SUBMERGED GRAVEL AND PEAT IN SOUTHAMPTON WATER.

By C. E. EVERARD, M.SC.

Summary.

DOCK excavations and numerous bore-holes have shown that gravel and peat-beds, buried by alluvial mud, occur at many points in Southampton Water and its tributary estuaries. A study of a large number of hitherto unpublished borings has shown that the gravel occurs as terraces, similar to those found above sea-level. There is evidence that the terraces mark stages, three in number, in the excavation of the estuaries during the Pleistocene Period, and that the peat and mud have been deposited mainly during the post-glacial rise in sea-level.

Introduction.

The Hampshire coast, between Hurst Castle and Hayling Island, illustrates admirably the characteristic estuarine features of a coast of submergence. It is probable that, following the post-glacial rise in sea-level, much of the Channel coast presented a similar appearance, but only in limited areas have the estuaries survived subsequent coastal erosion. The Isle of Wight has, for example, preserved from destruction the Solent and Southampton Water, and their tributary estuaries.

The fluviatile origin of these estuaries has been accepted for many years, following the work of Reid (1, 2) and Shore (3, 4), among others, but, as much of the evidence is below low water-level, detailed knowledge of their stratigraphy and history is limited. The deposits of gravel, peat and mud which largely fill the estuaries are known chiefly from dock constructions, borings and dredging. The shores of Southampton Water have been the scene of much activity of this nature during the past century, and a large quantity of information has accumulated concerning the submerged deposits, but surprisingly little has been published.

An early paper, and one of outstanding importance, is that by Shore and Elwes (5), which describes three gravel terraces uncovered during the excavations for the Empress Dock, Southampton. Reid, in the Southampton Geological Memoir (1), also refers to these excavations, and adds that " the alluvial deposits of Southampton Water fill up a valley descending considerably below the present sea-level, and even below the bottom of the existing estuary ".

The next detailed account of the drift deposits is that by Anderson (6), which is concerned with the New Docks area. Two sections are given, along and across the line of the quay-wall, which

show a continuous bed of gravel, about ten feet thick, overlying the Bracklesham Beds and covered with alluvial mud. This area is also mentioned by Wrigley (7).

The age of the submerged peat deposits has been determined accurately in only a very small number of sections. Analysis by H. and M. E. Godwin (8) of a section between —20ft. and —6ft. O.D. in the King George V Graving Dock has shown the base to be of pre-Boreal age (*c.* 7500 B.C.) and the top of Atlantic age (*c.* 3500 B.C.), at which point it was truncated by a marine invasion. It was suggested that the peat examined had been deposited in a wide valley filled with fen, which at times was dry and at times shallowly flooded.

Oakley (9) has reviewed the evidence dealing with the dating of peat and concludes that, although the main submergence of Southampton Water occurred during Mesolithic and Neolithic times, movement continued into the early historic period.

It has been possible, with the generous co-operation of the authorities acknowledged below, to assemble much of the data obtained over a number of years concerning the submerged deposits encountered in Southampton Water. The quantity of material available suggests that it is a suitable time to summarise what is known of the deposits, and to put forward one or two tentative theories concerning them.

The bulk of the data consisted of bore-hole records, and about 350 were examined and plotted. Large scale excavations, permitting in situ examination of strata, are becoming increasingly rare, and bore-holes are now the main source of information. They are by no means an ideal method of obtaining stratigraphical sections, and the results must be used with caution. The strata penetrated cannot be examined in situ, and the cores, when brought to the surface, are usually in a fragmentary state. Furthermore, the section obtained is not necessarily typical of a wider area. On the other hand, the strata with which we are at present concerned (*i.e.*, gravel, peat and mud) are easily recognised and are unlikely to pass unrecorded, or to be very inaccurately measured. Provided that their limitations are taken into account therefore, bore-hole records can be a valuable source of information.

The maps and diagrams illustrating this account are based upon the original bore-hole records and site plans. The depths have been reduced to Ordnance Datum (Liverpool), and interpolated contour maps of the top and bottom of the gravel sheets have been constructed (*e.g.*, Fig. 3). Of the cross-sections, some are based upon a line of borings (*e.g.*, Fig. 9), while others are representative sections (" projected sections ") of a strip a few tens of yards wide (see Fig. 2).

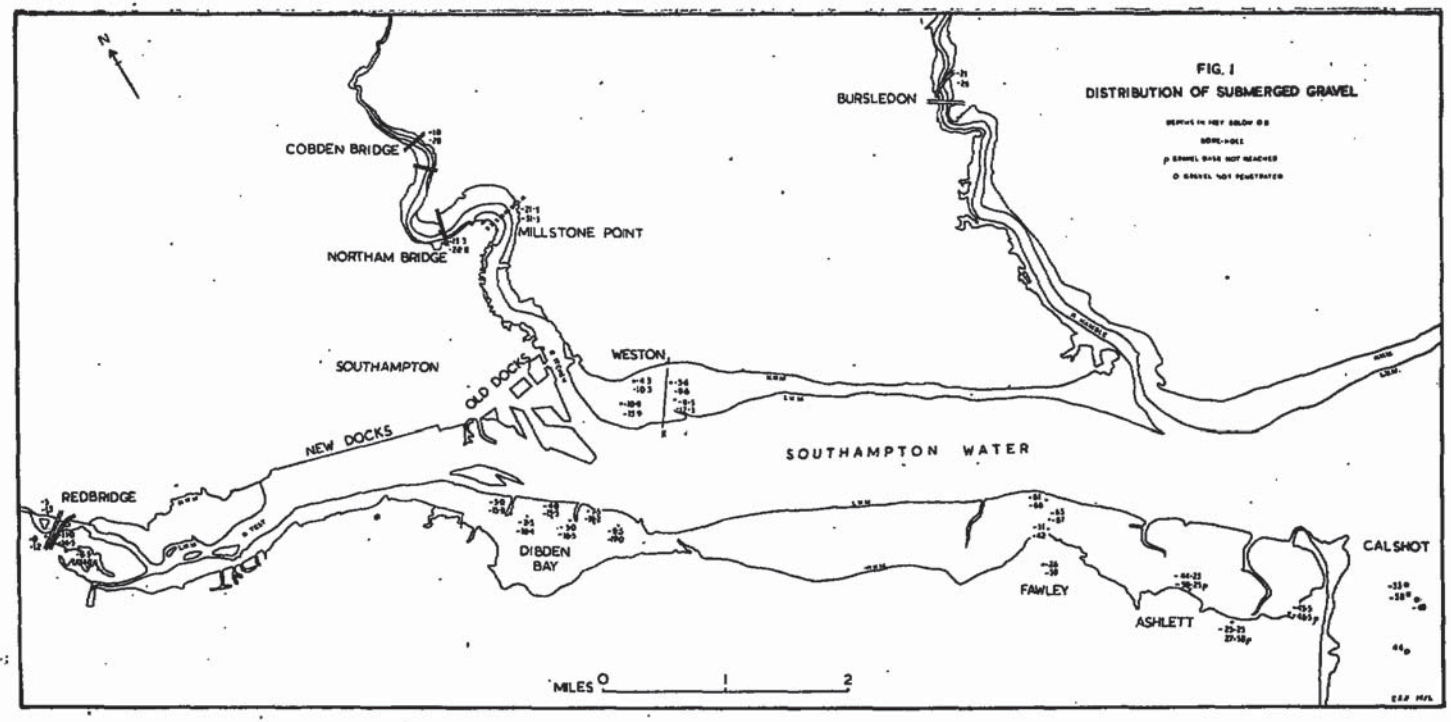


FIG. 1
DISTRIBUTION OF SUBMERGED GRAVEL
N
COBDEN BRIDGE
NORTHAM BRIDGE
MILLSTONE POINT
BURSLEDON
SOUTHAMPTON
OLD DOCKS
NEW DOCKS
WESTON
SOUTHAMPTON WATER
REDBRIDGE
DIBDEN BAY
FAWLEY
ASHLETT
CALSHOT
MILES 0 1 2

The Terraces.

The contour maps and sections show that, in at least three separate areas, the submerged gravel is laid down in a sequence of terraces. This arrangement closely resembles that of gravel terraces found above present sea-level. Three such steps, or terraces, have been recognised in Southampton Old Docks, and two in the New Docks and at Fawley.

The cross-section at Fawley (Fig. 9), prepared from exceptionally closely spaced borings, illustrates clearly the structure of the submerged terraces. Each terrace is a separate sheet of gravel, with a clearly defined base cut in the underlying solid rock. The regularity of outline, characteristic of the Fawley section, is not, however, always to be seen. The surfaces and bases of the submerged terraces are often undulating, and are more irregular than those of terraces found above sea-level. Some of these irregularities may result from incorrect measurement of the strata, but it is to be expected that the base of a gravel sheet will show irregularities related to variations in the resistance of the bed-rock, and to " pot-holing ". Thus referring to Empress Dock, Shore and Elwes (5) state : " after the denudation of the Eocene beds, an uneven surface must have been left, on which the deposit of gravel was laid ".

In appearance the gravel is a typical subangular flint gravel. It may become, laterally, very coarse, or alternatively, very fine, even passing into a sand. The submerged gravel resembles in many respects that found in terraces above sea-level, the only major difference being in the colour. This is grey instead of brown, probably due to leaching, and to the action of acids from overlying peat on the ferruginous constituents.

Gravel terraces or buried channels have been identified in the following areas (Fig. 1) :

(*a*) The Old Docks, Southampton.
(*b*) The New Docks, Southampton.
(*c*) Dibden Bay and Weston Shelf.
(*d*) The Test, Itchen and Hamble estuaries.
(*e*) Fawley and Ashlett.

The Old Docks, Southampton.

The Old Docks lie at the junction of the Test and Itchen estuaries, and formerly the peninsula was " a spit of mud, extending for more than half a mile from the beach, covered at high tide by from 12ft. to 17ft. of water, but uncovered at low water ". (5)

The distribution and depth of the gravel are known in some detail in this area, as it possesses the greatest concentration of borings, and, in addition, there are available descriptions, by

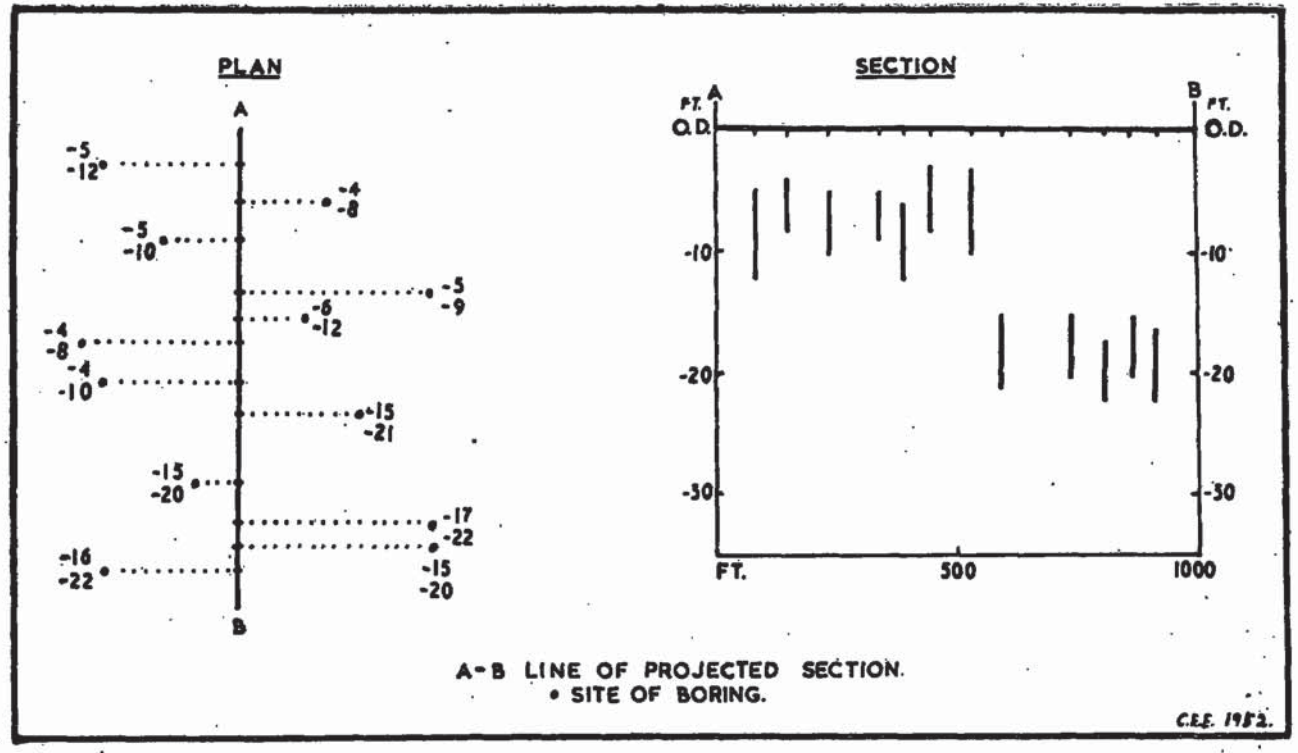


FIG. 2 CONSTRUCTION OF PROJECTED SECTIONS.

Shore and Elwes (5), and Reid (1), of important sections. It is therefore taken as the type area as regards the character and depth of the terraces.

Three terraces have been plotted, at the following depths below Ordnance Datum[1] :

— 5ft. to — 8ft. Terrace.
—16ft. to —21ft. Terrace.
—30ft. to —34ft. Terrace.

These terraces form a "staircase" descending southwards from the former shore towards the present main channel (Fig. 5, Section A B). The highest step or terrace adjoins the former shore-line, and the depths of the gravel surface vary from +0ft. 9in. to —12ft. 9in., a wide range for so small an area. Over half of the twenty-five sections lie between —5ft. and —8ft. The reality of the terrace is brought out by the prominent bluff which bounds it to the south and east (Figs. 3 and 4). Shore and Elwes (5) describe the bluff thus : "About halfway across the dock, the surface of the Bracklesham Beds rose rapidly several feet, as though it had been left as a low riverside bank or slope".

The outlier of this terrace to the south-east may be due either to a branch of the proto-Test flowing between it and the main remnant, or to the undercutting, during the —30ft. to —34ft. stage, of the eastern side of the peninsula joining it to the main part.

The —16ft. to —21ft. terrace has a rather more even surface, twenty-one of the twenty-five readings being within the given limits. It is bounded on the south-west and east by bluffs which descend to the —30ft. to —34ft. terrace. The latter bluff was referred to both by Reid (1) and by Shore and Elwes (5), who stated : "the gravel rose up sharply, sometimes at an angle of nearly twenty degrees, for twelve feet or more". (Fig. 5A, Sections C D, E F.)

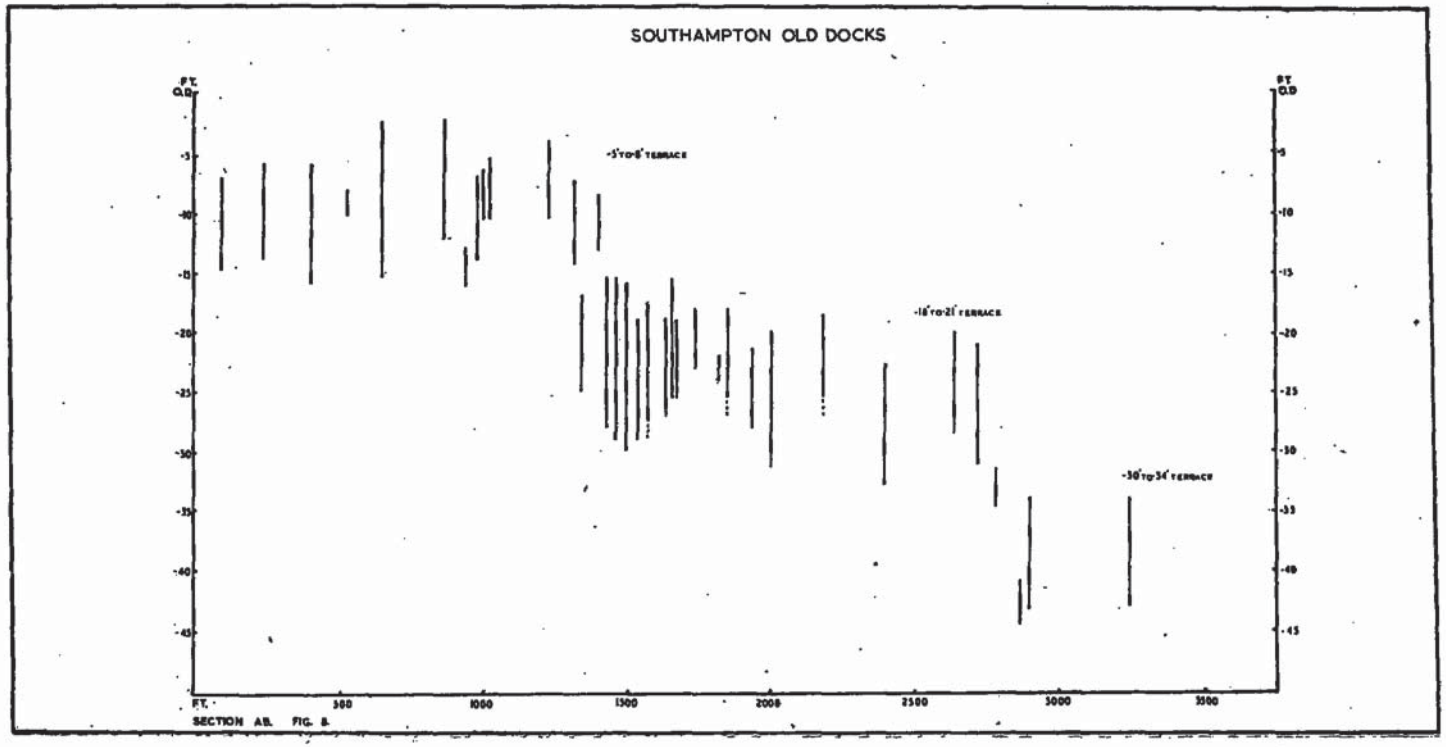
Finally, lying parallel to the Test and Itchen respectively, are the two narrow remnants of the —30ft. to —34ft. terrace. The Itchen remnant is the best developed. Evidence of the terrace along the Test is at present limited. This terrace is the lowest so far recorded in the Old Docks, and may represent the lowest stage of downcutting.

The contours of the sub-gravel surface are shown on Map 4. The repetition of the stepped pattern in this surface emphasises the individuality of each terrace.

1. For reasons given earlier, an exact depth cannot be assigned to any one terrace. It has been found necessary to use a range of depths, within which lie the majority of the surfaces of the gravel sections. Thus the terraces are referred to as the "—5ft. to —8ft. Terrace" etc.

FIG. 5

SUBMERGED GRAVEL TERRACES – GENERALISED SECTIONS



The New Docks, Southampton.

The area now occupied by the New Docks and the adjacent industrial estate was once a broad shallow bay. The submerged gravel terraces of this area are as yet imperfectly known. Deep excavations have been few, as the docks were constructed by reclamation, and, excluding one or two limited areas (Fig. 6), the borings are widely spaced. Interpolated contours are quite unreliable to illustrate the morphology of the gravel sheets, and the distribution of the terraces can be shown only in the broadest outline (Fig. 8). The detailed map (Fig. 6) gives the distribution and depths of the gravel sections so far recorded.

The two terraces which have been identified appear to correspond to the —5ft. to —8ft., and —16ft. to —21ft. terraces of the Old Docks.

Evidence for the existence of a —5ft. to —8ft. terrace is so far confined to the area of the King George V Graving Dock (Fig. 6), where there are a number of closely-spaced borings. The bluff between this terrace and that below is best seen at the entrance to the Dock (Fig 7, Section G H). To the S.E., however, the bluff appears to die out (*cf.* the group of borings at about —12ft. O.D.), but definite conclusions must await the sinking of more borings.

The lower terrace (—16ft. to —21ft.) underlies the greater part of the New Docks, and is illustrated clearly by Anderson's sections (6).

The surface of the terrace is fairly uniform in depth, but the thickness of the gravel varies considerably, in places being nearly twenty feet. It follows that the base is usually below the depth of that of the assumed equivalent terrace in the Old Docks. Some of these thick sections are made up entirely of gravel. Others show only the top two or three feet to be gravel, which is underlain by about ten feet of sand. This sand is distinguished in the records from the " Greensand " which is known to be the local bed-rock, and is taken to be a local replacement of the gravel, and has been grouped with it.

There is a broad embayment in the old shore-line in the S.E. of the Docks, bounded by a prominent bluff rising to 50ft. O.D., which was almost certainly cut by a meander. A semicircle of sections, a few feet lower than the general level of the terrace, coincide with the embayment (Fig. 8), and suggest that it was cut during a phase of the —16ft. to —21ft. terrace.

The two sections published by Anderson (6) bear out, in some degree, this analysis. His section along the quay-wall shows a gravel bed, approximately ten feet thick, the top of which lies about 18ft. below Ordnance Datum. In the south-east the sheet is shown to thin and the depth below O.D. increases. This is the position of the supposed meander.

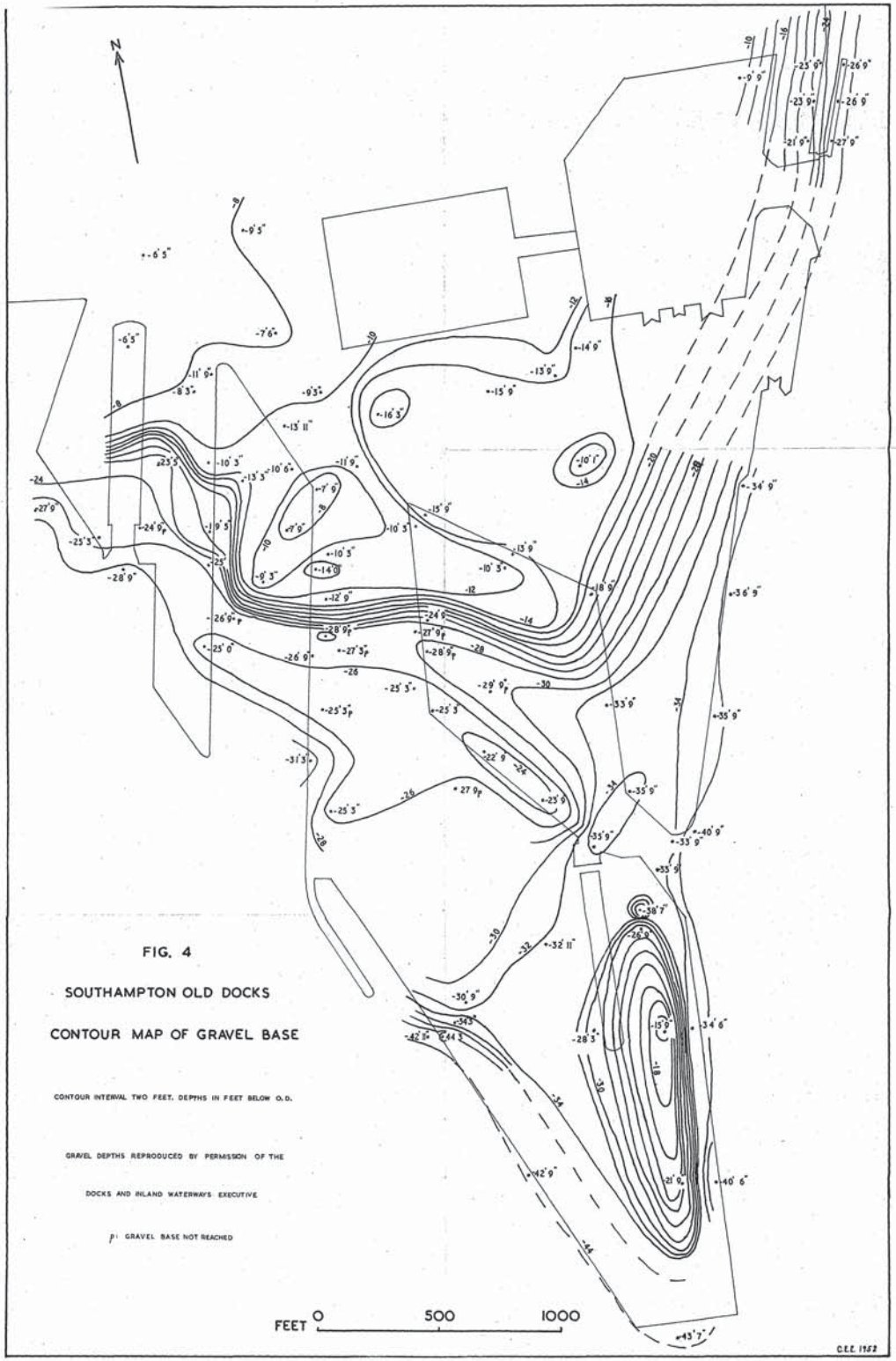


FIG. 4

SOUTHAMPTON OLD DOCKS

CONTOUR MAP OF GRAVEL BASE

CONTOUR INTERVAL TWO FEET. DEPTHS IN FEET BELOW O.D.

GRAVEL DEPTHS REPRODUCED BY PERMISSION OF THE DOCKS AND INLAND WATERWAYS EXECUTIVE

P: GRAVEL BASE NOT REACHED

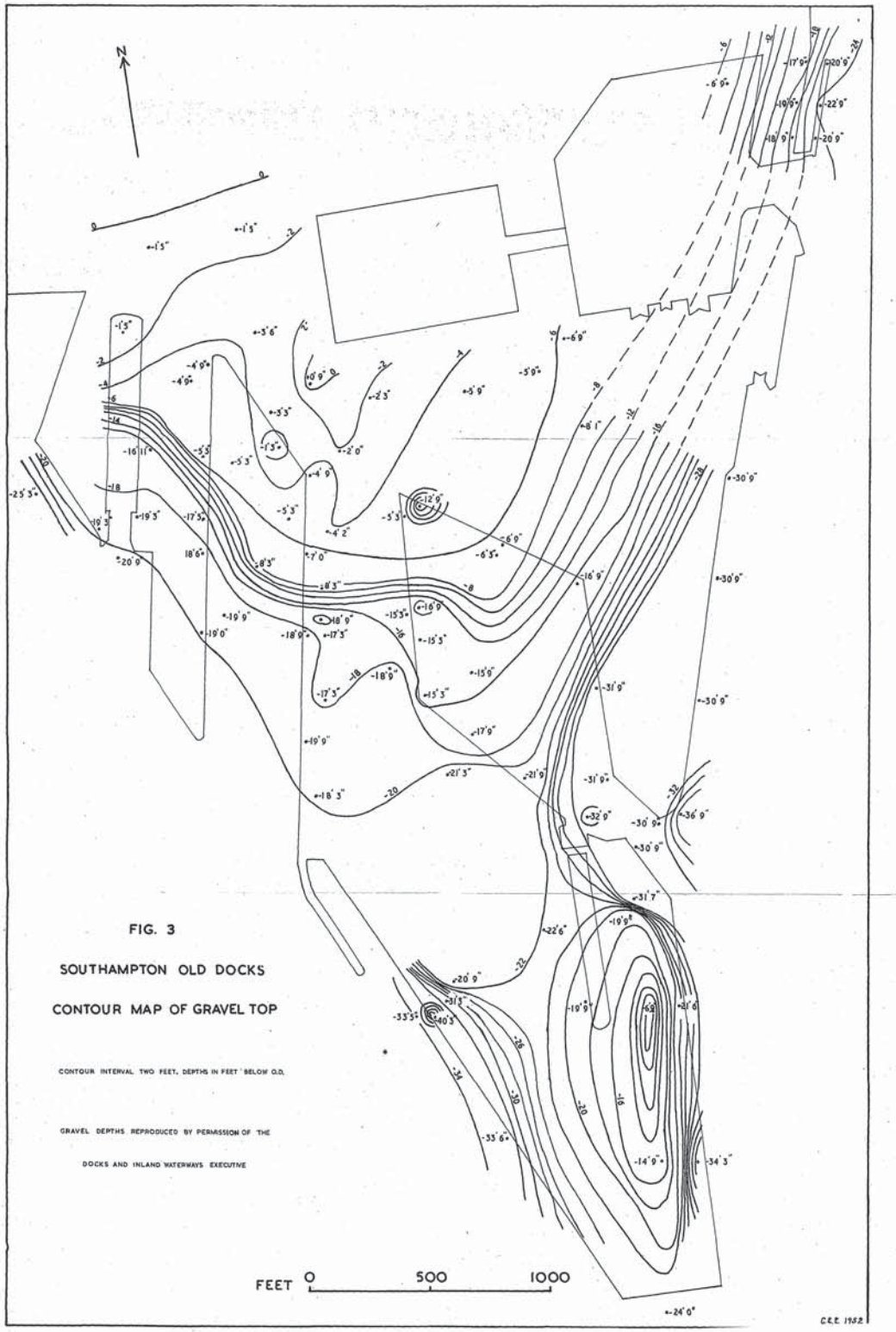


FIG. 3

SOUTHAMPTON OLD DOCKS

CONTOUR MAP OF GRAVEL TOP

CONTOUR INTERVAL TWO FEET. DEPTHS IN FEET BELOW O.D.

GRAVEL DEPTHS REPRODUCED BY PERMISSION OF THE DOCKS AND INLAND WATERWAYS EXECUTIVE

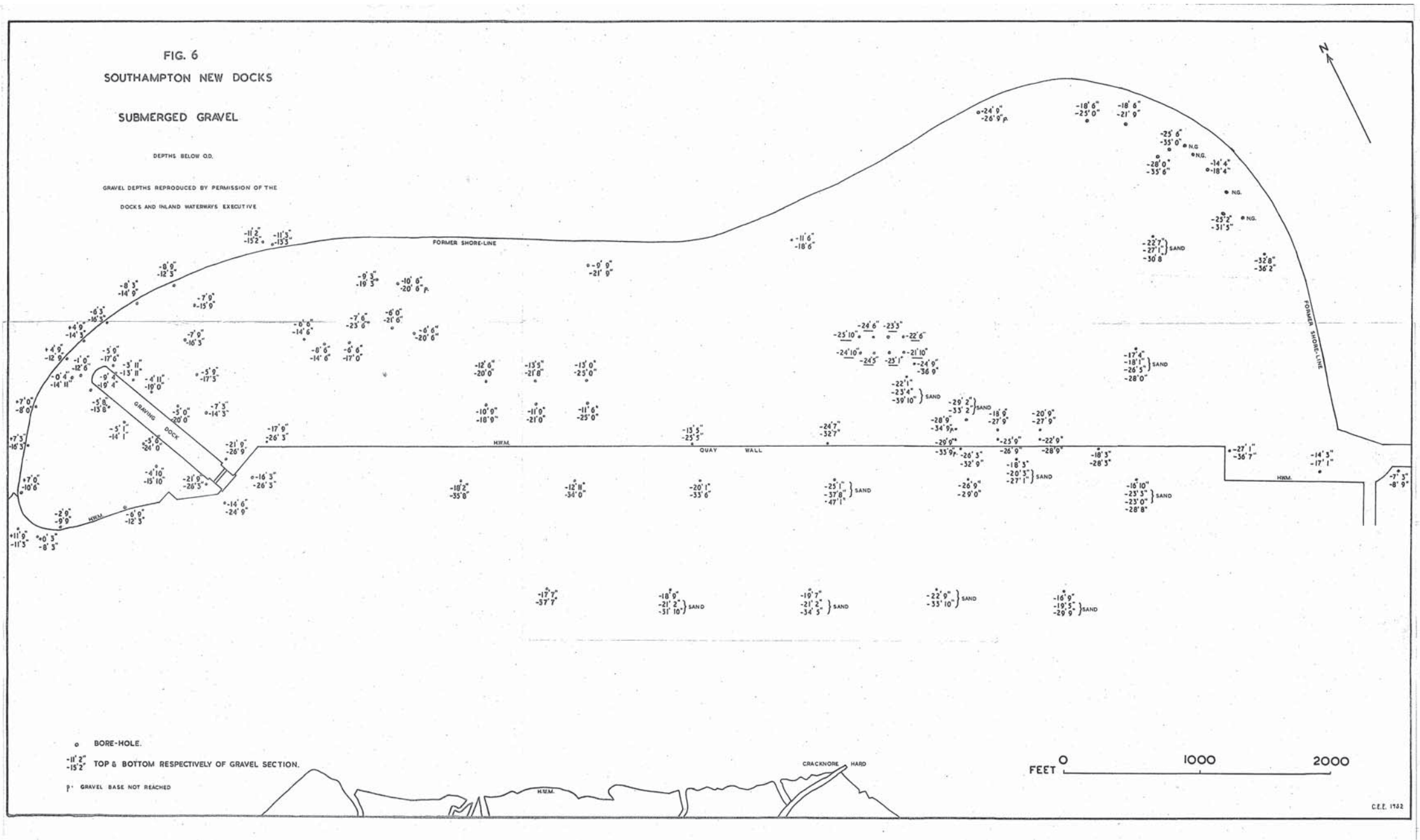
FIG. 6

SOUTHAMPTON NEW DOCKS

SUBMERGED GRAVEL

DEPTHS BELOW O.D.

GRAVEL DEPTHS REPRODUCED BY PERMISSION OF THE DOCKS AND INLAND WATERWAYS EXECUTIVE



o BORE-HOLE.

-11'2" / -15'2" TOP & BOTTOM RESPECTIVELY OF GRAVEL SECTION.

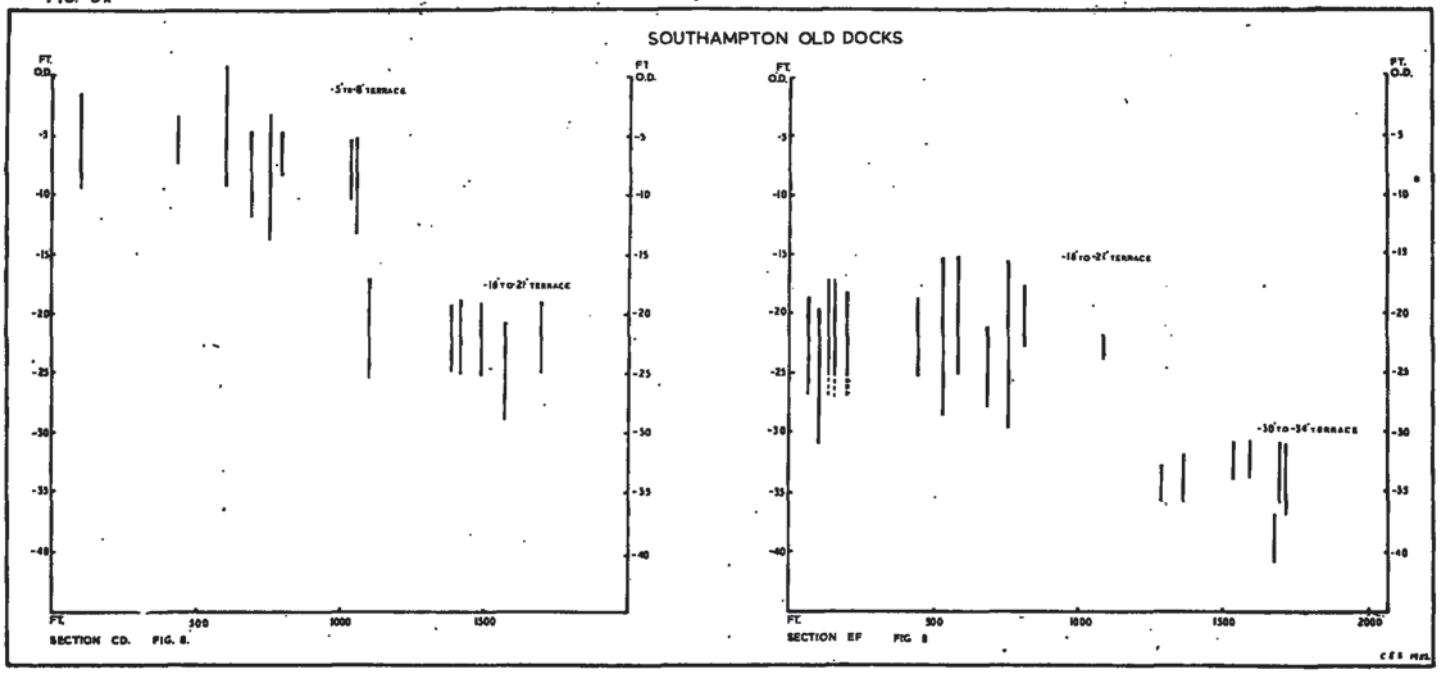
P GRAVEL BASE NOT REACHED

FEET 0 1000 2000

C.E.E. 1962

FIG. 5A

SUBMERGED GRAVEL TERRACES – GENERALISED SECTIONS



Weston Shelf and Dibden Bay.

Thirteen borings have been put down on Weston Shelf, which faces the Old Docks across the mouth of the Itchen estuary. A selection of these borings is shown on Fig 1, and a cross-section on Fig. 7.

Two steps may be recognised. The tops of seven of the sections lie between —3ft. and —6ft. O.D., and five lie between —9ft. and —16ft. The base of the gravel sheet does not show the two steps, and is fairly consistent in depth. The lower step is probably of artificial origin, as references to dredging of ballast off Weston are to be found in the Southampton Geological Memoir (1), and elsewhere. The upper step is provisionally correlated with the —5ft. to —8ft. terrace.

Dibden Bay also contains evidence of this terrace (Fig. 1). A line of six borings, parallel to the main channel, shows that the top of the gravel varies from —2ft. 6in. to —8ft. 6in. O.D.

Fawley, Ashlett, Calshot.

A number of borings have recently been put down on the S.W. side of lower Southampton Water, between Fawley and Calshot Spit (Fig. 1). The sections obtained indicate the existence of a peat bed at —9ft. to —12ft. O.D., and gravel sheets at —30ft. and —60ft. O.D.

Fawley.

Borings for the new jetty at Fawley have revealed the existence of terraces at —30ft. and —60ft. O.D. On the higher terrace the gravel is from ten to fifteen feet in thickness. Near the railway line the top is about —15ft. O.D., and at H.W.M.M.T. it has descended to —30ft. O.D., and shortly afterwards is terminated by a bluff. The sub-gravel terrace (cut in Barton Clay) descends towards the main channel in a similar manner. At present no information is available concerning the N.W.—S.E. extent of this terrace.

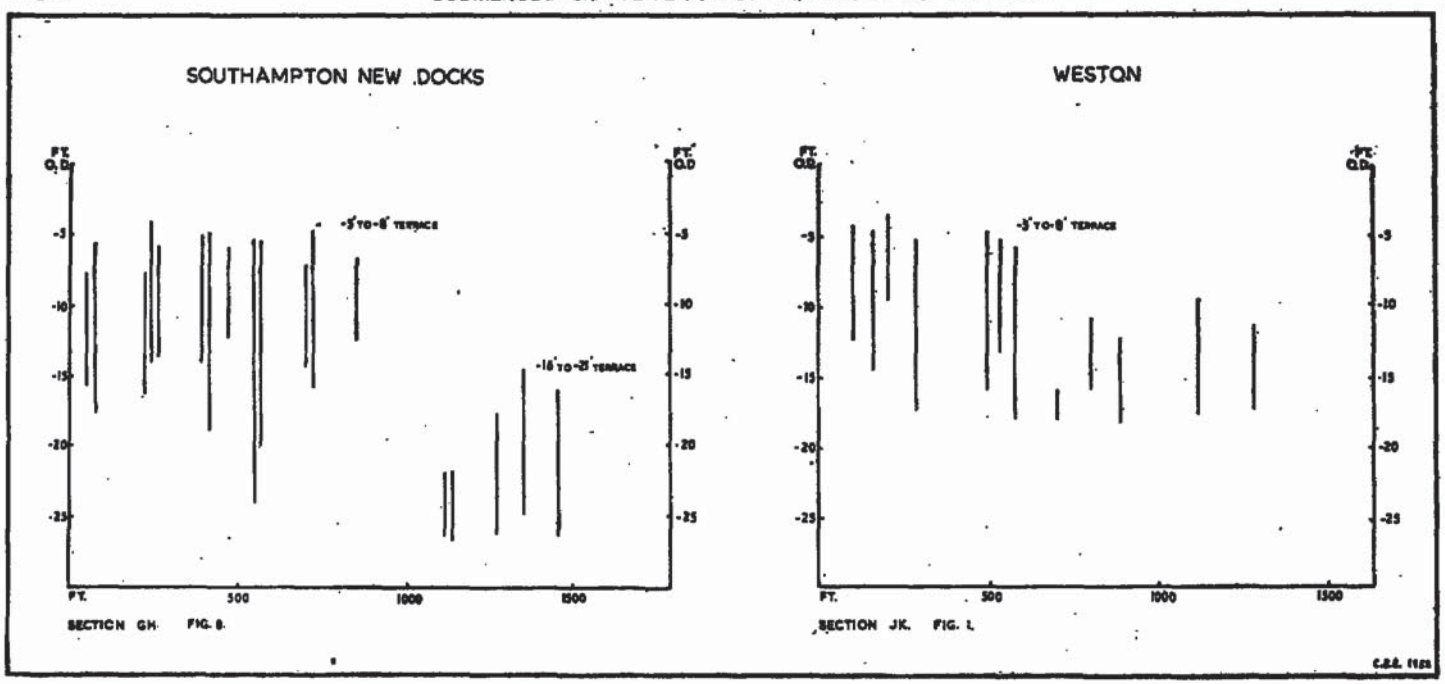
To the north-east of the above is the —60ft. terrace. It lies close to, and a little lower than, the present deep water channel. The gravel is about seven feet thick, and the top surface is just below —60ft. O.D. The terrace, which covers quite a large area, is the deepest so far found in Southampton Water and may represent the lowest phase of downcutting at this point.

Ashlett (Fig. 1).

Shallow borings at Ashlett have penetrated a consistent peat bed between nine and twelve feet below O.D. It is unusual in that it does not rest upon a gravel bed.

FIG. 7

SUBMERGED GRAVEL TERRACES — GENERALISED SECTIONS



Three deeper borings have penetrated a gravel layer, but did not reach the base. The gravel top slopes from —25ft. to —44ft. O.D. and is believed to be part of a steeply sloping gravel-mantled bluff.

Calshot.

South-east of Calshot Castle a series of borings have been put down on the edge of the main dredged channel (Fig. 1). They show gravel resting on alluvial mud, but the former is of recent accumulation and has been carried on to the spit by long-shore drift.

The base of the mud was not reached, the deepest bore-hole reaching —58ft. O.D. It is probable that the —60ft. terrace, of Fawley, passes under this area.

The Test, Itchen and Hamble Estuaries.

Bore-holes in the beds of the Test, Itchen and Hamble estuaries have revealed sheets of gravel, sometimes covered by peat, stretching from bank to bank beneath the alluvial mud. The gravel occasionally occurs at more than one level, but the lowest bed is always the best developed, and, as it rests directly on the Tertiary beds, it marks the lowest stage of downcutting in that particular part of the valley.

The River Test (Fig. 1).

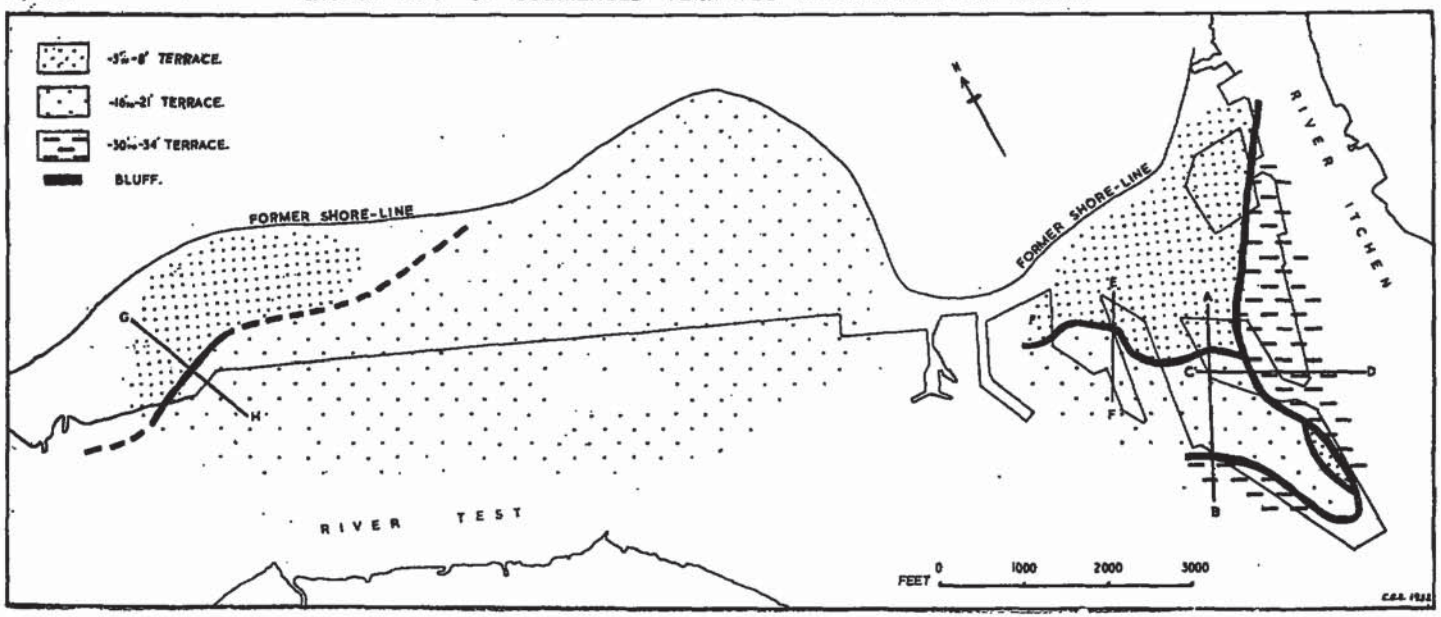
A small number of borings have been put down at Redbridge, and in these the gravel top ranges between —5ft. and —11ft. O.D. The base at one point falls to —24ft. O.D., although usually it is about —13ft. O.D. There is no evidence of deeper gravels, and it may be significant that at a comparable distance upstream on the River Itchen (Cobden Bridge), the deepest gravels are at approximately the same depths as those at Redbridge.

The River Itchen (Fig. 1).

This estuary has so far provided most of the data on submerged deposits, apart from Southampton Water itself. Three lines of borings have been put down along the lines of the bridges crossing it, and sketch sections of them are given in Fig. 10. The most northerly section is at Cobden Bridge. The gravel top slopes from —3·5ft. O.D. in the west, to —10ft. and —14·5ft. O.D. beneath the main channel. The sheet is about seven feet thick. In the west the gravel is only covered by a few feet of mud, but in the east it lies beneath several feet of peat.

Nine borings are available along the line of Northam Bridge. The gravel top is of fairly uniform depth, between —13ft. and —18ft.

FIG. 8 SKETCH-MAP OF SUBMERGED TERRACES IN SOUTHAMPTON DOCKS



O.D. In contrast to the other sections, the gravel is overlain by a practically continuous bed of peat, twelve feet thick at its maximum.

Further downstream another section is available at the site of a new bridge at Millstone Point. The main gravel sheet lies between −21·5ft. and −23·5ft. O.D., and is about twelve feet thick. It rests upon the "Greensand" of the Bracklesham Beds, met with so frequently in the Docks. Peat was recorded in the western part of the section.

The River Hamble (Fig. 1).

The information on buried gravel in the Hamble estuary is at present confined to the results of four trial-borings made along the line of the Bursledon railway bridge [(1) Appendix]. On the east side of the estuary was found a bed of "gravel mixed with clay" between −21ft. and −26ft. O.D.

Correlation.

Submerged gravel terraces, and those above sea-level, have so many features in common that they must be regarded as having essentially the same origin. It follows that the two may be studied by the same methods, namely, the recognition of a sequence of terraces related to their respective knick-points and graded reaches.[2]

The deepest gravel bed at any one place will represent the maximum amount of downcutting at that place, and an examination of these deepest gravels is perhaps the best approach to the problem of correlation.

There is evidence that, during the Pleistocene Period, there were several phases of river downcutting caused by low sea-levels.[3] The estuaries now seen at the mouths of our rivers were formed by the flooding of the valleys cut during the last phase of downcutting. The gravels found buried in the beds of these estuaries may be presumed to belong to this stage. Other "buried channels", as they are here termed, probably exist, marking even earlier channels unrelated to the present estuaries, and, as yet, undiscovered.

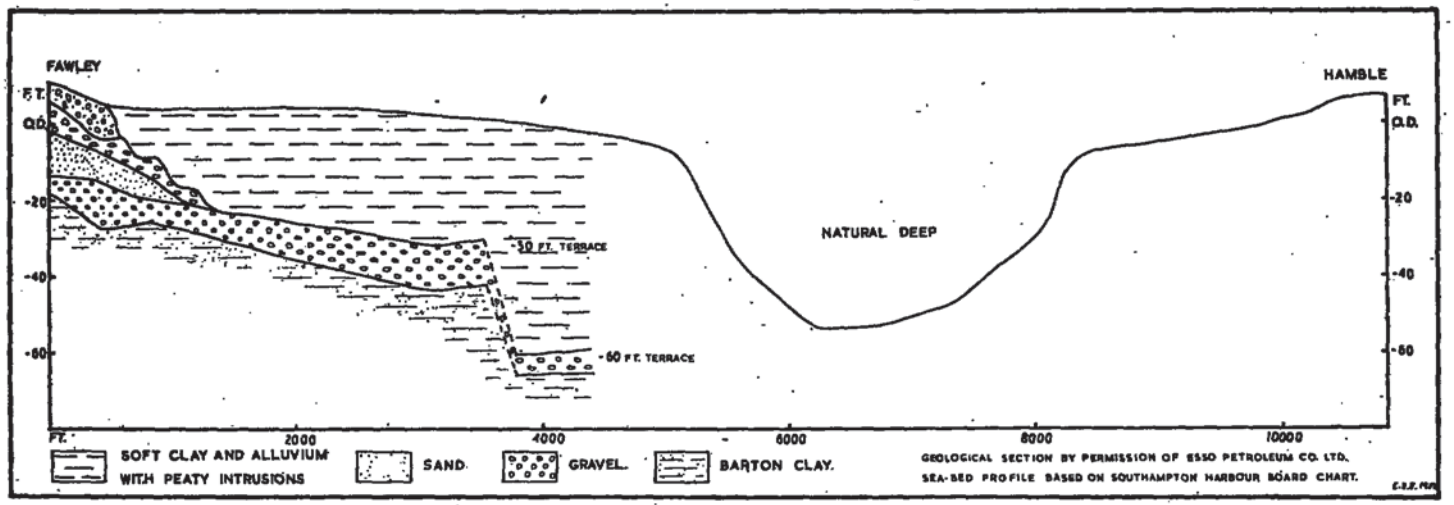
The top of the deepest gravel section at each of the bridges across the Itchen and in the Old Docks is given below, together with the gradients between them, measured along the centre line of the estuary.

	Depths in feet below O.D.	*Distance in feet*	*Gradient in feet per mile*
Cobden - -	−14·5		
		6000	3
Northam - -	−18·0		
		3000	9·7
Millstone Point -	−23·5		
		10000	5·5
Old Docks - -	−34·0		

2. See, for example, Wooldridge, S. W. and Kirkaldy, J. F., "River Profiles and Denudation Chronology in Southern England", *Geol. Mag.*, 1936, p. 1.

3. See, for example, Zeuner, F. E., *Dating the Past*, pp. 129-131.

FIG. 9 SOUTHAMPTON WATER. CROSS-SECTION FAWLEY TO HAMBLE.



It may be assumed that the gravel bed extends along the whole length of the estuary. The steep reach between Northam Bridge and Millstone Point (Fig. 11), separates two less steeply inclined sections. These may represent two distinct stages of downcutting, each being a graded-reach, with a knick-point in the vicinity of Northam Bridge. Alternatively, one stage, of somewhat irregular profile, may be present. More data is necessary before a definite conclusion may be reached, but the several terraces present at the mouth of the Itchen are presumably each related to a graded reach and knick-point further upstream.

Deep gravel beds are also present at Fawley. The deepest stage here is at —60ft. O.D. Its position and area suggests that it marks the maximum extent of downcutting. The gradient between the —34ft. Old Dock terrace and the —60ft. terrace at Fawley is 6·5 feet per mile. This is slightly greater than the gradient from the Old Docks to Millstone Point, but it is difficult to see what other correlation can be made (Fig. 11).

The lower step of the buried channel is therefore believed to extend from Millstone Point (—23·5ft. O.D.), through the Old Docks (—34ft. O.D.) to Fawley (—60ft. O.D.). The average gradient is about six feet per mile, which may be compared with the Thames buried channel gradient of four feet per mile (10).

The gravel at —11ft. to —14ft. O.D. (surface depths), at Redbridge is tentatively correlated with the upper step found on the Itchen between Northam and Cobden. Some of the deeper gravel sections off the New Docks almost certainly represent the buried channel, which here may have been partly filled in with detritus, making the gravel top much higher than elsewhere.

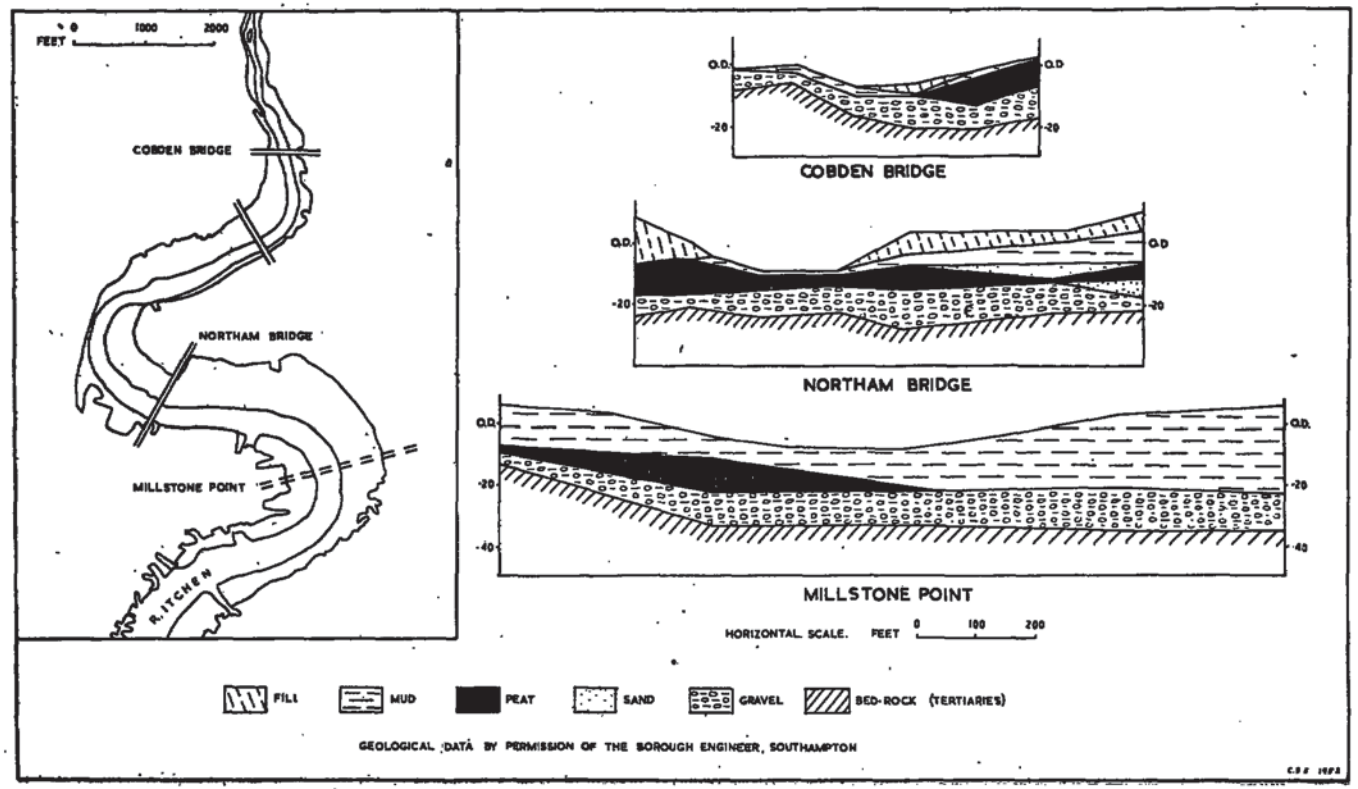
The gravel sections in the Hamble estuary, at Bursledon (—21ft. to —26ft. O.D.), are considered to be other remnants of the buried channel stage.

The path of the buried channel at the mouth of Southampton Water remains uncertain. The deep borings off Calshot Spit suggest that it passes beneath there, the mud descending to depths of —58ft. O.D.

The proto-Test must near this point have joined the " Solent River ". It is interesting to speculate whether the present marked bend of the main channel round the Brambles Bank has any significance in this connection. The Bank lies athwart the direct link between Southampton Water and Spithead, but its composition is unknown.[4] It may be a recent accumulation of detritus, blocking this direct link, or, alternatively, it may be a projection of Tertiary rocks, suggesting that the proto-Test turned west at Calshot when

4. See, however, Rupert-Jones, J. A. and Dyash, G. H. J., *The Physical Characteristics of Southampton Water.*

FIG. 10 RIVER ITCHEN ESTUARY — SECTIONS



about to join the Solent. In this event, a course to the sea *via* the West Solent, rather than Spithead, is conceivable.

It has already been suggested that the gravels at Redbridge and Northam-Cobden may belong to the same stage ("upper step" of the buried channel). With these may be included the —18ft. to —21ft. terraces of the Old and New Docks. In the latter, however, the terrace has no appreciable longitudinal slope over a distance of about one and a half miles, although there is a slight upstream gradient between its N.W. end and the supposed equivalents at Redbridge. Similarly there is practically no slope between the Itchen "upper step" of the buried channel, and the Old Docks —16ft. to —21ft. terrace.

The downstream equivalent of this terrace is not easy to trace. The terrace, at Fawley, which is in a comparable position above the supposed buried channel is the —30ft. terrace. The gradient between it and the Old Docks terrace is 2·5ft. per mile (Fig. 11). This is in marked contrast to the horizontality of the terraces upstream of the Old Docks. The exact relationship of the Fawley —30ft. terrace remains uncertain.

Finally, the terraces a few feet below O.D. in the New Dock, Old Dock, Weston Shelf, Dibden Bay, are placed in the highest stage.

The appended table summarises the correlations suggested above (see also Fig. 11).

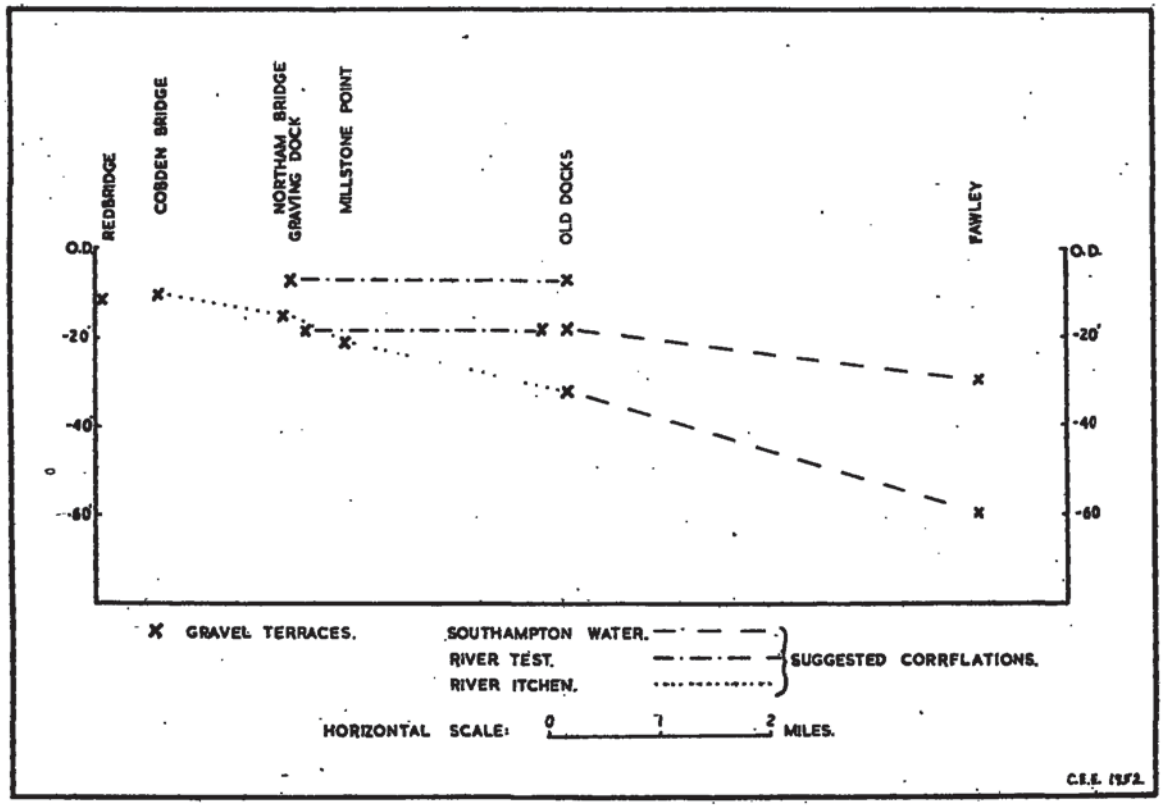
Test	*Itchen*	*Old Docks*	*Weston and Dibden*	*Hamble*	*Fawley*	*Spithead*
?	?	—5ft. to —8ft.	—5ft. to —8ft.	?	?	?
—11ft.	—18ft.	—16ft. to —21ft.	?	—21ft. to —26ft.	—30ft.	?
?	—23·5ft.	—30ft. to —34ft.		?	—60ft.	—98ft.

The Age of the Buried Deposits.

The peat beds may be accurately dated by the method of pollen analysis, and in time many samples of peat from the Southampton area will doubtless be dated in this way. The age of the gravel beds is, however, less readily determined. Archaeological evidence is valuable, but rarely available. Occasional implements are found, as, for example, that in the Empress Dock, assigned to the Mesolithic, but in most cases the exact depth and age is unknown. It is unlikely that discoveries will be any more numerous in the future than they have been in the past. Fossils are hardly ever preserved in gravels, and none that have been recorded are of great value for dating purposes.

It will be shown later that the age of a peat-bed may be very different from that of the gravel immediately beneath it, but there

FIG. II CORRELATION OF TERRACES.



would appear to be one important case in which the two may have approximately the same age.

The relative ages of the terraces may be deduced from a study of their structure and state of preservation.

The sequence of deposits upon any one terrace is, from the bottom to the top, gravel, peat, mud, which is therefore the order of deposition.

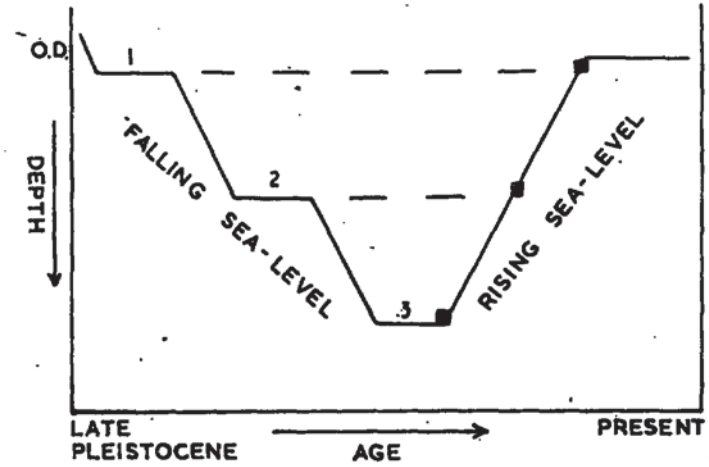
The transverse profiles of the terraces, especially in the Old Docks, resemble very clearly the " staircase " which may be traced in the Pleistocene terraces upon which the town of Southampton is built. The submerged terraces do, in fact, appear to continue this staircase to well below sea-level. It cannot be assumed, however, that the formation of the highest of the submerged terraces followed immediately upon that of the lowest of the terraces above sea-level.

The estuaries have undergone two distinct phases. The first was a period of emergence, which culminated in the cutting of the buried channel. This was followed by a period of submergence, which has led to the conditions to be seen to-day. The submerged terraces could conceivably have been cut during either phase.

Each terrace is well defined, and each sheet of gravel is clearly separated from that above and below. Had the terraces been formed during submergence they would have been buried in turn by the gravel and detritus produced during the formation of the terrace above. The cross-sections referred to earlier show that this is not the case, each gravel terrace being covered by peat and fine alluvial mud. The division into terraces and bluffs remains sharp, and supports the view that each terrace, after formation, was removed from the zone of rapid erosion, probably by a fall in sea-level, and a new terrace cut below it.

The terraces are therefore considered to have been formed during the emergent phase, and to become younger in descending order. They continue the terrace " staircase " found above sea-level.

It has been shown that the youngest gravels are those of the buried channel stage. They are of Pleistocene age, for they are part of the Pleistocene terrace sequence which is so widespread in South Hampshire. Furthermore, only the conditions during certain phases of the Pleistocene could have moved these coarse gravels. The quieter conditions of the post-glacial would be incapable of so doing. The so-called Neolithic Submergence appears to have immediately succeeded the deposition of the buried channel gravel, and the latter may therefore be confidently correlated with the low sea-level of the last major ice-advance. It follows that all the submerged gravel terraces are of Late Pleistocene Age.



KEY: 1, 2, 3. PERIODS OF TERRACE FORMATION.
■ PEAT BEDS ON THE TERRACES.

FIG. 12. THE RELATIVE AGES OF GRAVEL TERRACES AND THEIR ASSOCIATED PEAT BEDS.

C.E.E. 1951.

Godwin's analysis of the peat section in the King George V Graving Dock showed that the basal bed (—20ft. O.D.) is of pre-Boreal of Zone IV Age (Mesolithic), and that the highest bed (—6ft. O.D.) of Zone VII (Neolithic " B ") Age. The peat therefore becomes younger when traced upwards, and was formed in post-glacial times, during the period of submergence.

If, however, the interpretation of the gravel terraces given above is correct, their age is late glacial, and hence they considerably predate the peat which rests upon them.

The diagram (Fig. 12) illustrates this point and makes clear the important fact that the peat resting on the buried channel gravel is of approximately the same age as that gravel, whereas there is an increasing divergence in the age of the juxtaposed peat and gravel as present sea-level is approached. Hence it will be possible to date with some accuracy the buried channel gravels, once the age of the overlying peat has been determined.

To conclude, a brief summary of the probable sequence of events during the formation of Southampton Water is given below, based upon the theories given earlier. The highest of the submerged gravel terraces was the first formed, and may have been laid down along the shore of a narrow sea-inlet, not unlike Southampton Water at the present time. A fall in sea-level followed, which resulted in the withdrawal of the sea from at least the head of the inlet. River downcutting took place, and a pause in the fall of sea-level produced the —30ft. terrace at Fawley, which, being of fluviatile origin, slopes upstream. A further fall in sea-level resulted in the formation of a river of steeper gradient, the gravels of which remain as the Buried Channel. The rejuvenation head of this stage does not appear to have cut back further than the Lower Itchen.

Vegetation grew on the banks of this river, but within a comparatively short time, the so-called Neolithic submergence commenced. Conditions had changed and alluvial mud, instead of flint gravel, was now brought down by the ancestors of the Test, Itchen, and Hamble. The filling of the estuaries with this mud has gone on to the present. As the rising water reached the level of each terrace, the vegetation upon it was gradually submerged, and finally buried by mud. Shore and Elwes noted in Empress Dock that, at the base of the overlying Estuarine Mud, the gravel had been rearranged to form a beach, and included littoral shells. There would clearly be some re-working of the surface gravel by waves, and littoral shells are to be expected under such conditions (see also Godwin's evidence of a marine transgression in the King George V Graving Dock). Each terrace would in turn have been a coastal plain until submergence, and Oakley has given archaeological evidence of coastal plains along the shores of the Solent, and presumably the other estuaries, during post-glacial time (9).

Pauses in the submergence would have allowed vegetation to develop on the surface of the alluvial mud, giving rise to the peat beds found within the mud, as at Ashlett.

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