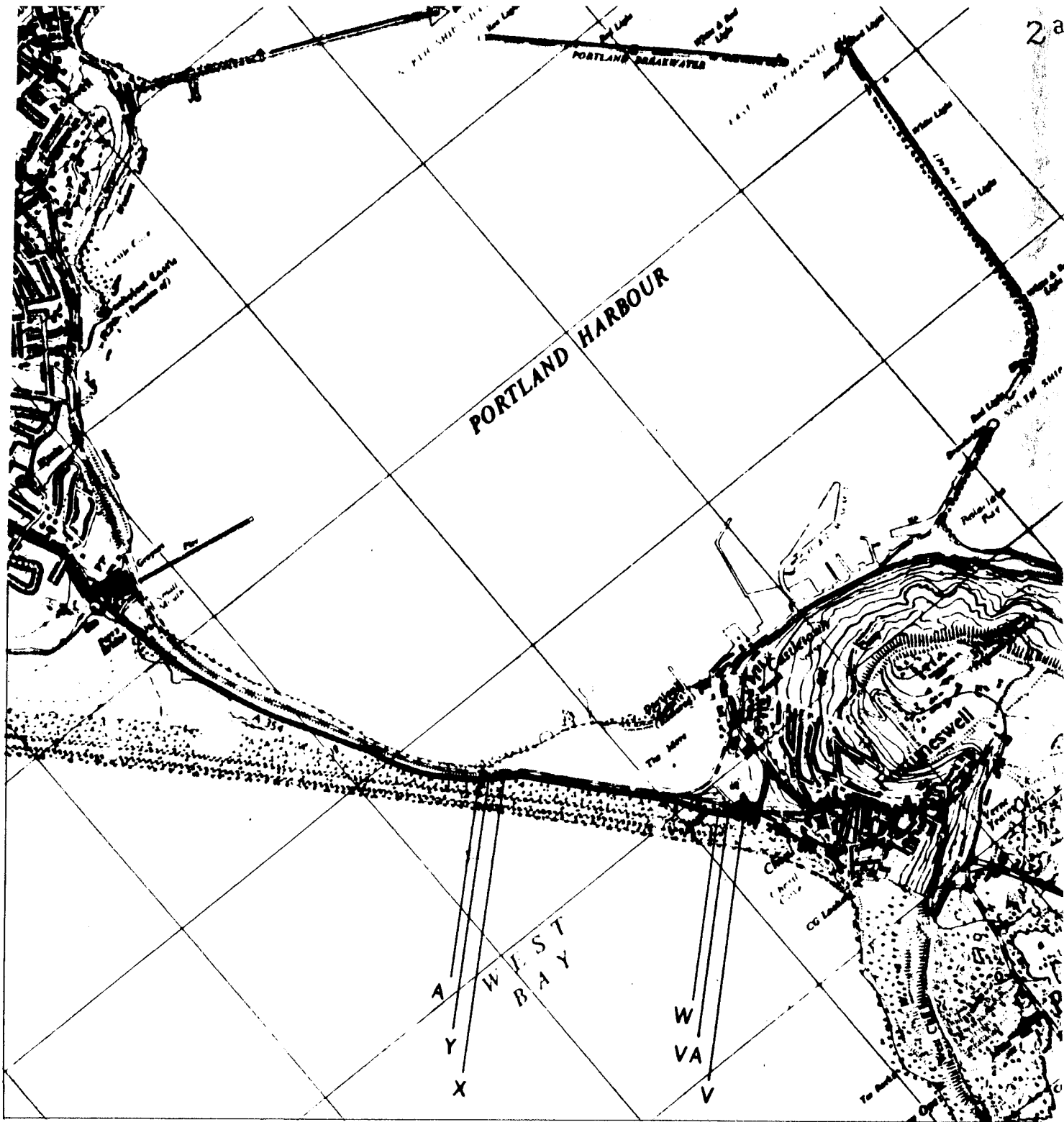
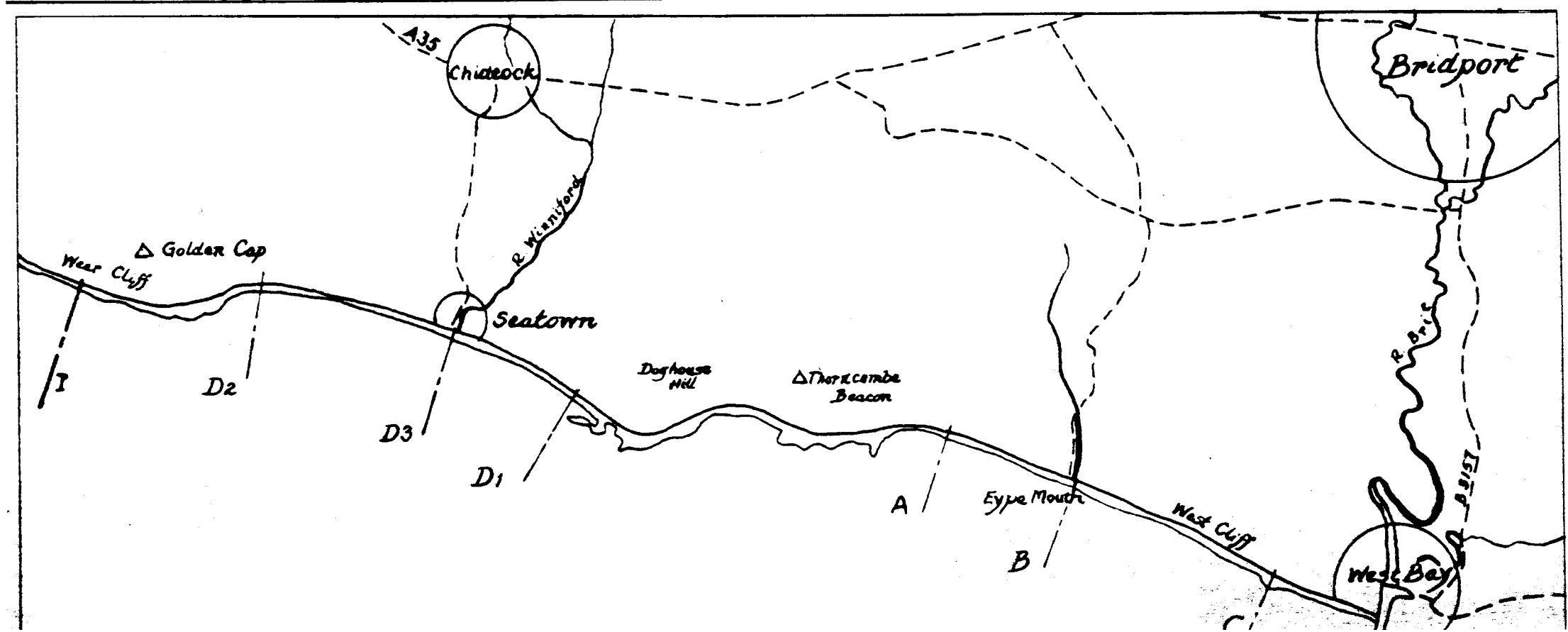
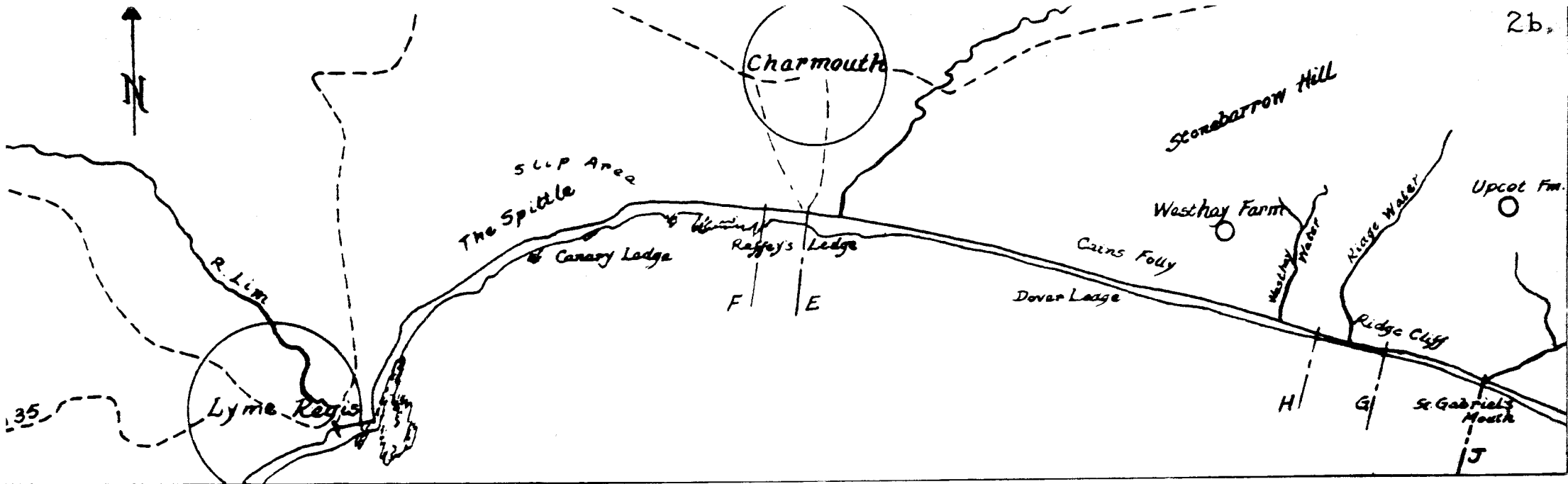
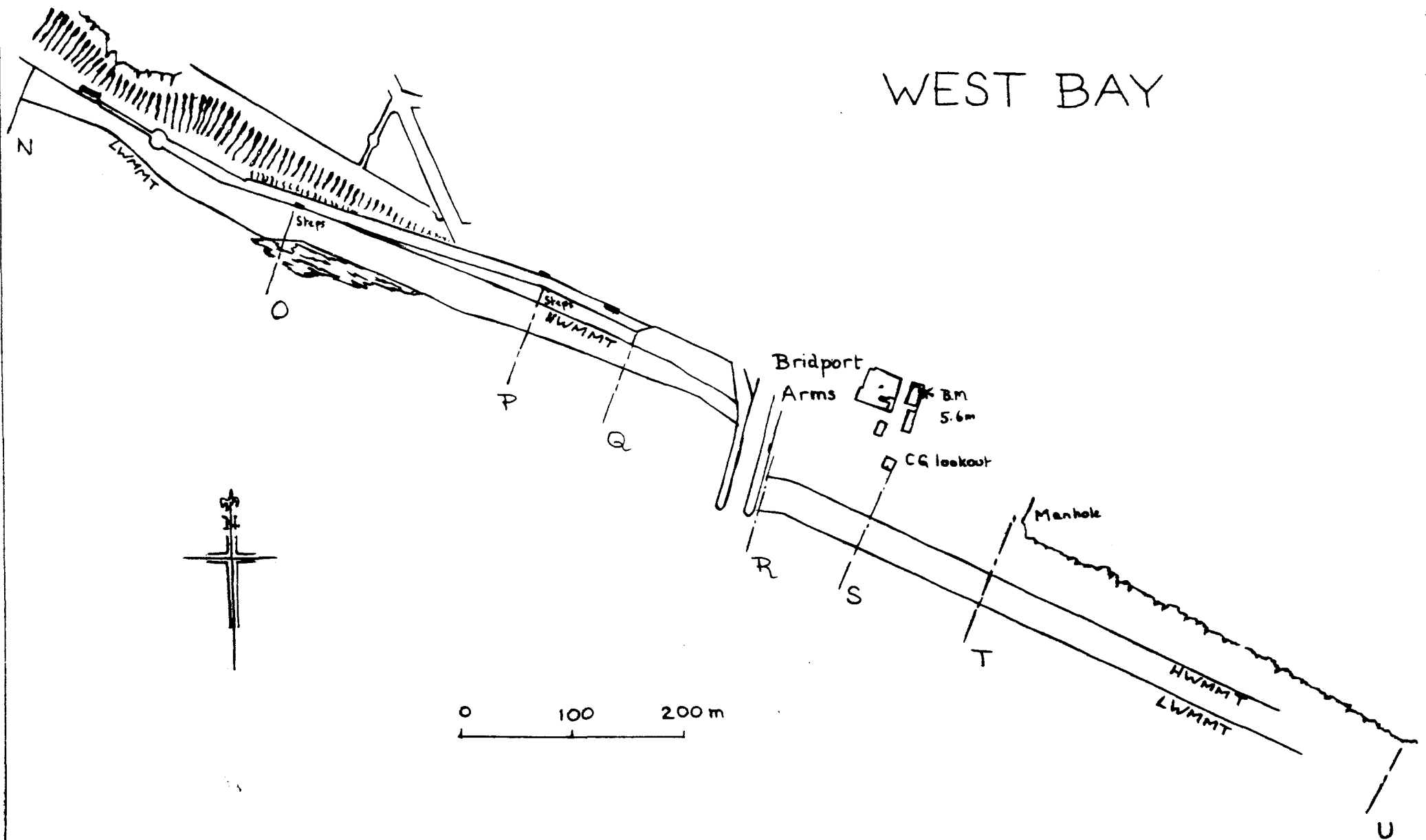


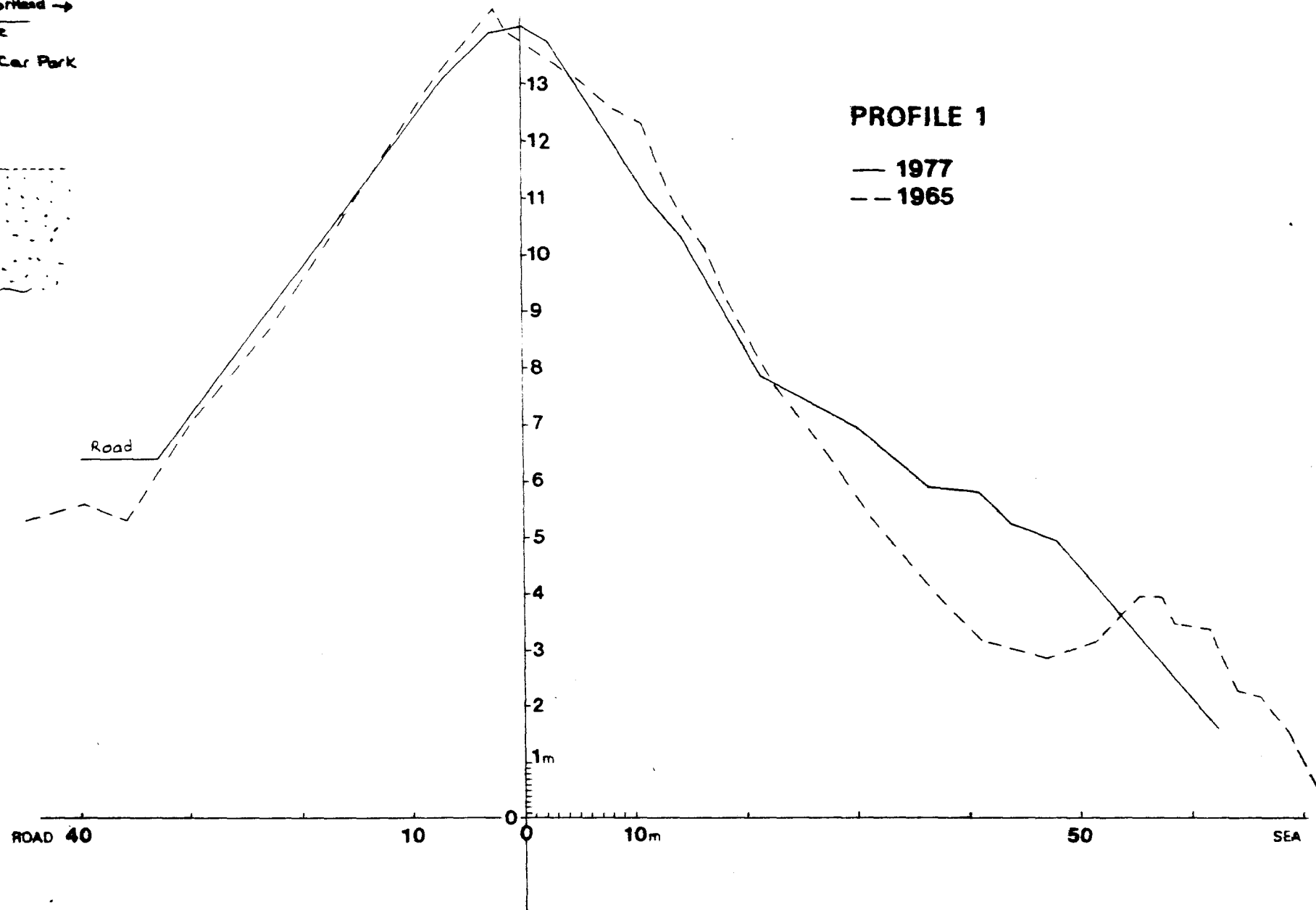
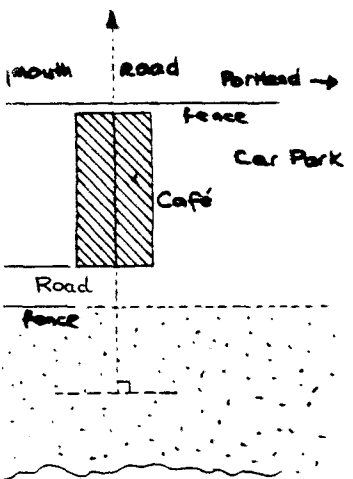
FIG. 1. Chesil Beach: site map showing location of Admiralty and Coode cross-sections and western limit of Nature Conservancy longitudinal section. Coode 1 and Admiralty A approx. position only.

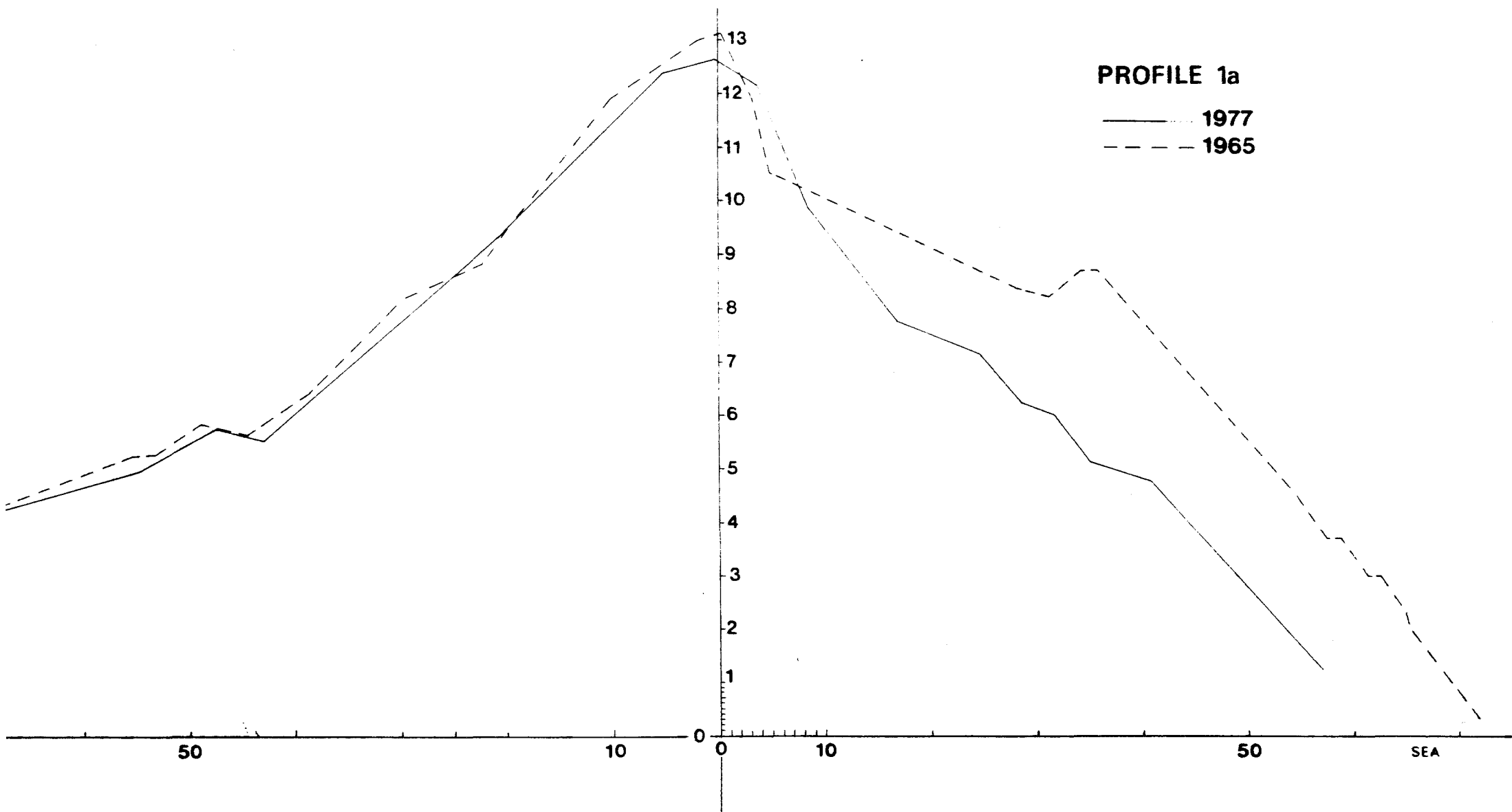


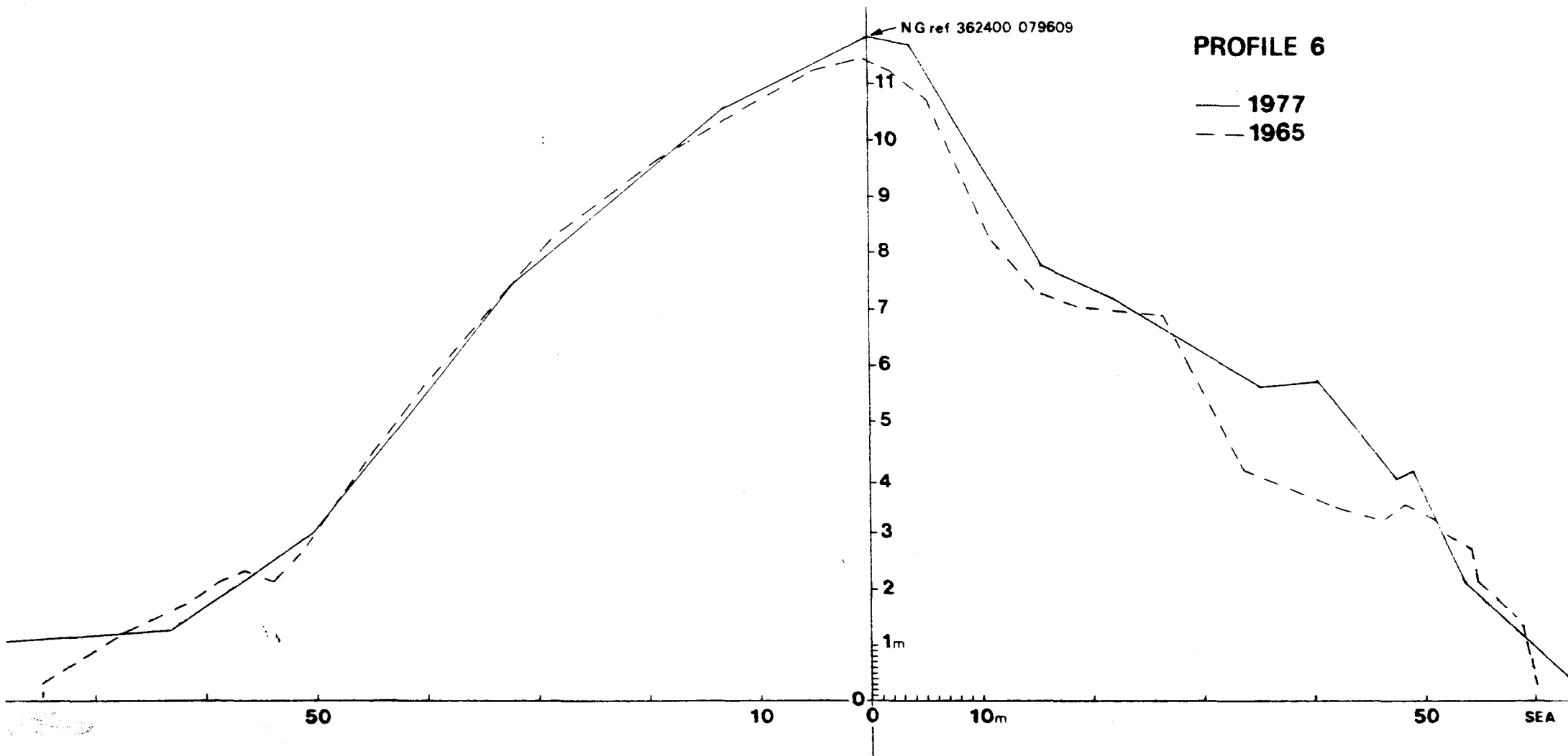


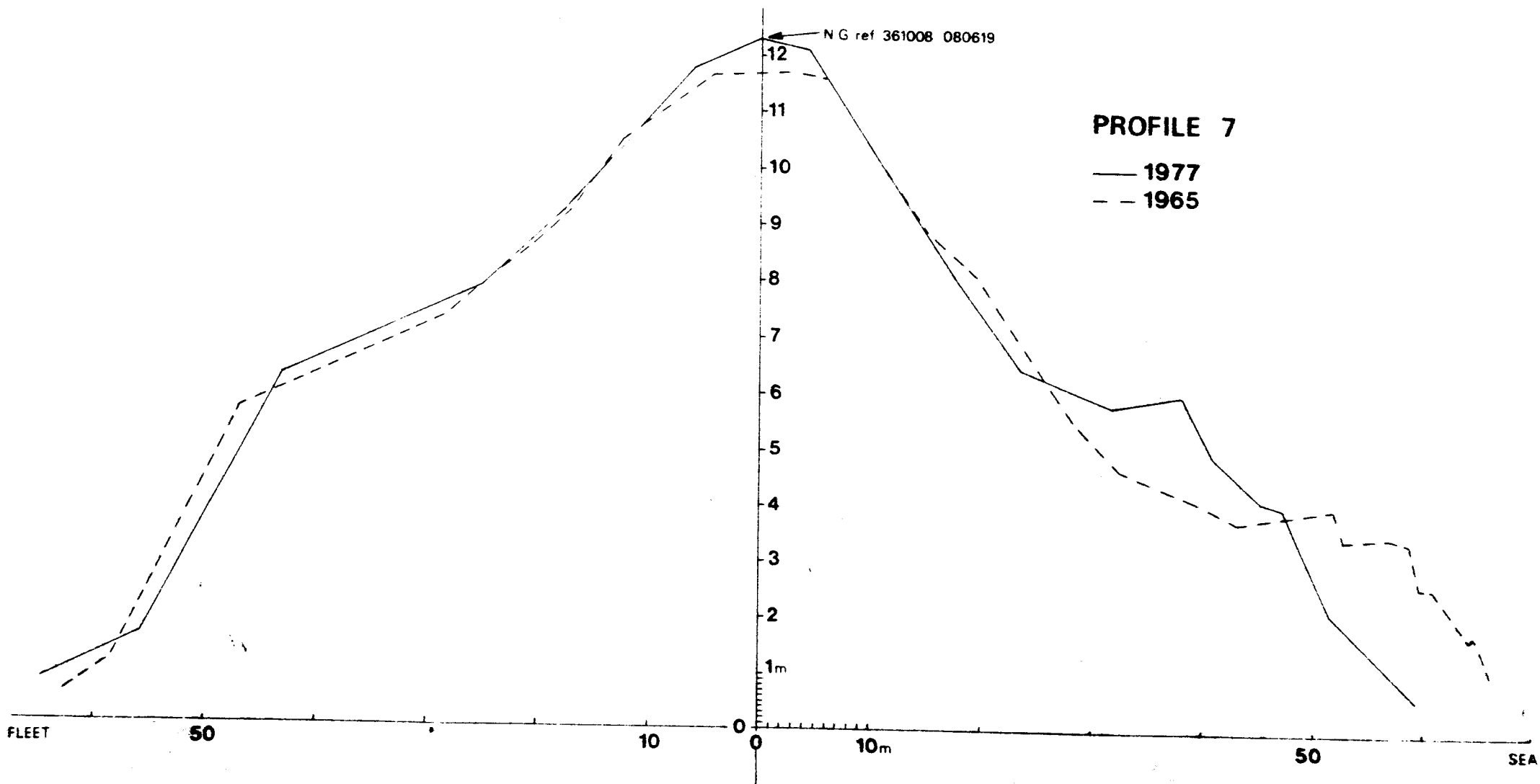
WEST BAY

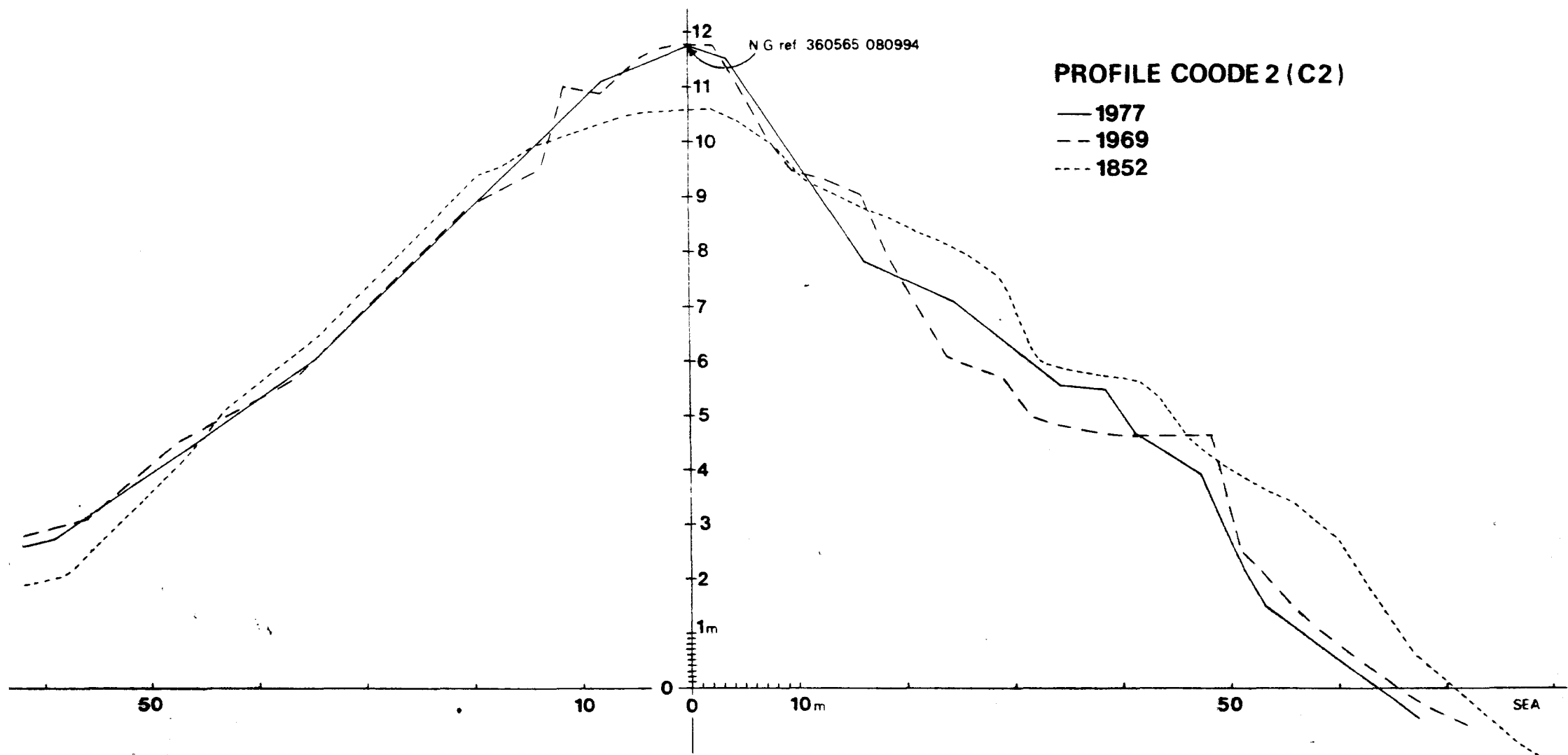


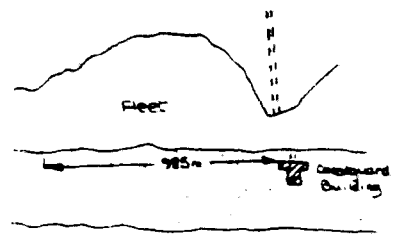








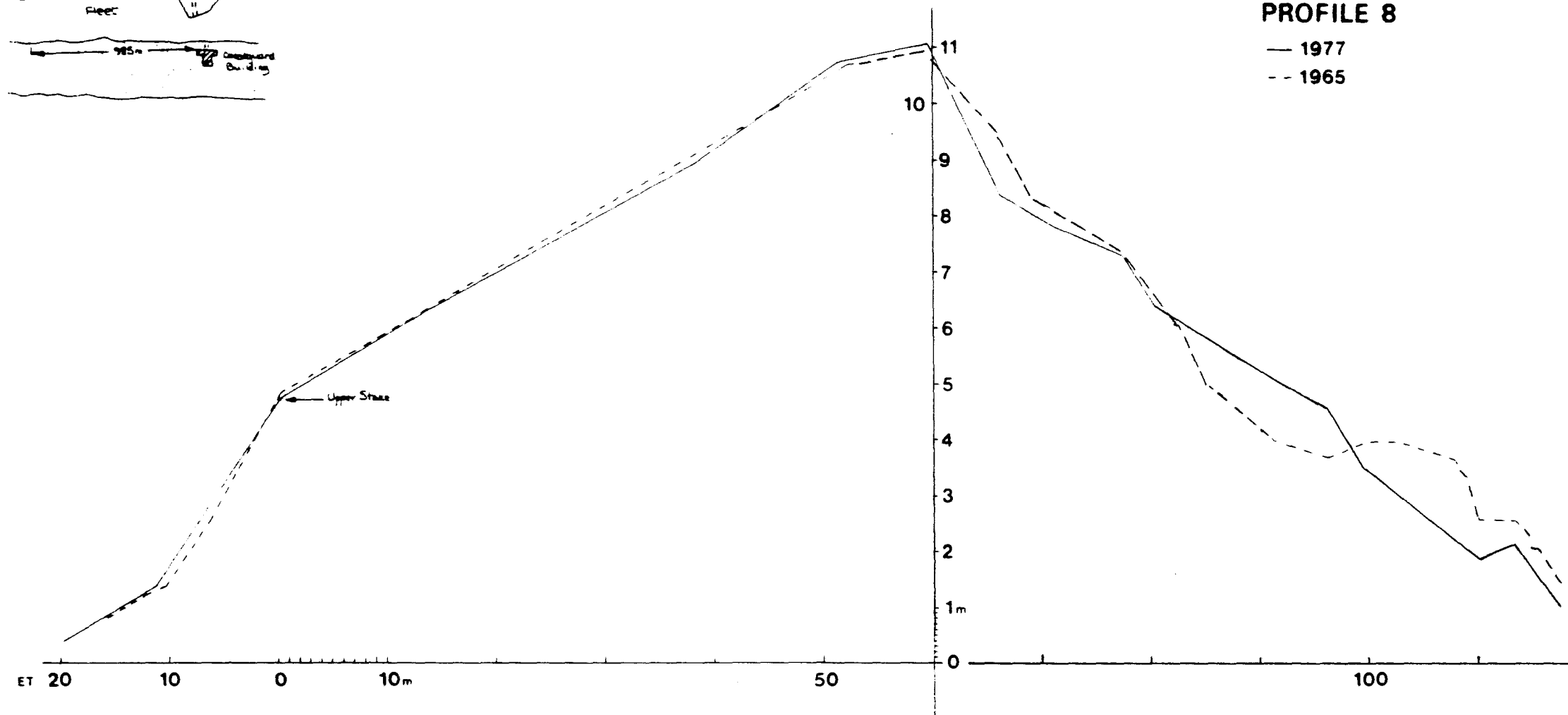




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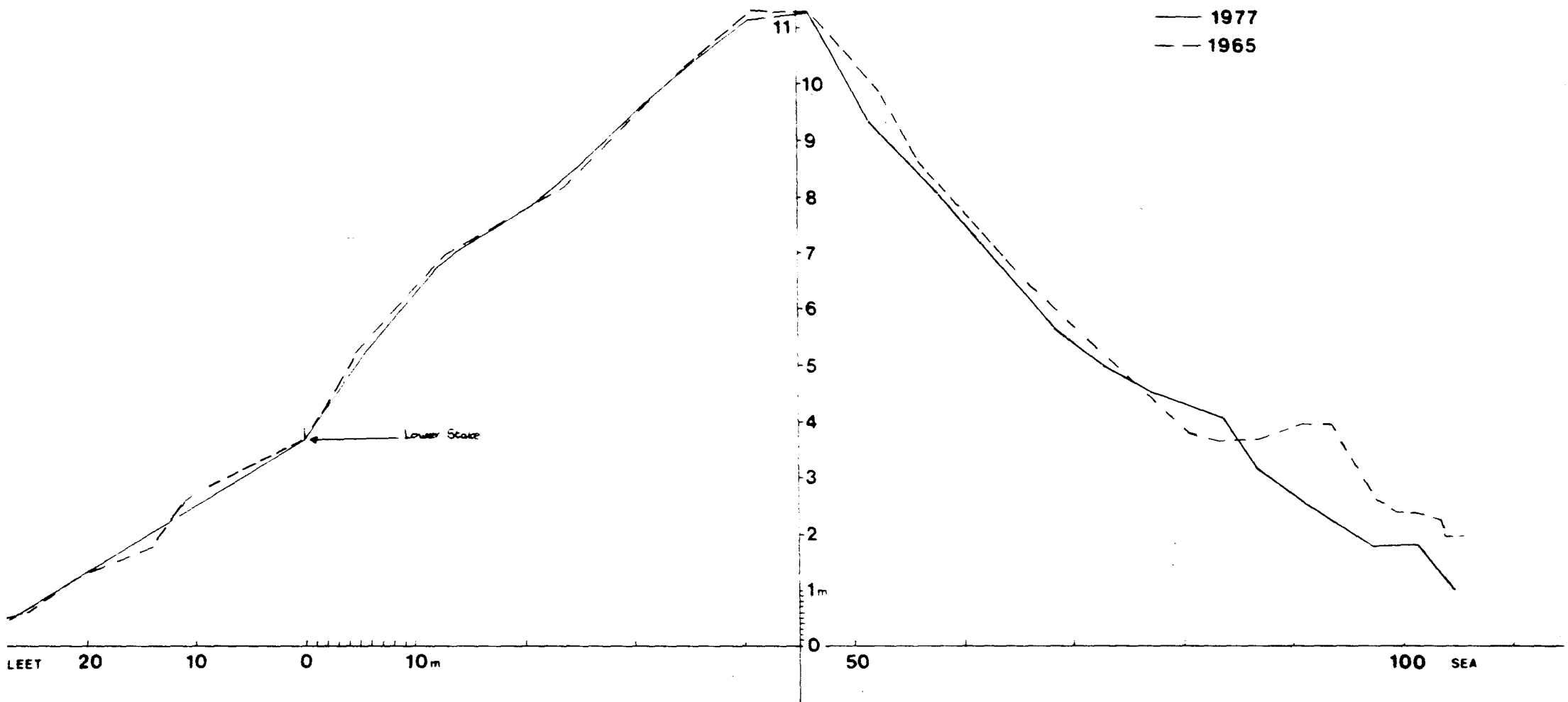
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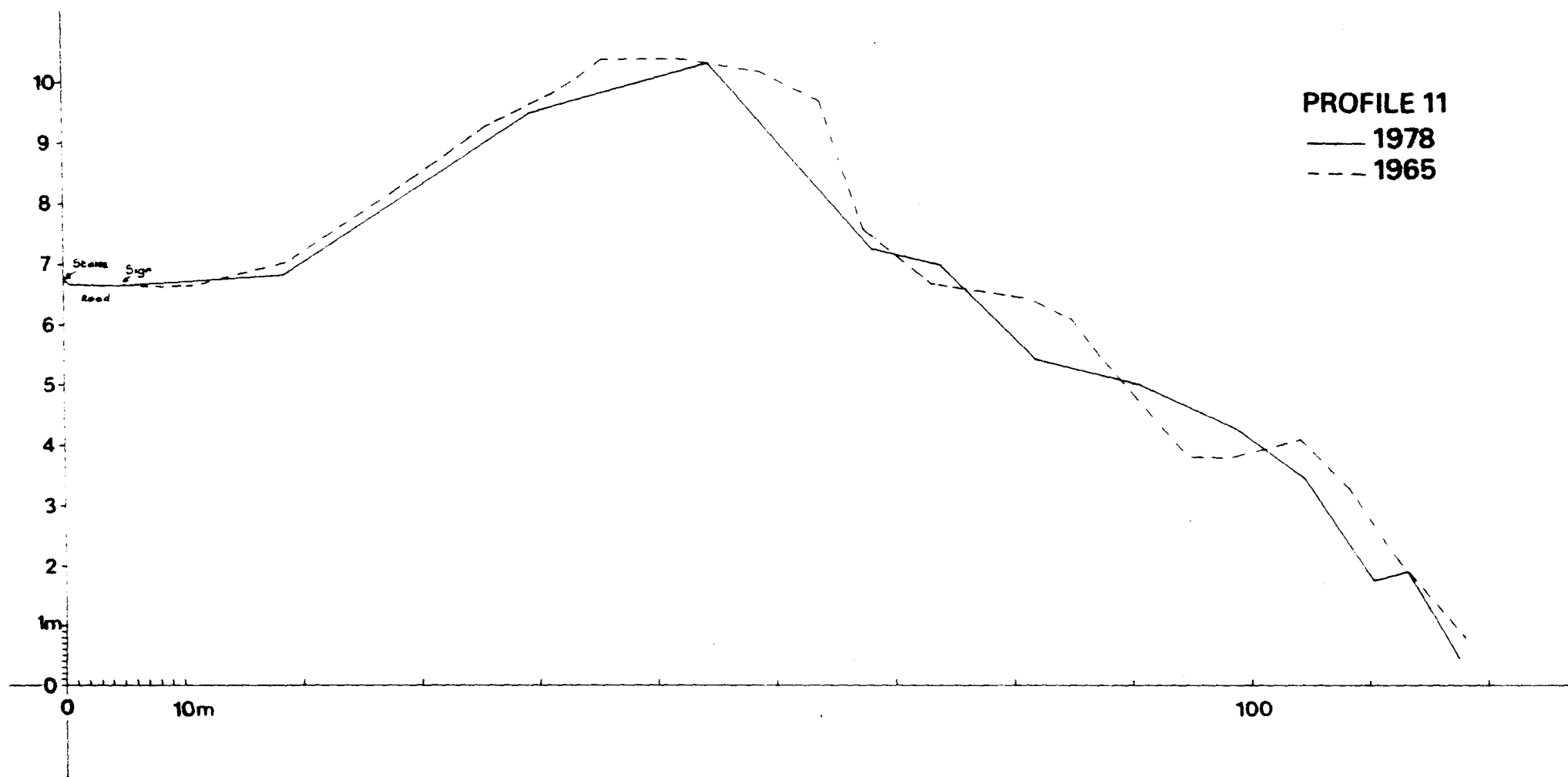


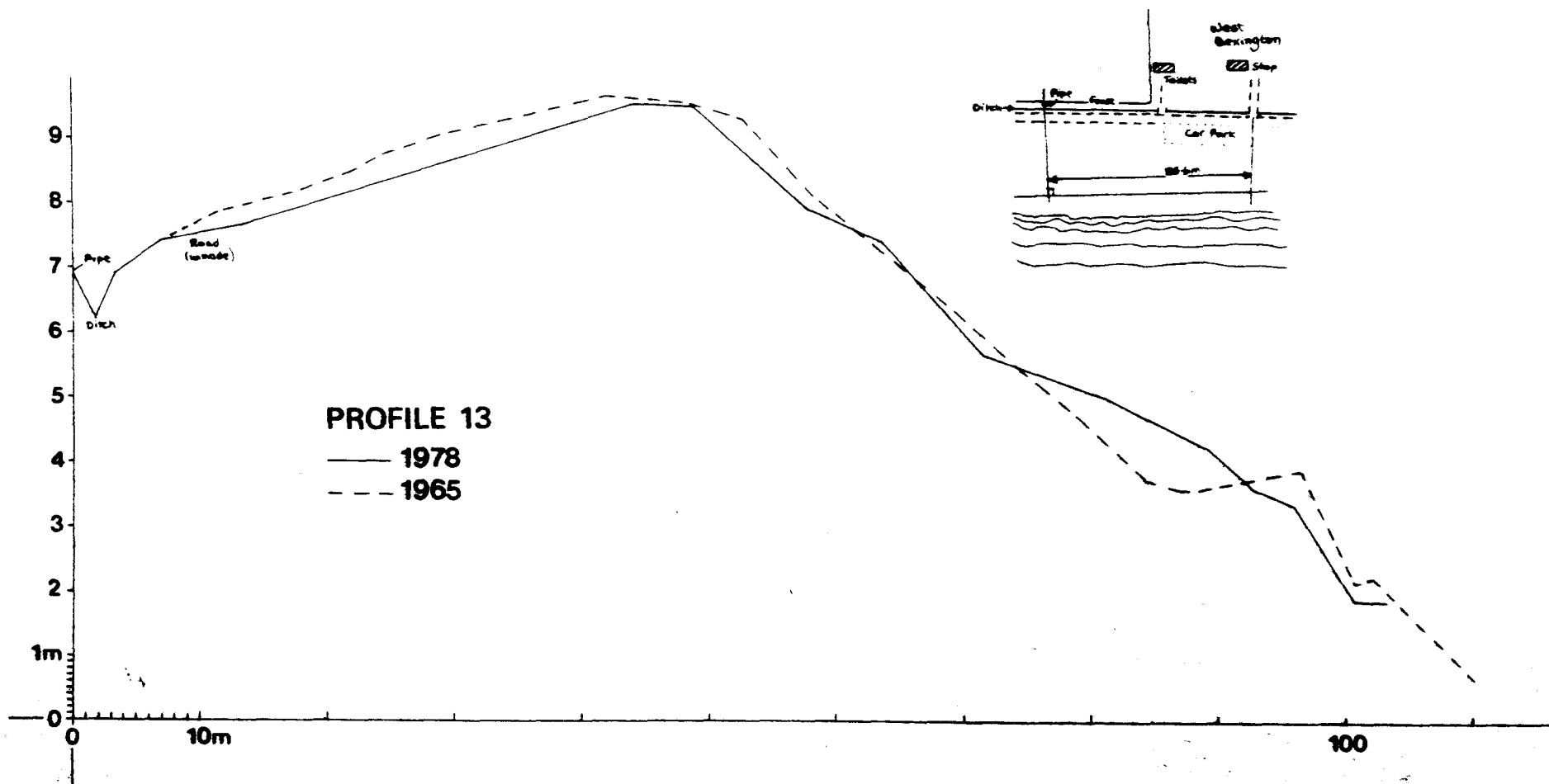
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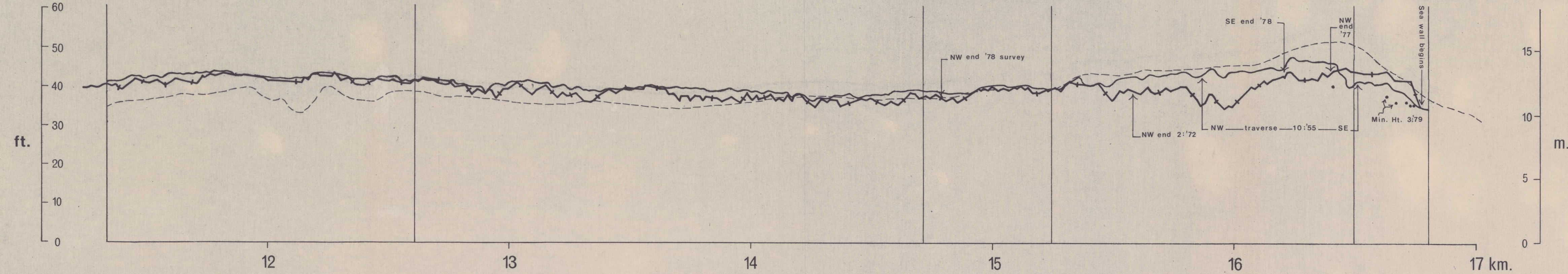
Section 5

Section 6

Section 7

Section 8

Section 9



----- Coode 1852 — Nature Conservancy 1968/69 —+ I. O. S. March 1979

