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GENERATION OF LONGSHORE CURRENTS BY WAVES AND VARIATIONS IN BREAKER HEIGHT OFF MADRAS

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ABSTRACT

Longshore currents may be generated within the nearshore zone either by waves approaching obliquely to the shoreline or by longshore variations in the breaker height, or by combinations thereof. In this paper, large variations in breaker height observed along the coast are studied in relation to longshore currents. The waves approaching the coast from northeast and east-northeast produce southerly longshore currents downcoast while the waves from southeast and east-southeast produce northerly currents upcoast. The magnitude of the currents along the coast are however variable and depend on the distribution of the breaker heights, refraction functions, and the breaker angles along the coast. The computations reveal that no feeder currents are produced in this region.

Key-words: Longshore currents, Breaker height, Madras coast.

INTRODUCTION

One of the earliest known scientific description of coastal currents was made by Johnson (1919). The longshore currents are induced by an oblique angle of wave incidence. Undertows or rip currents are said to occur when waves strike the shore at right angles. The wave-induced current that flows alongshore which is generally confined between the first breaker and the shoreline is termed the 'longshore current'. It was first measured by Putnam, Munk and Traylor (1949), using travel times and distances of floats and dye in the surf on the California coast. Longshore currents can create a two dimensional coastal current system within and beyond the surf zone termed 'nearshore circulation'. The first detailed and well-documented measurements of such a system of currents were reported by Shepard and Inman (1950). They described the nearshore circulation consisting of two current systems. There are; 1. The coastal currents which flow roughly parallel to the shore constituting a relatively uniform drift in the deeper water adjacent to the surf zone. There may be tidal currents, transient wind driven currents or currents associated with the distribution of mass in local waters. 2. A nearshore current system which may be superimposed on the inner portion of the coastal current or in the absence of a coastal current, may exist independently.

The nearshore system is associated with wave action in and near the breaker zone. A number of theories have been proposed to account for the generation of these currents, which also have been reviewed by Komar (1976). Komar (1975) presented an analytical equation that combined the two generating mechanisms.

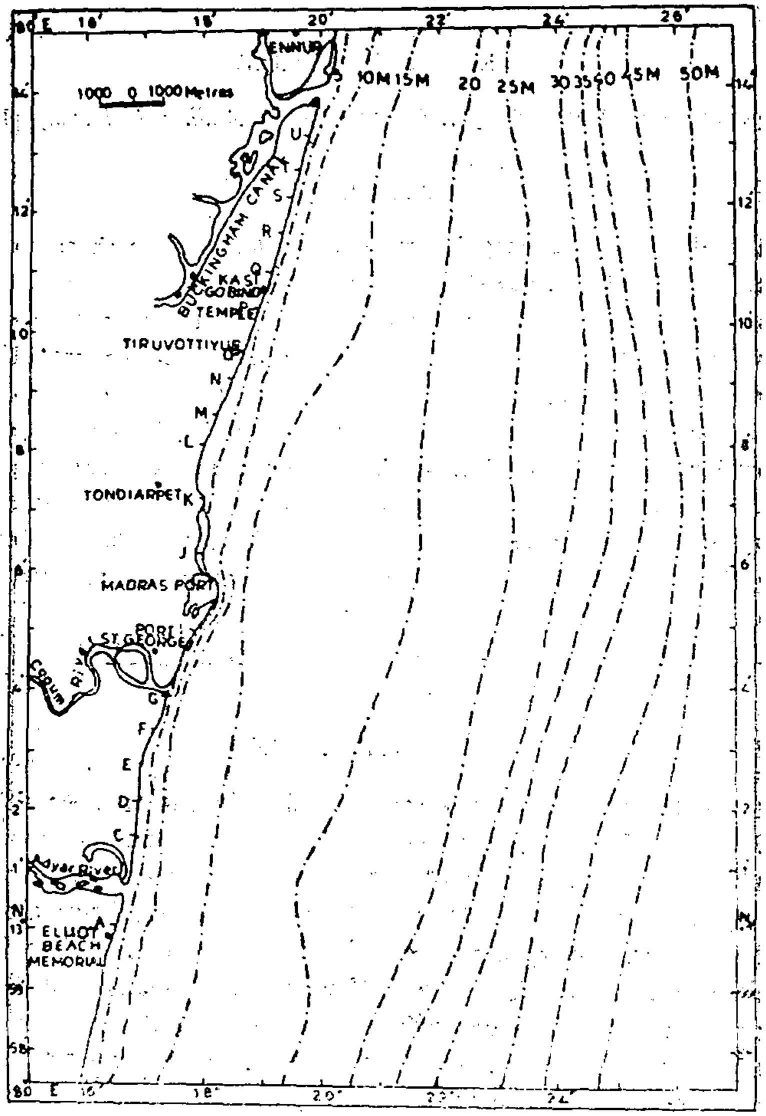

Fig. 1. Location map of Madras Coast

The study area near Madras (lat. 13°04′N, long. 80°17′E), extends for 25 km and is a nearly straight, sandy coast trending North-South with uncomplicated offshore bathymetry (Fig. 1). The present study area is under the influence of monsoonal type of climate in which winds blow consistently from a few directions over long periods except during periods of storms and depressions in the Bay of Bengal.

MATERIALS AND METHODS

Wave induced longshore currents off Madras coast have been computed *using the relationship* given by Komar (1975). The equation is as follows:

$$\overline{V}_1 = 2.7\ \mathrm{Um}\ \mathrm{Sin}\ \alpha b\ \ \mathrm{Cos}\ \alpha b - \frac{\pi\sqrt{2}}{Cf\text{-}rb^3}\left[1+\frac{3rb^2}{8}-\frac{rb^2}{4}\mathrm{Cos}^2\alpha\, b\right]\mathrm{Um}\ \frac{\partial H}{\partial y}$$

where $\overline{V}_1$ is longshore current velocity in the midsurf zone, Um is the maximum value of breaking wave orbital velocity, which is given by $(2\,Eb\,/\,\rho h_b)^{\frac{1}{2}}$, E_b is the wave breaker energy that can be evaluated from a knowledge of the breaker height H_b, h_b is the water depth at the wave breaking given by (4/3) H_b and ρ is the density of sea water. The drag coefficient c_f is 0.008. to 0.018 under normal field conditions and r_b is the ratio of the wave breaker height to water depth with a value between 0.8 to 1.2. for c_f and r_b are taken as 0.017 and 0.8 respectively the average deep water wave steepness and the beach shore off Madras coast from the curves of Longuet-Higgins (1970). The direction function αb and the refraction function K_b have been taken from the wave refraction diagrams (Prasad, 1985). The breaker wave heights H_b at different points along the coast have been calculated from the relation (Beach Erosion Board, 1954).

$$\frac{Hb}{Ho} = Kb\left[\frac{1}{3.3\ (Ho/Lo)^{\frac{1}{3}}}\right]$$

$\partial Hb\,/\,\partial y$ has been computed for different zones along the coast from a knowledge of the H_b values along the coast.

The term 2.7 Um Sin αb Cos αb in the above equation represents the longshore currents by oblique wave approach (v_1) while the term

$$\frac{\pi\ \sqrt{2}}{Ct\ \ rb^3}\left[1+\frac{3r_b{}^2}{8}-\frac{r_b{}^2}{4}\mathrm{Cos}^2\,\alpha\, b\right]U_m\ \frac{\partial Hb}{\partial y}$$

represents the longshore current due to variations in the wave breaker heights alongshore (v_2). If $\partial H_b/\partial y$ is positive then the driving forces are opposed to one another and the current is reduced. If $\partial Hb/\partial y$ is negative then the driving forces act together in the same direction giving rise to the stronger currents.

The currents in the surf zone at different points along Madras coast have been measured by observing the drift of the centre of the Rohdamin B - dye patch injected into the surf zone.

DISCUSSION

Wave refraction diagrams have been constructed for wave period 8 and 10 sec for four directions (Prasad, 1985). These diagrams show the refraction patterns to the north and south on either side of the port. The distribution of wave rays along the coast is by no means uniform and do not show any regular pattern.

Table I - Computation of the wave induced currents for northeast waves

Station	Period 8 sec				Period 10 sec			
	Breaker height H_b (metres)	Currents due to oblique V_1 (m/sec)	Currents due to height variation V_2 (m/sec)	Resultant current $\bar{V}_1$ (m/sec)	Breaker height H_b (metres)	Currents due to oblique V_1 (m/sec)	Currents due to height variation V_2 (m/sec)	Resultant current $\bar{V}_1$ (m/sec)
A	1.54	1.67			1.60	1.73		
			-0.16	1.51			-0.08	1.65
B	1.91	1.90			1.77	1.81		
			0.02	1.92			1.14	1.95
C	1.87	1.84			1.54	1.62		
			—	—			-0.34	1.28
D	—	—			2.46	2.52		
			—	—			0.04	2.56
E	1.39	1.64			2.27	2.73		
			-0.28	1.36			—	—
F	1.78	2.19			—	—		
			—	—				
G	—	—			1.79	2.19		
			—	—			-0.11	2.09
H	1.43	2.00			2.19	2.53		
			-0.20	1.80			0.36	2.89
I	1.67	2.36			1.54	1.99		
			-0.12	2.24			-0.02	1.97
J	1.95	2.69			1.73	2.22		
			0.30	2.99			0.05	2.27
K	1.52	1.44			1.54	1.78		
			-0.08	1.36			-0.19	1.59
L	1.67	1.81			2.31	2.79		
			0.19	2.00			0.18	2.97
M	1.46	1.79			1.69	1.99		
			-0.14	1.65				
N	1.65	2.11						

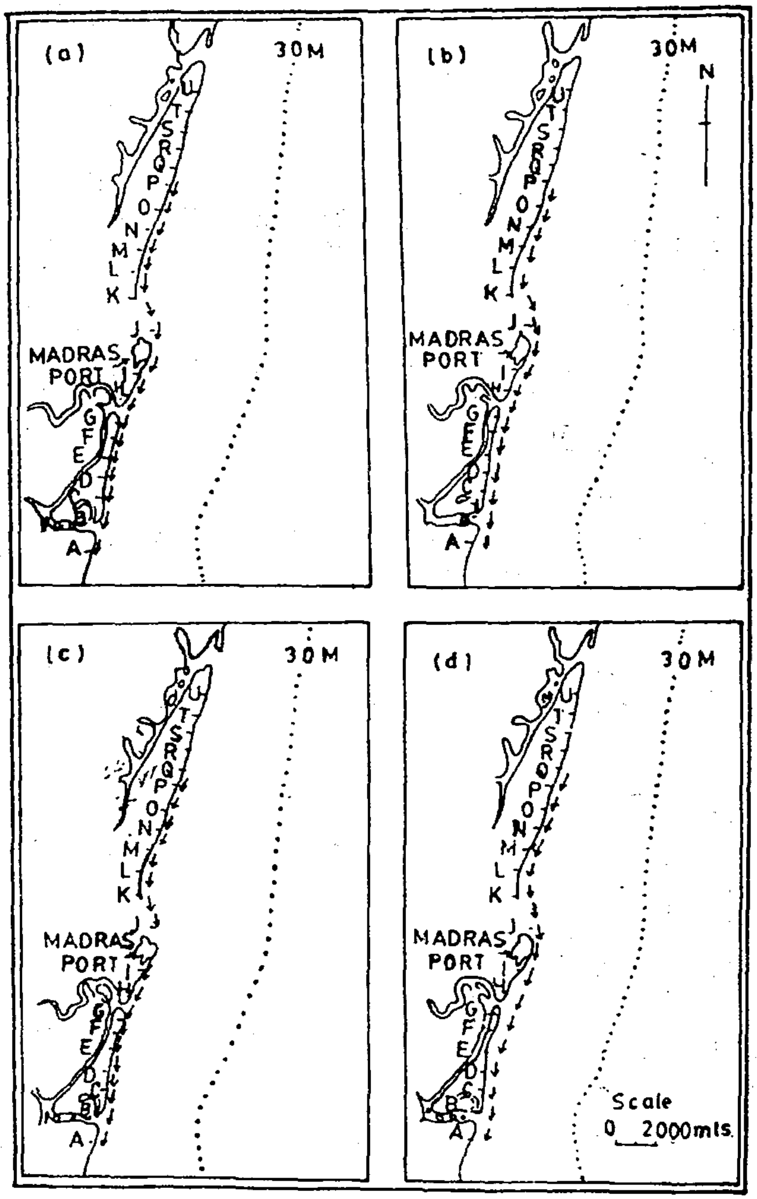

Fig. 2. Wave induced currents in the surf zone a) NE Waves, 8 sec, b) NE Waves, 10 sec. c) ENE Waves, 8 sec. d) ENE Waves, 10 sec.

The coast is exposed to Northeast waves during the months of October to January. The currents due to northeast waves (Table I) are maintained mainly by the oblique wave approach since the current vectors in general are directed towards south almost along the entire coast (Fig. 2a & b). Maximum current of about 2.99 m/sec is generated near station J towards north of Madras Port for 8 sec. weves. But for 10 sec. waves the occurence of maximum current shifted

Table II - Computation of the wave induced currents for east northeast waves

Station	Period 8 sec				Period 10 sec			
	Breaker height H_b (metres)	Currents due to oblique V_1 (m/sec)	Currents due to height variation V_2 (m/sec)	Resultant current $\bar{V}_1$ (m/sec)	Breaker height H_b (metres)	Currents due to oblique V_1 (m/sec)	Currents due to height variation V_2 (m/sec)	Resultant current $\bar{V}_1$ (m/sec)
A	2.00	1.55	0.20	1.75	1.89	1.39	0.06	1.33
B	1.67	1.24	-0.01	1.23	2.00	1.23	-0.05	1.18
C	1.69	1.17	0.05	1.22	2.08	12.0	0.13	1.33
D	1.63	1.32	-0.11	1.21	1.95	1.20	-0.06	1.14
E	1.76	1.63	0.02	1.65	2.02	1.08	0.06	1.14
F	1.73	1.88	0.08	1.96	1.95	1.96	-0.17	1.79
G	1.63	1.53	-0.29	1.22	2.13	2.27	0.14	2.41
H	1.97	2.31	-0.03	2.28	2.00	2.88	-0.20	2.08
I	2.00	1.94	0.16	2.10	2.19	1.85	0.15	2.01
J	1.67	1.48	0.04	1.52	1.87	1.38	-0.01	1.37

K	1.60	0.76			1.89	1.39		
			-0.03	0.73			-0.09	1.30
L	1.66	1.41			2.04	1.75		
			0.07	1.48			-0.25	1.50
M	1.58	0.95			2.27	2.02		
			-0.30	0.65			0.34	2.36
N	1.97	1.75			1.95	1.72		
			0.35	1.45			0.09	1.81
O	1.60	1.42			1.85	1.75		
			-0.36	1.06			-0.17	1.58
P	2.06	2.00			2.04	1.86		
			0.36	2.36			0	1.86
Q	1.69	1.56			2.04	1.86		
			0.07	1.63			0.08	1.94
R	1.60	1.44			1.95	1.67		
			-0.13	1.31			-0.18	1.49
S	1.76	1.56			2.15	1.76		
			0.04	1.60			0.14	1.90
T	1.73	1.34			2.04	1.86		
			0.04	1.38			0.04	1.90
U	1.69	1.30			2.00	2.01		

Table III - Computation of the wave induced currents for east southeast waves

Station	Period 8 sec				Period 10 sec			
	Breaker height H_b (metres)	Currents due to oblique V_1(m/sec)	Currents due to height variation V_2(m/sec)	Resultant current V_1(m/sec)	Breaker height H_b (metres)	Currents due to oblique V_1(m/sec)	Currents due to height variation V_2(m/sec)	Resultant current V_1(m/sec)
A	1.63	0.32	-0.04	0.28	1.98	0.63	-0.14	0.49
B	1.71	0.60	0.07	0.67	2.23	0.51	0.47	0.98
C	1.59	0.75	0.07	0.82	1.60	0.58	-0.29	0.29
D	1.50	0.80	-0.10	0.70	1.98	0.80	0.08	0.88
E	1.63	0.70	0	0.70	1.89	0.85	-0.11	0.74
F	1.63	0.26	0.03	0.29	2.02	0.64	0.28	0.92
G	1.59	0.38	-1.54	1.16	1.72	0.08	0.14	0.22
H	3.47	0.34	3.62	3.96	1.89	0.86	0.18	0.44
I	1.54	0.07	-0.03	0.04	1.70	0.15	0.01	0.16

J	1.63	0.31	0	0.31	1.68	0.90	-0.06	0.84
K	1.63	0.77	-0.32	0.45	1.81	0.81	0	0.81
L	2.20	0.25	1.02	1.27	1.81	0.41	0.02	0.43
M	1.38	0.59	-0.20	0.39	1.79	0.49	-0.37	0.12
N	1.68	0.59	0.17	0.76	2.23	0.54	-0.32	0.22
O	1.46	0.63	-0.12	0.51	2.55	0.58	1.04	1.62
P	1.63	0.55	-0.04	0.51	1.68	0.48	-0.22	0.26
Q	1.68	0.40	-0.02	0.38	1.98	0.54	-0.35	0.19
R	1.71	0.19	0.18	0.37	2.02	0.28	0.16	0.44
S	1.50	0.29	0.39	0.68	1.85	0.36	-0.10	0.26
T	1.92	0.28	0.48	0.76	1.94	0.35	0.16	0.51
U	1.45	0.28	-0.12	0.16	1.77	0.24	0.22	0.46
V	1.63	0.34			2.06	0.22		

Table IV - Computation of the wave induced currents for southeast waves

Station	Period 8 sec				Period 10 sec			
	Breaker height H_b (metres)	Currents due to oblique V_1 (m/sec)	Currents due to height variation V_2 (m/sec)	Resultant current $\bar{V}_1$ (m/sec)	Breaker height H_b (metres)	Currents due to oblique V_1 (m/sec)	Currents due to variation V_2 (m/sec)	Resultant current $\bar{V}_1$ (m/sec)
D					1.86	2.01		
E							-0.09	1.92
					1.96	1.81		
							0.17	1.98
F	1.60	1.52			1.78	1.59		
			-0.16	1.36			0.12	1.71
G	1.80	1.62			1.64	1.34		
			0.12	1.74			-0.32	1.02
H	1.67	1.31			2.03	1.54		
			0.14	1.45			-0.21	1.33
I	1.52	1.37			2.23	0.92		
			-0.02	1.35			0.30	1.22
J	1.56	1.86			1.64	1.35		
			-0.01	1.85			-0.01	1.34
K	1.60	1.46			1.67	1.55		
			0.09	1.55			-0.03	1.52
L	1.43	1.41			1.72	1.54		
			0.05	1.46			-0.26	1.28

M	1.38	1.35	-0.18	1.17	1.99	1.86	0.05	1.91
N	1.64	1.48	0.03	1.51	1.94	1.73	0.43	1.30
O	1.60	1.38	-0.32	1.06	2.42	2.47	0.82	3.29
P	1.64	1.37	-0.26	1.11	1.72	1.48	0.15	1.63
Q	1.97	1.70	-0.49	2.19	1.53	1.14		
R	1.45	1.36	-1.60	0.36				
S	2.80	1.64	1.90	3.54				
T	1.72	0.83	0.28	1.11				
U	1.42	0.81	-0.28	0.53				
V	1.85	0.91						

Table V - Mean observed wave direction, wave period, breaker height, breaker angle, current velocity and current direction

Month	Station	Wave direction	Wave period (sec)	Breaker height (m)	Breaker angle (degrees)	Current velocity (m/sec)	Current direction
January	G	Northeast	7	1.0	18	0.35	Downcoast
	I			1.2	20	1.10	
	J			1.2	15	1.00	
	M			0.75	12	0.50	
April	G	East-Southeast		1.25	2	0.50	Upcoast
	I			1.2	2	0.25	
	J			1.25	5	0.30	
	M			1.0	5	0.40	
July	G	Southeast	10	1.25	10	0.75	Upcoast
	I			1.5	10	1.20	
	J			1.0	8	1.00	
	M			1.25	10	1.20	
October	G	East-Southeast	8	1.0	18	0.50	Upcoast
	I			1.25	20	1.25	
	J			1.25	15	1.20	
	M			1.0	12	0.75	

Upcoast: South-southwest, Downcoast: North-northeast.

to the station L south of the Madras Port. The contribution due to variations in the breaker height (v_2) is positive at some station and negative at some other stations. But since the magnitude of v_2 is small throughout, reversal in the resultant current does not take place at any point. As such rip currents are not likely to occur along this coast during the period of the northeast waves. The values of the current magnitude along the south of the Madras Port is maximum. The current magnitude all along the coast are however very high because of the high breakers and higher direction function values.

The coast is exposed to east northeast waves during the months of November and December. The highest current of around 2.36 m/sec occur at station P towards the northern limit of the port for 8 sec period waves, where both v_1 and v_2 are in the same direction and are fairly strong (Table II). The occurrence of the strong current shifts slightly towards the south for 10 sec waves. Minimum currents of the order of 0.65 m/sec occur further south of this point, where v_1 and v_2 oppose each other. The resultant current V is generally towards south aolng the entire coast which shows a dominance of v_1 and v_2 (Figs. 2c & d). The mean magnitude of the current V_1 is 1.61 m/sec along the north of the port for 8 sec waves and 1.76 m/sec for 10 sec waves along the south of the port.

The coast is exposed to east southeast waves during the month of February and March. The magnitude of the longshore currents due to 8 sec waves varied from 0.04 m/sec to 3.96 m/sec. (Table III). Alongshore breaker heights are found to be highly variable along the coast, resulting in large values of v_2. The resultant current was found to reverse in direction at station G towards south of Cooum river inlet. A strong northerly current appeares to the north of this inlet at the station H. As per the computations, at station G and towards south of G rip currents are likely to occur. Similarly at station 'O' there are opposing currents and the rip currents may possibly occur for 10 sec waves. Thus the currents due to east southeast waves show high variability zones of rip currents which are shown in the diagram (Fig. 3a & b). The mean magnitudes of current along north of the port is fairly large.

The resultant circulation pattern due to southeast waves (during the month of April to September) in the surf zone is illustrated in Fig. 3c & d. The magnitude of the longshore currents due to waves of 8 sec period varied between 0.36 m/sec and 3.54 m/sec (Table IV). The currents are fairly strong near the entrance channel. The strength of the current is generally strong all along the coast except at station R and U where it is less than 1.0 m/sec. For 10 sec waves the magnitude of the longshore currents vary between 1.02 and 3.29 m/sec. The longshore currents along the north of the Port is relatively large. In general strongest currents are generated during this season. The current direction in the surf zone is generally towards north along the entire coast. However, between

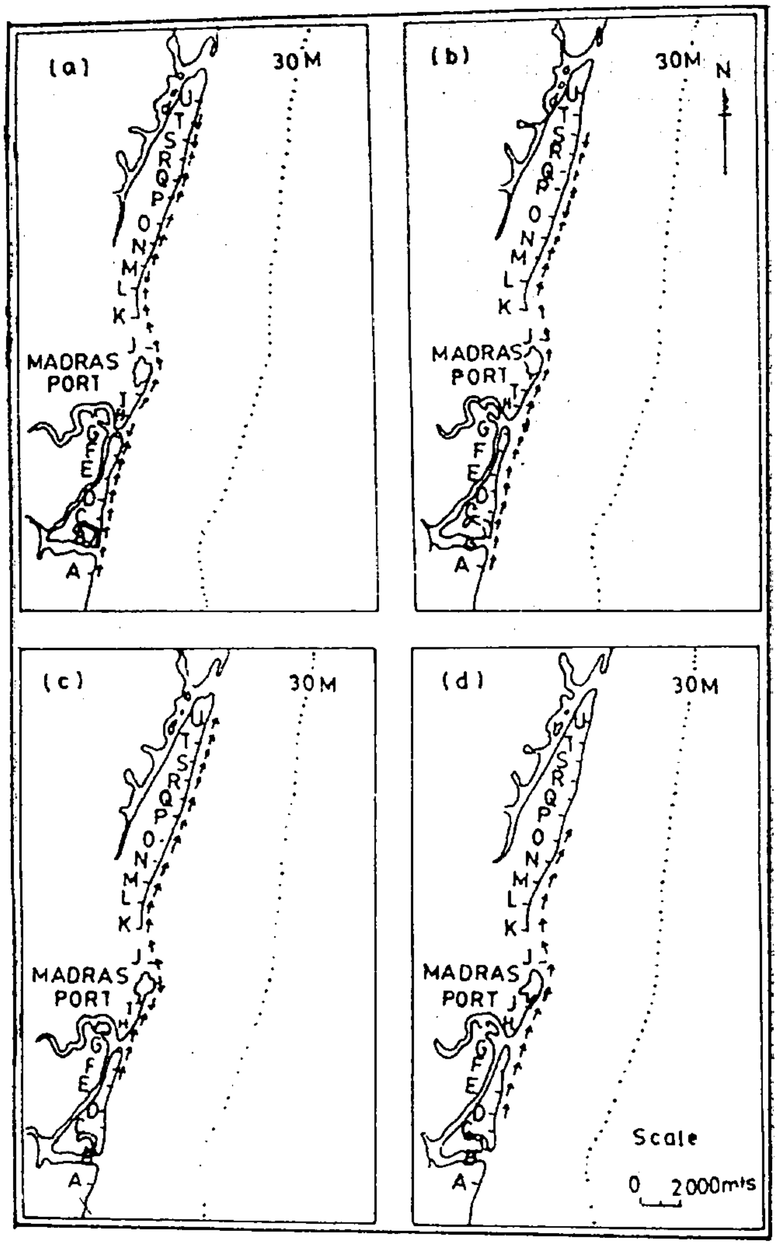

Fig. 3. Wave induced currents in the surf zone a) NE Waves, 8 sec, b) NE Waves, 10 sec. c) ENE Waves, 8 sec. d) ENE Waves, 10 sec.

stations S and T there is a reversal in current due to variations in the breaker heights. As a result of such distribution, rip currents could be produced theoritically between station S and T.

Observed Longshore Currents: Current observations have been taken at stations G and I on the southern side of the Madras port and at stations J and M on the northern side. During the same time the wave breaker characteristics like the wave direction, wave period, breaker height and the breaker angle have been noted through visual observations and are presented in Table V for representative months. The observations reveal that the currents on either side of the port entrance are fairly strong compared to the currents farther away along the coast. However, April seems to be an exception as the currents at I and J are weak compared to those at other stations. A comparison of these observed longshore currents with the computed currents show that the computed currents are generally stronger than the observed currents. This is because of the computed values are purely due to wave induced currents while the observed currents are the resultants of various components like the wave wind etc. Further no rip currents have been recorded throughout the observation in any month. although the computed current pattern indicates occurrence of some rip currents at station G and O for east southeast waves during April.

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