STUDY OF SEDIMENT MOVEMENT BY FLUORESCENT TRACERS AT HALDIA ANCHORAGE*

H. N. SIDDIQUIE AND P. C. SHRIVASTAVA

Marine Geology Unit, Geological Survey of India, Calcutta-13

ABSTRACT

A new and simple technique for preparation of bulk tracer samples based on varnishing sand with fluorescent dye (rhodamine) is described. An investigation of sediment movement using tracer prepared by this method was carried out at the Haldia anchorage in the Hooghly river. The fine sand sized tracer conforming to the sediment size at the Haldia anchorage was released at low water and its movement was traced with rising tide. An analysis of the tracer distribution pattern indicates that the predominant direction of movement is towards north-east and a probable subsidiary direction towards north. The former probably represents the direction of movement of sand and the latter the direction of fine sediments. The observed grain velocities range from 4·5 to 10·3 m./min., and the depletion rate 19·9 and 8·1 kg./min. for 50 and 120 minutes. These indicate the large transporting capacity of the flood tide

INTRODUCTION

FLUORESCENT tracers are increasingly being used to study the sediment movement in lacustrine, fluvial and shelf areas (*cf.* Zenkovich,[1] Aibulatov,[2] Ingle,[3] Seibold[4]). The studies are of considerable significance for problems of coastal engineering, especially in problems relating to harbour designs. In India, Gole[5] carried out a fluorescent tracer investigation at Mangalore and later some studies were also carried out by the Hydraulics Study Department of the Calcutta Port in the Hooghly river.

Present investigation.—The area of investigation is situated just north of the confluence of the Haldia river with the Hooghly (22° 0′ 42″ : 88° 4′ 12″). The Hooghly river below the Balari bar widens and the Nayachara island splits the channel into the eastern and western. The eastern channel with a large number of bars is largely silted; while the western channel is relatively deeper and is used for navigation. The western channel is about 3·5 km. wide, but most of it is shallow. The navigable part of the channel, mainly along the north-western bank and generally 8–10 m. deep and at places approaching 12 m., is about 500 m. wide. On the south-eastern side of the channel the depths are shallow, of the order of 3–5 m., and this defines the shoal which is marked by the Nayachara buoy.

The present studies form part of a large programme of studies of problems of coastal erosion and deposition undertaken by the Geological Survey of India. The fluorescent tracer investigation of the sediment movement on the Hooghly bars was taken up under this programme as the results of the studies are likely to be useful in the future planning and development of Haldia and Calcutta Ports.

The sediments in the area of investigation range from clay and silt to silty sand and fine sand. The shoal itself consists of fine sand which grades to a silty sand on the western side and farther in the deeper portions in the Haldia channel the sediments are mainly silt and clay. The records of surface and bottom current velocities maintained by the Hydraulics Study Department show that velocities range upto 225 cm./sec. and 195 cm./sec. respectively. The direction of surface and bottom currents at flood tide varies from 30° to 65° and 60° to 340° respectively. The tidal range at the time of investigation was about 3 m.

METHOD

Preparation of bulk tracer sample.—The authors have devised an improved technique for the preparation of bulk tracer sample. Fluorescent dye, Rhodamine B 500, is mixed with binders, Necol clear varnish and Duco thinner. Sand in lots is added to this mixture and mixed thoroughly to give a proper coating to all grains. Dyed sand is then dried. Mixtures of dyed and undyed sands were stirred in fresh and saline water in a laboratory stirrer for periods ranging from 1–12 hours to evaluate the performance of the tracer. The laboratory trials and later field studies indicated that the coating is durable. The technique obviates the need of baking sand at high temperatures and obviates the use of hazardous liquids. The method therefore appears simpler than those used by earlier workers and reported by Ingle.[3] The cost of preparation

* Published with the kind permission of the Director General, Geological Survey of India.

of tracer is around Rs. 1·40 per kg. and is, therefore, cheaper than the other methods reported by Ingle.[3] Thus the technique in suitable environments is much cheaper than radioactive tracers.

Release of tracer; sample collection and scanning.—The tracer was released at low water between 11·00 and 11·20 hrs. on 7-1-1968 and the movement was traced with rising tide. Twenty minutes after releasing, bottom samples were collected with a small Dutch or Van Veen Grab (area 120 cm.^{2}) first in a square pattern roughly at 300 metres around the release point. When the preliminary scanning of the samples indicated mainly northward movement of tracer particles two more traverses at 600 and 1,000 metres were made further north of the earlier grid perpendicular to the inferred direction of movement (Fig. 1). The bottom samples collected in the field were washed with freshwater to remove salts and dried. The entire samples were spread as a "one grain layer" and scanned under an ultraviolet lamp and the number of fluorescent grains counted.

Results of the Investigation

Tracer distribution patterns and the direction of sediment movement.—The tracer distribution patterns were prepared using the absolute values of tracer concentration in samples as also by applying correction for a standard elapsed time expressing tracer concentration in square centimetre (Fig. 2). The fluorescent tracer grains were traced to a maximum distance of 1,060 meters. The distribution pattern for the absolute values of the tracer grains shows the major concentration to be localised in the vicinity of the release point, the highest concentration (> 500) being in sample No. 20, which is located just north-east of the release point. The next higher concentration value (> 200) is located in the extreme north-east at station No. 38. The disposition of the contour for 100 and the higher values at station No. 38 show that the predominant direction of movement of sediments is towards north-east with a subsidiary movement to the north. The major direction of movement towards the north-east is mainly along a line across coarser sediments, while the subsidiary direction of movement to the north lies across an area covered by finer sediments. This probably indicates that sand is moving north-east and the finer material, silt and clay, is moving towards the north. It is also likely that the clay is moving towards the north-east but due to differences in the energy environments it is flocculated and deposited in the channel towards the north. Perhaps this clayey material cannot be deposited in the turbulent conditions on the shoal and is carried farther north-east beyond the sampled area. It is clear from the plotted tracks of the inferred direction of movement that in the later stages there has been an easterly veering of the direction of movement of sediments. This is indicative of changes in current direction during the later period of investigation.

Grain velocities.—Grain velocities were calculated from the observed distance travelled along the mean path of transport divided by the elapsed time between the release of tracer and arrival at a known point. The velocities for sand range from 4·5 to 5·3 m./min. and for silt and clay from 4·8 to 6·1 m./min. for the first and second sets of samples respectively. The maximum observed grain velocities for the first and second sets are 10·3 and 6·1 m./min respectively. The observed grain velocities are about 1/2 to 1/3 of the reported current velocities.

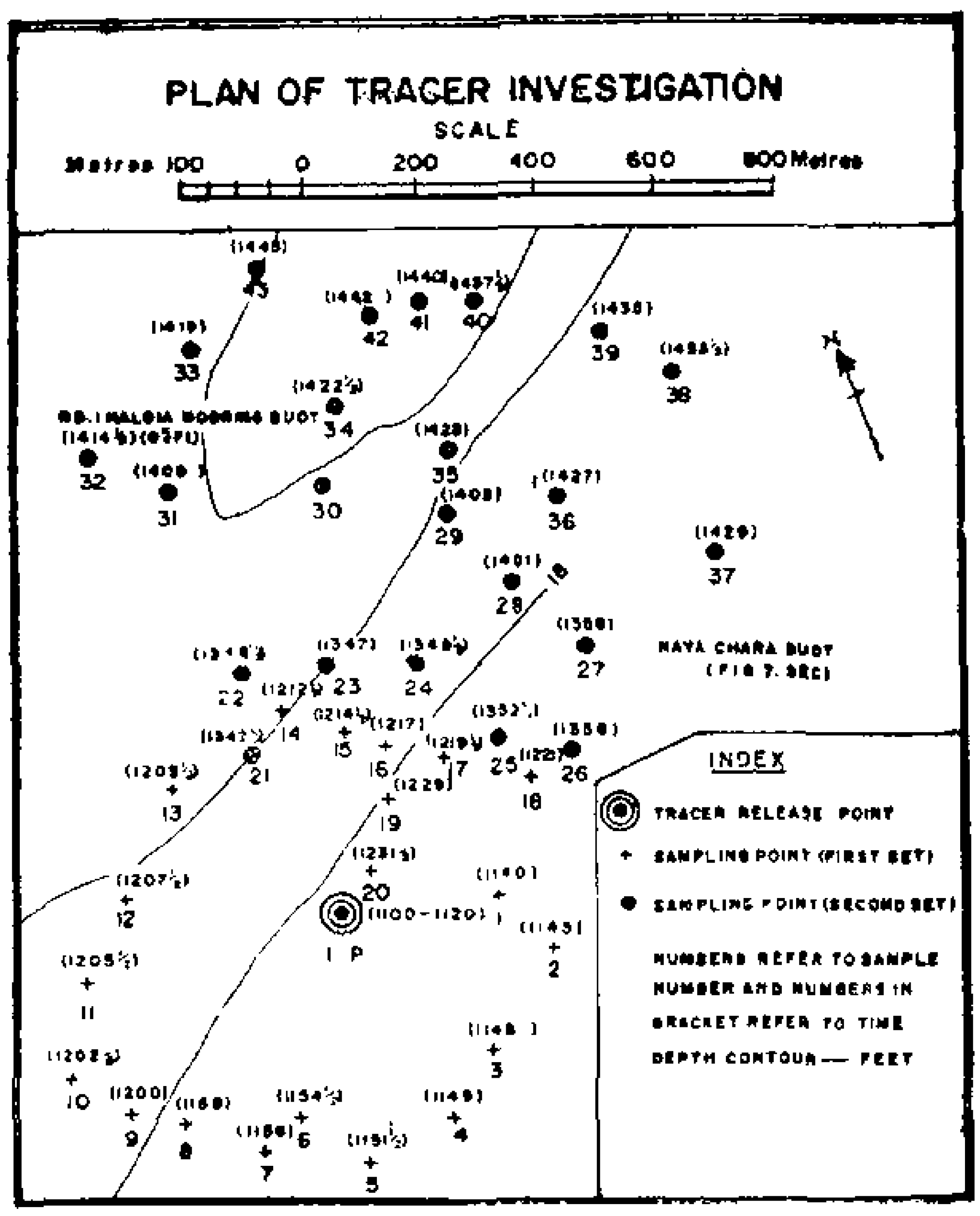

FIG. 1

Depletion rate.—The rate in kilogram of the fluorescent tracer leaving the sampled grid per minute is termed the depletion rate. The tracer depletion rate was calculated by Ingle's[3] method converting the quantity of tracer released to number of grains and a planimetric estimation of the total number of grains present in the sampled grid at a parti-

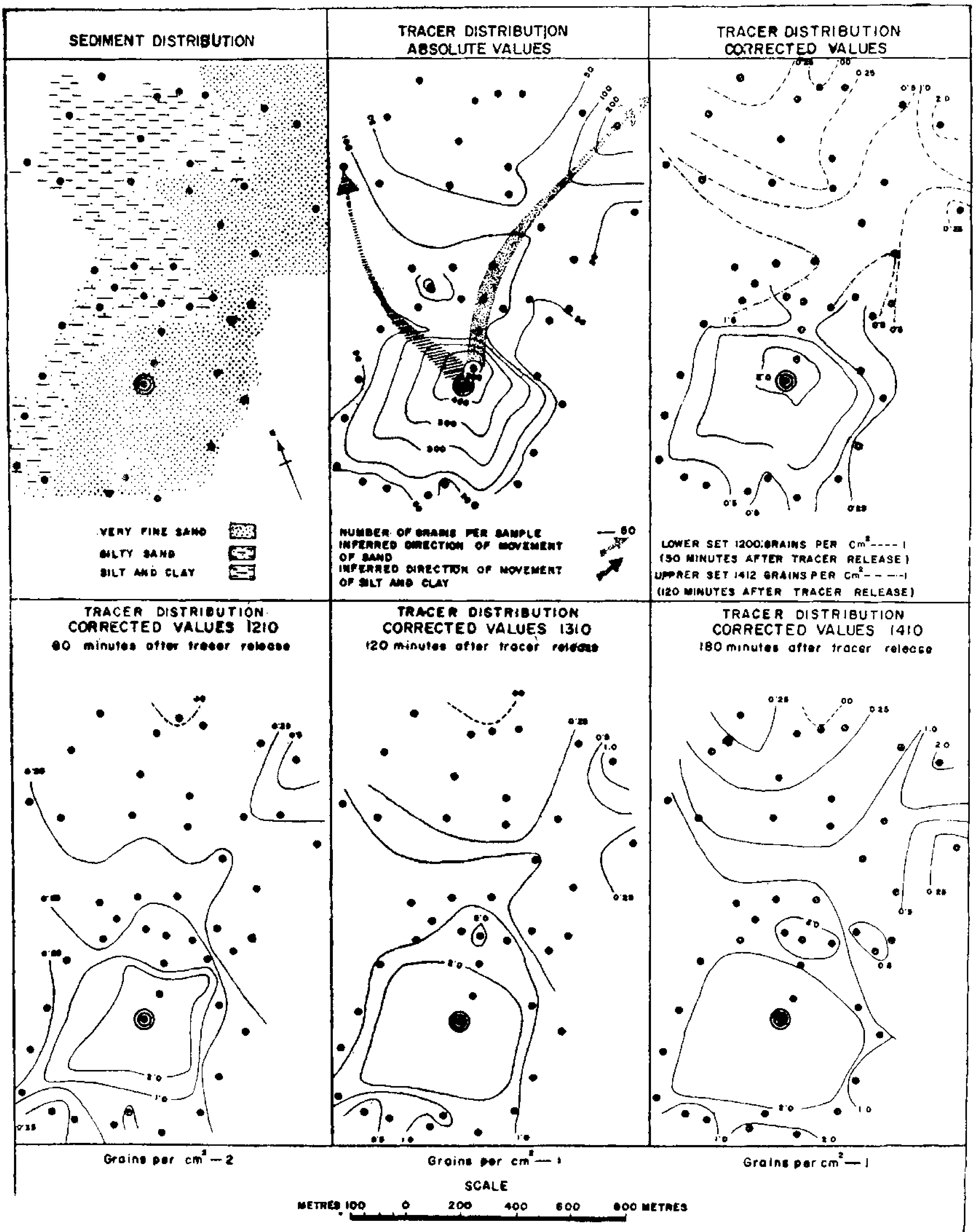

FIG. 2

cular standard elapsed time (Fig. 2). The computed depletion rates for the present investigation are given below.

Approximate number of grains in 1 gm. of tracer = 3,90,000 (average 4 counts). Approximate number of grains in 1 tonne of tracer = $3{,}900 \times 10^8$. Total number of grains remaining in the sample grid after 50 minutes = 28×10^8 or 0·7% of the grains released. Thus the total number of grains lost from the sampled grid in the first 50 minutes = 3,872 × 10^8 or say 992·8 kg. or 19·9 kg./min. Similarly the depletion rate for the first 120 minutes is 8·1 kg./min.

Conclusions

The results of the fluorescent tracer investigation at Haldia anchorage indicate that at flood tide the predominant direction of movement is towards the north-east and a probable subsidiary direction towards the north. The former probably represents the direction of movement of sand and the latter the direction of movement of finer sediments, *i.e.*, silt and clay. Further studies, with bicoloured tracers of two different sizes, are planned to confirm this observation. The fluorescent grains were traced to a maximum distance of over one kilometre and the observed grain velocities range from 4·5 to 10·3 m./min. and are roughly 1/3 to 1/2 of the observed bed current velocities. The computed depletion rate of 19·9 and 8·1 kg./min. for the first 50 and 120 minutes indicate the large transporting capacity of the flood tide.

Acknowledgements

The authors thank the Commissioners for the Port of Calcutta for providing facilities on the *RV Anusandhani* for the investigation†; Dr. S. K. Bhattacharya, Chief Engineer, Hydraulics Study Department, for his keen interest in the investigation; Shri G. S. Paul, River Research Officer and Capt. H. C. Malhotra, Commander of *RV Anusandhani.*

The programme of fluorescent tracer investigation of sediment movement was taken up mainly due to the keen interest evinced by Shri G C. Chaterji, Director-General and Shri C. Karunakaran, Deputy Director-General, Geological Survey of India, to whom the authors are particularly grateful.

† The opinions expressed in the paper are those of the authors and not of the Commissioners.

1. Zenkovich, V. P., "Osnovi ucheniya razvetiye beregov (Basic studies on the development of marine coasts)," *Acad. Sci. USSR*, Moscow, **1962**, p. 1.
2. Aibulatov, N. A., "Issleduvaniye vodolberegovo peremesheniya pecchanikh nanocov more (Investigation of along shore movement of sand drifts in the sea)," *Nauka*, Moscow, 1966 p. 157.
3. Ingle, James C., *The Movement of Beach Sand*, Elsevier Publishing Co., Amsterdam, **1966**, p. 1.
4. Seibold, E., "Geological investigation of nearshore sand transport," in M. Sears (Ed), *Progress in Oceanography*, Pergamon Press, New York, **1963**, p. I.
5. Gole, C. V., "Fluorescent tracer study at Mangalore Port," *Inter. Assoc. Hydraulic Res. Cong., 10th., London*, 1963, **1**, 275.

SOME RECENT STUDIES ON THE RESTORATION OF PERMEABILITY TO WATER OF SOILS RENDERED IMPERMEABLE EARLIER BY THE SWELLING ACTION OF SOIL COLLOIDS BY SODIUM CARBONATE

L. A. RAMDAS

Scientist Emeritus, National Physical Laboratory, New Delhi

Abstract

When the lower end of a column of soil packed in a glass tube is dipped in a 2% solution of sodium carbonate, it develops an impervious stratum at the bottom instantaneously and no capillary ascent takes place even after 30 days. In a similar soil column dipped in water, the water ascends rapidly, completing a capillary rise of 70 cm. within 23 days. A series of soil tubes initially rendered impermeable by dipping in sodium carbonate solution are later transferred to solutions of ammonium chloride, bromide, nitrate, sulphate and phosphate and of calcium, strontium and barium chlorides respectively. Within a short time, these solutions destroy the impermeable strata and resume capillary ascent with varying rapidity. Such restoration of permeability has immense potentiality for use in reclaiming the "alkali-ridden" soils of India.

1. Introduction

The movement of liquid water through a porous medium like the soil is of fundamental interest in Soil Physics as well as of immense practical importance to agriculture. While developing and directing the programme of research in Agricultural Meteorology at Poona (1932–1956), the present writer and collaborators had conducted extensive studies on many aspects of this topic. The results then obtained have been discussed in a series of published papers[1–18] and reviewed in a