CHAPTER 21

VARIABLE DISPERSION AND ITS EFFECTS ON THE MOVEMENTS OF TRACERS ON BEACHES

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SUMMARY

To arrive at a quantitative assessment of sediment transport using tracers it is usual to analyse the results using the "centroid method". It is quite satisfactory to apply such a method when the dispersion from any cause is constant over the area under study. However, when tracers are used in a variable dispersive field, as on a beach, the interpretation of the results by normal methods can give misleading results. A simple arithmetical model is used to illustrate the ideas put forward in the paper.

INTRODUCTION

It is the author's contention that the results of many fluorescent tracer experiments carried out on beaches, particularly with respect to the movement of tracer in an onshore/offshore direction, have been misinterpreted. The purpose of this note is to show that when tracers are used on or near beaches in a variable dispersive field even the net direction of sediment transport, as indicated by the trace elements, can be misleading if interpreted by normal methods. Although the author and his colleagues have questioned for some time the validity of some of the conclusions drawn from the results of tracer movements on beaches the main stimulus towards the formulation of the idea presented in this note came from reading the excellent book by J. C. Ingle. Jr. - "Developments in Sedimentology - The movement of beach sand". (Ref. 1). Ingle describes field tests carried out on beaches in Southern California where fluorescent tracers were used to track the movement of beach sand. One of the conclusions was that the tracer invariably moved offshore towards the breaker zone. Quoting from Page 54. (Ref. 1).

> "Since offshore tracer transport was dominant under all surf conditions (i.e. long-period low amplitude waves to short-period high-amplitude waves) an incongruity is presented as monthly beach profiles indicate that alternating periods of accretion and erosion occurred at all five test beaches over the period of the investigation".

The present author believes that the results are not as incongruous as they appear. When the beaches were building up (net onshore transport of material) or eroding (net offshore

transport of material) the tracer placed on the foreshore might well be expected to move in an offshore direction. Unless there is a large sediment transport in one direction tracers will move towards the area of maximum dispersion - in this case towards the breaker zone. Tracer placed seawards of this point will move onshore while tracer placed shorewards of this point will move offshore.

Arithmetical Model

An attempt will be made to explain this concept by means of a simple arithmetical model. For simplicity take the case of a beach subjected to regular waves in a laboratory wave tank. After some time stability will be reached and an equilibrium beach profile established. (Fig. 1).

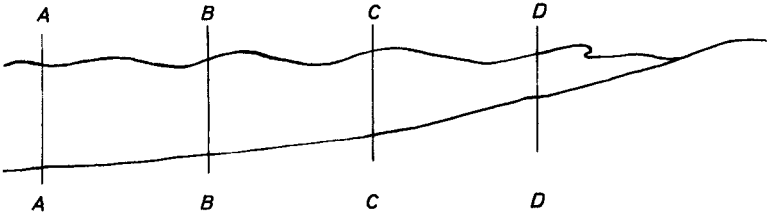

FIG. 1. A Stable beach

If the profile is stable a number of statements can be made.

1. There is no net transport of material past any section AA, BB, CC, DD.

2. The movement in a backwards and forewards direction will be greater at D than at C, greater at C than at B ..... etc. This follows from the fact that the wave orbits and the general level of turbulence are greater at D than at C etc.

3. Proceeding offshore, a point will be reached where even the maximum wave-orbital velocities are not large enough to move material and such a point could be at A.

Any arithmetical model, describing the way material moves on a stable beach, must satisfy the conditions in 1, 2 and 3.

At the Hydraulics Research Station, Wallingford, quite a lot of work is carried out in wave flumes on model beaches. What do we see? With relatively low waves the bed ripples and within a ripple the material moves back and fore. The activity of this movement varies with the position on the beach and the degree

of this activity will control the number of particles exchanged between adjacent ripples during one wave cycle.

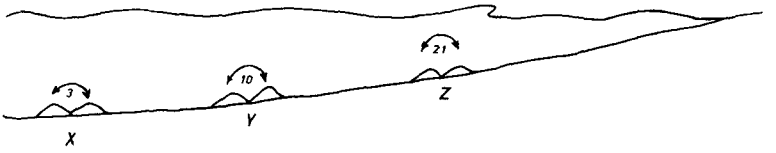

FIG. 2. Exchange of particles

For example, in one wave stroke, 3 particles might be exchanged between ripples in the vicinity of X, 10 particles between ripples in the vicinity of Y and 21 particles between ripples in the vicinity of Z (Fig. 2). Proceeding through the breaker zone the exchange will then decrease to zero. If this is the case then at a point on the bed in the area seawards of the breaker zone more material will be exchanged between this point and points right than this point and points left. An arithmetical model of a stable beach might, therefore be described as shown on (Fig. 3).

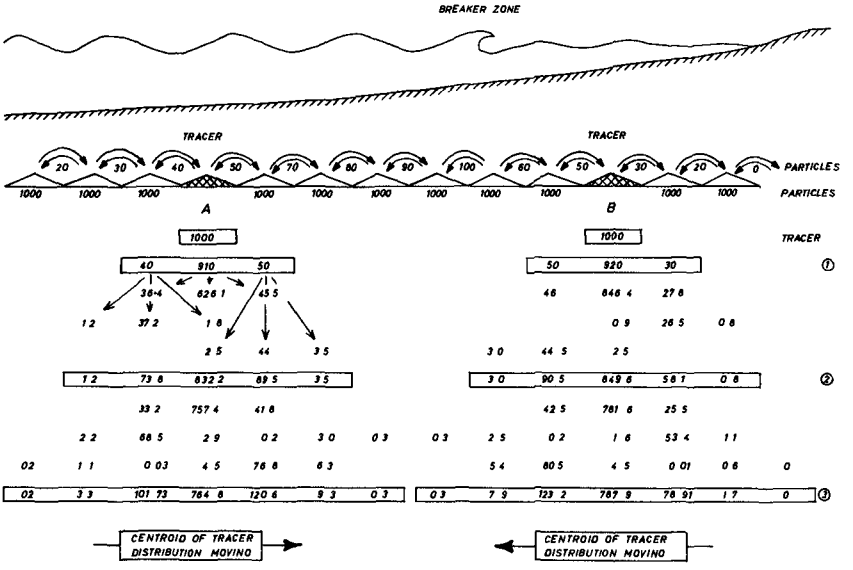

FIG. 3. Model of Tracer movement on a stable beach.

Although it is not necessary to interpret the model in terms of the exchange of particles between ripples the ideas are easier to put across on this basis. Consequently the triangular shapes in the diagram are meant to represent ripples and the figures between the ripples the number of particles exchanged in one wave stroke. The variation in the exchange of material between ripples has been exaggerated for illustrative purposes and it has been assumed that each ripple contains the same number of particles - in this case 1000. Also, any material entering a ripple is assumed to be uniformly mixed with that which was already present at the end of each wave stroke.

Suppose the ripples at A and B are now replaced by tracer. Its distribution can be calculated at the end of every wave stroke as shown in the diagram. Even by inspection it can be seen that the centroid of tracer distribution is moving onshore from A and offshore from B. If the normal "centroid" method is used to interpret the results then unreal directions of sediment transport will be indicated - the initial premise for a stable beach being no net movement of sediment. (The model can be extended to include net sediment movement in one direction and to demonstrate the anomolous situation of an apparent tracer movement in the opposite direction.)

Tracer distributions measured in one of our laboratory wave tanks confirm that qualitatively the arithmetical model describes the movement of tracers quite well. It was hoped that when we came to write the full paper we might have been able to describe the process quantitatively. Pressures of work from other sources, however, have prevented us proceeding any further. A number of problems have to be solved in the quantitative case. For example, what controls the number of particles exchanged between adjacent parts of the bed? Perhaps the exchange rate is proportional to the maximum wave orbital velocities, the orbit length, or the net movement of water close to the bed. Tests in a wave tank are now planned to resolve some of these questions.

THE EFFECT OF TIDAL VARIATION

So far the ideas have been explained in terms of a beach subjected to waves with a constant water level. However, the dominating influence of variable dispersion is perhaps more marked when the water level on the beach is subject to changes brought about by tides. Here the periods of time that the water stands on the beach varies from place to place and, therefore, the phenomenon for the part of the beach between L.W. level and H.W. level is now time dependent.

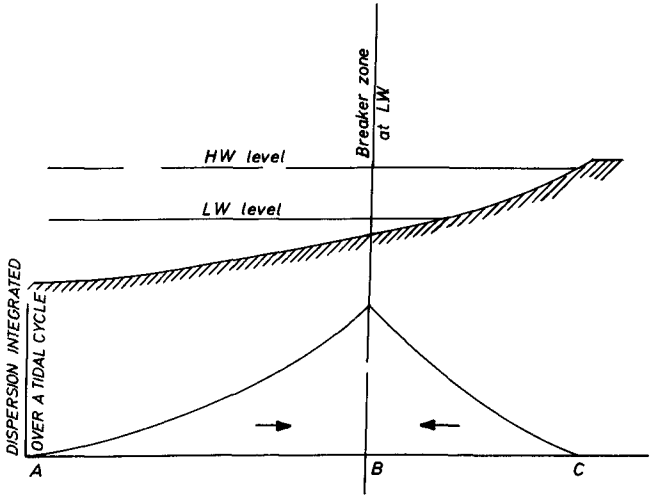

FIG. 4. Diagrammatic sketch showing dispersion with tides

Let us describe qualitatively the cumulative effect of dispersion over a tidal cycle. On the part of the beach below L.W. level the dispersive agencies integrated over a tidal cycle will increase towards the breaker zone (A B) in Fig. 4. Shorewards of point B the cumulative effect of dispersion will decrease because the time at which water stands at the various levels decreases when moving from L.W. to H.W. level (B C) in Fig. 4. On this basis, as shown earlier, tracer placed shorewards of L.W. level will tend to move seawards while tracer placed seawards of L.W. level will move shorewards.

SUMMARY AND CONCLUSIONS

It is realised that such a simple model, at least in its present form cannot represent the movement of beach material completely. For example, when violent movements of the bed material take place under large waves particles can be displaced many ripple lengths in one wave stroke. Nevertheless, it is hoped that the model demonstrates that it could be misleading to interpret the movements of tracers injected into a variable dispersive field, on and near a beach, by the normal methods.

It would be instructive in the field for a variety of reasons to measure the quantity of material travelling as littoral drift, not so much in total, but at various levels on the beach. The author and his colleagues have thought about this problem and have come up against the obvious difficulties of using tracers for this purpose. If, however, the present arithmetical model could be made to work quantitatively (that is values could be ascribed to the dispersion coefficients at all points on the bed) then tracer distributions measured in nature could be corrected for the apparent mass transport effect in the onshore/offshore

direction so that lateral distributions of tracer could then be used to establish the quantity of drift at various levels.

Finally, I would like to thank Mary Kendrick, George Lean and Maurice Crickmore for the many enjoyable arguments we have had on this subject.

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Ref. 1. Developments in Sedimentology 5. The movement of beach sand. James C. Ingle Jr. Elsevere Publishing Company, Amsterdam. London, New York 1966.