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PRELIMINARY REPORT ON SEDIMENT MOVEMENT

NEAR THE MERSEY RIVER ENTRANCE

by

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## INTRODUCTION

1. The purpose of this report is to examine the nature and extent of littoral drift of shore sediments in the neighbourhood of the Mersey entrance at Devonport. It deals mainly with work carried out along the coast from the Don Heads in the west to Northdown in the east but use has been made of the results of previous reconnaissance work along the Bass Strait coast as a whole. In addition some small attention was paid to the question of movement of sediments in to and out of the Mersey estuary, transverse to the littoral drift directions.

2. No wave records are available at Devonport but conclusions on the wave climate can be reached by deduction and from local information. Observations elsewhere indicate that much more long swell enters Bass Strait from the west than from the east. This is because much more swell in these latitudes is generated from the west and Bass Strait is more open to westerly than easterly swell. The nature of this swell is depicted in Figure 1 which is a refraction diagram computed for southwesterly oceanic swell of 14 seconds period entering Bass Strait. Experience has shown that these are by far the most important waves around the Tasmanian coast. The diagram shows that Devonport is comparatively sheltered from this swell although it gives big waves on the Victorian coast. Around Devonport it provides the small, fine weather waves which can be regarded as "background" to the local wind waves. Local wind waves can best be assessed from the wind records for Low Head which is the nearest appropriate recording station to Devonport. These show that winds from NW and NNW are much the most important onshore winds, whereas those from N round to NE are relatively scarce. This applies to gale force winds as well as to those of lower velocity. It is clear therefore that storm waves and smaller wind waves come overwhelmingly from the northwest. Figure 2 shows a refraction diagram for storm waves of 7 seconds period emanating from the NW which is also the direction of greatest fetch. Both swell waves and storm waves can therefore be deduced to approach Devonport most commonly from the northwest and this accords with local information. It should be noted however that swell is much refracted and storm waves are scarce so that the coast at Devonport is a relatively sheltered one.

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3. Tidal currents set westward along the Bass Strait coast on the flood and eastward on the ebb, but at Devonport they set more or less transversely in and out of the Mersey entrance. Maximum velocities are about  $1\frac{1}{2}$  knots. The tide is semidiurnal with a range of about 10 ft at springs and 6ft at neaps.

#### THE PRE-DEVELOPMENT INLET

4. The condition of the Mersey entrance before the beginnings of port development provides a useful guide to the natural processes which are still operating. The Stanley chart of 1884 shows this condition quite clearly and the main characteristics of the entrance at this time are indicated in Figure 3. Two major processes are discernable. The first is that of bar construction by waves which was tending to build a barrier along the line indicated in the figure. Stanley's chart shows a maximum depth of a little under 6ft at low water springs but this depth is known to have varied seasonally. At times the river was fordable. By analogy with what happens today in similar situations around the Tasmanian coast the bar would have been particularly shallow in summer when storm waves were scarce and the Mersey flow reduced; particularly deep in winter when big waves were more common and flood conditions occurred in the river. The bar indicated by Stanley's chart shows no evidence of having been built in a longshore direction under the influence of littoral drift. Its position and shape suggest strongly that it was built by sand pushed up from seaward parallel to the wave crests.

5. The second major process deducible from the 1884 chart is that of ebb and flood channel construction by tidal streams. On Figure 3 a hindcast of the main ebb and flood trajectories has been made, using the evidence of submarine contours drawn from the chart. The main flood and ebb trajectories indicated coincide largely with those indicated by arrows on the Stanley chart and are not very different from those experienced today. However in 1884 it appears that additional flood stream directions were important at certain stages of the tide and these are indicated by broken lines in Figure 3. From the point of view of this report the most significant is that from the northeast across the line of the present training wall. This would have been especially important near the time of high water.

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6. In 1884, then the entrance can be explained in terms of the sea tending to build a bar in fine weather; the flood tide tending to bring material across this bar along the directions indicated on Figure 3 and the ebb tide and Mersey run off tending to move material out along different but roughly parallel routes. The most important results of subsequent development works have been (1) to concentrate the flood tide stream and in particular to prevent it crossing the line of the existing training wall, thus reducing the amount of material being carried into the main river channel by the flood and (2) to inhibit bar building by concentrating the effect of the tidal streams and by dredging.

7. One other feature of the 1884 chart deserves special mention. The chart shows that low water mark in 1884 was very little different from that of today and that the projecting area of sand and shingle east of the river mouth was by no means wholly a result of the training wall. In fact the training wall was built upon it. The existence of this projection, subsequently utilised by the wall, was undoubtedly related to the location of the "breakers" marked on the 1884 chart further to seaward (see Figure 3). There appears to have been a shoal area of solid rock in this vicinity which sheltered the coast immediately to southward and encouraged deposition of sand flats to take place.

#### OFFSHORE BOTTOM CONDITIONS

8. Figure 4 shows the nature of the adjacent floor of Bass Strait as far as can be determined from soundings. The map was constructed from the unpublished working charts of recent Australian Navy surveys. It covers the zone from about 2 or 3 miles out to about 15 miles out. As will be seen, the major part of the bottom in this area is covered by sand but running northward from Port Sorell there is a band of mud averaging about 5 miles wide. I do not know the nature and origin of this but I shall refer to it again later.

9. Bottom conditions inshore of this zone are indicated in Figure 5, which has been constructed in the main from aerial photographs. It will be seen that within about  $\frac{1}{2}$  mile of the coast the greater proportion of the sea floor around Devonport is composed of solid rock. Much the greater proportion of this is almost certainly basalt.

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10. The sand at Coles Beach has only a tenuous contiguity with that off Laycocks Beach and neither the Bluff Beach nor East Beach are extensively connected with sand deposits to seaward. Pardoe Beach is separated from the nearest sand to the west by almost  $1\frac{1}{2}$  miles. Outside this zone however, beyond the 3 fathom contour where air photo interpretation cannot be carried out, sand appears to be continuous from west of the Bluff to the dredged section of the Mersey. Sampling arranged by the Board's Chief Engineer shows that a sandy bottom occurs within 50 ft of the Bluff opposite the lighthouse. The areas shown on the map as covered by pebbles are almost entirely underlain by rock. This can clearly be seen in many places and it appears that the only locations where pebbles can congregate are either where they have been piled into a rampart near high water mark or where they have been trapped by irregular rocky surfaces at lower levels. We can say then that, at less than 3 fathoms below low water springs, rock is dominant and sand is patchy and isolated in distribution. At more than 3 fathoms, sand is probably more or less continuous although further sampling would be desirable to confirm this.

11. The only important break in the offshore rock platform is that at the mouth of the Mersey along which dredging takes place. This is caused by the Mersey River having cut downward to a lower base level in the later stages of the Pleistocene when sea level was at least 300 feet lower than it is today. This Pleistocene channel was subsequently filled with sand and it is being re-excavated by present day dredging. Away from the line of present day dredging, sand is likely to form only a relatively shallow veneer over the rock platform base.

#### CHARACTER AND ORIGIN OF SAND

12. Sand samples were taken from the beaches and further sampling was arranged by the Board's Chief Engineer off the Bluff and in the dredged channel. The location of these is shown in Figure 6. In addition samples were taken from inter-tidal banks off the proposed Berth no 6 and near Quoiba. Preliminary laboratory examination of these indicates that the sand has three main constituents - (a) shell, (b) basalt and minerals derived from basalt, (c) quartz. The first two which are generally angular are derived locally from the break up of marine shells and the

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attrition of the basalt rock platforms. At different localities they can be identified in every stage of evolution from whole shells and large basalt particles down to fine sand. The quartz fraction on the other hand must have a much longer history. Grains are generally sub-angular to sub-rounded and it is impossible to assign them to any particular origin. They may have come down the rivers, been brought in from the floor of Bass Strait or been produced by erosion of quartz bearing rocks along the present coast. The first two sources are more likely than the third.

13. To the west of the Bluff the sand at Coles Beach and Laycocks Beach is particularly shelly, comprising between 30 and 40 per cent of shell. Off the end of the Bluff and at Bluff Beach and East Beach the shell content drops to about 20 per cent but rises again on Pardoe Beach to between 30 and 50 per cent. This pattern is in fact repeated at other locations along the Bass Strait coast - at Wynyard, at Ulverstone and Turners Beach and in Emu Bay. In each case the shell content decreases near the mouth of a large river and is a result either of a reduced molluscan fauna at this point or the introduction of larger amounts of quartz. It is noteworthy however that the shell content of sand taken from the dredged channel (25-35 per cent) is significantly higher than that of the beaches on either side. A possible reason for this is suggested later (para 38).

14. The basalt content of the sand is small throughout and does not appear to show any clearly discernible pattern. There is some evidence of an increase away from the river which parallels the variation in shell pattern but the figures obtained are not statistically significant.

15. A significant part of the sand around Devonport and conceivably all of it could therefore have been produced locally. There is a suggestion in the increase in shell content and possible increase in basalt content away from the river that the river may be a significant source of the quartz fraction. I have no proof of this as yet but similar circumstances in other parts of the world are normally interpreted in this way. Samples taken from within the river showed a heavy preponderance of quartz with decreasing shell landward. The sample from Quoiba is almost pure quartz.

16. There may be some seasonal changes in the shell content on the beaches. Samples taken from the Bluff Beach and also from East Beach after

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a period of rough weather which had produced cut on these beaches showed a significantly reduced shell content. This suggests that stormy onshore weather may result in a selective removal of beach shell seaward.

#### CHARACTER AND ORIGIN OF PEBBLES

17. The coast from Ulverstone to Point Sorell contains far more pebbles than any other comparable section of the Tasmanian coast. They are of two main kinds. One group is composed of basalt pebbles, angular to subangular in form and clearly quarried by the sea from the local rock platforms. The other is composed of well rounded pebbles of quartzite and other, mainly metamorphic, rocks which have almost certainly been brought down by the Forth and Mersey Rivers at a time or times when they carried meltwater from large glaciers occupying their headwaters. Similar pebbles can be found in the up-river terraces of both the Forth and Mersey and they are seen for instance where the Mersey enters its upper estuary at Latrobe. These old pebbles brought down at a time of low sea level have subsequently been concentrated by the sea mainly near high water mark on the coast around the mouths of the Mersey and Forth.

18. The basalt pebbles are being produced today but they are also being destroyed since they are not very resistant and break up relatively rapidly. Since their rate of production probably roughly equals their rate of destruction their total numbers remain about the same. What I shall call for convenience the quartzite pebbles are not being produced today, but their rate of destruction is very slow since they are extremely resistant to attrition. Their total numbers therefore also remain about the same, except where they are being removed by human action. The volume of quartzite pebbles is much greater than the volume of basalt pebbles.

#### DIRECTION OF LONGSHORE SAND MOVEMENT

19. The Bell Report of 1899 stated that "There is no evidence of sand coming from the westward. Silting comes from the eastward." The Keele Report of 1911 suggested that sand and shingle travelled from the west. The Adams Report (1936) pointed out that these two statements were not necessarily in contradiction since the eastern training wall had been built between 1899 and 1911 and "the only direction from which sand and shingle could come when Mr. Keele reported was from the west." The Adams

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Report concluded that "littoral currents are subject to considerable changes at times, sometimes eastwards and sometimes westwards." The Tydeman Report (1964) generally supported this conclusion. My own conclusion is that net littoral drift is very small but that what exists is from west to east. Although there may have been short period reversals, I think it highly unlikely that there has ever been any time when any significant drift occurred from the east. My reasons for this conclusion are given below.

20. In the first place, theory suggests that movement ought to be from west to east. Movement of material coastwise is carried out by three agencies which are listed below in what is usually considered their order of importance as conveyors of sand.

A. Beach drifting by waves impinging obliquely on beaches. This must be of very minor importance around Devonport because of the prevalence of rock and pebble at high water mark and the lack of continuity in the beaches. Where it does occur it should be dominantly from west to east because of the overwhelming prevalence of waves from this direction.

B. Longshore currents generated within the breaker zone again by obliquely impinging waves. In general, swell waves are more effective than big storm waves and the optimum angle of approach is thought to be about 40 to 50 degrees. Such currents are thought to be particularly effective especially where continuous beach drifting is impossible. Again because of the overwhelming prevalence of westerly swell they should operate from west to east around Devonport.

C. Tidal currents produced by the ebb and flood of the tides. These tend to be reversing and on the Bass Strait coast run westward on the flood and eastward on the ebb. They tend therefore to be self cancelling. They are generally weak on open coasts and important only in constrictions such as in the mouths of rivers. On the open coast off Devonport it is unlikely that there is much net movement along the coast solely as a result of tidal current action.

21. Work carried out along the Bass Strait coast in the last few years indicates clearly that drift has been from west to east as far back as the geological record goes. This is shown by a number of things. With the exception of those sediments trapped in Perkins Bay, sand has moved to

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the eastern section of the coast (that is, east of Devonport) where it has piled up in large dune sheets. The individual beaches east of the Tamar have become oriented to face westward and a normal process of coastal evolution is orientation of beaches towards the direction of supply of materials. At headlands sand is invariably piled against the western side and there is a comparative deficiency to the east. The investigation of variations in the character of beach sands suggests that sand of a particular type invariably appears to extend eastward from its source of supply and never westward.

22. Suggestions of drift from the east appear to be based on two grounds - reciprocal changes in beaches on either side of the Morsey entrance and the accumulation of sand on the eastern side of the training wall. The first argument is used in the Adams Report where it is stated as follows: "This conclusion appears to be confirmed by the information given me locally that beaches east and west of the river mouth are subject to considerable reciprocal changes. That is to say, when the beaches to the west almost disappear the beaches to the east pile up and, vice versa." But this argument completely ignores the possibility of seasonal movement of sand transverse to the beach, considerable information on which has accumulated since 1936 when the Adams Report was presented. Swell waves (long, low waves) tend to move sand shoreward and to build up the beach. Storm waves (short, high waves) tend to remove sand from the beach and to spread it over the inshore bottom. A given beach will therefore be subject to recurrent "cut" and "fill" with changes in the wave regime. At Devonport for instance a gale from the northwest causes sand to be removed from Laycocks Beach and other beaches exposed in that direction whereas strong onshore winds from the northeast cause cut on the Bluff Beach. It appears to me to be perfectly possible and more reasonable to explain the alternate appearance and disappearance of sand on different beaches in this way and without invoking any littoral drift whatsoever.

23. That sand appears to have piled up to the east of the eastern training wall may also appear to provide an argument for drift from the east but this argument too must be used with caution. Stanley's chart of 1884 shows clearly that low water mark at East Beach was in much the same position at that time as it is now. In fact a comparison I made among

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available charts and air photographs indicated that the position of low water mark has moved slightly shoreward rather than seaward since 1884. I do not think that this comparison is accurate enough to be relied on completely but I mention it to indicate that at least there is no evidence of progradation. However there has been an accumulation of surplus sand at East Beach and this has been moved behind the beach by wind to form low dunes. I believe that, before the construction of the training wall, this surplus sand would have been moved into the main Mersey channel on the flood tide (see Fig. 3 and para. 5) and I feel sure that this is what Napier Bell meant when he stated that silting comes from the east. But I would stress that this is not littoral drift in the sense in which we now understand it. I think that basically what happened before the construction of the training wall was that the prevailing northwesterly swell brought sand in the direction of the present East Beach. The flood stream carried it into the Mersey channel from whence it was moved out by the ebb only to be brought in again by the swell. A major effect of the training wall was to break this cyclic system and cause sand to be trapped to the east.

24. My investigations suggest that the build-up of dunes east of the training wall took place comparatively rapidly and that no further accretion has taken place at least over the last 30 years. Various estimates which I have made place the total quantity of sand in the dunes at between 50,000 and 80,000 cubic yards, which is small in relation to the amounts removed by dredging. I interpret this as meaning that, when the coast had prograded in such a way that the beach fitted the prevailing wave crest, a condition of equilibrium was achieved and this has since been maintained. Before the erection of the training wall this equilibrium could not be achieved because of the interference of the flood tide. If there were no Mersey River, no tides and no training wall the line of East Beach would be extended westward along the "Line of wave built bar" indicated in Figure 3. It is useful to bear this in mind as something which the waves are always attempting to do, even now when the Marine Board combines with the tides and the Mersey flow to defeat them so effectively.

25. If there had been any significant littoral drift from the east

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causing a build-up to the east of the training wall then world-wide experience suggests that there would have been corresponding erosion of the coast to the west of the training wall. Again a comparison of charts with air photographs shows that erosion here (northern end of Pardoe Street) has been very slight since 1884, and has in no way been aggravated by the construction of the wall. The appearance of the area west of the training wall is substantially the same today as it was in 1884.

26. Figure 5 shows that the only source of sand to the east of East Beach is at Pardoe Beach and that these localities are separated by almost  $1\frac{1}{2}$  miles of rock platform and shingle. Very small patches of sand that are to be found in this intervening section contain coarse shell and basalt particles and are obviously being derived locally. This sand is unlike that on East Beach but does show some resemblance to Pardoe Beach sands, which are coarser and have a higher proportion of shell and basalt than does the East Beach sand. This suggests that if there is any littoral drift it is eastward towards Pardoe Beach.

27. The present condition of Pardoe Beach indicates an overwhelmingly predominant west to east drift. The quantity of sand increases steadily in this direction and so does the width of the inshore zone occupied by sand. Pebbles have also obviously moved further and in greater numbers eastward from the western end than they have westward from the eastern end. The small stream which empties across the beach part way along is deflected eastward and although the extent of this deflection has varied in the past, the form of the dune barrier shows that it has never been deflected westward. Local information suggests that at times in the past there has been more sand at the western end of the beach. This may indicate a temporary reversal of the prevailing drift but it can also be explained in terms of variations in transverse cut and fill cycles at either end of the beach. In any event the evidence as I see it gives no indication that sand has ever escaped westward from Pardoe Beach. During the period covered by the air photographs (the last 20 years) there has been no significant change in sand distribution and the way in which dune sand has piled up over hundreds of years at the eastern end of Pardoe Beach shows that west to east movement has been prevalent for a very long period of time. The sand on Pardoe Beach is very similar to that of Northdown

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Beach further east but this sand differs very markedly from that around Port Sorell and on Baker's Beach. For this and other reasons it is very unlikely that sand finds its way on to Northdown and Pardoe Beaches from further east. The mud zone (Figure 4) extending seaward from Point Sorell also suggests little movement at depth past this point. Whatever else may be said therefore, there appears to be a considerable limit to sand supply from the east.

#### RATE OF LONGSHORE SAND MOVEMENT

28. In summary then all the evidence which I have collected within the Devonport area and on the Bass Strait coast as a whole points to a prevalence of littoral drift from the west. There may be occasional significant reversals but I have not seen undisputable evidence of them. However, having said this, it is necessary to emphasise my conclusion that the amount of this drift in terms of sediment movement is very small. The prevailing swell which is the main cause of beach drifting and longshore currents is relatively weak on the Tasmanian side of Bass Strait. On the Victorian side, for instance at Portland and Apollo Bay, it is much more powerful and movement of sediment is much more extensive. Figure 1 illustrates how the important southwesterly ocean swell is weakened on the Tasmanian north coast. There are important theoretical reasons therefore why the amount of longshore sediment movement should be small. I give below some reasons for believing that this is in fact the case.

29. Figure 5 shows that the beaches around Devonport almost qualify as pocket beaches. That is to say they are almost cut off from continuity with other sand bodies by areas of rock and pebble. As stated earlier, beach drifting is therefore minimal. It is further inhibited by the widespread presence of pebbles near high water mark. These are very effective in preventing sand from moving in the inter-tidal zone and their presence is therefore to be encouraged.

30. The abundance of rock at less than 3 fathoms low water depth suggests that movement of sand by longshore currents and tidal currents is

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also very limited since, except in the unlikely event of sand being carried for hundreds of feet in suspension, it would tend to be trapped by the rough surface. I examined such rock surfaces as are exposed at low water springs and could see no evidence of sand so trapped or in any way in transit. It is general experience that, where there is considerable littoral drift of sand, offshore rock surfaces are limited. The very extent of rock off the Devonport coastline in itself suggests limited drift.

31. If much longshore movement of sand took place it might be expected that the pattern of contact between sand and rock would change periodically. Sand would invade the rock surfaces in places and be removed from them in others. With this in mind I have examined carefully the air photographs for 1945, 1953 and 1963. I cannot find any change in the pattern of sand and rock distribution between any of these three years. To my mind this is a very powerful piece of evidence pointing to the limited nature of littoral drift.

32. It has been pointed out, for example in the Adams Report (1936), that comparison of the Admiralty Charts of 1908 and 1934 shows that the inshore submarine contours have not changed. In my view this is mainly a reflection of the extensiveness of the rock bottom and cannot be used as evidence of little drift.

33. The observed diminution in shell content of sand on either side of the river and the possible diminution in basalt content suggests either that littoral drift is too weak to produce greater uniformity or that there is an excessively large output of quartz from the river. The first explanation is more likely.

34. The conclusion expressed in para. 4 may be repeated, that the original Mersy bar as illustrated in the 1884 chart shows no evidence of having been formed by littoral drift. It is characteristic of those built parallel to wave crests.

35. The degree of sorting and grading of sand on the beaches is consonant with there being little longshore movement. Samples taken from all beaches except Pardoe Beach showed good sorting and also good grading with particle size increasing from the more sheltered part of the beach towards the more exposed part. In my experience this is good evidence for

minimum longshore movement, for, where there is strong drift, both sorting and grading tend to be poor. The Pardoe Beach samples, particularly that from the eastern end showed distinctly poorer sorting and did not seem well graded, but since I took only three samples along this extensive beach the results may not be significant. Further sampling of Pardoe Beach would be valuable as indicating whether or not there is more tendency to movement back and forward along the shore here.

36. It is worth drawing attention again here to the Point Sorrell mud zone (Figure 4, para. 8). Very little if anything is known of movements at depth in Bass Strait but the presence of this mud zone does suggest that there is not much sand passing across it.

37. In conclusion one may cite the opinion of virtually all modern authorities that littoral drift decreases rapidly seaward from high water mark. It is because the processes capable of giving rise to drift in the intertidal and breaker zone are so relatively ineffective that the sum total of drift in the Devonport district appears to be small.

#### TRANSVERSE SAND MOVEMENT

38. Movement of sand may take place at right angles to the shore as well as parallel to it. As indicated previously our knowledge of these transverse movements has increased considerably in the last twenty years or so and therefore reports on conditions at Devonport made before that time pay little attention to it. In my opinion transverse movement of sediments (in and out) are of much more importance in connection with the Mersey entrance than are longshore movements (east and west).

39. The phenomenon of "cut" and "fill" whereby variations in wave attack cause transverse movement on beaches has already been mentioned (para. 22). In addition there has come increasing evidence from some regions (other parts of Tasmania, Victoria, New South Wales, east coast of U.S.A. and the Gulf of Mexico, west coast of France) that long swell waves may move material shoreward from rather greater depths. The exact depths are not known but are probably related to the length of the operative waves. This onshore "creep" may be especially important in supplying sediments to beaches which are exposed to big swell of long wave length and where littoral drift is negligible or non-existent.

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If such a movement occurs at Devonport it will be of small extent because of the general weakness of the swell, but what does exist will be almost entirely from a northwesterly direction. In Figure 7 the wave orthogonals (lines drawn at right angles to the wave crests) will indicate the directions along which swell is likely to move material shoreward. Over a long period of time an equilibrium slope will probably be attained so that such onshore creep is very small or is even eliminated, but if excess material is introduced at any time (for instance by longshore drift, by river deposition at times of flood or by the dumping of dredgings) such excess material is almost certain to move shoreward in the direction of the wave orthogonals. Conversely if a deficiency of material is created (for instance by drift away or by dredging) then onshore creep will tend to fill the depression thus created.

40. This suggests that movement of sand by swell from the northwest may be important in the partial refilling of the outer part of the dredged channel at Devonport. Figure 5 shows that it is possible and even likely that the approach from this direction would be over a sand bottom. It would be of value if bottom sampling was carried out in this apparently crucial area northwest of the limit of dredging.

41. As stated previously (para 13) sand samples from the bottom of the dredged channel show a consistently larger shell content than those of adjoining beaches and from off the Bluff. The six samples showed that the sand being moved into the channel contained from 24 to 34 per cent of shell. Although the work done is not conclusive, it does suggest that there may be some selective accumulation of shell and this may be contrasted with the apparent selective removal of shell from the beaches under storm conditions which was noted in para 16. It is not hard to imagine some connection between these findings but until further work is carried out such a connection cannot be proved.

42. In contrast to their relative inefficiency in open coastal waters tidal currents become very effective when they set in and out of the Mersey entrance. Because of their different initial trajectories, differences in the level at which they flow and in the density and turbidity of their constituent water the ebb and flood currents tend to

follow different paths. Commonly also ebb currents will begin to flow before the end of the flood and vice versa. It follows that sediment brought in by the flood may be by-passed by the ebb which may itself be moving sediment in the reverse direction. Figure 3 shows that in 1884 the Mersey entrance showed some development of such an ebb and flood channel system. In succeeding years, river training works have been aimed at forcing the ebb and the flood into one main channel, although in spite of this, they still maintain different trajectories through the port area. I have not been able to carry out any work which would throw light on the efficiency of these currents as movers of sediment but I think it likely that a certain amount of material moves through the port in both directions, particularly seaward.

43. The Bell Report suggested that marine sand was carried a certain distance up the Mersey, but the general conclusion of this and all subsequent reports seem to have been that virtually no sediment moves in the reverse direction. The assumption is that the Latrobe estuary acts as a great settling basin in which river material is trapped. While this assumption is almost certainly true in the main, I would doubt whether it is sufficiently true that it has no bearing on sedimentation in the port area. In any case there seems to be no evidence in existence at the moment to prove the point one way or the other. Sand which I have examined from a tidal flat in the lower Latrobe estuary at Quoiba and from the bar near proposed Berth 6 contained about 75 per cent quartz grains in the fine sand category (0.125 to 0.25 mm diameter) and so did sand obtained from the Bluff Beach and East Beach. In itself this is not significant except in so far as it shows that there could be a sediment connection between the Latrobe estuary and the sea. What may be significant, as suggested in part earlier (para 15), is that this fine quartz sand becomes very much scarcer to the west of the Bluff on Coles and Laycocks Beaches and on Pardoe and Northdown Beaches in the east. There is a distinct implication here that the river is the source of this fraction, but more work would be necessary to show that this is definitely so. Similar sand appears to occur in the river bed at the town of Latrobe but I have

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not been able to examine this. It also makes up 40 to 60 per cent of the sand sampled from the dredged channel but here there is a much greater amount of quartz in the very fine sand and silt grades (less than 0.125 mm diameter). The only other site where I have obtained this finer material in significant quantities is on the tidal flat at Quociba. No real attempt was made to investigate this question of movement of sediment by tidal currents and the results are inconclusive. However they do go to show that further investigation appears very desirable.

44. The third agency which may cause transverse movement is the river flow. In general this runs with the ebb tidal current and occupies the same channels. It will therefore reinforce this current and its effects are obviously tied up with those discussed above (para. 43). The effect of the Mersey flow is generally discounted as an important factor in its own right. Hydro-electric Commission engineers have calculated (Tydeman Report, page 31) that maximum tidal flows of up to 25,000 cusecs could be expected in the port area without any contribution from the Mersey. They have concluded that the normal contribution of the Mersey River flows to the natural scouring velocities in the harbour area is negligible. At the gauging station at Kimberley the average mean annual flow of the Mersey is about 1600 cusecs but this decreases to about 1000 cusecs in some years and may rise to about 2500 cusecs in others. At times of flood it may rise to 25,000-30,000 cusecs, and The Admiralty Pilots Handbook states that after heavy rains the outgoing stream at the port has been known to attain a rate of 4 knots. It seems to me probable that the Mersey flow when added to ebb tide currents is at least occasionally important in influencing the movement of sediments seaward, but the problem is a very complex one and I have not yet had an opportunity to evaluate it.

45. In summary I repeat my conclusion that the problems of sediment movement in the Mersey entrance are basically those of transverse movement in and out of the estuary and not those of movement along the coast westward and eastward. Such problems are not very great in relation to a port of the importance of Devonport, but they are worth

investigating further.

#### MOVEMENT OF PEBBLES

46. The pebbles are much less mobile than the sand in normal circumstances. They are moved shoreward by fine weather waves and are not cut to the same extent as sand by storms. In fact they may be thrown up by storm waves to form a high storm ridge. Such ridges occur particularly between East Beach and Pardoe Beach but pebbles occur almost everywhere at high tide mark on the coast around Devonport. All indications are that they move about relatively little and the same applies to those pebbles trapped on the surface of rock platforms and forming small sheets about low water mark. Examination of photographs and charts suggests that the location of these pebble sheets has remained more or less constant at least during the last fifty years. However some pebbles become detached from the main body and, when they find their way on to sand, may move about with great rapidity. In these circumstances they are moved either up to high water mark, where they may become more or less stable again, or into the dredged channel, where they end up in the dredger. It is probable also that a certain number of pebbles are still being brought in from the floor of Bass Strait by onshore creep. Sample 285 from off the Bluff consisted of quartzite pebbles and some were brought up in sample 283. My conclusion is that movement of pebbles is a negligible problem.

#### PRACTICAL CONCLUSIONS

47. Dredging of channel. The depth of the bar is the result of a balance between onshore creep and bar building on the one hand and tidal and river scour on the other. In 1884 this depth was about 6ft: in 1965 the undredged depth is apparently about 19ft. Obviously anything which will reduce the effectiveness of onshore creep, bar building and tidal deposition on the one hand and increase the effectiveness of tidal and river scour on the other will lessen the amount of dredging required. Of the material accumulating in the dredged channel, at least 25-35 per cent (the shell fraction) definitely comes from seaward. There is some evidence (paras. 15, 42) that most

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of the remainder comes down the river, but this is not yet proven. Dredgings should be dumped to the east of the Mersey entrance and not to the west and never within the 7 fathom line.

48. Proposed western breakwater. If built to about 1700 feet (recommended first stage) the proposed breakwater should help to reduce onshore creep into the channel. Extension to about 2400 would be more effective but it is doubtful whether the amount of the extra cost would be justified only by the amount of dredging it would save. I doubt whether the first 1000 ft of the breakwater will have any appreciable effect on the rate of deposition in the channel except in so far as it may help to increase tidal scour. There should be some slight accumulation of sand to the west of the new breakwater but this accumulation will be very slow.

49. Development of eastern side of entrance. The scheme for ultimate development at the eastern side of the entrance (present East Beach area) outlined in the Tydesman Report appears perfectly safe from a sedimentation point of view and should enhance the effectiveness of the western breakwater in maintaining channel depth. I would predict however that the dredging of the area now occupied by the eastern training wall will present difficulties as it is very likely that bedrock will be encountered (see para. 7). I would not expect sand to accumulate to the east of the proposed ultimate eastern breakwater.

50. Exploitation of pebble resources. There has been considerable excavation and use of quartzite pebbles for aggregate in the Devonport district and it is important that the Board watches such development closely. The pebbles are virtually a non-renewable resource (paras 17, 18) and they fulfil at least two useful functions as far as the Board's activities are concerned. In the first place they are effective absorbers of wave energy and help to prevent erosion of softer materials to landward. The less erosion there is in the Devonport area the less sediment is being produced to enter the channel. In the second place they are important inhibitors of beach drifting of sand. Their presence about high water mark helps therefore to prevent littoral movement of the more troublesome finer sediment.

51. Development of the Latrobe estuary. If it should prove that an appreciable amount of the sediment accumulating in the dredged channel at Devonport does come from up-river then plans for development of the Latrobe estuary need particularly careful consideration.

52. Further information. Arising from the conclusions presented in this report it seems that the following further investigation would prove profitable:

- (i) Establishment of a wave recorder near the Mersey entrance so that a proper quantitative record of wave period and height can be built up. This would be of great value in planning the proposed engineering works around the entrance and would also serve to show whether the assumptions made in this report about the wave climate are correct.
- (ii) Sampling of the sea floor between the 3 and 6 fathom low water contours, particularly between the Bluff and the end of the dredged channel. This would help to check the hypothesis of onshore creep as a factor in shallowing the dredged channel. It might also help to show whether the seaward bulge in the 6 fathom line represents a submarine delta of deposition off the Mersey mouth as seems possible. This too would have an obvious bearing on sediment source. Such sampling would help to fix the position of the outer edge of the rock platform which is not yet known (Figure 5).
- (iii) Probing of the intertidal region near the eastern training wall to determine the depth of bedrock. This could be done by augering or by using a portable refraction seismograph. Augering would probably be adequate. This will be necessary to assess the feasibility of the ultimate east side development scheme.
- (iv) More sampling on Pardoe Beach and possibly some beach tracer experiments to check the conclusions arrived at regarding the negligible character of drift from eastward.
- (v) An investigation of water and sediment movement through the port area to try to determine more closely the extent to which sedimentation proceeds from seaward or landward. This I believe

to be the most essential need of all since an important part of the effect of the proposed new works near the entrance will depend upon the extent to which the river supplies sediment. It is also relevant to proposals to divert part of the present Mersey discharge and to reclaim sections of the Latrobe estuary.

- (vi) Maintenance of photographic records. Considerable advantage was gained in the present study from the availability of vertical air photographs taken in 1946, 1953 and 1963. The Board might keep in mind the advisability of re-photographing the coast around Devonport and also the Latrobe estuary at regular intervals in the future.