CHAPTER 81

DESIGN AND BEHAVIOUR OF SANDTRAPS IN REGIONS OF HIGH LITTORAL DRIFT

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1. Introduction :

Siltation in harbours and their approach channels is one of the major problems connected with the development of harbours. The economics of harbours are directly related to their annual maintenance dredging, and as such a proper assessment of the quantity of siltation and provision of adequate measures for the maintenance of depths would form an important part of planning the development programmes.

Siltation could occur due to various reasons viz. deposition of littoral drift which is interrupted by the approach channel, deposition of sediments brought into suspension by wave action (including during storm/cyclone) Whenever the alongshore drift is large, wave action obviously is quite substantial which renders the maintenance of depths during this period by dredging difficult. In such cases it would be necessary to make adequate provision to ensure that the depths are not deteriorated to any substantial extent by the movement of the drift. One of the common means for achieving this is the provision of sandtraps on the updrift side of the approach channel which would 'store' the drift material temporarily and from where the material could be dredged at convenience. The design of the sandtrap would be governed by a number of factors such as the extent over which a major part of the drift takes place, quantity of material transported, size distribution of sediments, velocity of currents, mode of dredging etc.

Waves of moderate to high intensity occurs along the eastern coast of India from south and south west direction during south west monsoon period from May to September and from North Easterly direction during North East monsoon beginning from November. In view of this climate the direction of drift along the shore changes with season. The quantities of drift during these periods are also different owing to the magnitude and periods of wave action which differs between the two seasons.

The net drift along this coast varies from 0.60 million m^3 at Madras on the south which increases progressively to 1.00 million m^3 at Paradip further North (Fig. 1).

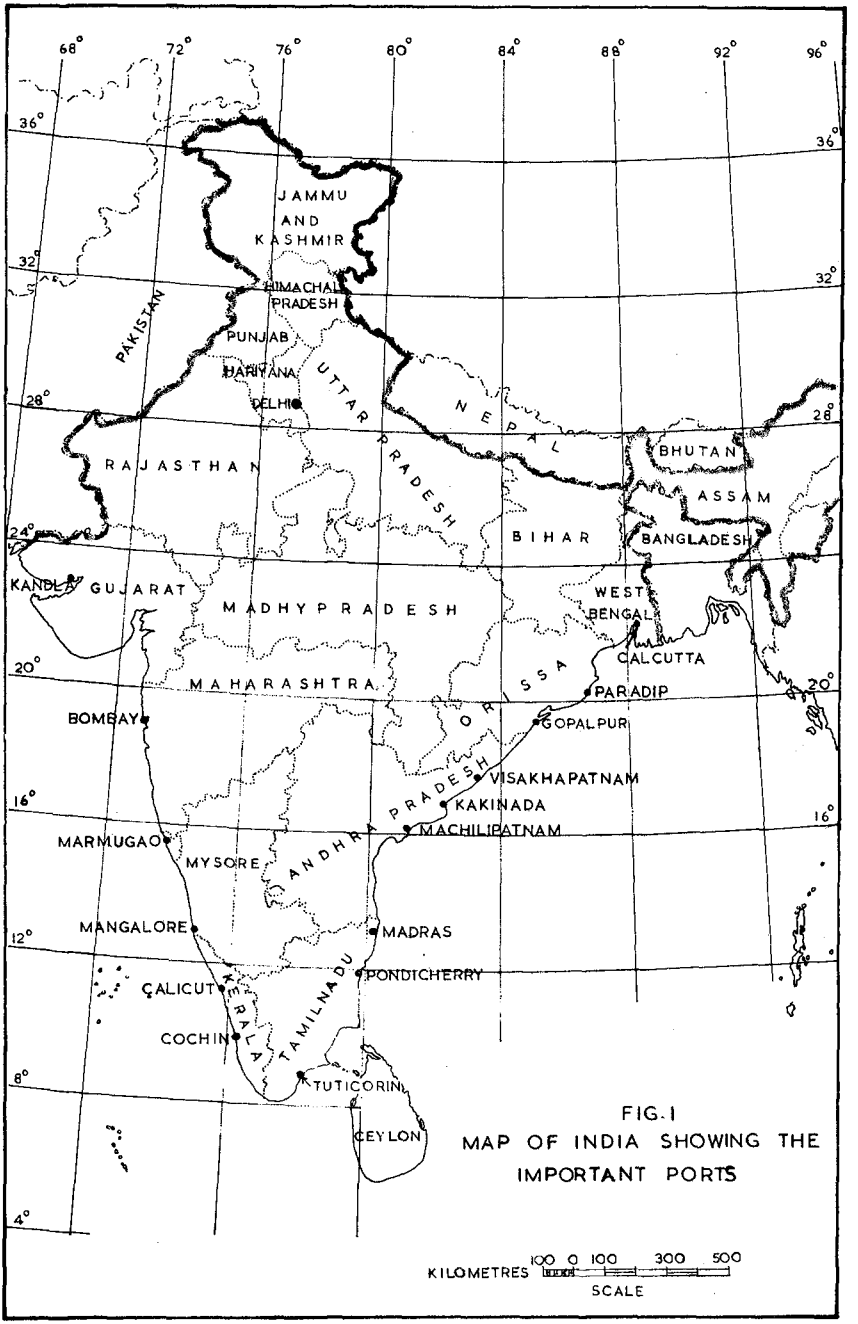


FIG.1
MAP OF INDIA SHOWING THE IMPORTANT PORTS

Sandtraps are successfully employed for a number of ports along this coast to prevent the drift from deteriorating the channels. In this paper the case histories of some of these ports are discussed together with reference to the model studies carried out at the Central Water and Power Research Station, Pune for the design and layout of these sandtraps.

2. Methods of tackling littoral drift :

The method adopted for the tackling of littoral drift would be governed by the wave climate, the quantum of drift, the nature of operation of the port etc. The configuration of the coastline would also be modified by the drift as shown by Silvester *(1) who has made a comprehensive study of the sediment movement along the various coastlines of the world. Though this information is qualitative, it helps in a broad sense for the identification of the length of coastline which can affect the sediment supply to any specific location.

An idea of the rate of drift is generally obtained by making observations of the rate of accretion updrift of jetties as well as from the records of maintenance dredging. Johnson (2) has used this method of analysis in order to tabulate the rates of drift along the coastlines of the world. It could be seen from his tabulation that the littoral drift along Madras coast obtained by the measurement of rate of accretion south of the breakwater of Madras port is of the order of 0.60 million m^3 (0.74 million cubicyards).

It is also well known that a major portion of the littoral transport occurs within the breaker zone. Hence other things remaining the same, the rate of drift per unit width of the coastline would be higher along a steeper coast as compared to a flatter one.

One of the methods adopted to maintain the inlets for navigation in a littoral drift zone has been by use of sand pumps. The material dredged from the entrance to the inlet by the sand pumps are generally pumped on to the down drift side for re-establishing the littoral drift cut off by the inlet. This method has been found to be successful along the Atlantic coast of USA for the maintenance of small inlets. Similar method was also adopted for the maintenance of the approach channel to Durban Harbour South Africa. In India, this type of dredging for a major harbour was considered for the first time in the case Paradip port (in Orissa State) on the east coast.

Though a Sand pump mounted on a trestle forms a fairly simple method for tackling the drift problems, various difficulties connected with the maintenance of the pumps, cavitation and their limited mobility render them unsuitable for universal adoption. Accordingly, provision of sand traps of maintenance by mobile dredger etc. have been found to be more favourable during recent times.

*. References are given at the end of the text.

3. Types and sizes of sandtraps :

Depending upon the site conditions, the orientation, size and location of the sandtraps would vary from place to place. A shallow irregular natural depression at Durban Harbour has been utilised to serve as a sandtrap whereas at Paradip and Visakhapatnam Ports trapezoidal shapes have been adopted. As already mentioned earlier, the inability to dredge during the period of occurrence of littoral drift necessitates storage of the drift material in the trap. The quantum to be stored (and the allowable extent of sand bypassing) would depend upon the individual site conditions. Where the coastline is steep the available space for provision of the trap would also be limited in the seaward direction.

The provision of an island breakwater would considerably help in overcoming this difficulty in that the capacity requirement of the trap could be somewhat reduced since the tranquillity conditions made available by the breakwater would help in continuing the dredging operations over a longer period of time than otherwise possible. Such an example is found in the case of Visakhapatnam Outer Harbour, a major port on the east coast of India, as well as in the case of the Port of Gopalpur also located along the same coast (Fig. 1). The following illustrations are given in order to highlight the aspects mentioned above.

4. Case histories:

4.1 Visakhapatnam Port:

The Port of Visakhapatnam is located on the eastern coast in the State of Andhra Pradesh at a distance from 12.50 km north of the tip of the Indian Peninsula. This port is one of the oldest ports in India and was originally brought into operation in order to cater to vessels drawing upto 10 m for a traffic of 4 million tonnes of general cargo (Fig. 2). The littoral drift being large, a sandtrap existed updrift of the approach channel from where the material was periodically dredged. During 1967, with the advent of iron ore mining industry and the mechanisation of mining at Baladilla, Madhya Pradesh and the expansion of the harbour facilities the development of an Outer Harbour for deep draft ocean carriers was found essential. The total traffic anticipated was then estimated to be of the order of 12 million tonnes of iron ore. The layout of the outer harbour consisting of three breakwaters (southern, northern and eastern) providing thereby a sheltered basin for the development of berths was envisaged to cater for this traffic. The net littoral drift in this region is estimated to be of the order of 0.70 million cubic metres per annum with the predominantly northerly drift of 0.88 million cubic metres during the SW monsoon period

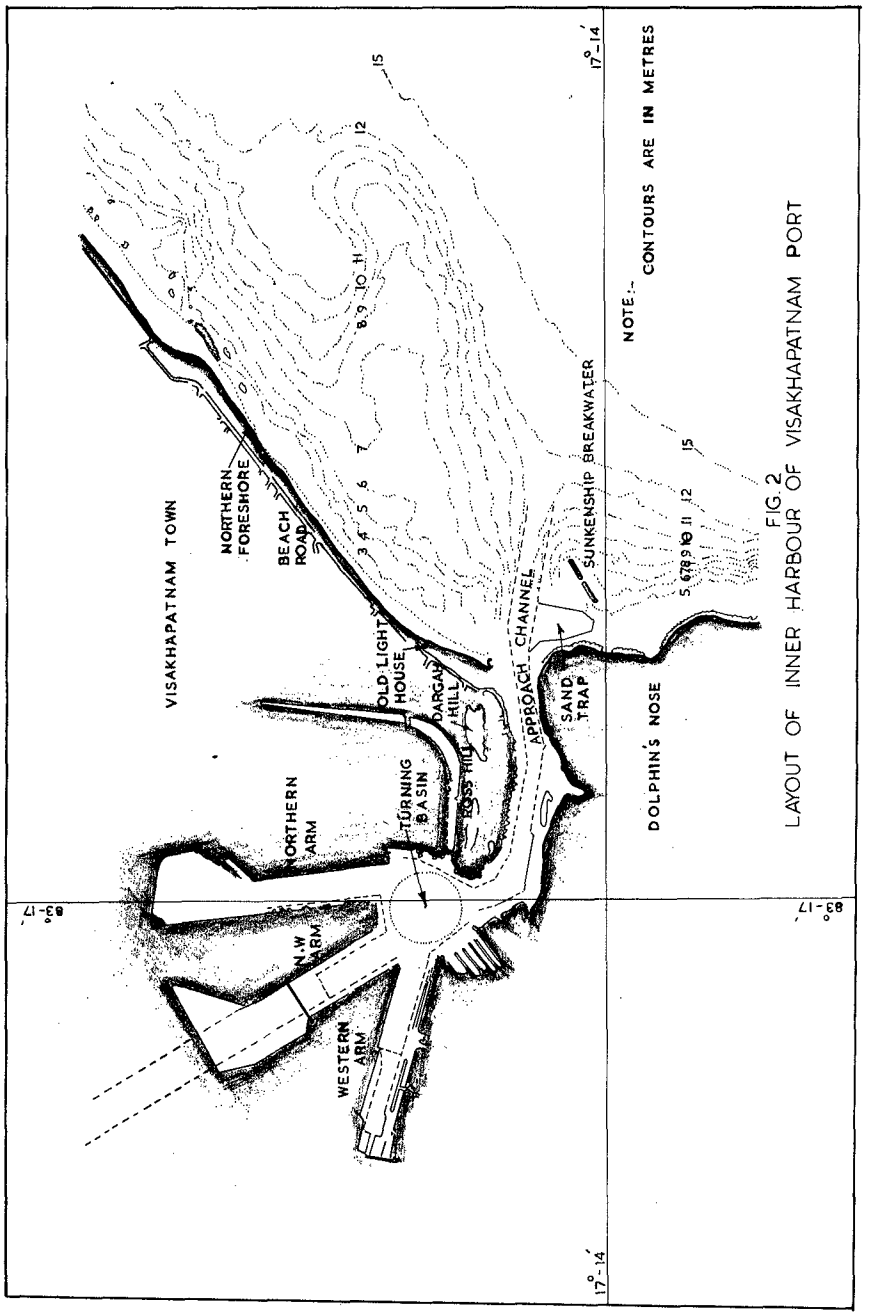


FIG. 2
LAYOUT OF INNER HARBOUR OF VISAKHAPATNAM PORT

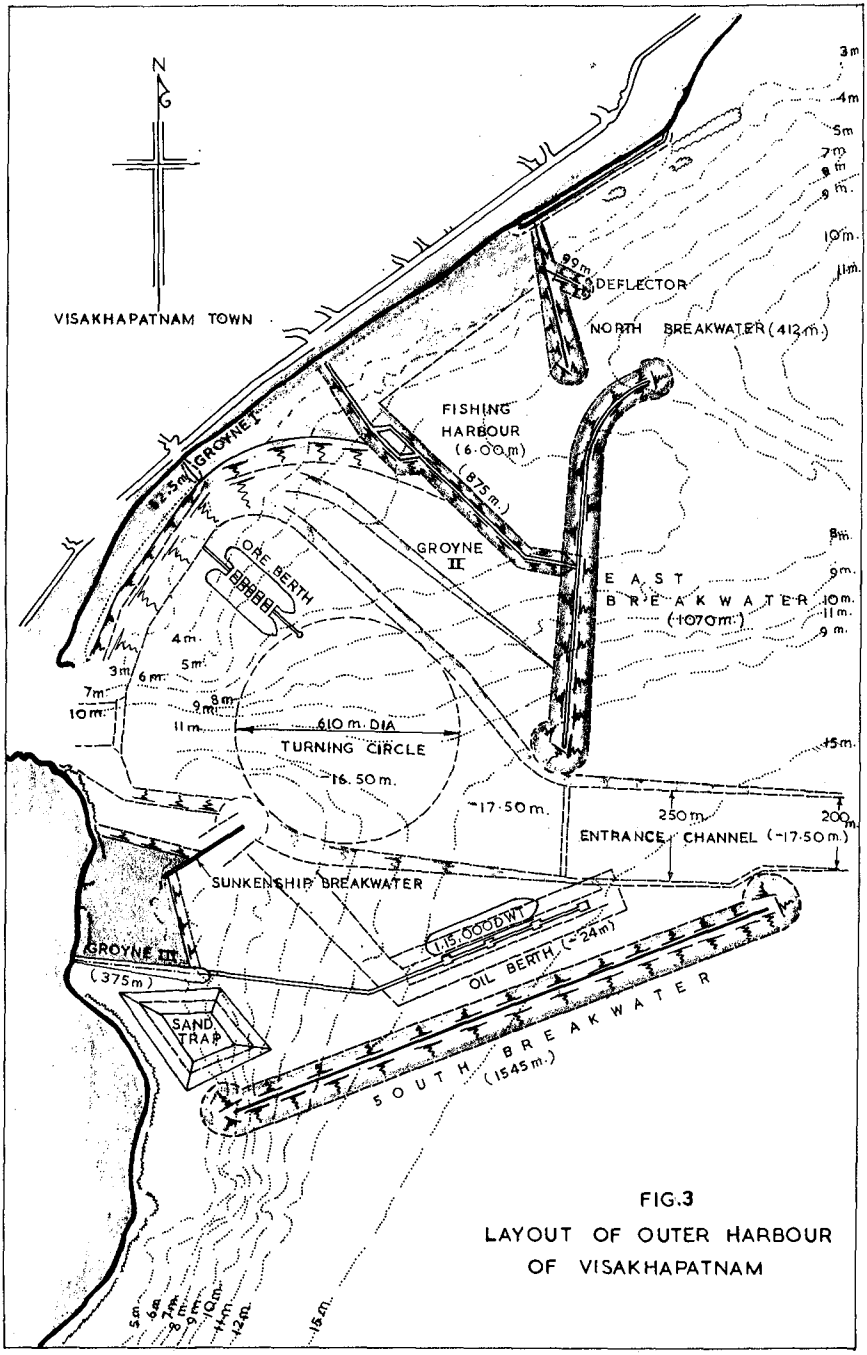


FIG.3
LAYOUT OF OUTER HARBOUR
OF VISAKHAPATNAM

from April to September and weaker return drift of 0.18 million cubic metre during the NE monsoon period from November-January. The coastline in this region is very steep being of the order of 1:10 in the nearshore region, and the 6 m contour is only at a distance of 150 m from the coastline. This obviously would result in the establishment of the breaker zone near the shoreline. As a major part of the drift is confined only to the region between the shoreline and the breaker zone, the conditions for locating the sandtrap are critical and accordingly a sandtrap was located in the gap between the sunkership breakwaters and the shoreline as shown in Fig. 2. With the development of the outer harbour, this sandtrap originally provided no longer served the needs and its location had to be changed.

Extensive model studies were carried out at the CWPRS in order to determine the best location and the alignment of the sandtrap. The southern breakwater was located in this layout in such a way as to provide the necessary width for the entry of littoral drift into the sandtrap. It was found necessary to ensure that consequent upon the filling of the sandtrap the entrance does not get choked which, if allowed to happen, would have the result of making the trap ineffective during subsequent seasons. A mobile bed wave model built to scales 1:240 H, and 1:80 V was utilised for these studies and the sediment movement was reproduced by using crushed walnut shell having a specific gravity of 1.36 and a mediam diameter of 0.50mm.. Deposition in different areas with the drift reproduced was ascertained from these model studies from which it was ensured that the trap having dimensions of 260m x 180m should provide a capacity of 0.62 million cubic metre which would be quite effective in trapping the material. The final layout is shown in Fig. 3. The sandtrap has been recently dredged at the Port and it is understood that its performance is satisfactory.

4.2 Paradip Port:

Paradip, another major harbour on the eastern coast of India is located 450 km north of Visakhapatnam Port. The main export through this port is iron ore to Japan to an extent of 2 million tonnes. The facilities at present consist of an iron ore jetty capable of accommodating 60,000 DWT ore carriers and a cargo berth for 18,000 tonne cargo vessels. The physical conditions at Paradip are somewhat different from those existing at Visakhapatnam. The slope of the beach at Paradip is much flatter, of the order of 1:80. The frequency and intensity of cyclones at Paradip are also much higher as compared to Visakhapatnam. Flatter beach slopes at this Port result in much longer approach channel for this port and as the littoral drift will be taking place over a much wider region, the size of the sandtrap would also have to be larger to trap a substantial part of the drift. This would necessitate providing a much wider gap between the shoreline and the island breakwater which would increase the transmission of wave energy into the harbour entrance and consequently create more wave disturbance. Accordingly it was necessary to modify the location of the sandtrap and the layout of

the breakwaters to overcome this problem. This layout is shown in Fig. 4. In order to bypass the northerly drift material which would get accumulated south of the southern breakwater, it was proposed to use a sand pump having a capacity of 350 cubic metres per hour moving on a trestle 250 m long for pumping sand and discharging the same to the northern side for nourishment by means of a floating pipeline across the harbour entrance. This would also help in minimising erosion of the coastline north of the harbour.

The harbour construction was completed during 1965 and the port started functioning formally from March 1966. However, due to various problems, the sand pump could not come into operation within the stipulated time. Consequently considerable accretion on the southern side of the breakwater took place besides erosion on the northern side. By 1967 the fillet on the south side was completely saturated with drift material and gradually the material found its way into the approach channel around the tip of the roundhead resulting in the formation of a shoal in the approach channel restricting the entrance width and depth considerably.

Detailed studies were carried out in a hydraulic model and it was considered that a sandtrap having a capacity of 0.8 m cubic metre as shown in Fig. 4 was necessary for this port. This sandtrap could intercept the drift during the south-west monsoon period and could be dredged during the subsequent fair weather season by the port's dredger (cutter suction hopper dredger). Accordingly the sandtrap was dredged during 1969-70 by a contract dredging. The data available subsequently has been analysed in order to examine the behaviour of the trap. Fig. 5 shows the differential depth contours during the monsoons from 1970 to 1974 at the sandtrap. It could be seen from this figure that during the year, 1970 and 1971, the loss of depth outside the sandtrap is practically negligible, whereas considerable loss of depth is found to occur east-wards beyond the confines of sandtrap subsequent to 1971 thereby indicating that the zone of pre-dominant sediment movement is extended east-wards due to the flattening of the beach slope. Fig. 6 shows a comparison of the cross sections of the beach updrift of the trap. It may be mentioned that the design of the sandtrap is evolved assuming that the sand pump could come into the operation so that it could help in maintaining the beach slope updrift of the trap. However, even after the installation of the pump during 1971, the dredging was not very satisfactory resulting in the flattening of the slope mentioned earlier. Fig. 7 shows the loss of mean depths during different monsoons at various sections of the channel. It could be seen from this figure, that during the initial periods after the dredging of the trap, the loss of depth was confined only to a small distance from the approach channel from the tip of the breakwater, the length extending further east-wards during the subsequent periods for reasons already mentioned.

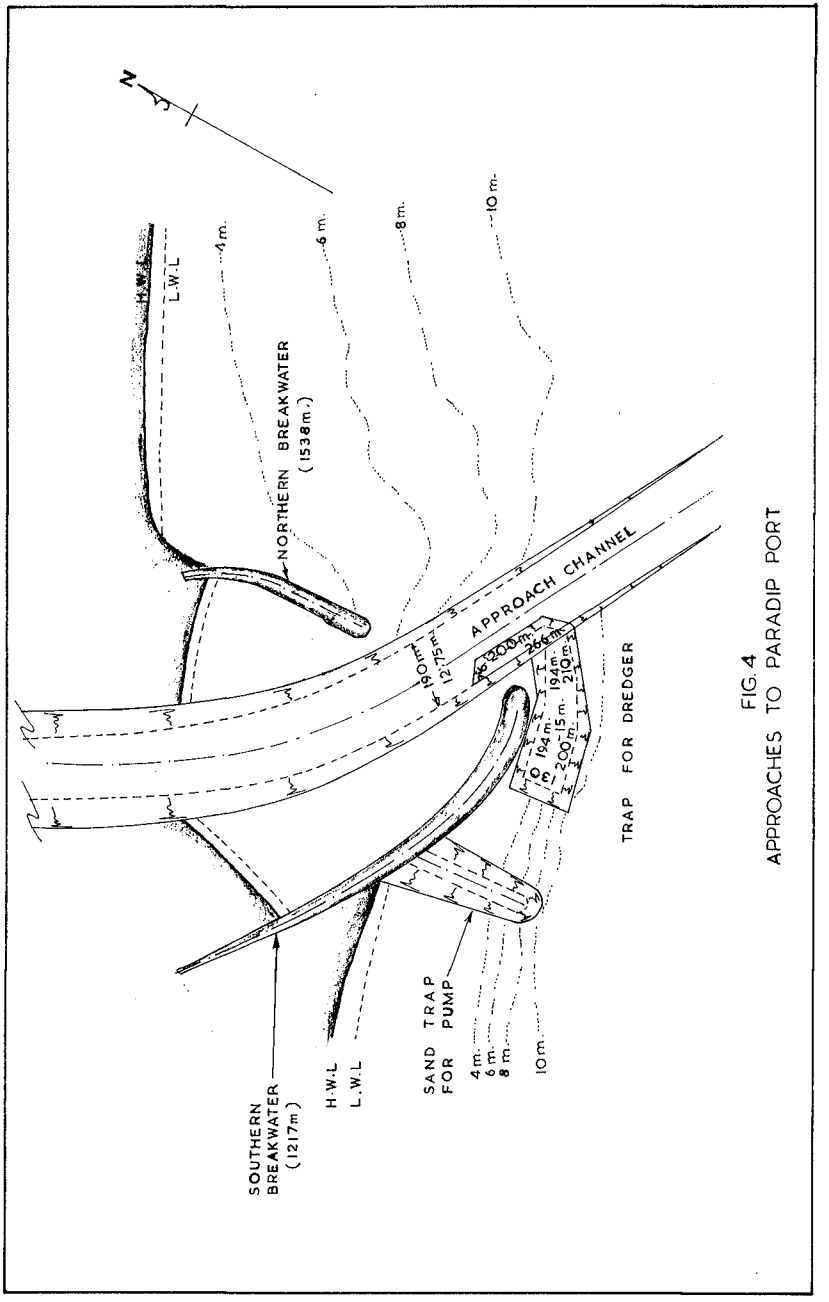


FIG. 4
APPROACHES TO PARADIP PORT

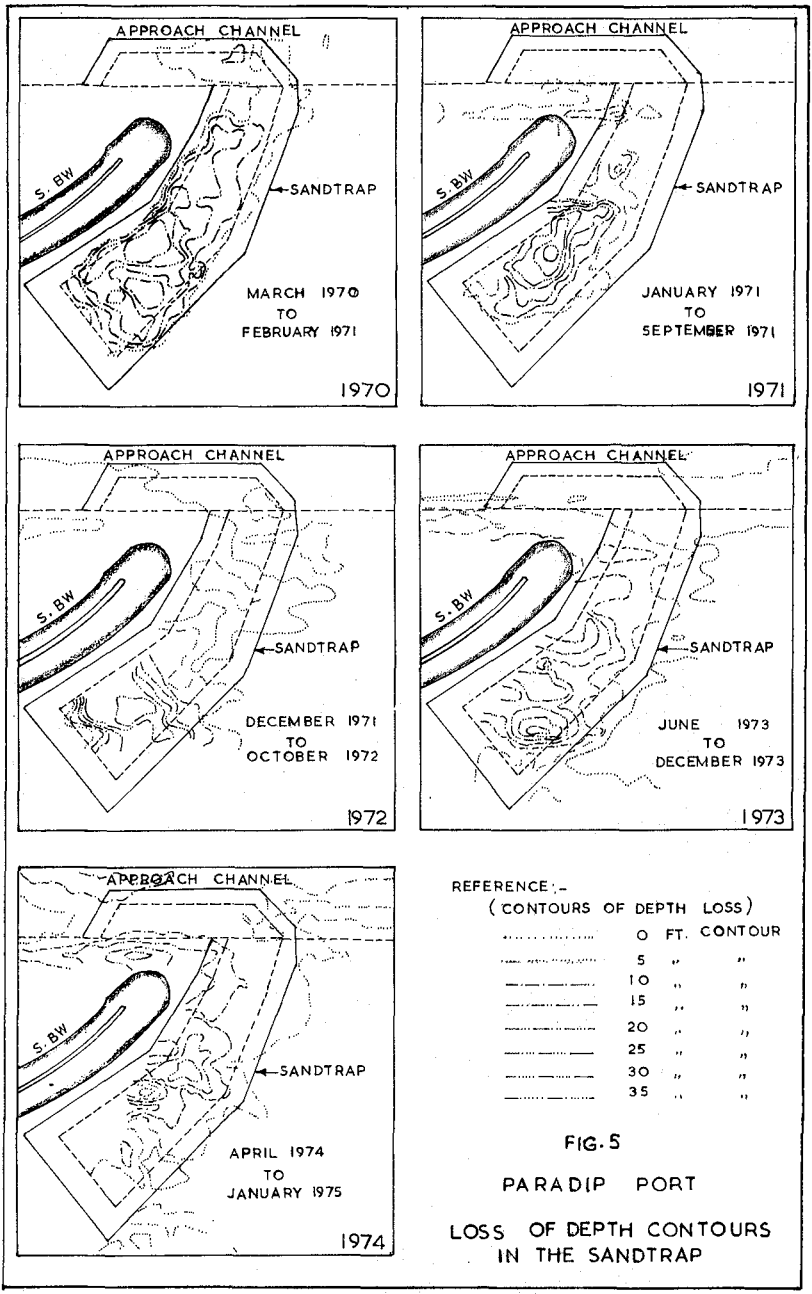


FIG. 5

PARADIP PORT

LOSS OF DEPTH CONTOURS IN THE SANDTRAP

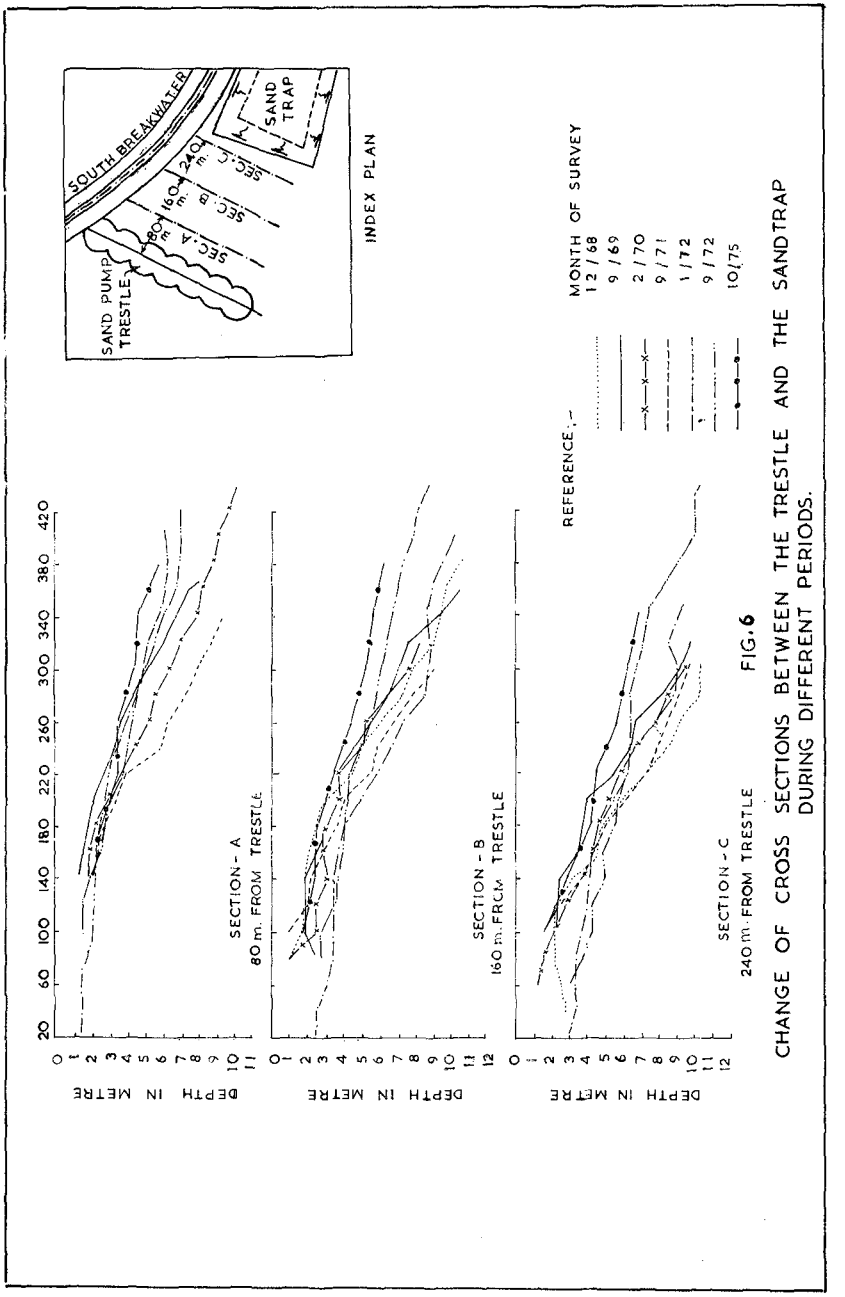


FIG. 6

CHANGE OF CROSS SECTIONS BETWEEN THE TRESTLE AND THE SANDTRAP DURING DIFFERENT PERIODS.

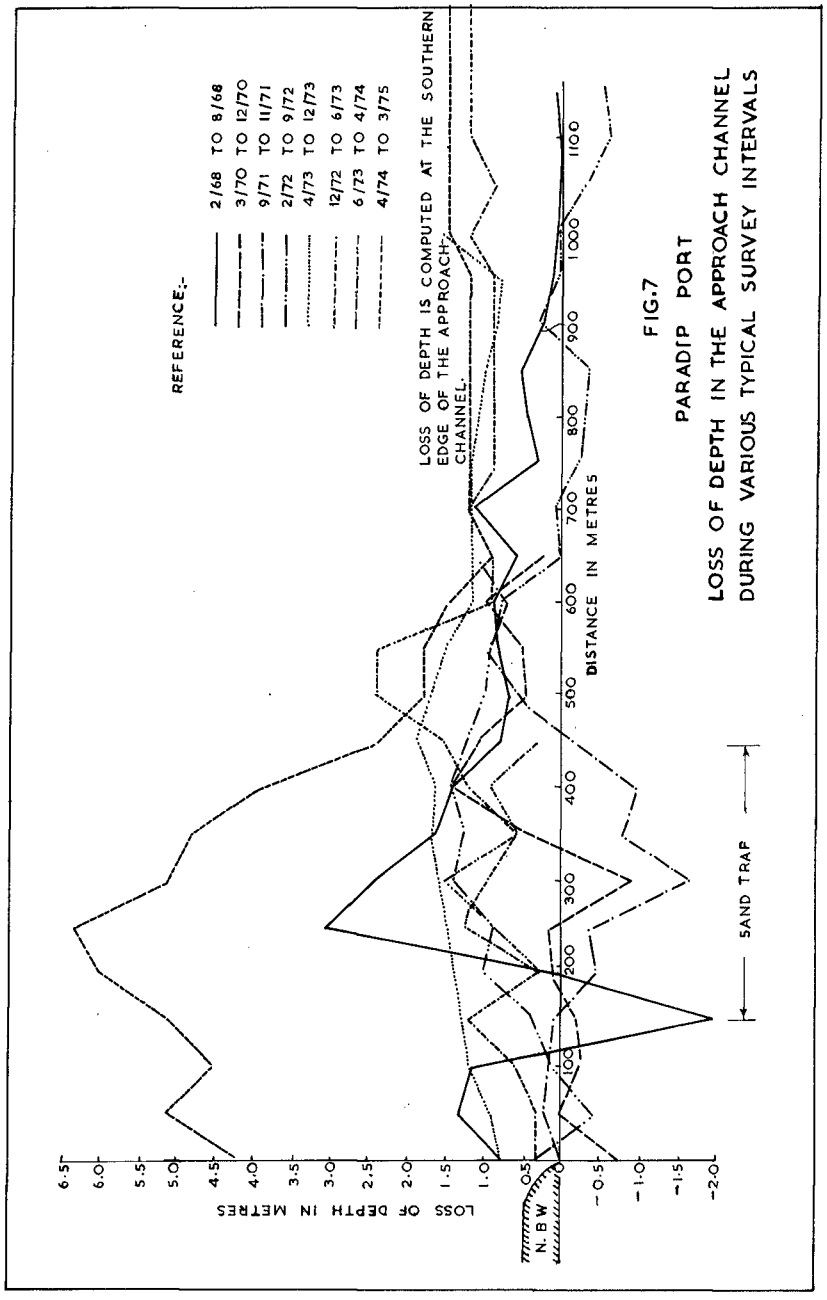


FIG.7

PARADIP PORT

LOSS OF DEPTH IN THE APPROACH CHANNEL DURING VARIOUS TYPICAL SURVEY INTERVALS

Since this region is situated in an intensely cyclonic zone, the effect of cyclones on the siltation pattern in the approach channel also needs consideration. The currents due to cyclones some times tend to act in a direction opposite to the prevailing littoral currents and affect siltation in the approach channel. This could be seen from the effect of a typical cyclone which occurred during 1-10-1971, during which the siltation was along the northern edge of the channel. An additional sandtrap in continuation with the approach channel along the northern edge of the approach channel was dredged by the port authorities in order to provide for such eventualities.

4.3 Kakinada Port:

The Port of Kakinada is an intermediate port located at Kakinada to a distance of 120 km south of Visakhapatnam. The total traffic through this port is of the order of 0.3 million tonnes consisting mainly of iron ore , rice bran etc. The old port is located 4 km inside a canal into which barges requiring upto 2 m draft navigate. The canal meets the bay called the Kakinada Bay which is formed by a sandspit about 10 km long bordering along the eastern side (Fig. 8).

The history of the sandspit is very interesting from the engineering point of view. Before 1850 the sandspit was completely absent in this region and subsequently due to the changes in the outfall in the river Godavari the formation of the sandspit took place gradually. Fig. 9 shows the formation of the sandspit at different times. With the absence of river flows into the Kakinada bay, the flushing characteristics changed considerably, and siltation of the bay started taking place from the south and SW side. The bay was gradually converted into a tidal bay. The opening at the mouth of the bay would therefore be the function of the relative flushing ability of the bay vis a vis strength of the littoral drift. The cross section area of the mouth of the inlet would therefore follow a law similar to O'Brien [3] who studied the effect of tidal prism in maintaining the inlets in the number of cases.

Recently, expansion of the port has been envisaged by the port authorities for traffic upto 1.5 million tonnes. One of the proposals for this expansion is the provision of mooring facilities west of the sandspit taking advantage of the shelter offered by the spit from wave action. The development and the stabilisation in the sandspit would therefore be of major importance in this programme.

Extensive model studies were conducted in a tidal-cum- wave model built to scales 1:600 Horizontal and 1:40 Vertical and injecting crushed walnut shell for reproducing littoral drift. It

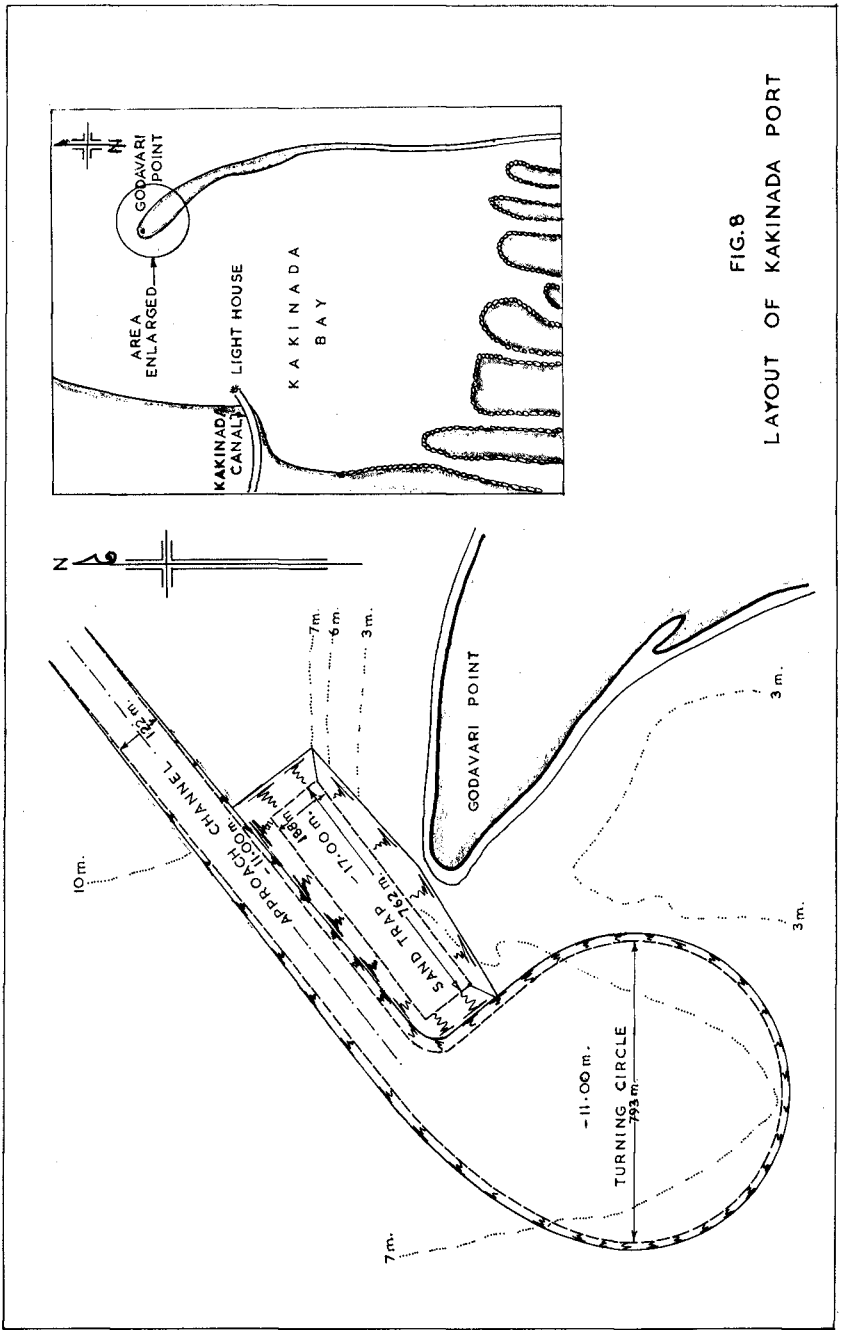
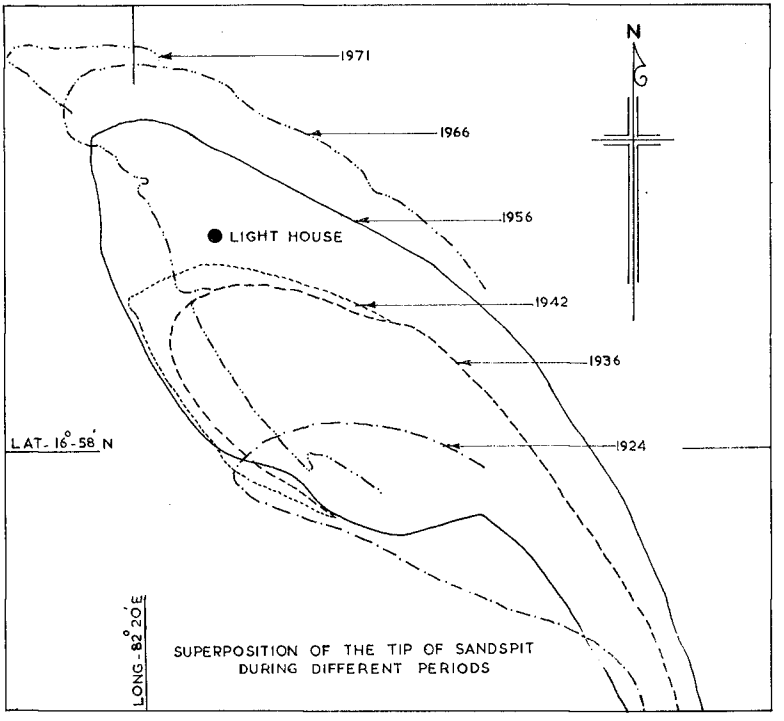


FIG.8
LAYOUT OF KAKINADA PORT



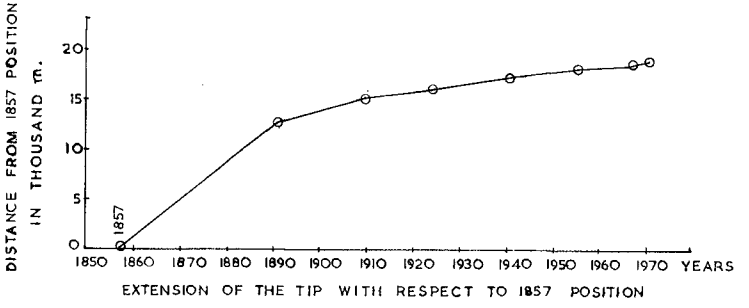


FIG.9

EXTENSION OF THE SAND SPIT AT KAKINADA PORT

SCALE

250 0 250 500 METRES

was found that the provision of a sandtrap in the vicinity of the tip of the sandspit would be helpful in preventing the deterioration of the channel due to littoral drift.

These experiments were carried out reproducing in the model a duration equivalent of 25 years in the prototype. The annual maintenance dredging was also reproduced during these tests. It was found that during initial years when the tip of the sandspit is away from the edge of the sandtrap the quantity of siltation in the trap is low and a major part of the drift is utilised only in shallowing of the regions between the edge of the trap and the tip of the sandspit. As this region becomes shallower, the quantum of siltation in the trap increased progressively so that after a period of 10 years, the total quantity of siltation is 60 % of the drift which increases to practically the entire drift after a period of 20 years.

These studies illustrate the long term experiments that would be required as a progressive increase in the quantum of siltation necessitate a corresponding increase in the capacity of the trap.

A proposal to construct a breakwater across the bay from the shore and provide berthing facilities near the entrance where depths are adequate is also under consideration. Studies in the model indicated that this would result in increasing the flushing velocities to a considerable extent because of the constriction of the bay and the area at the mouth. As a consequence it was also found necessary to alter the orientation and location of the sandtrap since a shifting of the direction of extension of the sandspit was seen to take place towards the easterly direction.

5. Conclusions:

The above examples are intended to illustrate the means of effectively maintaining the channel and prevent the drift from affecting depths at the approach channel and the harbour entrance. The variation in the meteorological, geomorphological and physical conditions would require different considerations in their design and where one type would be suited, it may prove to be unsuitable in a different location even along the same coast because of the different physical factors. Further the fact that the slope of the beach on the updrift side should be maintained without too much of a change for an efficient functioning of sandtrap is well brought out in the case of Paradip. The experience in Paradip also indicates that besides the pre-dominant direction of drift due to wave action the effects of currents generated by storms would also need to be carefully considered. The sandspit development in the case of Kakinada is a unique feature which calls for a different type of analysis and studies in the proper location and design of sandtrap. The need for studying the behaviour of the sandtrap over a long term period has also been brought out.

The above studies also indicated the relatively minor role played by sand pumps in the regions where the littoral drift are substantially large. It is necessary to go in for more reliable dredging equipment and methods in order to ensure the infallability of the proposals.

Acknowledgements:

The data obtained from the respective project authorities have been made use of in the above discussions which is gratefully acknowledged. Extensive use has also been made of the various reports and notes of the Research Station prepared from time to time.

The authors also acknowledge the help received from Mr. V.V.Vaze in the analysis of the data and carrying out the model studies.

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