II-1-5-4 Preparatory process for statistical analysis

The final data are recorded by the magnetic tapes which are exclusively applied for the computers, and transferred to the process of analytical calculation.

The analytical calculation process is divided into time series analysis and other statistical analysis. In this chapter, time series analysis is described.

The data obtained through the field survey show remarkable flucutation as shown in Table II-1-5-(3).

The preliminary time series analysis is divided in (i) the processing of time series data and (ii) the plotting of time series data.

The low pass filtering of time series data is for the purpose of data smoothing and removing any frequency of the arbitrary time. The examples of those processing are shown in the following paragraph.

The data plotting is the process to show the data of current direction, velocity, temperature, and salinity by plotting on the coordinates as the time series curve by the XY plotter of large capacity computer.

In this study, the process has been conducted as shown in Table II-1-5-(4).

Table II-1-5-(4) Examples of plotting of time series data

Names of Diagram	Used Data	Mean Calculation
i) Time Series of Tidal Current	Current Direction & Velocity Values	– (Raw Data)
ii) Time Series of Salinity & Temperature (Hourly value)	Temperature & salinity Values	– (Raw data)
iii) Time Series of Tidal Current Curves	North & East Components Values calculated from current direction & velocity values	Hourly running mean
iv) Time Series of Tidal Current Vectors	Vector values of current direction & velocity	Hourly running mean 25 hours running mean

Using these procedures, the fluctuations of current direction and velocity, temperature and salinity of the survey areas are able to show. Each procedure is further described hereunder.

1) The fluctuations of current direction and velocity

This figure is illustrated with the curve derived from the current direction and velocity values which were measured at every 5 minutes. The current velocity values measured at every 5 minutes are plotted in solid line and current direction values of every 5 minutes measurement are plotted in dotted line.

The purpose of producing these figures is to observe the situation of raw data which are not averaged yet.

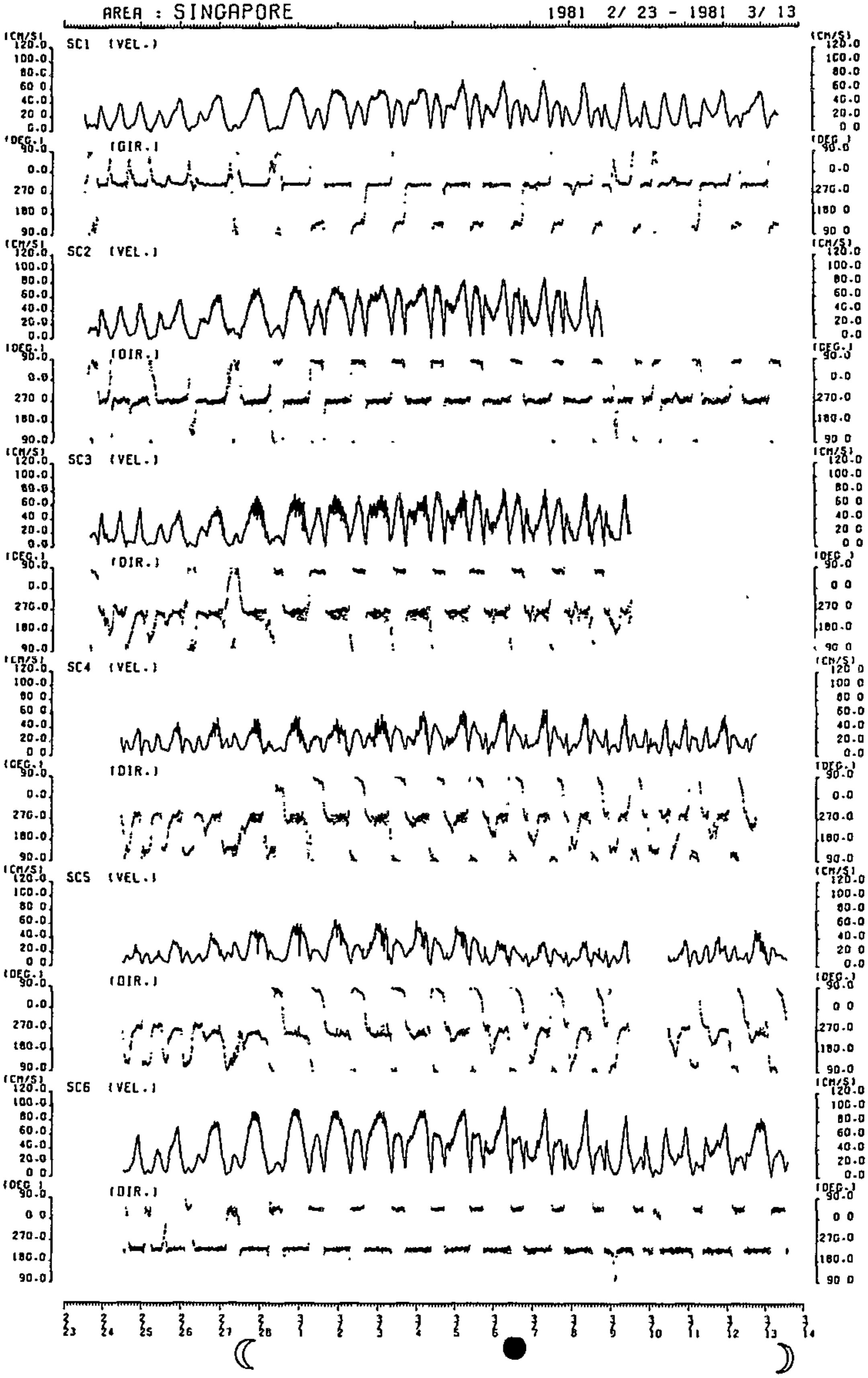
Figs. II-1-5-(4) and II-1-5-(5) show the examples of the diagrams based on the data obtained in this study at SC1 of Seraya Area and TC1 of Tekong Area. From these figures, it can be observed that the current direction and velocity of both SC1 and TC1 are fluctuating with the regular cycles of time, although the situations of SC1 and TC1 are different from each other. From the figures, the followings are confirmed.

(1) The regular cycle fluctuation pattern of current direction and velocity are observed

Seraya Area --- about 1 day cycle period
Tekong Area --- about ½ day cycle period

(2) The distinct turning of current direction is observed.

(3) The duration of slack water is short. The turn of direction is generated within short time.



AREA : SINGAPORE
1981 2/ 23 - 1981 3/ 13
SC1 (VEL.)
(DIR.)
SC2 (VEL.)
(DIR.)
SC3 (VEL.)
(DIR.)
SC4 (VEL.)
(DIR.)
SC5 (VEL.)
(DIR.)
SC6 (VEL.)
(DIR.)

Fig. II-1-5-(4)

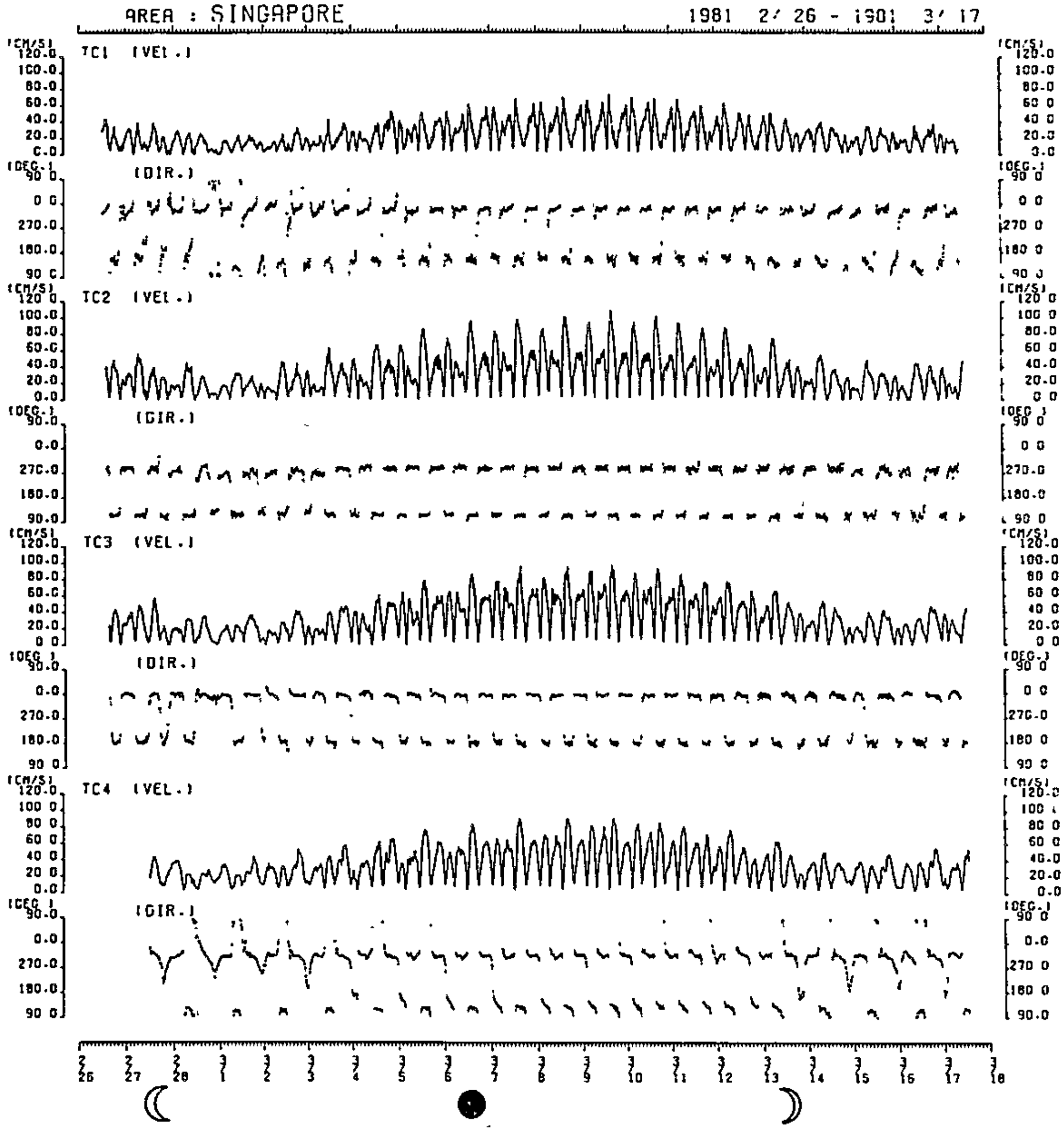

AREA : SINGAPORE
1981 2/ 26 - 1981 3/ 17
TC1 (VEL.)
(DIR.)
TC2 (VEL.)
(DIR.)
TC3 (VEL.)
(DIR.)
TC4 (VEL.)
(DIR.)
(CM/S)
(DEG.)

Fig. II-1-5-(5)

2) Time Series data of salinity and temperature

These are illustrated with the curve derived from the temperature and salinity date measured at every 5 minutes by the same way as the velocity. And the plots of every 5 minutes are linked by the solid line.

It can be observed the fluctuations of temperature and salinity are correlated with fluctuation of current direction and velocity.

The examples of plottings based on the data obtained in this study at SC1 and TC1 are shown in Figs. II-1-5-(6) and II-1-5-(7).

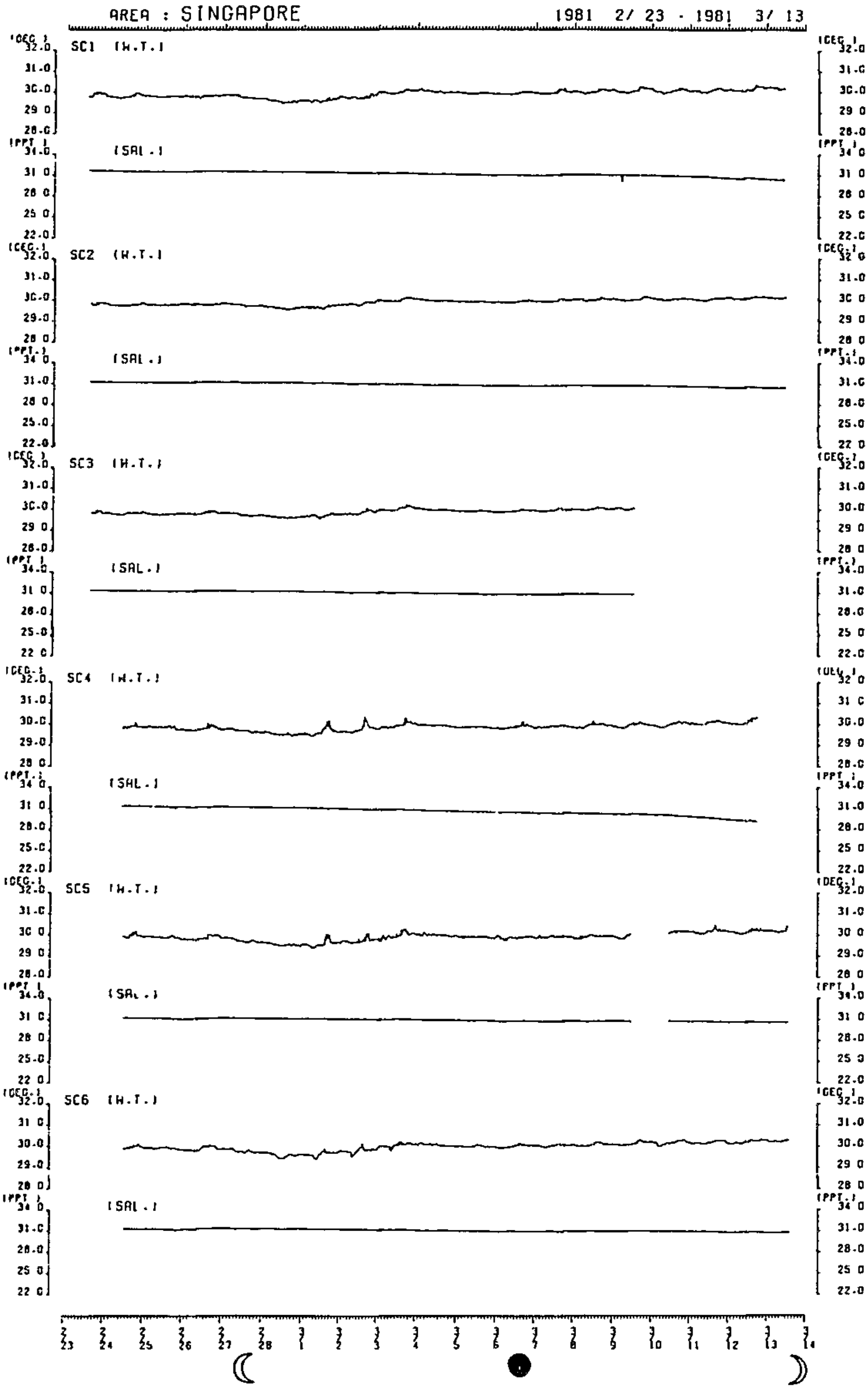


Fig. II-1-5-(6) Time series of tidal current

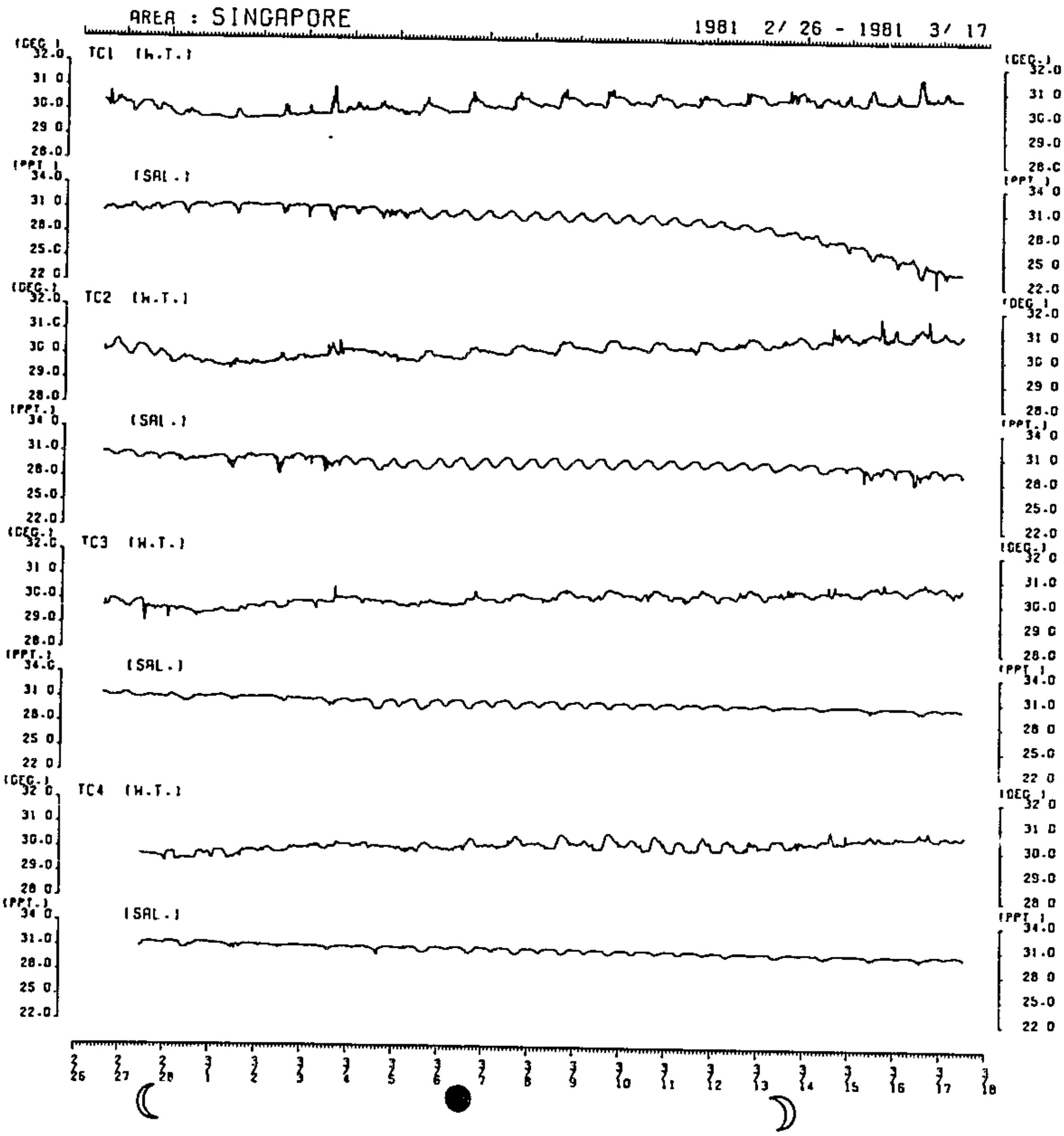


Fig. II-1-5-(7) Time series of salinity and temperature

From the plotting, the followings are confirmed.

(1) The fluctuations magnitude of salinity and temperature in Seraya Area are very small.

(2) At Tekong Are, the clear cycle of about ½ day is observed both in terms of salinity and temperature. This seems due to the effects of two rivers, Sugai Juhor and Sungai Uebam, are located in the northern side of the island and about ½ day cycle current is dominant.

3) Time series plotting of tidal current velocity data

Current velocity data are decomposed into two coordinate components, that is, N-S & E-W component or alongshore and offshore components.

if Coast line = Compass line

North component (N- comp.) $V_n = V\cos\theta$

East compoennt (E- comp.) $V_e = V\sin\theta$

and if Coast line ≠ compass line

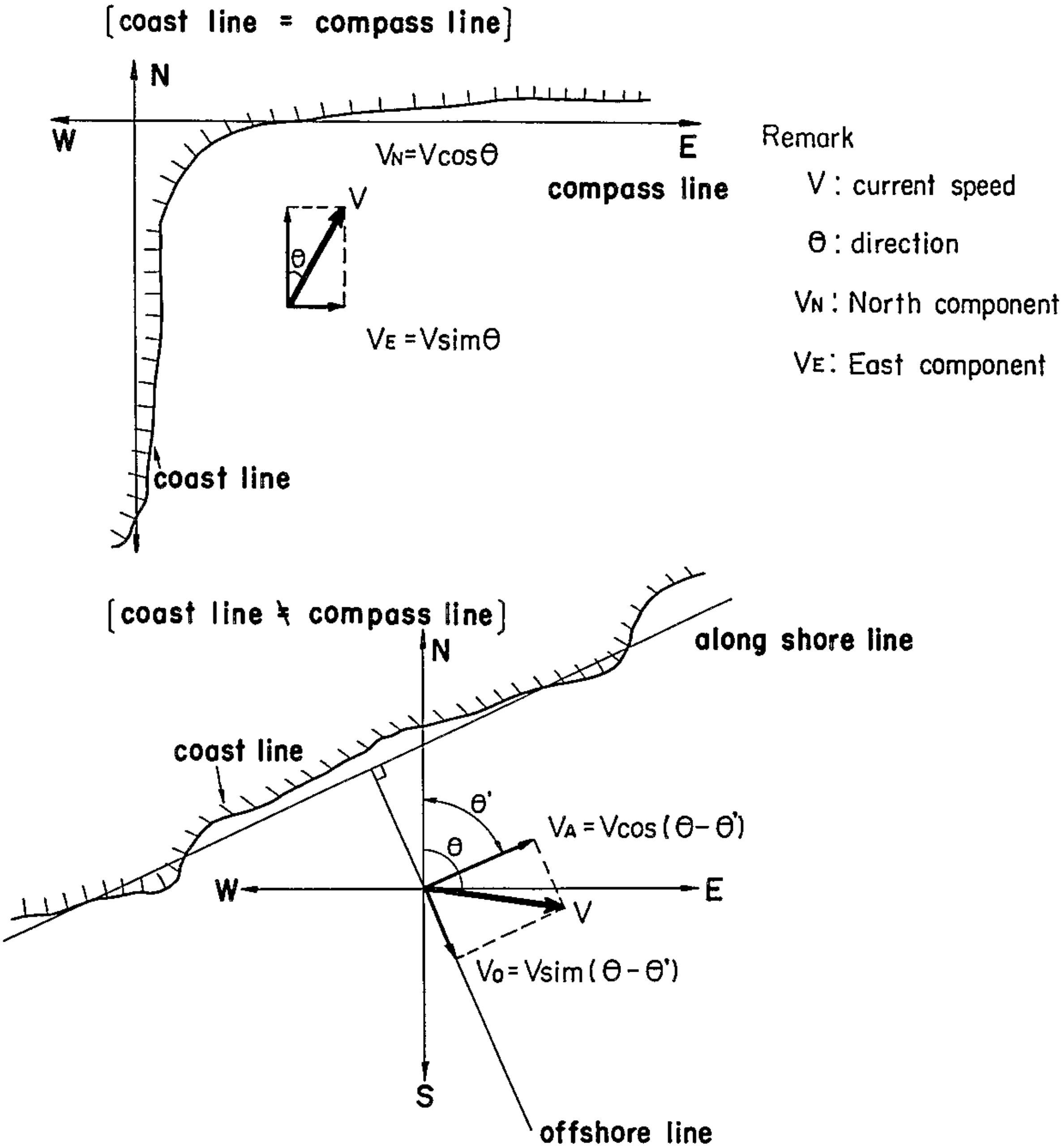
Alongshore component (alongshore-comp.) $V_a = V\cos(\theta - \theta')$

Offshore component (offshore-comp.) $V_o = V\sin(\theta - \theta')$

θ' means the direction of coast line to the north.

The component values thus obtained are plotted in curves of time series by determining the north as (+) and the south as (-) in case of North/West components, and the east as (+) and west as (-) in case of East/West component. And from the each time series, the dominant period in current velocity fluctuations is observed.

The examination of the time series plotting are carried out taking the following matters into consideration; (1) ½ or 1 day cycle pattern generated by the tide is observed or not, (2) if not, what cycle is dominant? Figs. II-1-5-(9) and II-1-5-(10) show the time series of current velocity data obtained through the survey in this study at Seraya and Tekong Areas.



Two examples of composing method of tidal current

In these figures, the first curve shows the time series of raw data of current velocity of every 5 minutes before filtering, and the second curve represents the time series after low pass filtering by 1 hour running mean, and the third curve after low pass filtering by 25 hours running mean.

When compared these 3 curves, the time series after filtering become more smoothly.

Low pass filtering of 1 hour runing mean show that the fluctuation period of less than 1 hour is excluded. In the same manner, the case of 25 hours running mean data excludes the component of less than about 25 hours.

The purpose of 25 hours running mean is to find out whether any other current fluctuations generated by other influences than the tide is existing in the area or not, as the curve shows the existence of the cycle longer than 1 day.

From the above, it can be confirmed the filtering techniques are effective to exclude the arbitrary time scale components by filtering the data. The filters employed in the study are shown in Table II-1-5-(5).

Table II-1-5-(5) Low-pass filters

Name of filter		Remarks
1 hour	Running mean	Employed for data smoothing
25 hour	Running mean	Employed for analysis of varaition longer than one day. The components shorter than about one day are excluded.
Cosine filter		Same as 25 hour filter, the components shorter than about one day are excluded, particularly more effective to exclude the influence of tidal current.

In the Figs. II-1-5-(9) and II-1-5-(10), the tidal curves obtained from the time series fluctuation of observed tide is shown in the bottom part in order to observe the relation with the tidal current. In Fig. II-1-5-(9) the tidal curve observed at Jurong Wharf, Seraya Area, and in Fig. II-1-5-(10) the tidal curve observed at Slave One, Tekong Area, are shown.

The symbols in the figures represent the age of moon; ☾ is last quarter, ● is new moon and ☽ is first quarter.

In the survey aras, the spring tide (tidal range is largest) is generated about 2 days after new moon and full moon (○), and the neap tide (tidal rnge is smallest) is generated about 2 days after last and first quarter.

The current conditions of the survey areas seem the tide generated by the tidal current is dominant, and so by the symbols mentioned in the figures will enable to observe the relation between the tide and the tidal current. The results of observation of the figures are as follows:

— Seraya Area

(1) From the figures of raw and 1 hour running mean, the dominant period at the spring tide is ½ day and 1 day, and 1 day at neap tide.

(2) The dominant periods more than 1 day are not observed from the data obtained through the current survey duration. (Refer to 25 RUN.M)

(3) The difference of velocity is observed between the spring tide and the neap tide, and the velocity of the spring tide is faster.

(4) By the influence of the coastal line topography, magnitude of current speed of North/South component is smaller at SC2, 3, 4 and 5.

— Tekong Area

(1) From the figures of raw and 1 hour running mean, the dominant period of this survey area is ½ day. And at the spring tide after the new moon, the velocity is fastest.

(2) By the influence of the coastal line topography, the values of velocity are larger at TC2 where East/West component is dominant and at TC3 where South/North component is dominant.

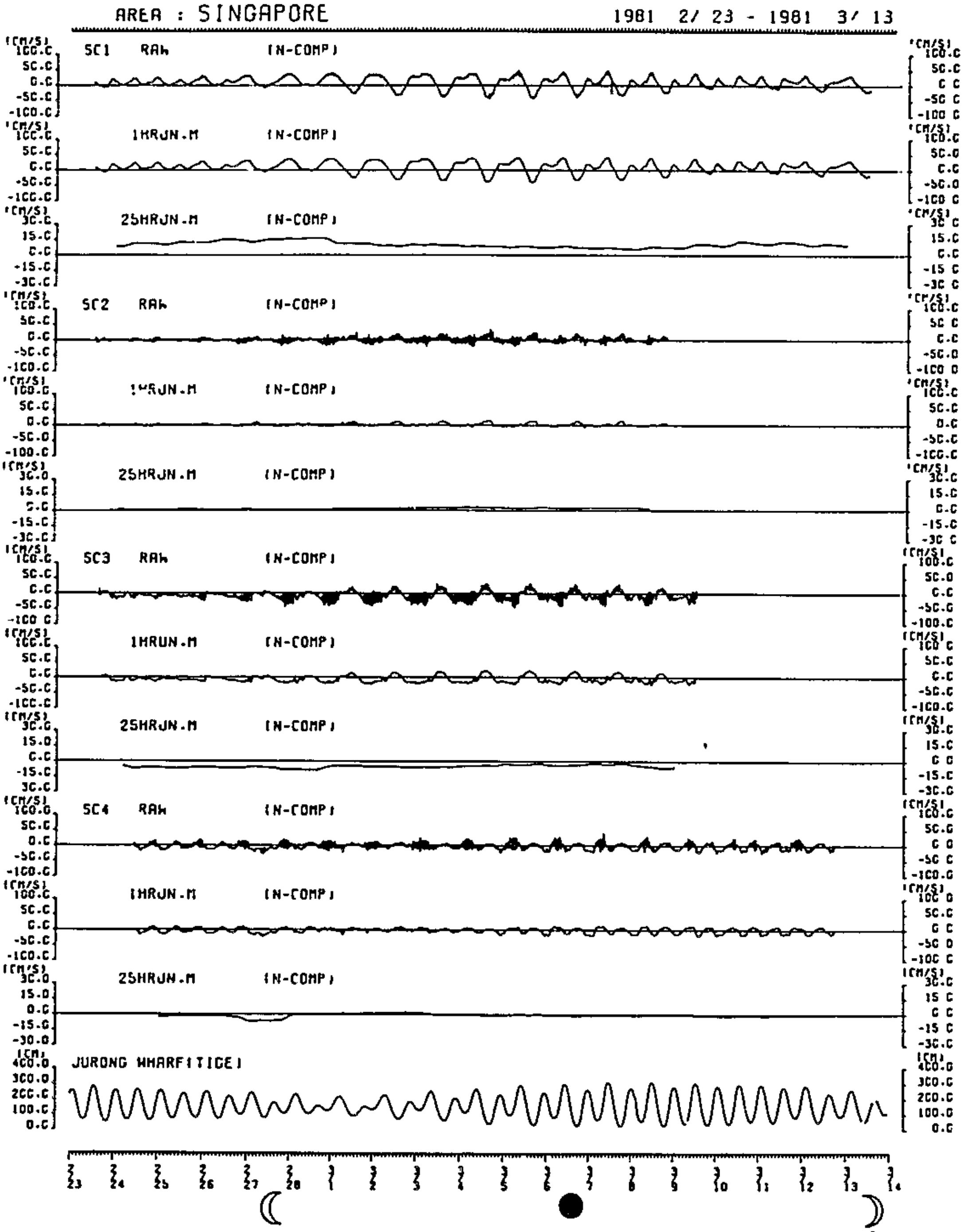


Fig. II-1-5-(9) Time series plotting North/South components of current velocity at Seraya Area (1)

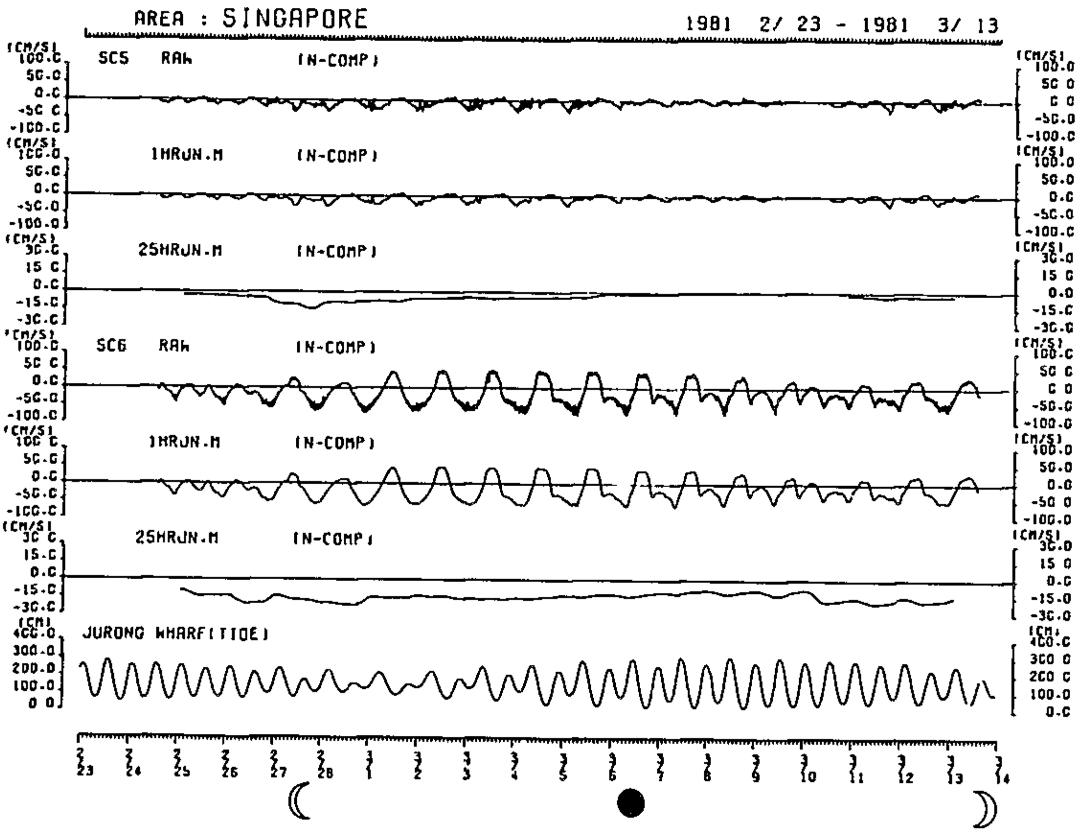


Fig. II-1-5-(9) Time series plotting North/South components of current velocity at Seraya Area (2)

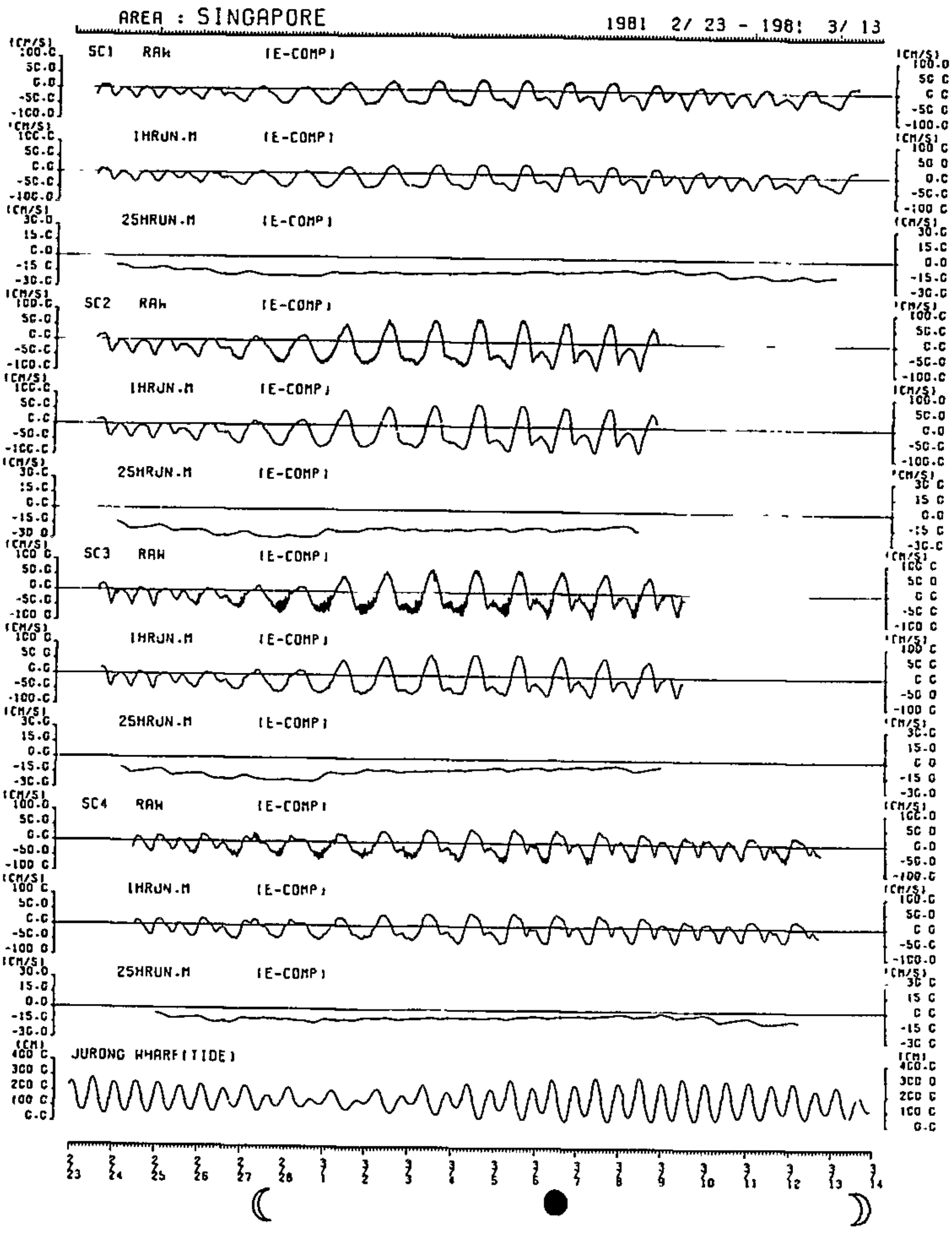


Fig. II-1-5-(9)' Time series plotting of East/West components of current velocity at Seraya Area (1)

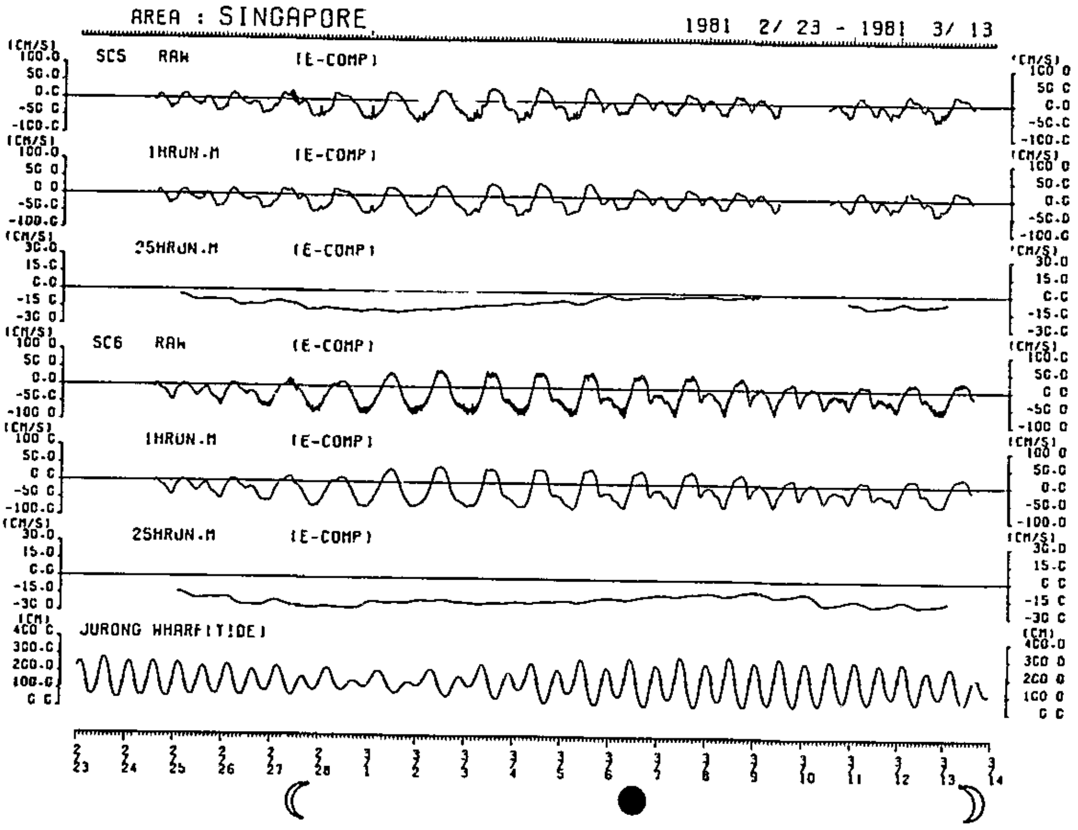


Fig. II-1-5-(9)' Time series plotting of East/West components of current velocity at Seraya Area (2)

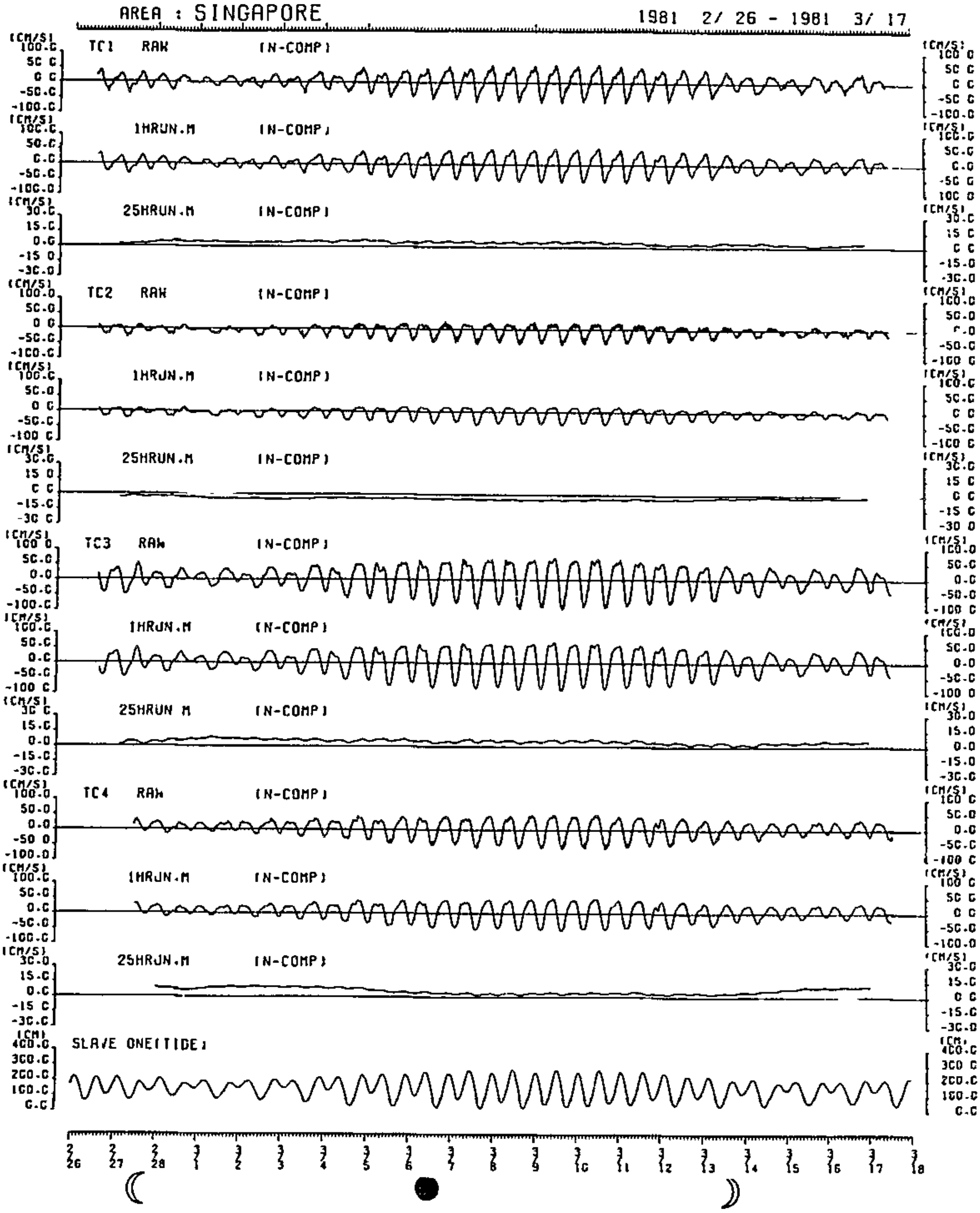


Fig. II-1-5-(10) Time series plotting North/South components of current velocity at Tekong Area

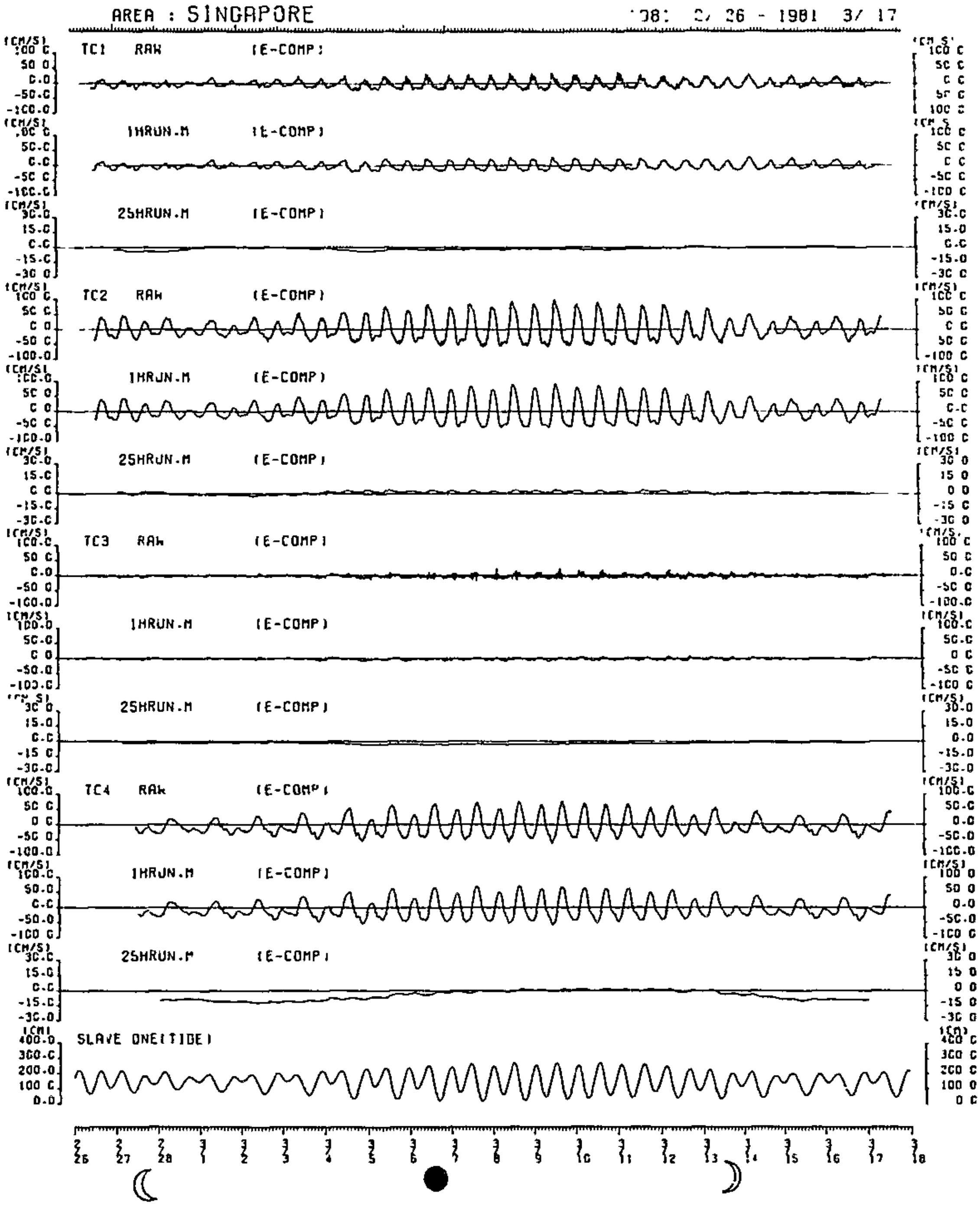


Fig. II-1-5-(10)' Time series plotting East/West components of current velocity at Tekong Area

4) Vector time series

This figure illustrates the current direction and velocity by vectors and is drawn in time series manner.

Different from the time series plotting of current velocity components, the current direction and velocity are expressed by vectors and so the actual fluctuation of the current velocity can be observed directly.

Fig. II-1-5-(11) shows the vector time series and the horizontal line represents East/West direction and the vertical line represents North/South direction, and hourly fluctuation of direction and velocity are expressed by vectors.

From the vector time series, the dominant periods of the current flucutation of the survey areas can be also observed. Particularly the vector time series which excludes the cycle flucutation of longer than 24 hours by 25 hours filter is the basic data for the analysis of low frequency fluctuation.

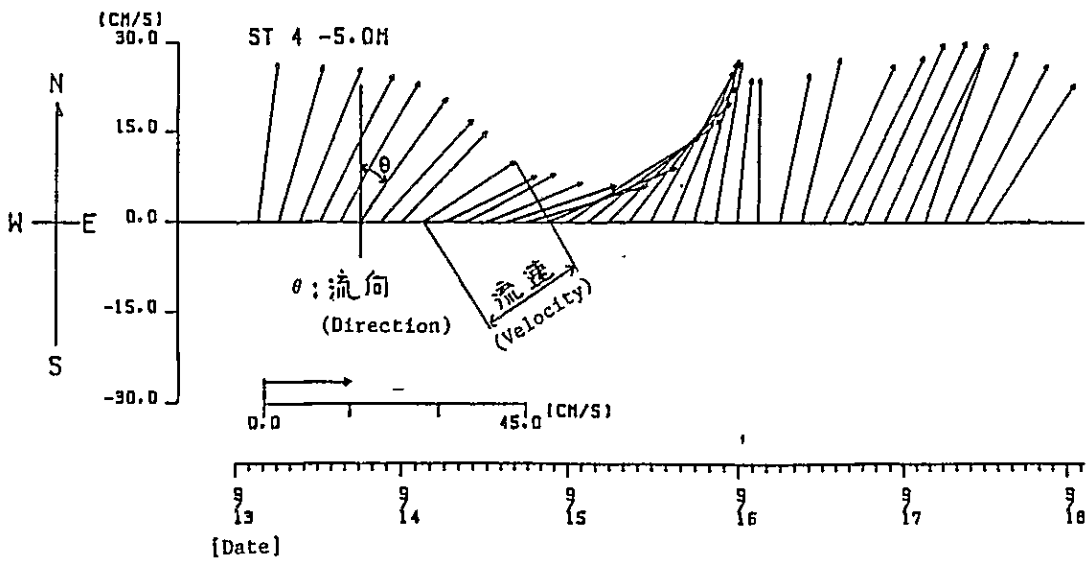


Fig. II-1-5-(11) Vector time series

The examples of vector time series based on the results of survey at Seraya and Tekong aeeas are shown in Figs. II-1-5-(12) and II-1-5-(13). In these figures, the first line is for raw data, the second line is for 1 hour filter and the 3rd line is for 25 hours filter. And at the bottom of figures, the survey points maps are attached which illustrate the generated behaviour of the current conditions.

From these figures, the following conclusion are obtained.

— Seraya Area

(1) At all the survey points, the current flow which is parallel with the coastal topography is observed.

The velocity of SC6 and SC1 is the fastest and it seems that the surrounding topography is the narrow water way in these two survey points.

(2) It is the charactristics of all the suvey points that the duration of slack water is short and the current is changing its direction rapidly by 180° within the short period.

(3) From the figures of 25 hours running mean, the average current direction after excluding the flucutations shorter than 1 day are as follows:

SC 1	North/West current
SC 2	West current
SC 3	South/West current
SC 4	South/West current, North/East current and South/East current
SC 5	South/West current
SC 6	South/West current

Thus general tendency of averaged current direction is westward.

— Tekong Area

(1) At all the survey points, the current flow is parallel with the coastal topography is observed. The velocity of all the survey points is faster than the case of Seraya Ara. This might be due to the reason that the topography of the areas surrounding the survey points are the narrow waterway.

(2) It is the characteristics of all the survey points that the duration of slack water is short and the current is changing its direction rapidly by 180° within the short period.

(3) From the figures of 25 hours running men, the average current direction after excluding the fluctuations shorter than 1 day are as follows:

TC 1	North current
TC 2	South/East current
TC 3	North current
TC 4	North current

Thus general tendency of averaged current direction is northward.

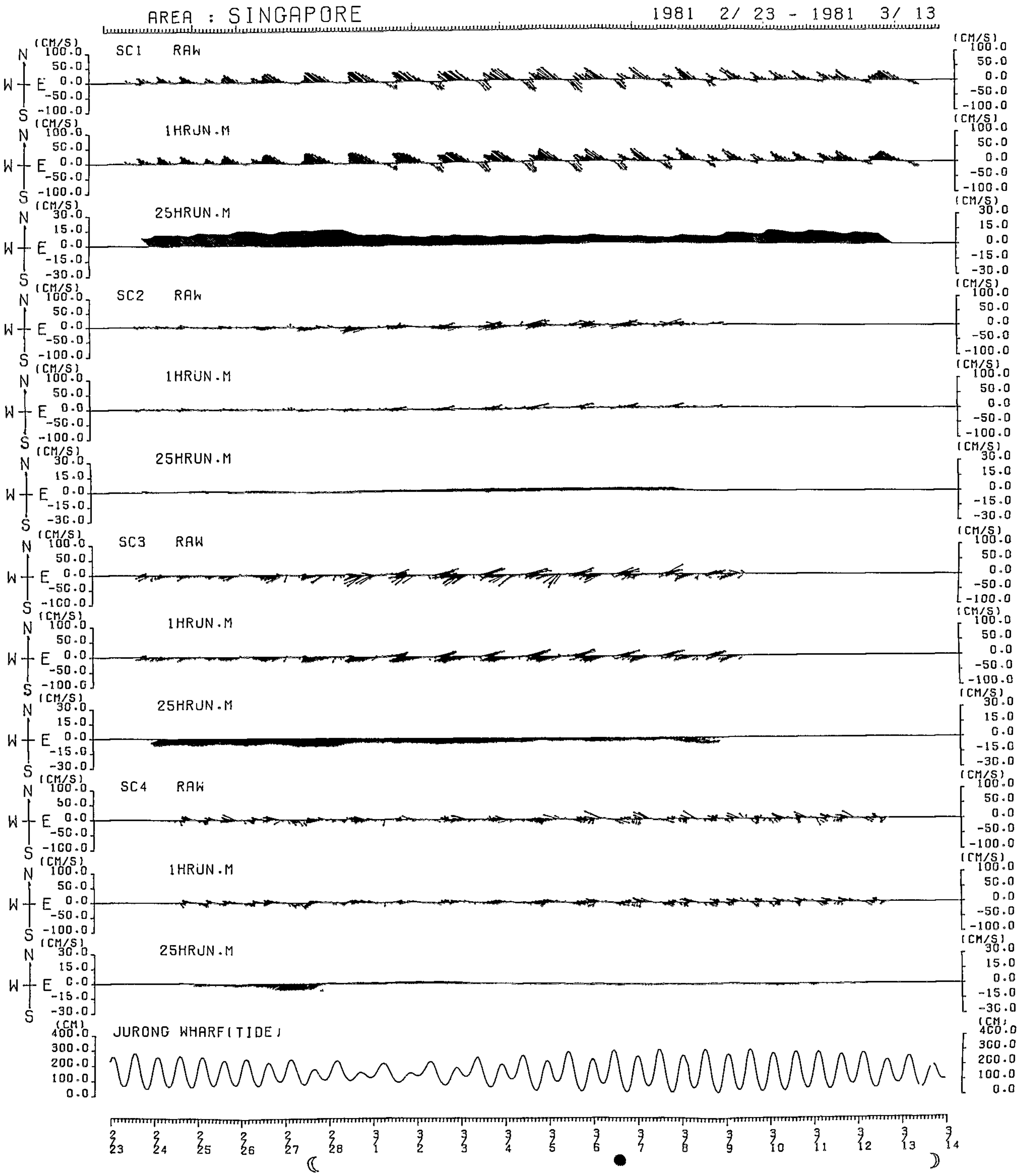


Fig. II-1-5-(12) Vector time series at Seraya Area (1)

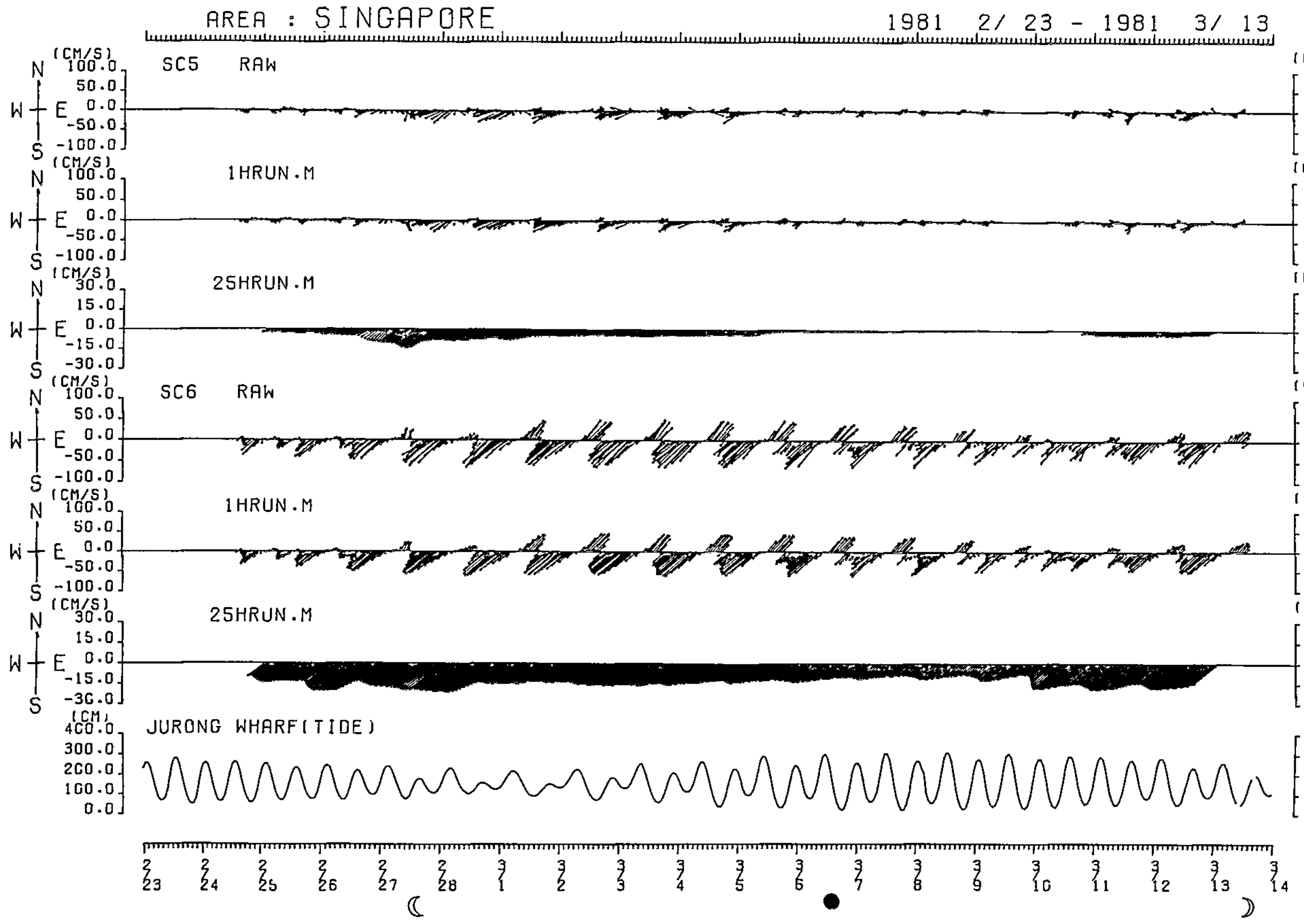


Fig. II-1-5-(12) Vector time series at Seraya Area (2)

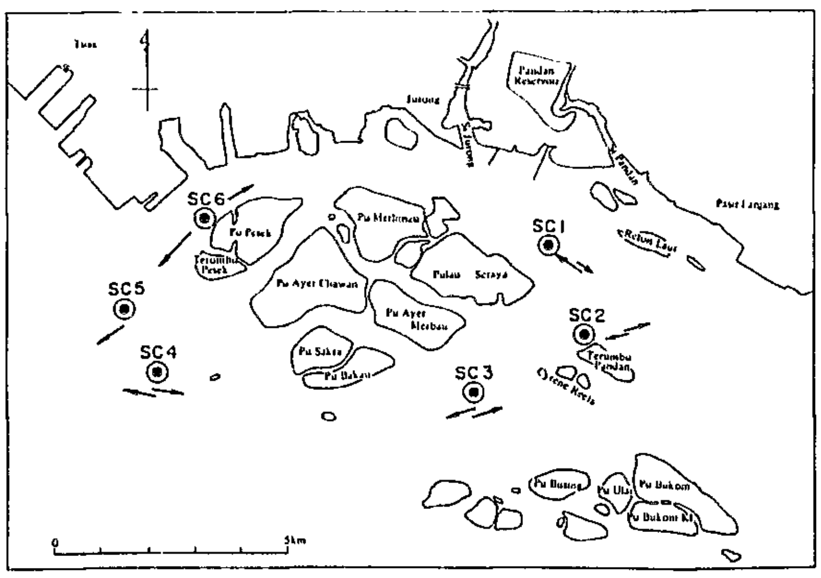


Fig. II-1-5-(12)' Survey points chart of Seraya Area

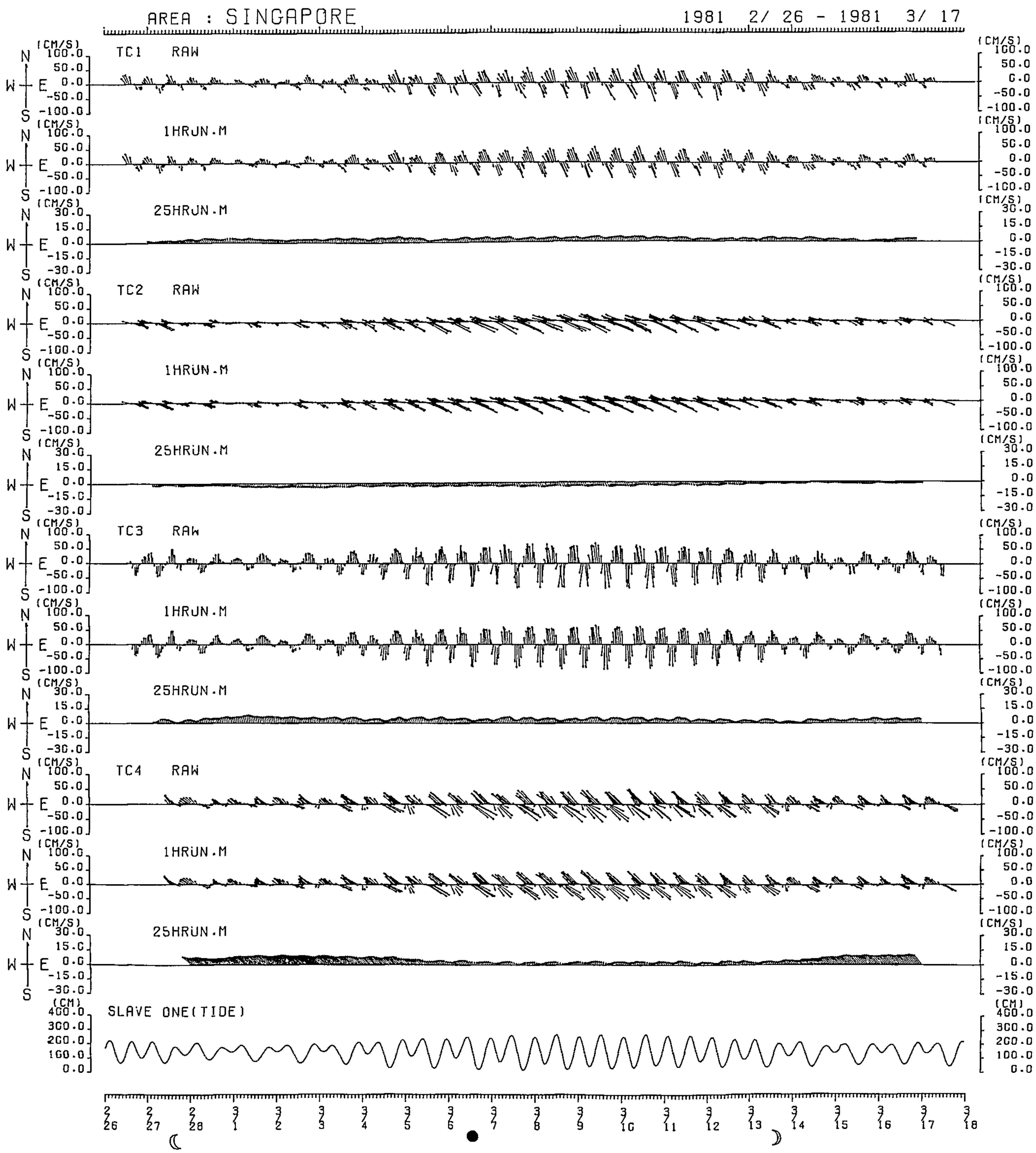


Fig. II-1-5-(13) Vector time series at Tekong Area

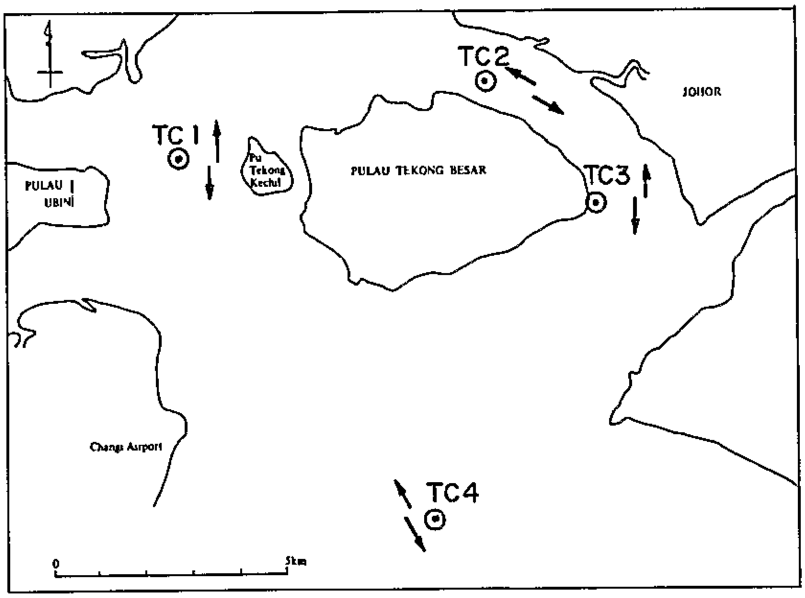


Fig. II-1-5-(13)' Survey points chart of Tekong Area

II-1-5-5 Statistical analysis

For the statistical analysis, the various computer programs are established according to the objectives. Table II-1-5-(6) shows the items of statistical analysis and the results of such analysis.

Table II-1-5-(6) Items and results of statistical analysis

	Item		Results
1)	Harmonic analysis of tidal component		Result table of harmonic analysis current ellipse
2)	(1)	Statistics of fluctuation	Table of calculation results
	(2)	Power spectrum	Power spectrum
	(3)	Auto correlation	Auto correlation

1) The hormonic analysis of the tidal current

For the analysis of the tidal current, the harmonic analysis is the most common.

It is called as hormonic analysis of the tidal current for the tidal current, and hormonic analysis of the tide for the case of the tide.

From the standpoint that the tidal current is generated by the tidal force, the method of analysis is the same in principle. As for the method of harmonic analysis of the tide and tidal current, Darwin method, Tidal Institute method, Method of Least Squares and so on are established.

In this study, the method of Least Squares has been employed.

— On harmonic analysis of tidal current

The tidal generation theory (I. Newton equilibrium theory of tidal) defines as the tidal current is generated by the fact the gravitation of the sun and moon are different in each point of the earth surface. Fig. II-1-5-(14) shows the model figure of the earth surface changing shape by the tidal force.

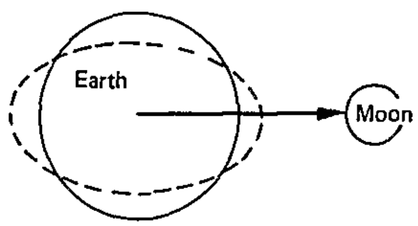


Fig. II-1-5-(14) The earth surface change by tidal force

It can be seen from the earth that the movement of the sun and the moon is not regular, and the movement cycles, the distance from the earth, the orbiting paths and etc. fluctuate all the time. From this fact, the tidal current is composed by the complicated movements.

Fig. II-1-5-(14) shows the simple model of the tidal current behaviour. In order to analyse these behaviour, the assumption is made that the tidal force is generated by one virtual artificial star, after classifying the complicated tidal froce from the sun and moon.

This virtual artificial star is assumed as being located in the certain distance from the earth and moving around on the equator of the earth by the certain speed. The tide generated by this virtual artificial star is called component tide. The tidal current thus generated is called as component current. From the above, it is considered as the tidal current is composed by these component current.

The tidal component is classified into various tides as shown in Table II-1-5-(7).

Table II-1-5-(7) Table of tidal component

Symbol	Constituent	Speed (360^o - period)	Period (mean solar time)
	- Semidiurnal tide -		h
M_2	Lunar semidiurnal tide	28.98410	12.42
M_2	Solar semidiurnal tide	30.00000	12.00
N_2	Lunar ellipse tide	28.43973	12.66
K_2	Luni-solar semidiurnal tide	30.08214	11.97
	- Diurnal tide -		
K_1	Luni-solar diurnal tide	15.04107	23.93
O_1	Lunar diurnal tide	13.94304	25.82
P_1	Solar diurnal tide	14.95893	24.07
Q_1	Lunar ellipse tide	13.39867	26.87
	- Overtide -		
M_4	(O_1 x ¼)	57.96821	6.21
MS_4	($M_2 + S_2$)	58.98410	6.01

The representative component tides from the aove table are described.

M_2 tide (Lunar semidiurnal tide) is the most importnat one among the semidiurnal tides generated by lunar. It is generated when the lunar is supposed to move on the equator keeping the constant distance between the earth and lunar.

The average time the lunar transits the meridian is 24 hours and 50.6 minutes. During these hours, the tides change twice and so the period is 12 hours and 25.3 minutes and the speed is "$360^o - 12.421 = 28.984^o$/h".

S_2 tide (Solar semidiurnal tide) is the tide generated by the sun, and its speed is 30^o/h and cycle period is 12 hours.

K_1 tide (Luni-solar diurnal tide) is generated by the moon and sun is not moving on the equator, and its speed is 15.041^o/h and cycle period is 23.93 hours.

O_1 tide (Lunar diurnal tide) is generated by the moon which is not moving on the equator, and its speed is $13.943^{o}/h$ and cycle period is 25.82 hours.

There are many constituents besides the above, but the above explained 4 component tides are the most important and typical ones. From these 4 constituents, the general behaviours of the tide and tidal current can be observed.

The derived current velocity from the observation is divided in South/North components (UN) and East/West components (UE). The obtained current velocity can be expressed by the following equation.

$$U^2 = U^2N + U^2E \quad --- (1)$$

In this equation, UN and UE are the leveling movement to the one way and so it can be harmonic-analysed, same as the tide. These current velocity can be expressed as the total of constituents which has the deviation and phase lag peculiar to the corresponding constituent current.

$$UN,E = Uo + \sum fNUNcos (Vo,n + \delta nt - Kn) \quad --- (2)$$

In this equation, (n) represents the constituent.

Uo is the mean velocity (constant current) which is different from the tidal current, and is something like ocean current.

fn is the number near to 1 which changes slightly by the cylce period of about 18.6 year.

vo,n is the astronomic constant of the each constituent at the epoch time and are compiled in the table after calculation.

δ n is the angular velocity of the constituent and is determined by the astronomic movement.

UN, KN are the maximum speed and phase lag of constituent, and they are the constant values peculiar to the locations.

These UN and KN are called as the harmonic constant of the tidal currrent. And the harmonic analysis is to obtain such harmonic constant from the results of the observation by calculation. For the calculation of harmonic constant of the tidal current by the harmonic analysis, it usually takes at least about 15 days for duration although it depends on the number of constituent duration.

An example of the harmonic analysis of the tidal current based on the observation data for one day is described as follows.

The tidal current is divided in 2 components of East/West and South/North direction and both East/West component and South/North component are expressed by the following equation.

$$U = Uo + U_1 \cos(\delta t - \zeta_1) + U_2 \cos(2\delta t - \zeta 2) + U_4 \cos(4\delta t - \zeta_4) \quad \text{--- (3)}$$

In this equation, Uo is usually called as constant current. This constant current is necessary to be carefully observed particularly when the one day observation result is arranged. The second and third term of the equation are semidiurnal tide and diurnal tide respectively and the fourth term is the quarter diurnal tide of the component current.

The tidal current as same as the tide is mostly generated by moon. As the moon moves around the earth once per one lunar diurnal day (by mean solar time-about 24 hours and 50 minutes), the period of dirunal current, semidiurnal current and quarter diurnal current are considered as one lunar diurnal day, ½ lunar diurnal day and ¼ lunar diurnal day respectively. And the speed of 1, ½ and ¼ day cycle current is considered as 15^o, 30^o and 60^o respectively. From the observation data of current direction and velocity, East/West component and South/North component are obtained by analysis and the velocity curve is illustrated by plotting the time series data of the velocity of the two components.

After obtaining the time from calendar when the lunar transist on the meridian of the particular location, after reading the velocity from the velocity curve for 24 times at each one lunar hour (1 hour and 2 minutes), and mean solar hour, the harmonic analysis is conducted.

The results of such harmonic analysis is shown in Table II-1-5-(8).

Table II-1-5-(8) Results of harmonic analysis

	Constant Current U_0	Diurnal current		1/2 diurnal current		1/4 diurnal current	
		U_1	ζ_1	U_2	ζ_2	U_4	ζ_4
North Component Current	0.18 kt	0.25 kt	223°	0.63 kt	64°	0.01 kt	290°
East Component Current	−0.03 kt	0.25 kt	51°	0.73 kt	232°	0.06 kt	66°

Fig. II-1-5-(15) is hodograph which illustrates the variation of the constituent obtained by analysis. This is called as the current ellipse of the tidal constituent.

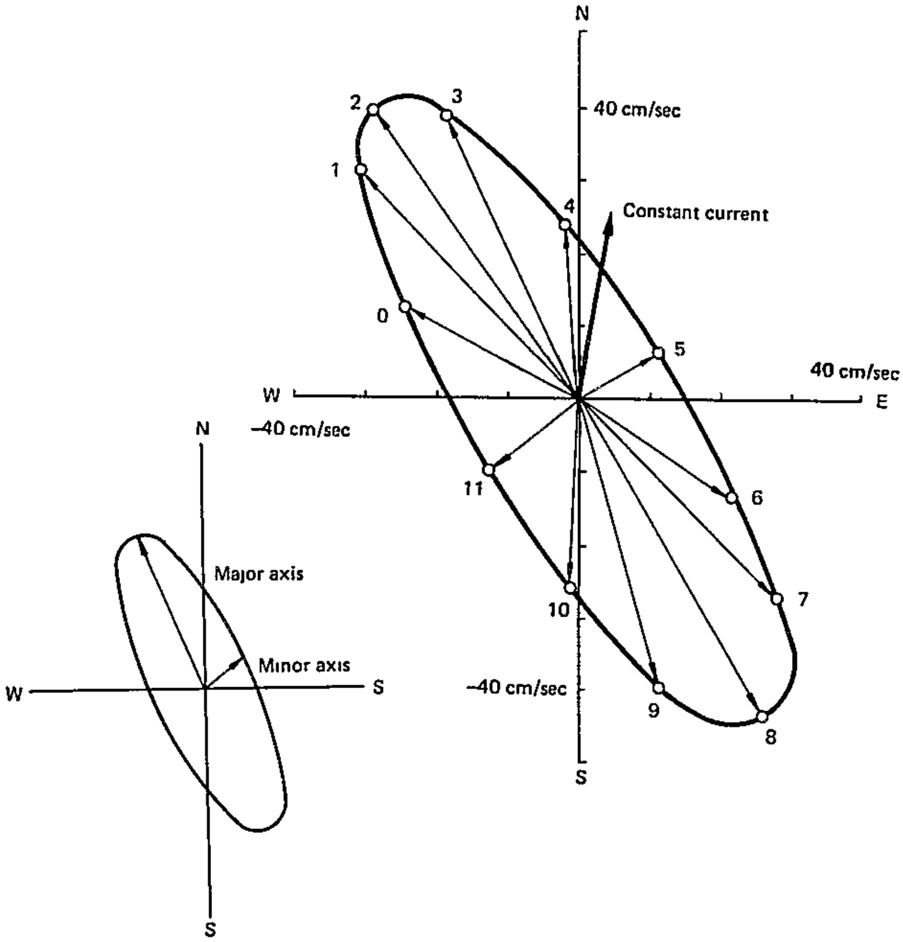
The current ellipse is obtained from the results of harmonic analysis of the tidal current, and it is the most important diagram as the results of analysis of the tidal current. The current ellipse sometimes shows the shape near to the circle or the straight line. Its rotating sense shows the direction of tidal current rotation at the observation point and so depends on the locations.

Table II-1-5-(9) shows the results of calculation for current ellipse and it is called as the element table of current ellipse.

Table II-1-5-(9) Current ellipse elements

	M_1			M_2			M_4			Constant Current	
	Direction	U_1	1	Direction	U_2	2	Direction	U_4	4	Direction	Velocity
Major Axis	315°	0.35 kt	227°	311°	0.96 kt	57°	97°	0.06 kt	67°	351°	0.18 kt
Minor Axis	45°	0.03 kt	137°	41°	0.10 kt	147°	7°	0.01 kt	337°		

M_1 . . . . . diurnal current
M_2 . . . . . semi-diurnal current
M_4 . . . . . quarter diurnal current



(1) Put the velocity value scale in the cartesian coordinates.
(2) Illustrate the current direction and velocity values of 0 to 11 hours by vector.
(3) Connect the tops of vector of 0 to 11 hours by line.

Remarks: In case of semidiurnal current, plot the values of 0 to 11 hours (total 12 hours) as the cycle period is ½ day.

In case of diurnal tidal current, plot the values of 2 to 23 hour (total 24 hours) as the cycle period is one day.

Fig. II-1-5-(15) Current Ellipse of respective component current and diagramming methods

Table II-1-5-(10) shows an example of the hormonic analysis of the tidal current. The Table II-1-5-(10) is the integrated table of Table II-1-5-(8) and Table II-1-5-(9), and the elements of constituents (mentioned by symbols) obtained by the harmonic analysis of the tidal current are shown.

As explained in Fig. II-1-5-(15), the elements of ellipse are shown as the major axis and minor axis. The current direction and velocity of the major axis are the maximum velocity of the constituent. The constituent of the highest velocity in the table is the dominant current at the observtion point and the current behaviour of the location is considered that the current is dominated by the dominant constituent.

Generally at the sea area where the tide is dominant, the observation is good enough by investigating of M_2, S_2 component current (about ½ day cycle) and K_1, O_1 (about 1 day cycle) constituents.

In this study, K_1 at Seraya, and M_2 at Tekong were dominant.

Table II-1-5-(10) Results of harmonic analysis of tidal current

SC -1	Position					From · To					Observation Layer	
	Lat. 1°17'01"N Long 103°44'31"E					Feb. 25 1981 00·00 Mar. 12 1981 00·00					– 11 m	
Constituents	N Comp		E-Comp		Elements of Ellipse: Major Axis			Minor Axis			Main Dir.	
	V (cm/s)	k (°)	V (cm/s)	k (°)	Dir. (°)	V (cm/s)	k (°)	Dir. (°)	V (cm/s)	k (°)	V (cm/s)	k (°)
K_1	19 07	54	22.79	229	309	29 69	51	39	1.27	141	29.69	51
O_1	19 21	18	23 00	196	309	29.97	17	39	0 56	107	29 97	17
Q_1	2.19	50	2.13	208	315	3.00	40	45	0.57	130	2 99	38
M_2	8 10	235	10 81	47	126	13 48	50	216	0.83	140	13.47	230
S_2	6.09	243	6 93	70	131	9.21	67	41	0.51	157	9.20	247
N_2	3.88	254	4.87	51	128	6.11	60	218	1.24	150	6.10	240
M_4	1.36	ˉ17	1.70	229	307	2 10	37	217	0.58	127	2.10	37
MS_4	1.57	130	2.04	305	307	2.58	127	37	0.10	217	2.58	127
K_2	1 65	243	1.88	70	131	2.50	67	41	0 13	157	2.50	247
P_1	6.31	54	7.54	229	309	9 82	51	39	0.42	141	9 82	51
V_0	10 69 cm/s		14.43 cm/s			17.96 cm/s			306°		17.93 cm/s 309°	

— Results of harmonic analysis

Table II-1-5-(11) shows the results of harmonic analysis of the tidal current of Seraya Area and Table II-1-5-(12) shows the result of harmonic analysis of the tidal current of Tekong Area.

In the tables, the symbol, K_1 - P_1 represent the tital constituents. V is the maximum tidal current velocity of corresponding tidal constituent.

K is the phase lag and it is expressed by the angle which represents the time when the velocity of the component current reaches to maximum after the moon and sun transit on the meridian of the area.

The elements of ellipse is the factor of the tidal currnt ellipse. The tidal curret ellipse is expressed by curve, connecting the top of each vectors corresponding to component hours. Component hour is defined as "2 x (period of component tide)/24". In case of M_2 constituent, component hour equal to about 1 hour.

From this current ellipse, the deviation and direction of the tidal current constituent can be obtained.

Table II-1-5-(11) Analysed results of tidal current of Seraya Area (1/3)

SC-1	Position	From : To	Observation Layer
	Lat. 1°17'01"N Long. 103°44'31"E	Feb. 25 1981 00.00 Mar. 12 1981 00:00	– 11 m

Constituents	N-Comp.		E-Comp.		Elements of Ellipse: Major Axis			Elements of Ellipse: Minor Axis			Main Dir.	
	V (cm/s)	k (°)	V (cm/s)	k (°)	Dir. (°)	V (cm/s)	k (°)	Dir. (°)	V (cm/s)	k (°)	V (cm/s)	k (°)
K_1	19.07	54	22.79	229	309	29.69	51	39	1.27	141	29.69	51
O_1	19.21	18	23.00	196	309	29.97	17	39	0.56	107	29.97	17
Q_1	2.19	50	2.13	208	315	3.00	40	45	0.57	130	2.99	38
M_2	8.10	235	10.81	47	126	13.48	50	216	0.83	140	13.47	230
S_2	6.09	243	6.93	70	131	9.21	67	41	0.51	157	9.20	247
N_2	3.88	254	4.87	51	128	6.11	60	218	1.24	150	6.10	240
M_4	1.36	17	1.70	229	307	2.10	37	217	0.58	127	2.10	37
MS_4	1.57	130	2.04	305	307	2.58	127	37	0.10	217	2.58	127
K_2	1.65	243	1.88	70	131	2.50	67	41	0.13	157	2.50	247
P_1	6.31	54	7.54	229	309	9.82	51	39	0.42	141	9.82	51
V_0	10.69 cm/s		–14.43 cm/s			17.96 cm/s			306°		17.93 cm/s 309°	

SC-2	Position	From To	Observation Layer
	Lat 1°15'53"N Long. 103°45'09"E	Feb 25 1981 00:00 Mar 8 1981 19:00	– – 15 m

Constituents	N-Comp		E-Comp		Elements of Ellipse: Major Axis			Elements of Ellipse: Minor Axis			Main Dir.	
	V (cm/s)	k (°)	V (cm/s)	k (°)	Dir. (°)	V (cm/s)	k (°)	Dir (°)	V (cm/s)	k (°)	V (cm/s)	k (°)
K_1	3.18	231	40.26	224	265	40.39	44	175	0.42	134	40.38	44
O_1	3.98	162	38.31	188	264	38.48	8	354	1.77	98	38.46	8
Q_1	0.45	304	2.48	220	268	2.48	40	178	0.45	130	2.48	41
M_2	1.41	162	19.51	51	91	19.52	51	1	1.32	141	19.44	231
S_2	0.97	7	11.37	58	86	11.38	58	176	0.75	148	11.38	238
N_2	1.60	132	8.13	59	86	8.14	60	356	1.52	150	8.15	240
M_4	0.72	191	3.24	218	258	3.31	37	348	0.32	127	3.28	38
MS_4	0.60	202	3.57	269	266	3.58	88	356	0.55	178	3.58	88
K_2	0.26	7	3.09	58	86	3.09	58	176	0.20	148	3.09	238
P_1	1.05	231	13.32	224	265	13.36	44	175	0.13	134	13.36	44
V_0	1.91 cm/s		19.69 cm/s		19.79 cm/s				275°		19.52 cm/s 266°	

Table II-1-5-(11) Analysed results of tidal current of Seraya Area (2/3)

SC-3	Position				From To					Observation Layer		
	Lat. 1°15'05"N Long 103°43'57"E				Feb 23 1981 17 00 Mar. 9 1981 12 35					12 m		
Constituents	N-Comp.		E-Comp		Elements of Ellipse						Main Dir	
					Major Axis			Minor Axis				
	V (cm/s)	k (°)	V (cm/s)	k (°)	Dir. (°)	V (cm/s)	k (°)	Dir. (°)	V (cm/s)	k (°)	V (cm/s)	k (°)
K_1	10.54	233	35.77	228	253	37.28	48	163	0.89	138	37.28	48
O_1	10.31	185	36.15	184	254	37.59	5	164	0.09	95	37.59	5
Q_1	0.79	189	3.10	206	256	3.19	25	346	0.22	115	3.19	25
M_2	4.62	82	15.24	42	76	15.67	44	346	2.89	134	15.66	224
S_2	2.37	61	10.97	51	77	11.21	52	347	0.36	142	11.20	232
N_2	1.93	71	4.10	72	64	4.54	72	154	0.01	162	4.47	252
M_4	0.88	168	2.73	220	257	2.78	37	347	0.68	127	2.78	36
MS_4	0.70	296	4.33	272	261	4.38	93	171	0.27	183	4.35	93
K_2	0.64	61	2.98	51	77	3.05	52	347	0.10	142	3.04	232
P_1	3.49	233	11.84	228	253	12.34	48	163	0.29	138	12.34	48
V_0	−4.85 cm/s		−12.55 cm/s		13.46 cm/s			248°			13.39 cm/s 254°	

SC-4	Position				From : To					Observation Layer		
	Lat 1°15'26"N Loing 103°40'12"E				Feb. 25 1981 00.00 Mar. 12 1981 00.00					- 8 m		
Constituents	N-Comp.		E-Comp.		Elements of Ellipse						Main Dir	
					Major Axis			Minor Axis				
	V (cm/s)	k (°)	V (cm/s)	k (°)	Dir (°)	V (cm/s)	k (°)	Dir. (°)	V (cm/s)	k (°)	V (cm/s)	k (°)
K_1	1.75	260	22.98	219	266	23.01	40	176	1.14	130	22.60	39
O_1	2.20	36	26.21	184	274	26.27	5	4	1.15	95	26.23	5
Q_1	0.85	196	0.94	223	228	1.24	31	318	0.29	121	0.83	47
M_2	7.94	153	12.91	355	300	14.95	169	210	2.49	259	13.78	173
S_2	2.92	216	10.09	32	106	10.51	32	196	0.23	122	10.39	212
N_2	1.90	170	3.34	23	117	3.73	16	27	0.93	106	3.53	201
M_4	0.44	124	2.01	203	267	2.02	23	357	0.43	113	1.99	25
MS_4	0.85	171	3.93	267	271	3.93	87	1	0.84	177	3.91	89
K_2	0.79	216	2.74	32	106	2.85	32	196	0.06	122	2.82	212
P_1	0.58	260	7.60	219	266	7.61	40	176	0.37	130	7.48	39
V_0	0.57 cm/s		−7.94 cm/s		7.96 cm/s			265°			7.80 cm/s 277°	

Table II-1-5-(11) Analysed results of tidal current of Seraya Area (3/3)

SC 5	Position					From - To				Observation Layer		
	Lat	1°16'27"N				Feb 25 1981 00.00				– 8 m		
	Long	103°39'33"E				Mar 9 1981 10:45						
Constituents	N Comp		E-Comp		Elements of Ellipse: Major Axis			Elements of Ellipse: Minor Axis			Main Dir.	
	V (cm/s)	k (°)	V (cm/s)	k (°)	Dir (°)	V (cm/s)	k (°)	Dir (°)	V (cm/s)	k (°)	V (cm/s)	k (°)
K_1	7 74	233	22 71	215	251	23 88	37	161	2.32	127	23 42	36
O_1	5 18	206	23 95	190	258	24 47	11	168	1.40	101	24 38	11
Q_1	0 62	260	1.67	333	262	1 68	151	352	0.58	241	1 68	151
M_2	5 14	166	8 71	343	300	10 12	164	30	0 29	254	8 05	162
S_2	1 70	221	6.47	27	104	6 67	28	194	0.40	118	6 23	206
N_2	1.26	100	1.28	39	46	1 54	69	316	0.91	159	1.35	225
M_4	1 08	216	2 01	249	244	2 22	62	334	0 52	152	2 11	67
MS_4	0 79	183	1 83	288	277	1.84	112	7	0 76	202	1.80	106
K_2	0.46	221	1.76	27	104	1 81	28	194	0.10	118	1 69	206
P_1	2.56	233	7.51	215	251	7.90	37	161	0 77	127	7 75	36
V_0	–4 10 cm/s		–9 26 cm/s			10 13 cm/s			246°		9 68 cm/s 263°	

SC–6	Position					From - To				Observation Layer		
	Lat	1°17'18"N				Feb. 25 1981 00 00				– – 10 m		
	Long	103°40'51"E				Mar. 12 1981 00 00						
Constituents	N Comp		E-Comp		Elements of Ellipse: Major Axis			Elements of Ellipse: Minor Axis			Main Dir.	
	V (cm/s)	k (°)	V (cm/s)	k (°)	Dir (°)	V (cm/s)	k (°)	Dir. (°)	V (cm/s)	k (°)	V (cm/s)	k (°)
K_1	33 15	221	33.34	222	225	47 02	42	315	0.37	132	47 02	42
O_1	33 71	190	35 61	191	226	49.03	11	316	0.63	101	49.03	11
Q_1	2.00	204	1 62	227	218	2.52	33	308	0.51	123	2 51	35
M_2	10 66	37	10 37	31	44	14 85	34	314	0 72	124	14.85	214
S_2	8 00	44	8 14	46	45	11.41	45	135	0 24	135	11.41	225
N_2	4.45	59	4 95	51	48	6 64	55	318	0 41	145	6 64	235
M_4	2 18	222	2 78	230	231	3.52	47	321	0 24	137	3.50	47
MS_4	3.55	271	4 06	273	228	5 40	92	318	0.09	182	5.39	92
K_2	2 17	44	2 21	46	45	3.10	45	135	0.06	135	3.10	225
P_1	10 97	221	11 03	222	225	15.56	42	315	0 12	132	15 56	42
V_0	14 52 cm/s		18 21 cm/s			23.30 cm/s			231°		23.19 cm/s 225°	

Table II-1-5-(12) Results of harmonic analysis of tidal current of Tekong Area (1/2)

TC-1	Position						From To				Observation Layer	
	Lat 1°25'00"N						Feb 28 1981 00.00				- 16 m	
	Long. 104°00"08"F						Mar. 15 1981 00.00					
Constituents	N-Comp		E-Comp		Elements of Ellipse: Major Axis			Minor Axis			Main Dir	
	V (cm/s)	k (°)	V (cm/s)	k (°)	Dir (°)	V (cm/s)	k (°)	Dir. (°)	V (cm/s)	k (°)	V (cm/s)	k (°)
K_1	4 80	354	2 40	204	155	5 26	179	65	1 10	269	5 25	179
O_1	3 34	337	1.38	133	158	3 57	154	248	0 54	244	3.57	154
Q_1	2 21	331	1.49	174	146	2 62	158	56	0 49	248	2.57	156
M_2	28 07	226	13.63	37	154	31.14	45	244	1.95	135	31.09	45
S_2	11 32	278	3 41	89	163	11.81	97	253	0 49	187	11.75	97
N_2	6 36	205	2.18	8	161	6 70	23	251	0 59	113	6.68	23
M_4	7.74	205	3.12	54	159	8.23	28	69	1 43	118	8.22	29
MS_4	7.34	269	2.64	94	160	7.80	90	70	0 18	180	7.79	90
K_2	3.07	278	0.92	89	163	3.21	97	253	0.13	187	3.19	97
P_1	1 59	354	0 79	204	155	1.74	179	65	0 36	269	1.74	179
V_0	4 78 cm/s		-1.27 cm/s			4.95 cm/s			345°		-4.91 cm/s 157°	

TC-2	Position						From To				Observation Layer	
	Lat 1°26'03"N						Feb. 28 1981 00 00				- - 7 m	
	Long 104°04'03"N						Mar 15 1981 00 00					
Constituents	N Comp		E-Comp.		Elements of Ellipse: Major Axis			Minor Axis			Main Dir	
	V (cm/s)	k (°)	V (cm/s)	k (°)	Dir (°)	V (cm/s)	k (°)	Dir (°)	V (cm/s)	k (°)	V (cm/s)	k (°)
K_1	3 06	1	9.76	178	107	10.23	179	197	0 16	269	10 21	179
O_1	3 04	319	8 97	137	108	9.47	137	198	0 11	227	9 46	137
Q_1	0 07	72	1.45	70	87	1.45	71	357	0.001	161	1.33	70
M_2	15 77	211	40 48	30	111	43.44	30	201	0 45	120	43 44	30
S_2	6.78	256	16.27	80	112	17.62	80	22	0.42	170	17.61	80
N_2	3 66	216	9.02	24	111	9.71	26	201	0 69	116	9.71	26
M_4	4.36	223	9 86	40	113	10 78	41	203	0.21	131	10 77	41
MS_4	3 85	283	8 63	103	114	9.45	103	24	0 003	193	9 44	103
K_2	1.84	256	4.42	80	112	4 79	80	22	0 11	170	4.79	80
P_1	1 01	1	3.23	178	107	3 38	179	197	0 05	269	3.38	179
V_0	3 64 cm/s		1 01 cm/s			3 78 cm/s			164°		2.26 cm/s 111°	

Table II-1-5-(12) Results of harmonic analysis of tidal current of Tekong Area (2/2)

TC-3	Position: Lat 1°24'39"N, Long. 104°05'20"E				From · To: Feb. 28 1981 00:00 – Mar 15 1981 00:00						Observation Layer: −7 m	
Constituents	N-Comp V (cm/s)	N-Comp k (°)	E-Comp. V (cm/s)	E-Comp. k (°)	Elements of Ellipse, Major Axis Dir (°)	Major Axis V (cm/s)	Major Axis k (°)	Minor Axis Dir. (°)	Minor Axis V (cm/s)	Minor Axis k (°)	Main Dir. V (cm/s)	Main Dir. k (°)
K_1	9.65	349	0.82	211	176	9.67	169	86	0.55	259	9.67	169
O_1	9.33	310	0.30	140	178	9.33	130	88	0.05	220	9.33	130
Q_1	0.16	265	1.10	170	90	1.10	169	0.9	0.16	259	0.18	106
M_2	43.55	210	2.39	81	178	43.58	31	88	1.85	121	43.56	31
S_2	18.01	260	1.31	124	177	18.04	80	87	0.90	170	18.04	80
N_2	10.64	201	1.14	328	176	10.66	21	266	0.91	117	10.66	21
M_4	10.08	221	0.70	14	176	10.10	41	266	0.31	131	10.10	41
MS_4	9.64	282	0.79	154	177	9.66	102	87	0.62	192	9.66	102
K_2	4.90	260	0.35	124	177	4.90	80	87	0.24	170	4.90	80
P_1	3.19	349	0.27	211	176	3.20	169	86	0.18	259	3.20	169
V_0	5.44 cm/s		−1.97 cm/s			5.79 cm/s			340°		−5.55 cm/s 176°	

TC-4	Position: Lat. 1°21'06"N, Long. 104°03'07"E				From To: Feb. 28 1981 00:00 – Mar. 15 1981 00:00						Observation Layer: −8 m	
Constituents	N-Comp. V (cm/s)	N-Comp. k (°)	E-Comp. V (cm/s)	E-Comp. k (°)	Elements of Ellipse, Major Axis Dir. (°)	Major Axis V (cm/s)	Major Axis k (°)	Minor Axis Dir (°)	Minor Axis V (cm/s)	Minor Axis k (°)	Main Dir. V (cm/s)	Main Dir. k (°)
K_1	4.43	5	15.60	201	285	16.18	20	195	1.18	110	15.13	19
O_1	3.77	339	11.32	170	108	11.92	169	18	0.66	259	11.34	348
Q_1	2.19	302	2.42	128	132	3.26	126	42	0.16	216	3.24	306
M_2	29.24	217	30.90	46	133	42.40	41	43	3.40	131	42.06	222
S_2	11.88	268	13.97	92	130	18.32	90	40	0.75	180	18.27	271
N_2	6.59	207	8.41	45	127	10.56	38	37	1.61	128	10.56	218
M_4	6.20	225	5.48	67	138	8.14	55	48	1.52	145	7.95	237
MS_4	4.80	280	3.46	131	145	5.72	110	55	1.53	200	5.41	296
K_2	3.23	268	3.80	92	130	4.98	90	40	0.20	180	4.97	271
P_1	1.46	5	5.16	201	285	5.35	20	195	0.39	110	5.01	19
V_0	5.72 cm/s		−4.00 cm/s			6.98 cm/s			225°		6.60 cm/s 306°	

From the results shown in Tables II-1-5-(11) and II-1-5-(12), the largest constituent and the second large constituent have been taken up and shown in Table II-1-5-(13).

Table II-1-5-(13) Dominant tidal current constituent in survey area

Area	Survey point	The First Dominant N-comp	Component Current E-comp	The Second Dominant N-comp	Conponent Current E-comp
Seraya Area	SC1	O_1(19.21)	O_1(23.00)	K_1(19.07)	K_1(22.79)
	SC2	O_1(3.98)	K_1(40.26)	K_1(3.18)	O_1(38.31)
	SC3	K_1(10.54)	O_1(36.15)	O_1(10.31)	K_1(35.77)
	SC4	M_2(7.94)	O_1(26.21)	S_2(2.92)	K_1(22.98)
	SC5	K_1(7.74)	O_1(23.95)	O_1(5.18)	K_1(22.71)
	SC6	O_1(33.71)	O_1(35.61)	K_1(33.15)	K_1(33.34)
Tekong Area	TC1	M_2(28.07)	M_2(13.63)	S_2(11.32)	S_2(3.41)
	TC2	M_2(15.77)	M_2(40.48)	M_4(4.36)	S_2(16.27)
	TC3	M_2(43.55)	M_2(2.39)	S_2(18.01)	S_2(1.31)
	TC4	M_2(29.24)	M_2(30.90)	S_2(11.88)	K_1(15.60)

From the above, it can be seen that except SC4-N-comp, O_1 component current or K_1 component, tidal current is dominant in Seraya Area. These constituent are so-called diurnal tidal current and the cycle period is about 1 day.

In Tekong Area, M_2 component is dominant and M_2 & S_2 component are so-called semidiurnal tidal current.

The results of current ellipse are described hereunder. The tidal current constituents K_1, O_1, M_2 and S_2 are generally called as the 4 main constituents. In general, among tidal currents, these 4 are the highest constituents.

Through the study, it was found that K_1 and O_1 component current were most dominant in Seraya Area and M_2 was dominant in Tekong Area.

Figs. II-1-5-(16) and II-1-5-(17) show the current ellipse of 4 major component current of Seraya Area and Tekong Area respectively. The number noted on the ellipse is component hour.

From the Fig. II-1-5-(16), it can be also confirmed that the current ellipse of K_1 and O_1 component current are larger than other components at SC1 and M_2 component is larger than other components at Tekong Area.

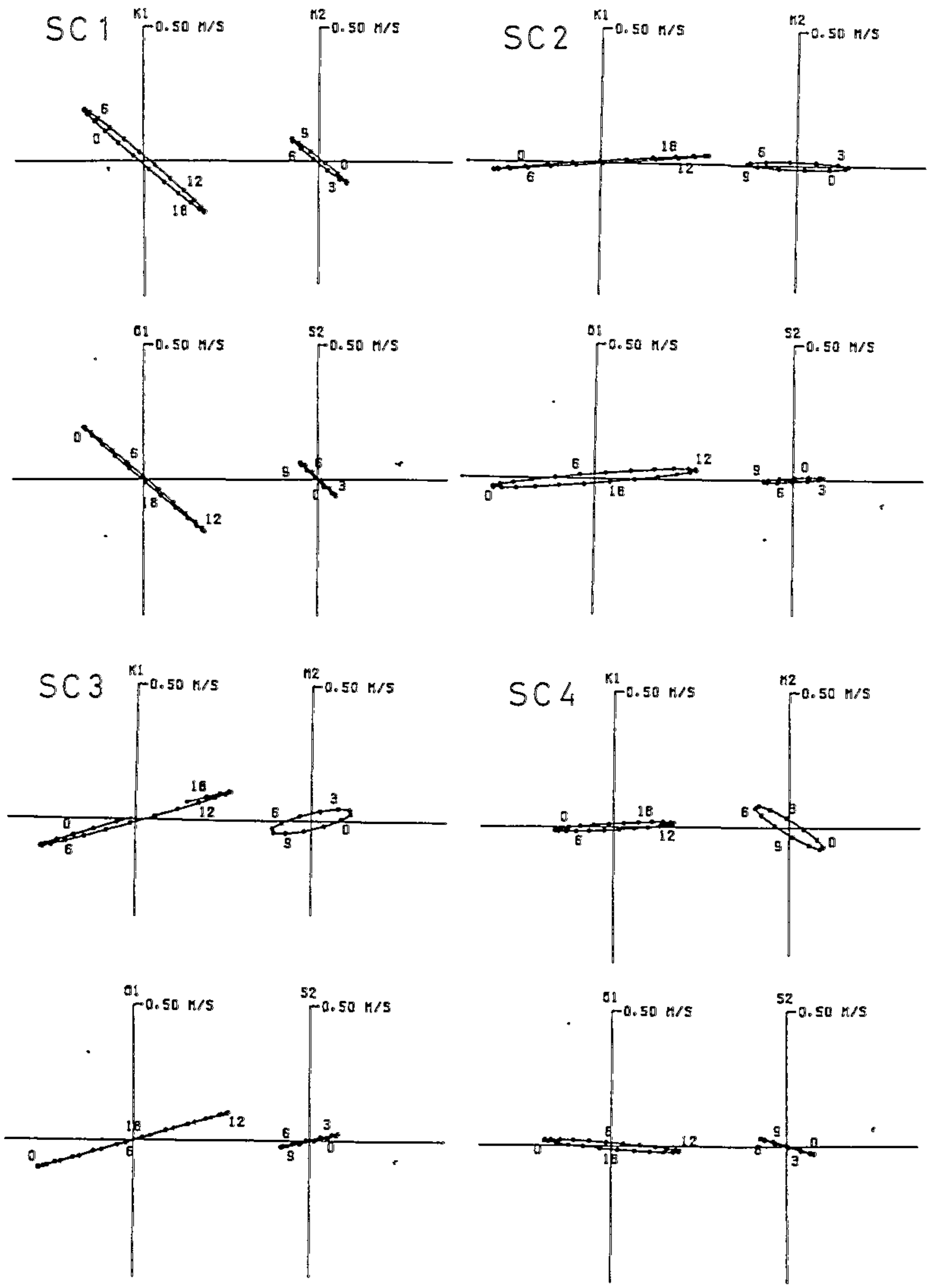


Fig. II-1-5-(16) Curent ellipse of Seraya Area (1)

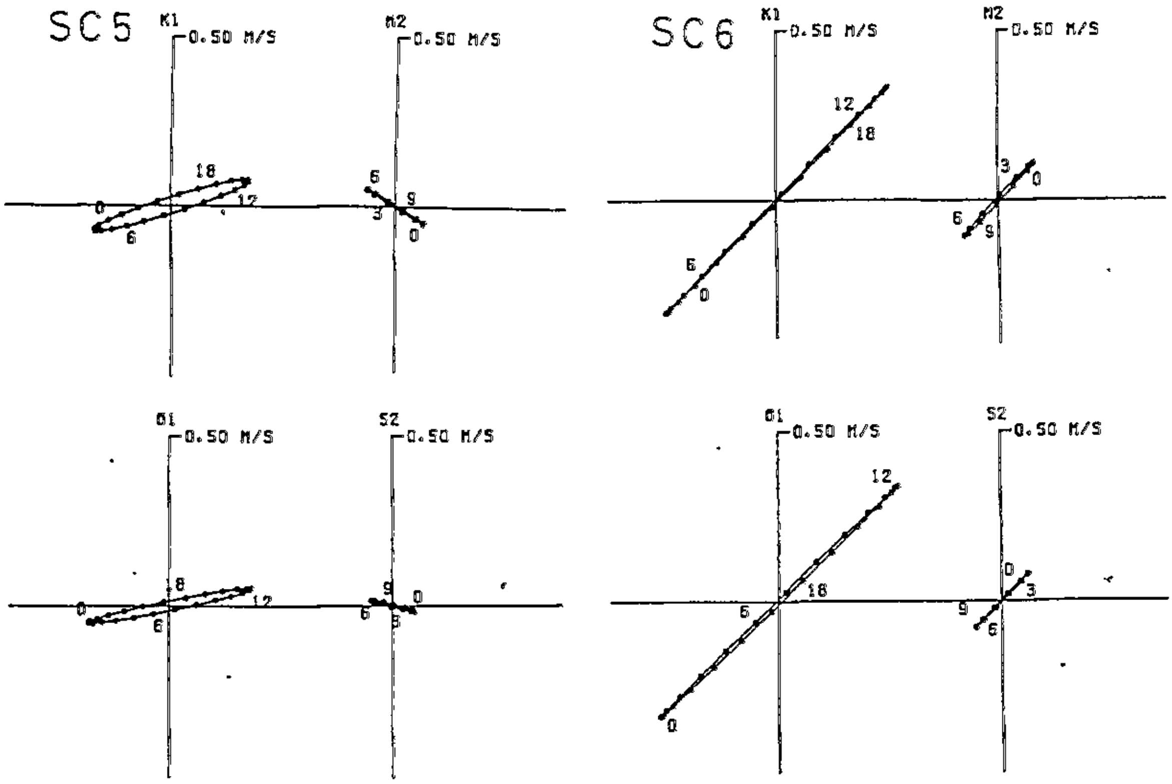


Fig. II-1-5-(16) Curent ellipse of Seraya Area (2)

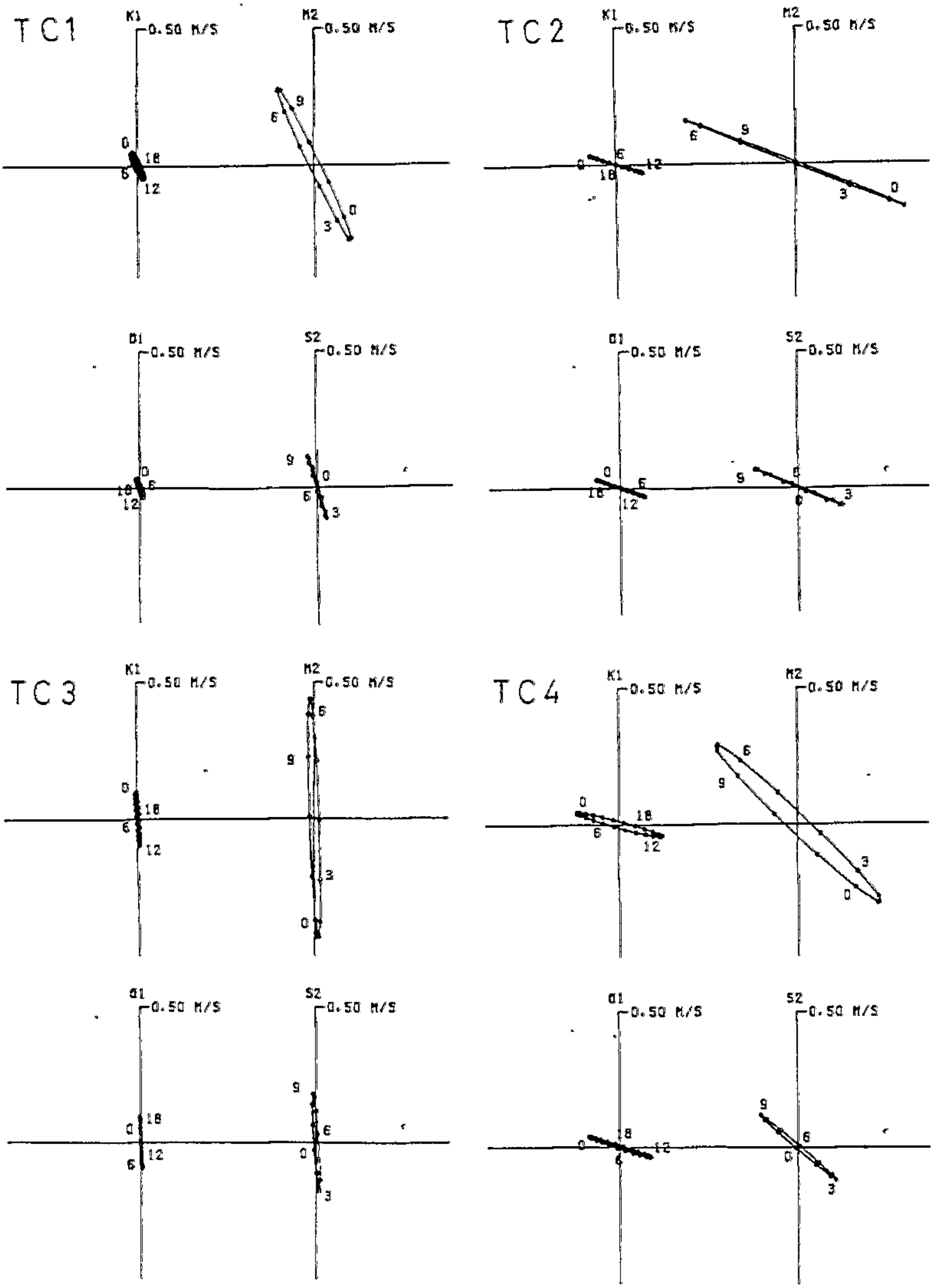


Fig. II-1-5-(17) Current ellipse of Tekong Area

2) Statistical analysis of current fluctuation

The purpose of statistical analysis of current fluctuation is to obtain the statistical natures of fluctuation. The items of calculation are (1) mean velocity and standard deviation which means the intensity of fluctuation, (2) power spectrum and (3) auto correlation.

Table II-1-5-(14) Period for data analysis

Survey point	Period of harmonic analasis of tidal current	Period of calculation of current fluctuation
SC1	00^h-00^m Feb. 25 ~ 00^h-00^m Mar. 12 (15 day)	12^h30^m Feb. 23 ~ 10^h-35^m Mar. 13 (18 day)
SC2	00^h-00^m Feb. 25 ~ 19^h-00^m Mar. 8 (11 day)	14^h15^m Feb. 23 ~ 19^h-00^m Mar. 8 (13 day)
SC3	17^h-00^m Feb. 23 ~ 12^h-35^m Mar. 9 (14 day)	15^h35^m Feb. 23 ~ 13^h-05^m Mar. 9 (14 day)
SC4	00^h-00^m Feb. 25 ~ 00^h-00^m Mar. 12 (15 day)	11^h35^m Feb. 24 ~ 18^h-20^m Mar. 12 (16 day)
SC5	00^h-00^m Feb. 25 ~ 10^h-45^m Mar. 9(12.5day)	12^h35^m Feb. 24 ~ 10^h-45^m Mar. 9 (15 day)
SC6	00^h-00^m Feb. 25 ~ 00^h-00^m Mar. 12 (15 day)	13^h20^m Feb. 24 ~ 14^h-25^m Mar. 13 (18 day)
TC1	00^h-00^m Feb. 28 ~ 00^h-00^m Mar. 15 (15 day)	11^h50^m Feb. 26 ~ 09^h-55^m Mar. 17 (19 day)
TC2	00^h-00^m Feb. 28 ~ 00^h-00^m Mar. 15 (15 day)	13^h30^m Feb. 26 ~ 11^h-35^m Mar. 17 (19 day)
TC3	00^h-00^m Feb. 28 ~ 00^h-00^m Mar. 15 (15 day)	14^h45^m Feb. 26 ~ 12^h-00^m Mar. 17 (19 day)
TC4	00^h-00^m Feb. 28 ~ 00^h-00^m Mar. 15 (15 day)	11^h40^m Feb. 27 ~ 13^h-00^m Mar. 17 (18 day)

(1) Mean velocity and standard deviation

The mean velocity is obtained for two components (N-comp, E-comp) of current velocity. The mean currrent is defined in the harmonic analysis as constant current. The analysed period of the statistical computation are shown in Table II-1-5-(14).

Together with mean velocity, the standard deviation is obtained. Table II-1-5-(15) shows the results of these processes. The right side of the table shows the dominant frequency of the current velocity fluctuations at the survey points which are obtained by power specturm described later.

Based on the mean velocity of N-comp. and E-comp. enumerated in this figure, the mean velocity of each survey points of Seraya and Tekong Area are illustrated on the survey points chart by vectors. (Figs. II-1-5-(18) and II-1-5-(19).)

From Fig. II-1-5-(18), the mean current of Seraya Area during the survey period is found as the westward flow pattern.

From Fig. II-1-5-(19), the mean current of Tekong Area except TC2 during the survey period is found as the northward flow pattern.

The standard deviation is found magnificent at all the survey points and it means the intensity of current fluctuation is very strong due to existing the dominant tidal constituents.

Table II-1-5-(15) Statistical values of current fluctuation

Station	Average velocity (cm/s)		Standard deviation (cm/s)		Dominant period (hour)	
	N-comp.	E-Comp.	N-Comp.	E-Comp.	N-Comp.	E-Comp.
SC1	10.4	−13.9	17.5	21.1	25.82 12.13	25.45 12.30
SC2	1.8	−18.8	4.3	38.2	23.37	24.74 11.95
SC3	−4.9	−12.7	10.4	34.7	23.37	24.74 11.62
SC4	−0.7	−7.7	8.2	24.5	12.48	24.74 11.95
SC5	−4.2	−9.2	8.3	22.9	24.39	24.74
SC6	−14.1	−17.7	29.1	30.2	25.45 12.13	25.45 12.30
TC1	4.5	−1.2	24.4	11.3	12.30	12.48
TC2	−3.4	1.1	13.9	34.9	12.30	12.30
TC3	5.0	−1.8	38.0	2.9	12.30	12.66
TC4	6.5	−5.0	25.1	29.4	12.48	27.73 12.30

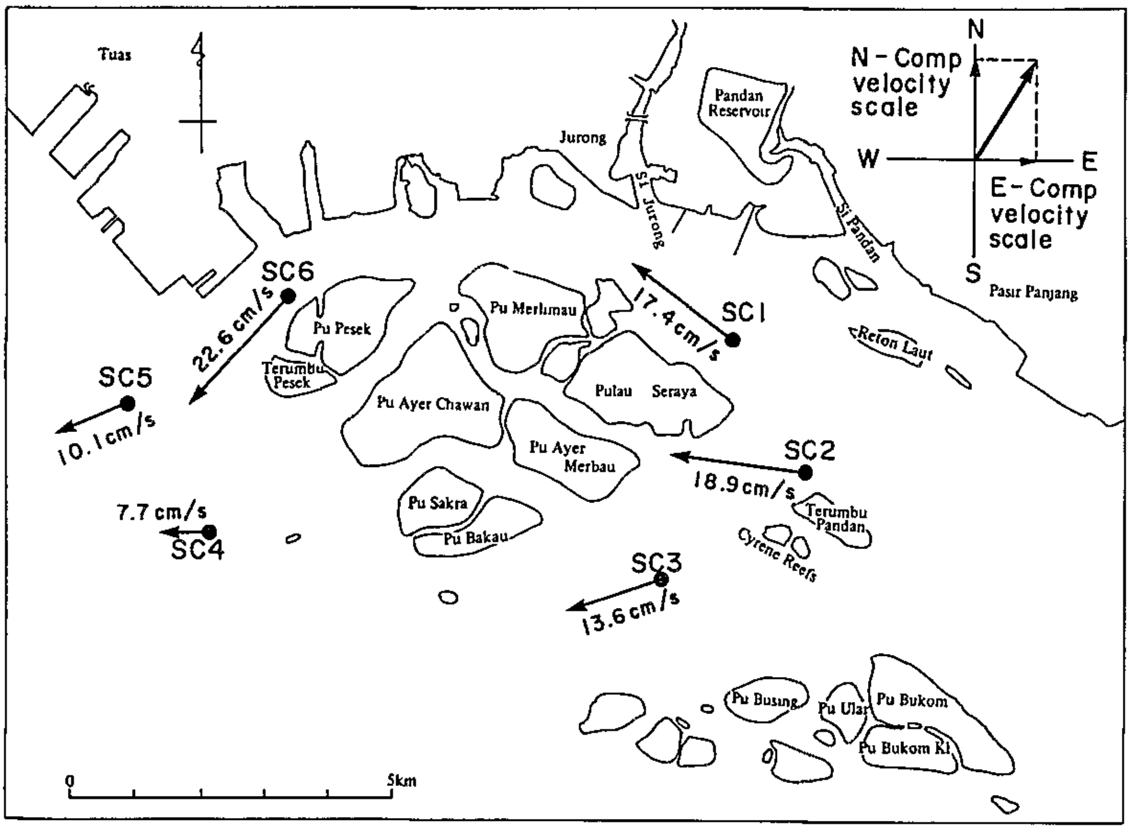


Fig. II-1-5-(18) Mean current of Seraya Area (End/Feb. - Mid/Mar. 1981)

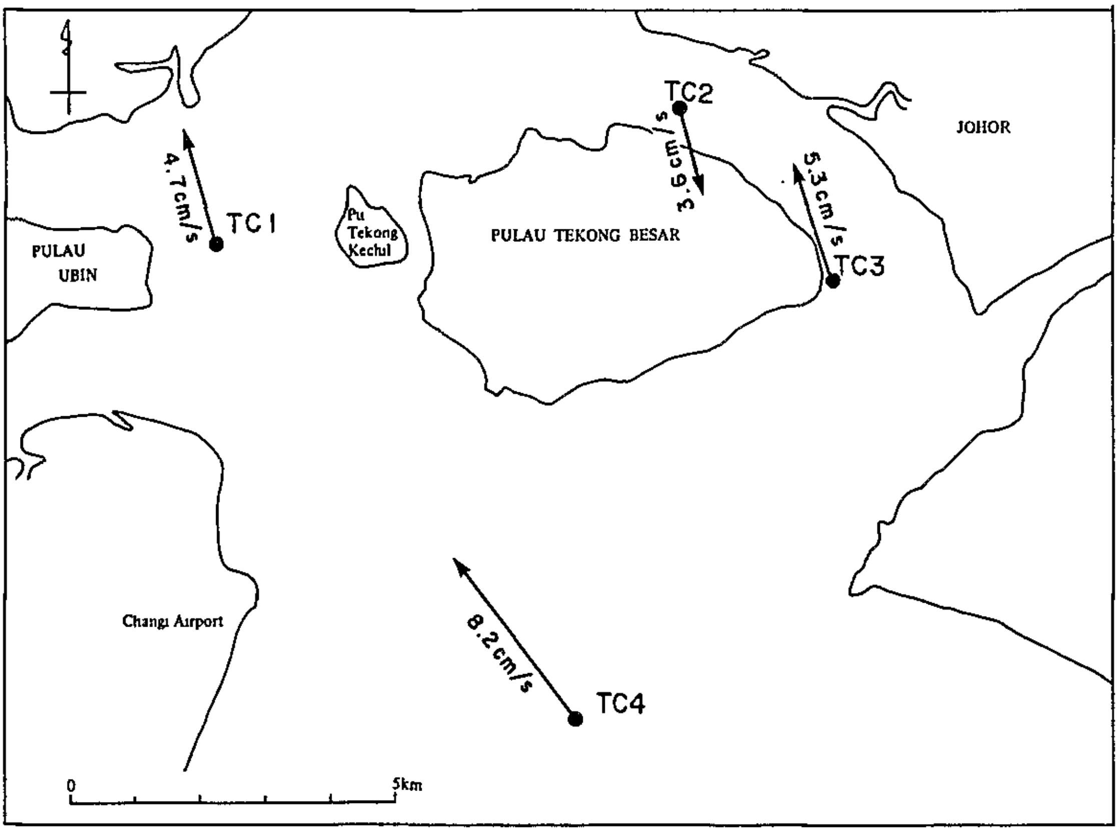


Fig. II-1-5-(19) Mean current of Tekong Area (End/Feb. - Mid/Mar. 1981)

(2) Power spectrum gives the information on the fluctuation energy density distribution frequency domain. If energy concentrates on a certain frequency component, then power spectrum shows the significant peak of energy distribution at corresponding frequency.

There are 3 Algorithums which compute the power spectrum; (a) Blackman-Turkey Method(BT method), (b) Fast Fourier Transform Method (FFT method) and (c) Maximum Entrophy Method (MEM). In this study, the calculation has been conducted by BTmethod and MEM. For reference, the equation of BT method is shown.

When Pxx (τ) and Pyy (τ) are power spectrum, there are given by

$$P_{xx}(\tau)=\left\{R_{xx}(0)+2\sum_{j=1}^{m-1}R_{xx}(i)cos(\frac{\pi\tau j}{m})+R_{xx}(m)cos\tau\pi\right\}\Delta t$$

$$P_{yy}(\tau)=\left\{R_{yy}(0)+2\sum_{j=1}^{m-1}R_{yy}(i)cos(\frac{\pi\tau j}{m})+R_{yy}(m)cos\tau\pi\right\}\Delta t$$

Where Rxx & Ryy are the auto-correlation function of x & y component respectively. To obtain the values of power spectrum, the smoothing is usually performed by multiplying the weighting window function. As the weighting window, there are Hamming, Hanning, Akaike and other windows, but in this study Hamming has been employed as co-efficient.

That is;

$$\hat{P}_{xx}(0) = 0.54\,P_{xx}(0)+0.46\,P_{xx}(1)$$
$$\hat{P}_{xx}(\tau) = 0.23\,P_{xx}(\tau-1)+0.54\,P_{xx}(\tau)+0.23\,P_{xx}(\tau+1)$$
$$P_{xx}(m) = 0.46\,P_{xx}(m-1)+0.54\,P_{xx}(m)$$

Further Pyy (τ) has also been smoothed.

The power spectrum is the diagram to illustrate the calculation results of power spectrums as shown in Figs. II-1-5-(20) and II-1-5-(21). In the figures, the peak expresses the energy concentration and peak frequency is the dominant frequency of the flctuation in the survey area. The dominant period can be seen from the list of the calculation results. These results are shown in the previous table (Table II-1-5-(15)).

Fig. II-1-5-(20) shows the results of Seraya Area and the most significant peak of all the survey points are at about 1 day cycle and the secondary peak is at about ½ day cycle. So these cycles are dominant at Seraya Area.

Fig. II-1-5-(21) shows the results of Tekong Area and the most significant peaks of all the survey points are at about ½ day cycle. So ½ day cycle is found dominant in Tekong Area. These results show reconfirmation of the result of harmonic analysis.

From Table II-1-5-(11), the exact period (dominant cycle) of the peak at SC1 to SC6 and TC1 to TC4 can be obtained.

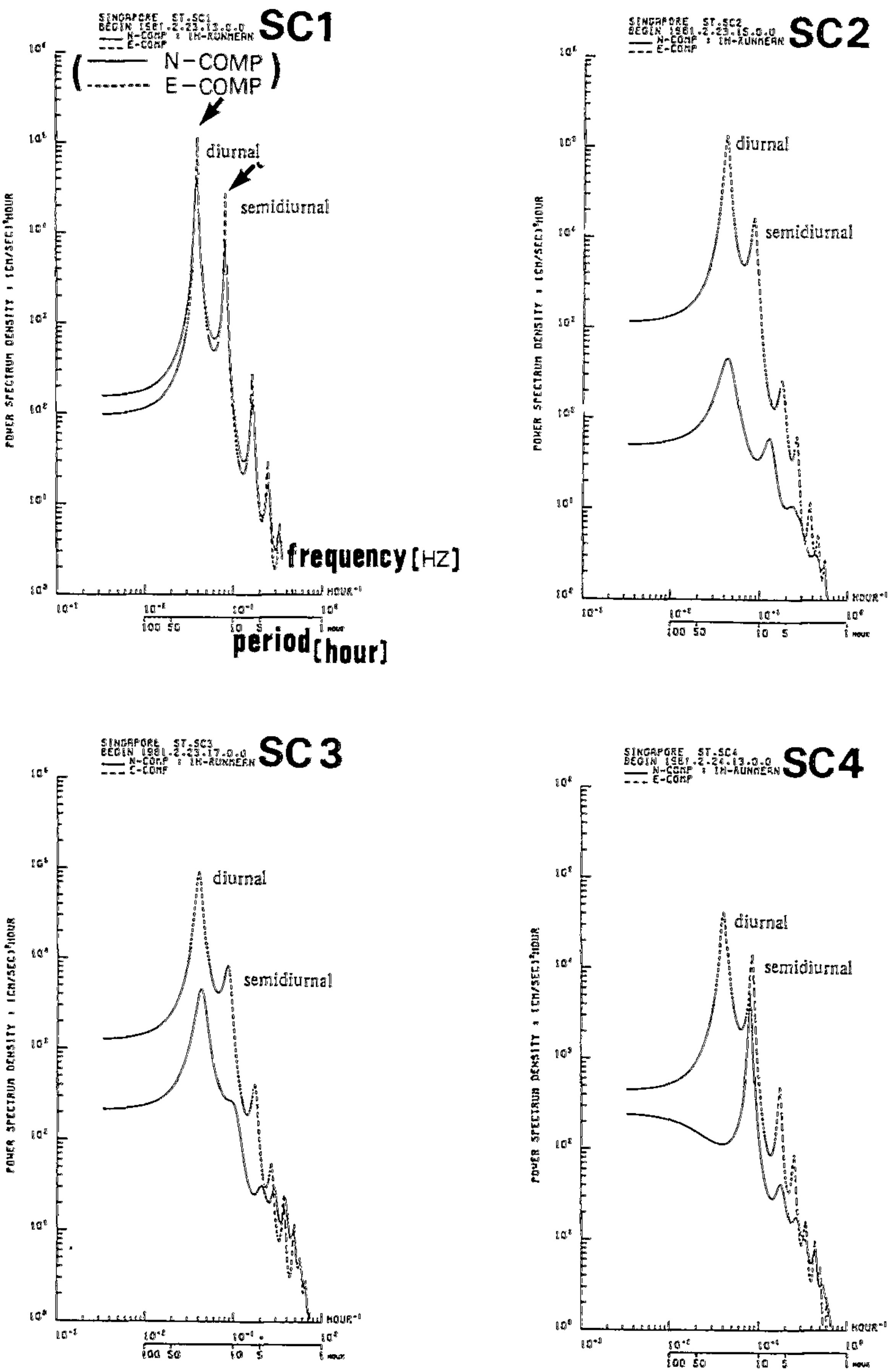
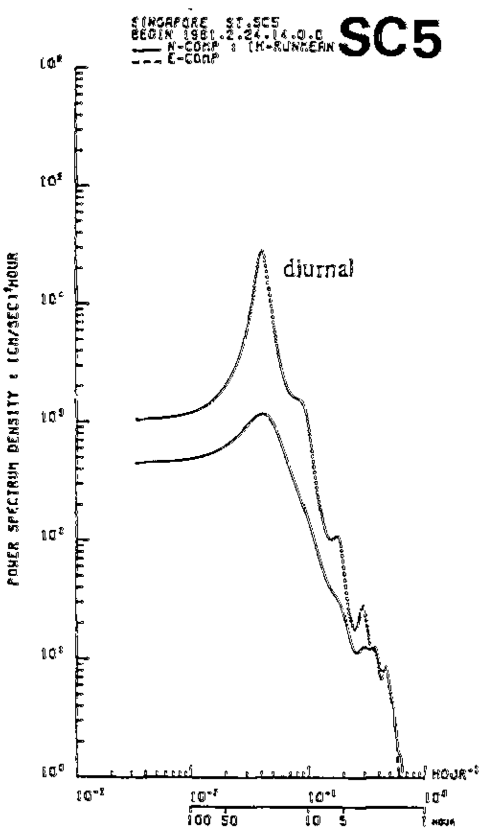


Fig. II-1-5-(20) Power spectra of velocity fluctuation for Seraya Area (1/2)



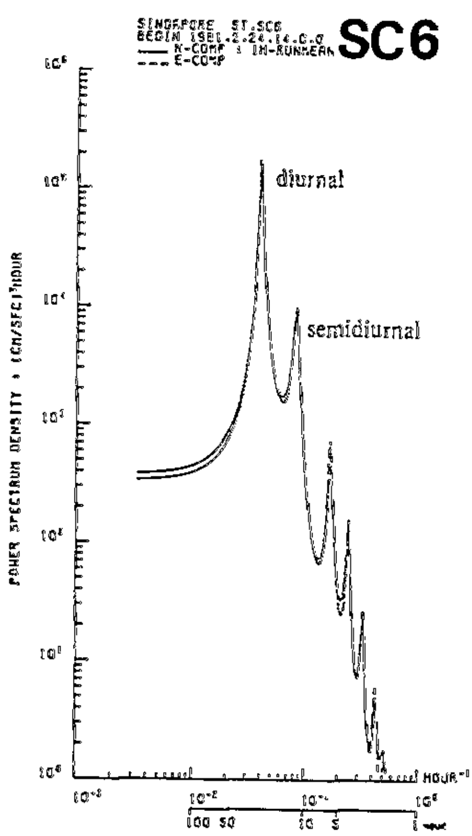


Fig. II-1-5-(20) Power spectra of velocity fluctuation for Seraya Area (2/2)

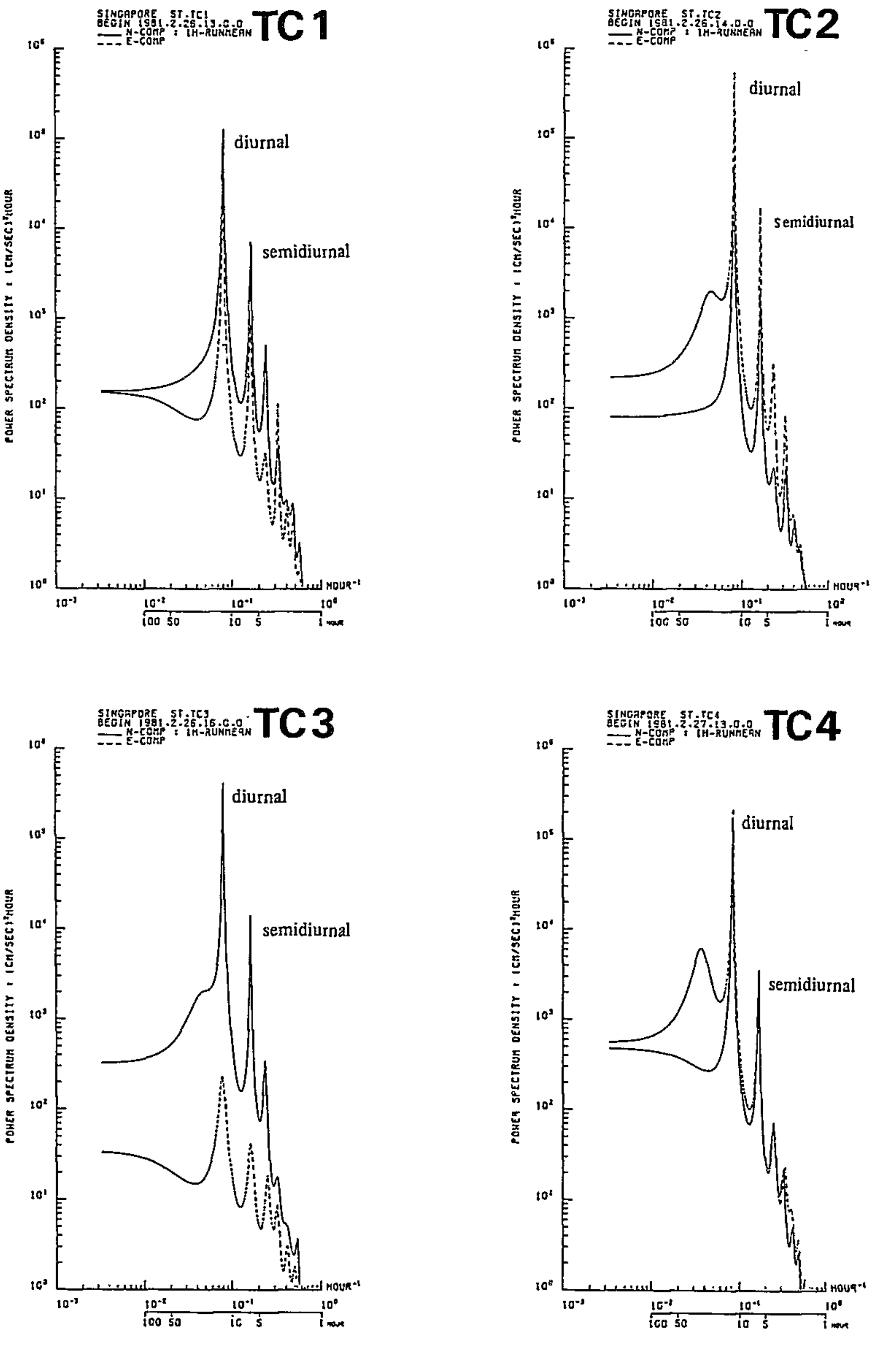


Fig. II-1-5-(21) Power spectrum for Tekong Area

(3) Auto correlation gives the confirmation for time domain of statistical characteristics in fluctuations.

When the time series, X(t), Y(t) are sampled for N pieces by t time intervals, and the first reading is mentioned as X(i), Y(i), the average values X and Y are expressed by

$$\bar{X}=\frac{1}{N}\sum_{i=1}^{N}X(i) \qquad \bar{Y}=\frac{1}{N}\sum_{i=1}^{N}Y(i) \qquad (1-4-1)$$

Auto correlation Rxx(τ) and Ryy(τ) are

$$R_{xx}(\tau)=\frac{1}{N-\tau}\sum_{i=1}^{N-\tau}\left\{X(i+\tau)-\bar{X}\right\}\left\{X(i)-\bar{X}\right\} \qquad (1-4-2)$$

$$R_{yy}(\tau)=\frac{1}{N-\tau}\sum_{i=1}^{N-\tau}\left\{Y(i+\tau)-\bar{Y}\right\}\left\{Y(i)-\bar{Y}\right\} \qquad (1-4-3)$$

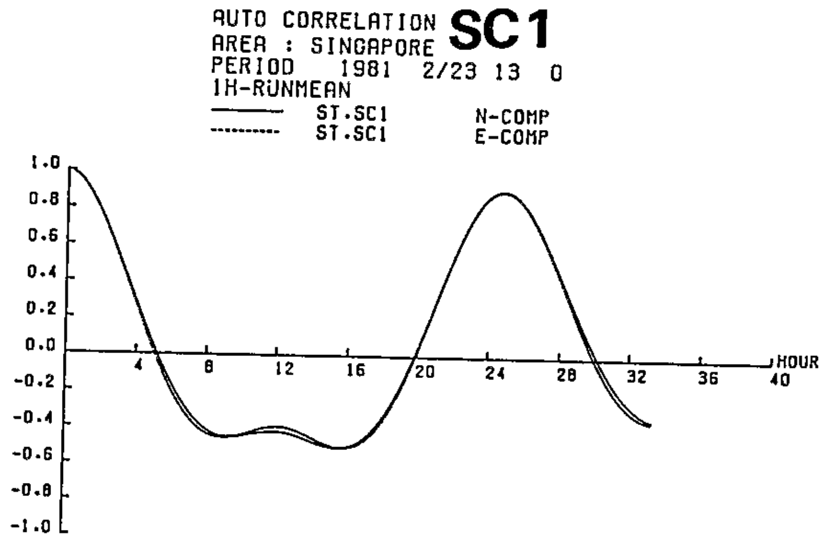
$$\tau=0,1,\ldots\ldots,m$$

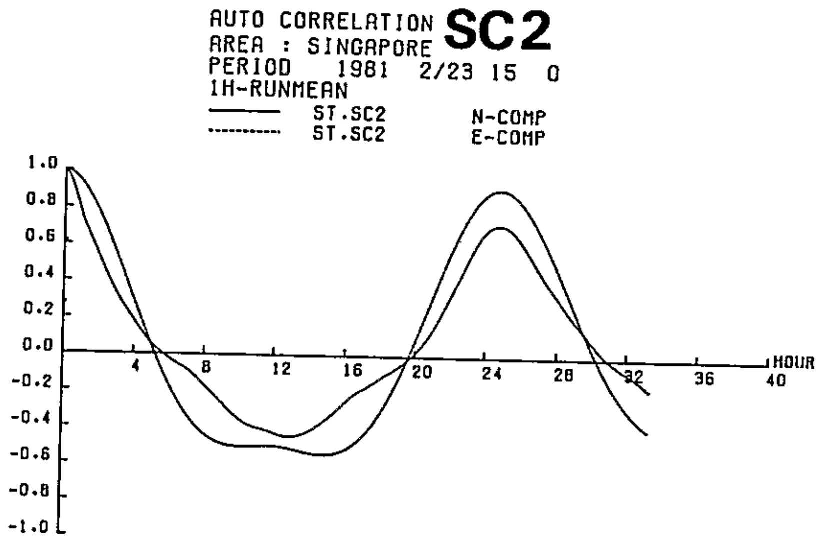
In the above equation, τ is shifted number and m is maximum shifted number and the auto correlation is the regularized number divided by Rxx(0) and Ryy(0). Figs. II-1-5-(22) and II-1-5-(23) show the auto correlation function.

The vertical axis is the correlation coefficient in which nearer to 1 and -1 highest the correlation.

Fig. II-1-5-(22) shows the results of Seraya Area and the curve in the figure indicates diurnal period at about 24 hours except the North component of SC4.

Fig. II-1-5-(23) is the results of Tekong Area and the curves in the figure are indicating semidiurnal period at about 12 hours at all the survey points.





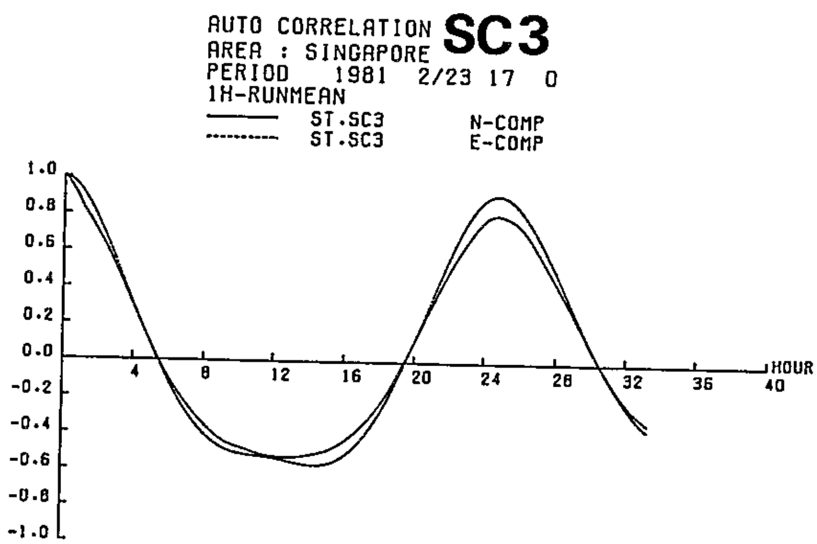
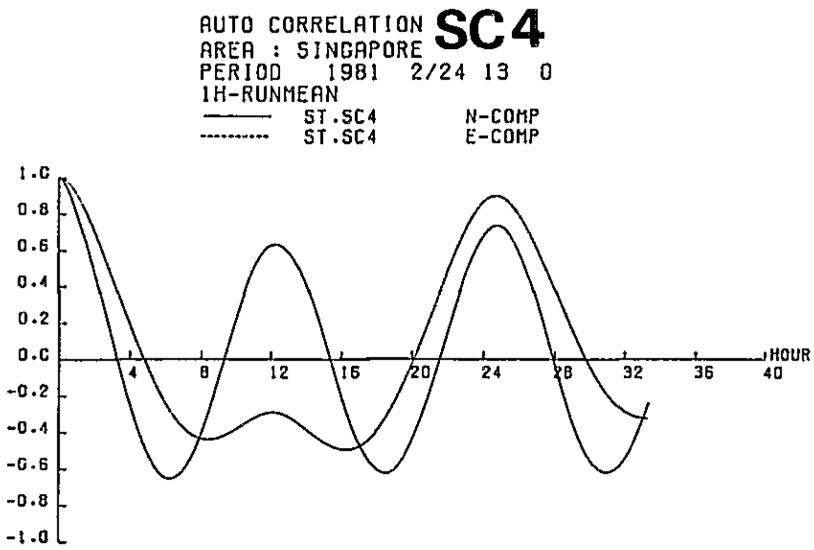
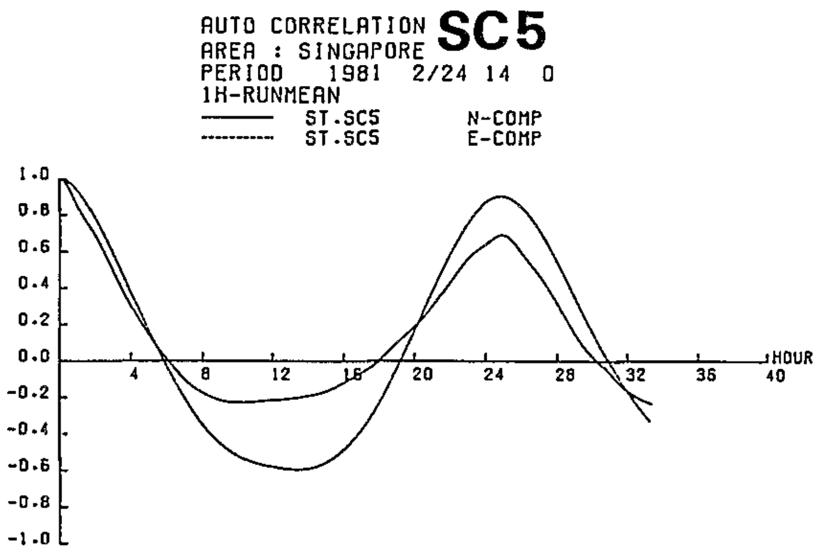


Fig. II-1-5-(22) Auto correlogram for Seraya Area (1)





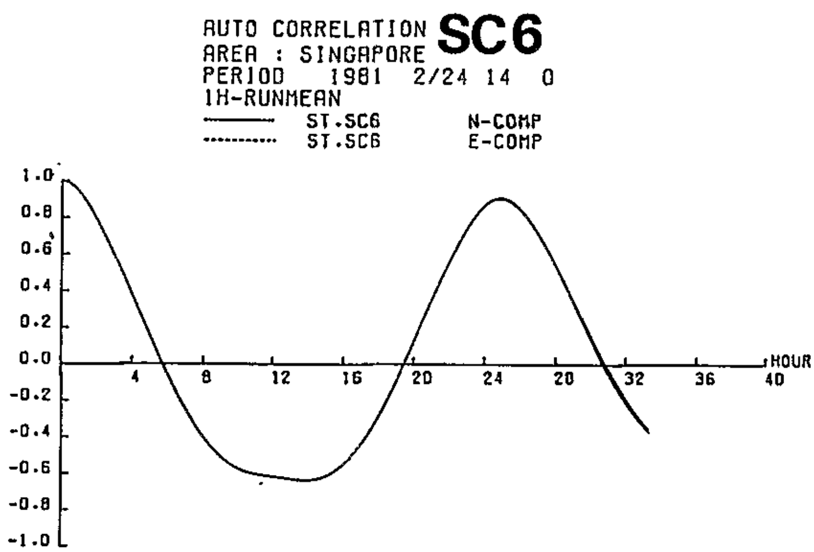
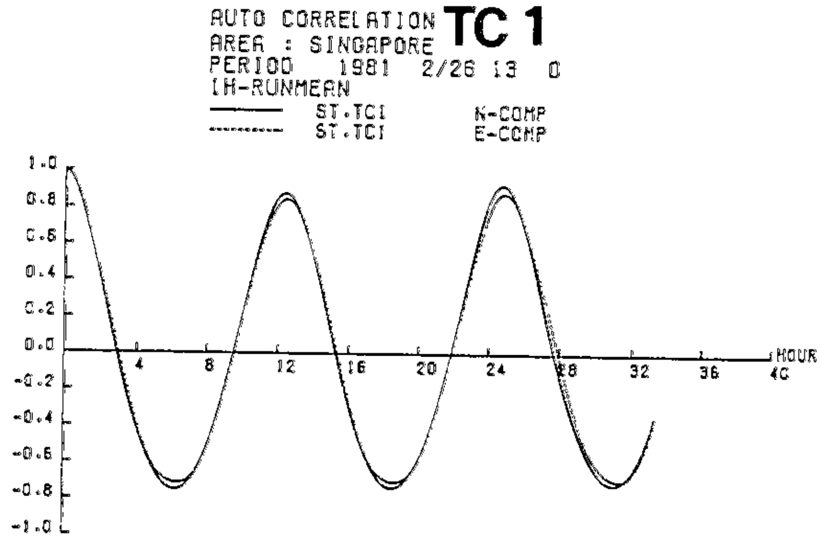
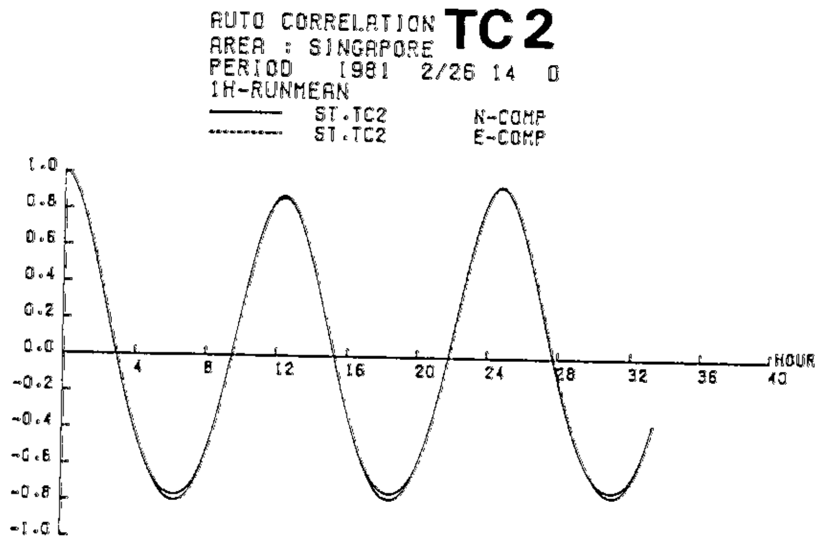


Fig. II-1-5-(22) Auto correlogram for Seraya Area (2)





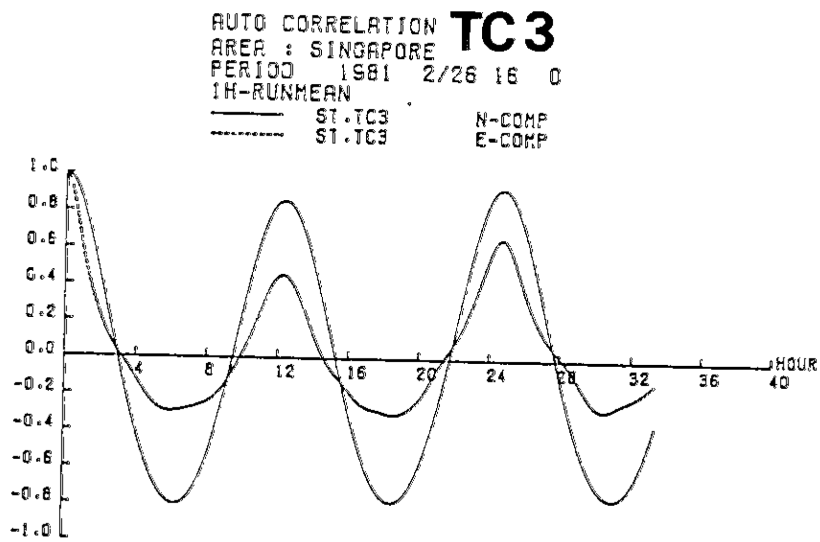


Fig. II-1-5-(23) Auto correlogram for Tekong Area (1)

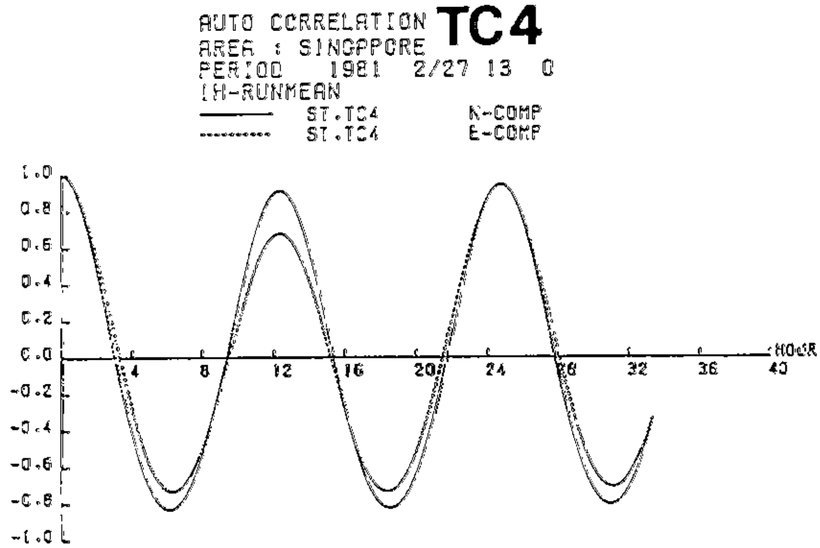


Fig. II-1-5-(23) Auto correlogram for Tekong Area (2)

II-1-5-6 Analysis of current pattern

In this paragraph, the analysing methods for the spatial pattern of the current conditions of the survey area are described.

Table II-1-5-(16) shows the analysing items and results of the current patterns. The diagrams of these results are produced by XY plotter of the large capacity computers and plotting programs are prepared for the various expressions according to the objectives.

Table II-1-5-(16) Analysing items and results of current pattern

	Analysing Items	Results
(1)	Frequency distribution of current direction and velocity	o List of calculation results o Frequency distribution map of current direction o Frequency distribution map of current velocity o Frequency distribution map of classified current direction and velocity
(2)	Scattering plot	o Horizontal distribution map of scattering plot
(3)	Diagram of current conditions based on the results of harmonic analysis of tidal current	o Horizontal distribution map of current ellipse o Diagram of current conditions of respective component current o Constant current map
(4)	Diagram of current conditions based on the time series of vectors	o Diagram of current conditions of 1 hour running mean

(1) Frequency distribution of current direction and velocity give the frequency of current direction and velocity fluctuation.

Table II-1-5-(17) is the calculation results of frequency distribution calculation of Seraya and Tekong Areas. The data used for the calculation is 1 hour runnig mean.

And at the calculation, the current direction is divided into 16 directions category and the velocity is classified by every 5 cm/sec. These results are illustrated in Figs. II-1-5-(24) and II-1-5-(25). From Table II-1-5-(17), the maximum velocity values, their directions and appearance time of the respective survey points are shown in Table II-1-5-(18).

Table II-1-5-(18) Maximum velocity, direction and appearance time

Survey Point	Maximum Velocity	Direction	Appearance Date	Appearance Time
SC1	69.07 cm/sec	308°	1981 3/ 7	08h – 15m
SC2	83.09	273	3/ 6	08h – 50m
SC3	74.80	74	3/ 4	13h – 10m
SC4	55.63	279	3/ 4	03h – 50m
SC5	63.76	246	3/ 1	22h – 15m
SC6	92.86	227	2/28	21h – 30m
TC1	64.68	152	3/ 9	15h – 15m
TC2	103.43	114	3/ 9	15h – 25m
TC3	89.56	179	3/ 9	15h – 25m
TC4	89.75	127	3/ 8	15h – 20m

From Table II-1-5-(18), it is confirmed that in Seraya Area the maximum velocity current were appeared at the spring tides which were generated after the new moon (March 6th) and their direction was the westward except SC3. In Tekong Area, the maximum velocity current were also appeared at the spring tides which were generated after the new moon (march 6th) and their direction was the southward.

From Figs. II-1-5-(24) and II-1-5-(25), the velocity distribution between 0 to 60 cm/sec are found almost even in the appearance rate except SC4, SC5 and TC1. And referring to the undermentioned survey maps, the directions are distributing towards the directions parallel to the coastal line. Comprehensively Seraya Area is dominated by eastward and westward, and Tekong Area is dominated by southward and northward.

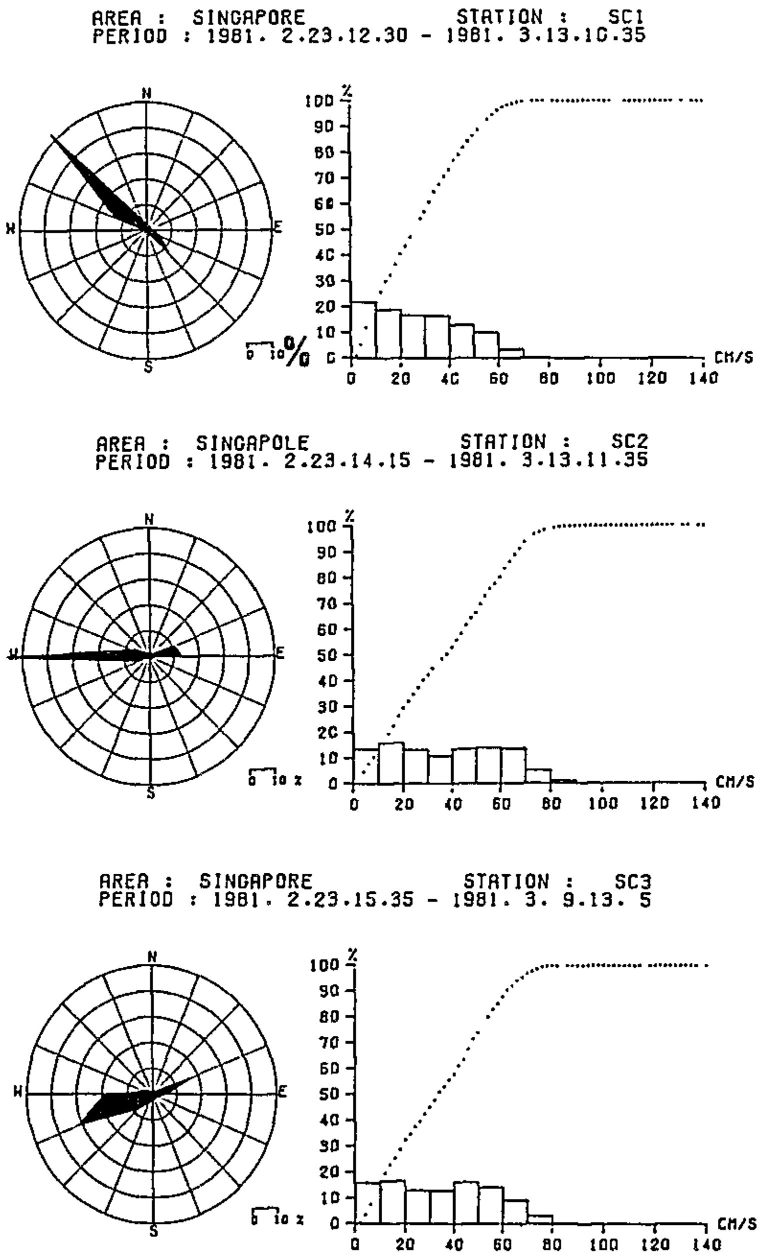


Fig. II-1-5-(24) Frequency distribution of current direction and velocity of Seraya Area (1)

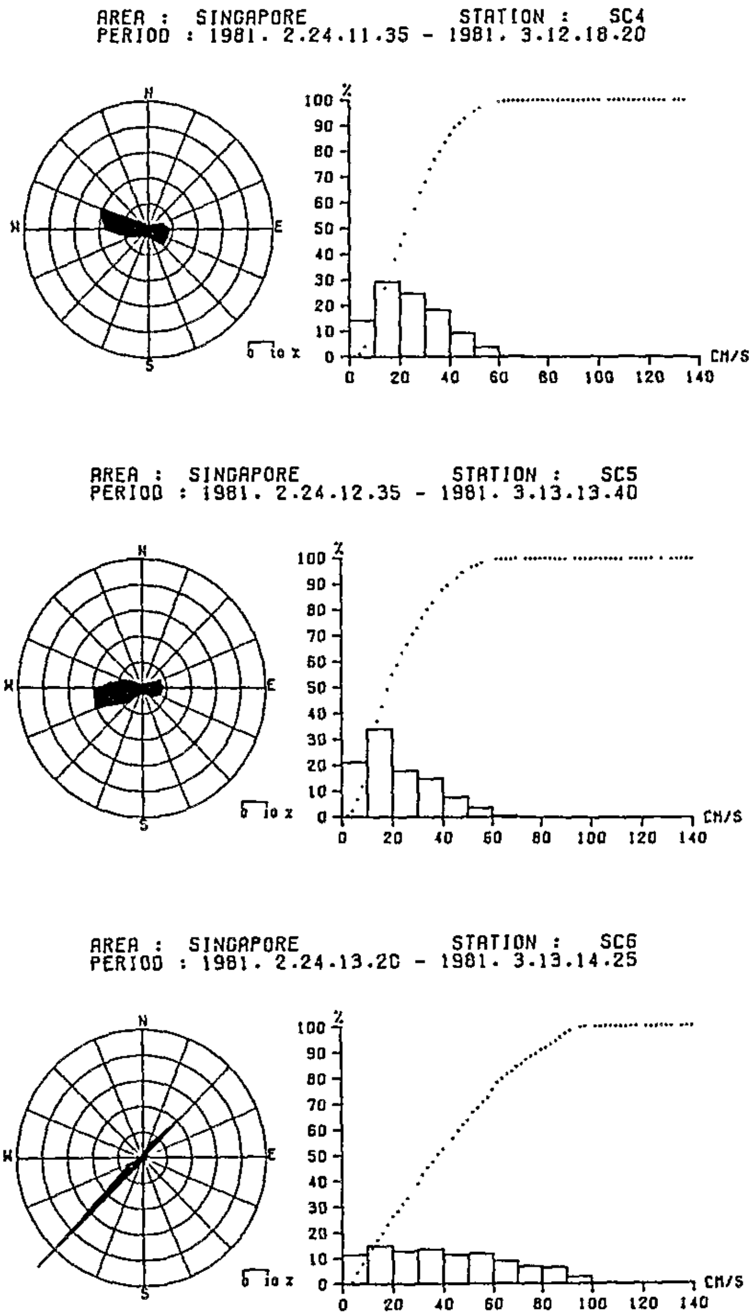
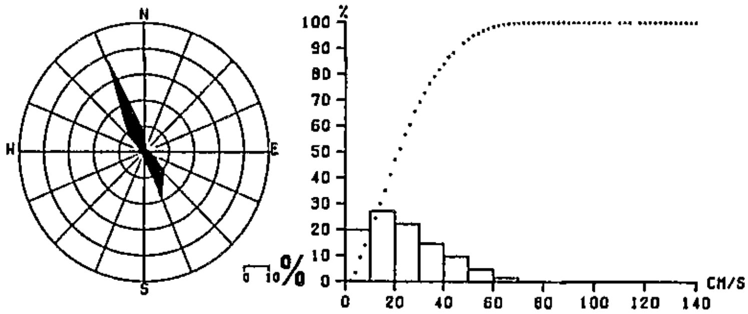
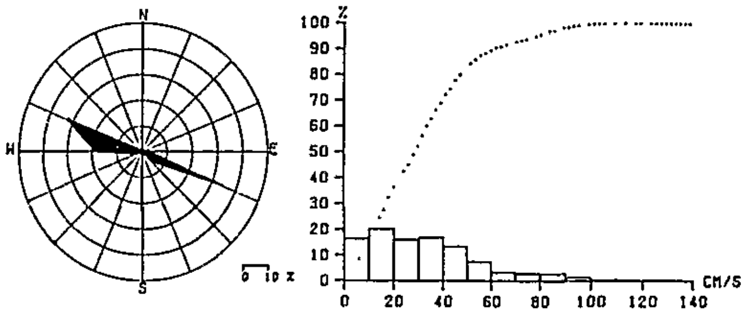


Fig. II-1-5-(24) Frequency distribution of current direction and velocity of Seraya Area (2)

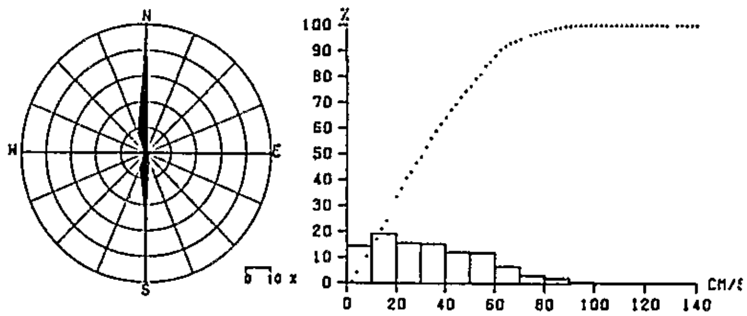
AREA : SINGAPORE STATION : TC1
PERIOD : 1981. 2.26.11.50 - 1981. 3.17. 9.55



AREA : SINGAPORE STATION : TC2
PERIOD : 1981. 2.26.13.30 - 1981. 3.17.11.35



AREA : SINGAPORE STATION : TC3
PERIOD : 1981. 2.26.14.45 - 1981. 3.17.12. 0



AREA : SINGAPORE STATION : TC4
PERIOD : 1981. 2.27.11.40 - 1981. 3.17.13. 0

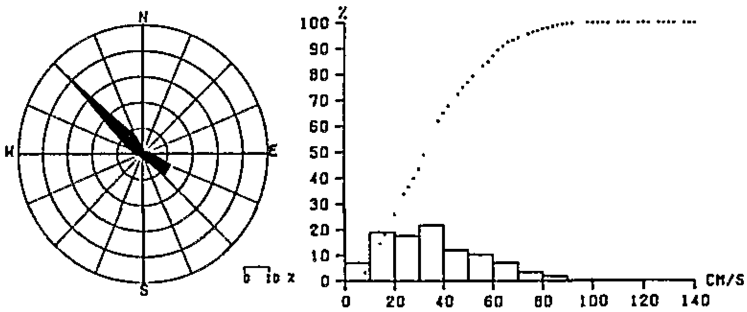


Fig. II-1-5-(25) Frequency distribution of current direction and velocity of Tekong Area

Table II-1-5-(17) Calculation results of frequency distribution of current direction and velocity for Seraya Area (1/10)

AREA : SINGAPORE
STATION NUMBER :

SAMPLING PERIOD : 1981 2 23 13 0 - 1981 3 13 10 5

(RANGE)/(DIR.)	(N)	(NNE)	(NE)	(ENE)	(E)	(ESE)	(SE)	(SSE)	(S)	(SSW)	(SW)	(WSW)	(W)	(WNW)	(NW)	(NNW)	TOTAL
0. - 9.9	83 (1.6)	110 (2.1)	93 (1.8)	50 (1.0)	89 (1.7)	86 (1.7)	48 (0.9)	15 (0.3)	13 (0.3)	12 (0.2)	11 (0.2)	11 (0.2)	38 (0.7)	71 (1.4)	246 (4.8)	152 (3.0)	1128 21.9
10.0 - 19.9	0 (-)	0 (-)	0 (-)	0 (-)	9 (0.2)	146 (2.8)	97 (1.9)	23 (0.4)	3 (0.1)	0 (-)	0 (-)	0 (-)	9 (0.2)	166 (3.2)	461 (9.0)	20 (0.4)	934 18.1
20.0 - 29.9	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	39 (0.8)	171 (3.3)	2 (0.0)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	139 (2.7)	552 (10.7)	0 (-)	903 17.5
30.0 - 39.9	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	2 (0.0)	185 (3.6)	8 (0.2)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	50 (1.0)	593 (11.5)	0 (-)	838 16.3
40.0 - 49.9	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	158 (3.1)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	7 (0.1)	504 (9.8)	0 (-)	669 13.0
50.0 - 59.9	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	9 (0.2)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	521 (10.1)	0 (-)	530 10.3
60.0 - 69.9	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	148 (2.9)	0 (-)	148 2.9
70.0 - 79.9	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 0.
80.0 - 89.9	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 0.
90.0 - 99.9	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 0.
100.0 -	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 0.
* SUBTOTAL (%)	83 (1.6)	110 (2.1)	93 (1.8)	50 (1.0)	98 (1.9)	273 (5.3)	668 (13.0)	48 (0.9)	16 (0.3)	12 (0.2)	11 (0.2)	11 (0.2)	47 (0.9)	433 (8.4)	3025 (58.7)	172 (3.3)	
MEAN(VELOCITY)	3.43	3.22	3.29	5.05	6.82	13.36	29.91	14.88	7.15	7.02	6.32	7.12	7.25	19.47	34.45	6.44	27.31
MAX VELOCITY	8.28	5.91	6.79	9.62	12.48	30.33	50.28	34.47	10.88	9.17	8.91	9.74	13.36	44.96	69.07	13.52	69.07
DIRECTION	349.	32.	51.	79.	99.	126.	139.	146.	174.	195.	236.	257.	281.	304.	308.	327.	308.
DATE	2/24 17:30	3/ 9 14:30	3/ 9 14:40	2/23 15:50	3/ 8 14:20	3/ 3 11:50	3/ 4 13: 5	3/ 2 13:40	3/ 2 15:50	3/ 2 16: 5	3/ 2 16:30	3/ 2 16:45	3/ 3 17:50	3/12 20:20	3/ 7 8:15	2/25 17:10	3/ 7 8:15
**DIR(ONLY)	83 (1.6)	110 (2.1)	93 (1.8)	50 (1.0)	98 (1.9)	273 (5.3)	668 (13.0)	48 (0.9)	16 (0.3)	12 (0.2)	11 (0.2)	11 (0.2)	47 (0.9)	433 (8.4)	3025 (58.7)	172 (3.3)	5150 100.00

SOKUTOKU RITSU(DIR.ONLY) 100.0% ,KESSOKU 0 ,SLACK 0 0. %

VECTOR MEAN

DIR.	VEL.	N-COMP	E-COMP
307.	17.35	10.42	-13.87

* TOTAL 5150

Table II-1-5-(17) Calculation results of frequency distribution of current direction and velocity for Seraya Area (2/10)

AREA : SINGAPORE
STATION NUMBER 1

SAMPLING PERIOD : 1981 2 23 15 0 - 1981 3 13 11 5

(RANGE)/(DIR.)	(N)	(NNE)	(NE)	(ENE)	(E)	(ESE)	(SE)	(SSE)	(S)	(SSW)	(SW)	(WSW)	(W)	(WNW)	(NW)	(NNW)	TOTAL
0. - 9.9	26 (0.7)	37 (1.0)	16 (0.4)	50 (1.3)	54 (1.4)	16 (0.4)	16 (0.4)	32 (0.8)	9 (0.2)	4 (0.1)	11 (0.3)	52 (1.4)	81 (2.1)	45 (1.2)	36 (0.9)	33 (0.9)	513 13.5
10.0 - 19.9	8 (0.2)	0 (-)	5 (0.1)	88 (2.3)	112 (3.0)	10 (0.3)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	13 (0.3)	258 (6.8)	86 (2.3)	6 (0.2)	0 (-)	586 15.4
20.0 - 29.9	0 (-)	0 (-)	0 (-)	43 (1.1)	48 (1.3)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	1 (0.0)	386 (10.2)	26 (0.7)	0 (-)	0 (-)	504 13.3
30.0 - 39.9	0 (-)	0 (-)	0 (-)	42 (1.1)	63 (1.7)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	301 (7.9)	0 (-)	0 (-)	0 (-)	406 10.7
40.0 - 49.9	0 (-)	0 (-)	0 (-)	43 (1.1)	88 (2.3)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	412 (10.9)	0 (-)	0 (-)	0 (-)	543 14.3
50.0 - 59.9	0 (-)	0 (-)	0 (-)	45 (1.2)	56 (1.5)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	436 (11.5)	0 (-)	0 (-)	0 (-)	537 14.2
60.0 - 69.9	0 (-)	0 (-)	0 (-)	47 (1.2)	107 (2.8)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	355 (9.4)	0 (-)	0 (-)	0 (-)	509 13.4
70.0 - 79.9	0 (-)	0 (-)	0 (-)	8 (0.2)	32 (0.8)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	123 (3.2)	0 (-)	0 (-)	0 (-)	163 4.3
80.0 - 89.9	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	30 (0.8)	0 (-)	0 (-)	0 (-)	30 0.8
90.0 - 99.9	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 0.
100.0 -	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 0.
* SUBTOTAL	34 (0.9)	37 (1.0)	21 (0.6)	366 (9.6)	560 (14.8)	24 (0.6)	16 (0.4)	32 (0.8)	8 (0.2)	4 (0.1)	11 (0.3)	66 (1.7)	2386 (62.9)	157 (4.1)	42 (1.1)	33 (0.9)	
MEAN(VELOCITY)	6.45	3.61	6.48	33.22	38.45	8.84	2.79	1.56	1.45	1.15	3.91	7.81	42.85	13.99	6.10	6.22	36.58
MAX VELOCITY	11.25	9.69	12.50	71.67	73.78	15.61	3.47	3.63	3.01	1.56	5.14	27.56	83.09	29.06	12.57	9.61	83.09
DIRECTION	2.	30.	33.	79.	81.	111.	129.	168.	184.	211.	235.	259.	273.	282.	306.	328.	273.
DATE	2/27 5:20	3/ 1 6:30	3/ 1 6:45	3/ 6 14: 0	3/ 6 12:35	2/23 15:40	2/28 7:10	2/28 6:30	3/ 1 15:10	2/28 6:20	2/24 16:45	2/27 15: 0	3/ 6 6:50	3/ 6 19:10	2/27 3:30	2/27 3:50	3/ 6 6:50
**DIR(ONLY)	34 (0.9)	37 (1.0)	21 (0.6)	366 (9.6)	560 (14.8)	24 (0.6)	16 (0.4)	32 (0.8)	8 (0.2)	4 (0.1)	11 (0.3)	66 (1.7)	2386 (62.9)	157 (4.1)	42 (1.1)	33 (0.9)	3793 100.00

SOKUTOKU RITSU(DIR.ONLY) 73.8% ,KESSOKU 1345 ,SLACK 0 0. %

VECTOR MEAN DIR. VEL. N-COMP E-COMP
275. 18.72 1.79 -18.63

* TOTAL 5138

Table II-1-5-(17) Calculation results of frequency distribution of current direction and velocity for Seraya Area (3/10)

AREA : SINGAPORE
STATION NUMBER : SC3

SAMPLING PERIOD : 1981 2 23 17 0 - 1981 3 9 12 35

(RANGE)/(DIR.)	(N)	(NNE)	(NE)	(ENE)	(E)	(ESE)	(SE)	(SSE)	(S)	(SSW)	(SW)	(WSW)	(W)	(WNW)	(NW)	(NNW)	TOTAL
0. - 9.9	15 (0.4)	19 (0.5)	30 (0.8)	33 (0.8)	40 (1.0)	61 (1.5)	41 (1.0)	55 (1.4)	64 (1.6)	57 (1.4)	58 (1.5)	36 (0.9)	30 (1.3)	49 (1.2)	16 (0.4)	10 (0.3)	632 15.9
10.0 - 19.9	0 (-)	0 (-)	7 (0.2)	144 (3.6)	13 (0.3)	19 (0.5)	27 (0.7)	18 (0.5)	37 (0.9)	59 (1.5)	87 (2.2)	112 (2.8)	104 (2.6)	30 (0.8)	1 (0.0)	0 (-)	658 16.5
20.0 - 29.9	0 (-)	0 (-)	0 (-)	56 (1.4)	31 (0.8)	25 (0.6)	1 (0.0)	0 (-)	0 (-)	9 (0.2)	43 (1.1)	288 (7.2)	77 (1.9)	6 (0.2)	0 (-)	0 (-)	536 13.5
30.0 - 39.9	0 (-)	0 (-)	0 (-)	80 (2.0)	36 (0.9)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	320 (8.0)	65 (1.6)	1 (0.0)	0 (-)	0 (-)	507 12.6
40.0 - 49.9	0 (-)	0 (-)	0 (-)	108 (2.7)	14 (0.4)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	507 (12.7)	21 (0.5)	0 (-)	0 (-)	0 (-)	650 16.3
50.0 - 59.9	0 (-)	0 (-)	0 (-)	136 (3.4)	2 (0.1)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	502 (12.6)	6 (0.2)	0 (-)	0 (-)	0 (-)	644 16.2
60.0 - 69.9	0 (-)	0 (-)	0 (-)	142 (3.6)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	143 (3.6)	6 (0.2)	0 (-)	0 (-)	0 (-)	291 7.3
70.0 - 79.9	0 (-)	0 (-)	0 (-)	67 (1.7)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	67 1.7
80.0 - 89.9	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 0.
90.0 - 99.9	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 0.
100.0 -	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 0.
* SUBTOTAL	15 (0.4)	19 (0.5)	37 (0.9)	764 (19.2)	136 (3.4)	105 (2.6)	69 (1.7)	73 (1.8)	101 (2.5)	125 (3.1)	188 (4.7)	1906 (47.9)	329 (8.3)	86 (2.2)	17 (0.4)	10 (0.3)	
MEAN(VELOCITY)	3.97	3.81	6.49	43.16	23.15	11.27	10.15	7.55	8.63	12.24	14.67	42.09	23.66	10.67	5.57	4.43	33.45
MAX VELOCITY	6.26	7.68	13.52	74.80	51.84	29.42	21.15	13.89	13.05	27.03	26.85	68.22	65.01	30.93	10.74	6.98	74.80
DIRECTION	350.	33.	54.	74.	79.	103.	124.	148.	176.	208.	233.	255.	260.	281.	305.	330.	74.
DATE	3/ 5 9:35	2/27 11:10	3/ 6 18:45	3/ 4 13:10	3/ 3 10:40	3/ 8 14:10	3/ 8 13:40	3/ 2 6:55	3/ 3 8: 0	3/ 8 11:35	3/ 6 0:25	3/ 6 6:55	3/ 7 8:20	3/ 7 10:10	3/ 5 9:20	3/ 5 9:30	3/ 4 13:10
**(DIR(ONLY)	15 (0.4)	19 (0.5)	37 (0.9)	764 (19.2)	136 (3.4)	105 (2.6)	69 (1.7)	73 (1.8)	101 (2.5)	125 (3.1)	188 (4.7)	1906 (47.9)	329 (8.3)	86 (2.2)	17 (0.4)	10 (0.3)	3980 100.00

SOKUTOKU RITSU(DIR.ONLY) 100.0% ,KESSOKU 0 ,SLACK 0 0. %

VECTOR MEAN DIR. VEL. N-COMP E-COMP
247. 13.75 -4.70 -12.85

* TOTAL 3980

Table II-1-5-(17) Calculation results of frequency distribution of current direction and velocity for Seraya Area (4/10)

AREA : SINGAPORE
STATION NUMBER : SC4

SAMPLING PERIOD : 1981 2 24 13 0 - 1981 3 12 17 50

(RANGE)/(DIR.)	(N)	(NNE)	(NE)	(ENE)	(E)	(ESE)	(SE)	(SSE)	(S)	(SSW)	(SW)	(WSW)	(W)	(WNW)	(NW)	(NNW)	TOTAL
0. - 9.9	25 (0.5)	27 (0.6)	39 (0.8)	18 (0.4)	17 (0.4)	30 (0.6)	86 (1.8)	63 (1.3)	56 (1.2)	39 (0.8)	61 (1.3)	57 (1.2)	72 (1.5)	32 (0.7)	30 (0.6)	23 (0.5)	675 14.5
10.0 - 19.9	14 (0.3)	23 (0.5)	70 (1.5)	88 (1.9)	42 (0.9)	101 (2.2)	268 (5.7)	85 (1.8)	64 (1.4)	92 (2.0)	88 (1.9)	95 (2.0)	133 (2.8)	153 (3.3)	43 (0.9)	19 (0.4)	1378 29.5
20.0 - 29.9	0 (-)	0 (-)	0 (-)	117 (2.5)	95 (2.0)	173 (3.7)	108 (2.3)	1 (0.0)	0 (-)	7 (0.1)	24 (0.5)	147 (3.1)	274 (5.9)	239 (5.1)	5 (0.1)	0 (-)	1190 25.5
30.0 - 39.9	0 (-)	0 (-)	0 (-)	15 (0.3)	175 (3.7)	75 (1.6)	7 (0.1)	0 (-)	0 (-)	0 (-)	0 (-)	10 (0.2)	355 (7.6)	206 (4.4)	0 (-)	0 (-)	843 18.1
40.0 - 49.9	0 (-)	0 (-)	0 (-)	0 (-)	52 (1.1)	28 (0.6)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	190 (4.1)	168 (3.6)	0 (-)	0 (-)	438 9.4
50.0 - 59.9	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	84 (1.8)	59 (1.3)	0 (-)	0 (-)	143 3.1
60.0 - 69.9	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 0.
70.0 - 79.9	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 0.
80.0 - 89.9	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 0.
90.0 - 99.9	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 0.
100.0 -	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 0.
* SUBTOTAL	39 (0.8)	50 (1.1)	109 (2.3)	238 (5.1)	381 (8.2)	407 (8.7)	469 (10.0)	149 (3.2)	120 (2.6)	138 (3.0)	173 (3.7)	309 (6.6)	1108 (23.7)	857 (18.4)	78 (1.7)	42 (0.9)	
MEAN(VELOCITY)	8.23	8.80	10.76	20.28	30.61	24.22	16.23	11.70	10.66	12.95	12.91	18.79	31.50	30.73	12.09	9.21	23.85
MAX VELOCITY	12.05	13.49	16.38	32.26	46.44	46.61	30.72	20.86	18.59	21.74	23.29	39.91	55.63	54.94	24.66	13.75	55.63
DIRECTION	350.	31.	55.	78.	101.	101.	125.	146.	191.	209.	231.	258.	279.	282.	305.	328.	279.
DATE	3/ 8 19:20	3/ 8 18:50	3/ 8 18:20	3/ 2 12:30	3/ 5 12:25	3/ 5 12:10	3/ 9 14:20	3/10 0:50	3/ 7 1:55	3/ 7 2:40	3/ 6 23: 5	3/ 1 21:20	3/ 4 3:50	3/ 6 7: 5	3/ 9 10:40	3/ 9 11:25	3/ 4 3:50
**DIR(ONLY)	39 (0.8)	50 (1.1)	109 (2.3)	238 (5.1)	381 (8.2)	407 (8.7)	469 (10.0)	149 (3.2)	120 (2.6)	138 (3.0)	173 (3.7)	309 (6.6)	1108 (23.7)	857 (18.4)	78 (1.7)	42 (0.9)	4667 100.00

SOKUTOKU AITSU(DIR.ONLY) 100.0X ,KESSOKU 0 ,SLACK 0 0. X

VECTOR MEAN	DIR.	VEL.	N-COMP	E-COMP
	265.	7.76	-0.66	-7.73

* TOTAL 4667

Table II-1-5-(17) Calculation results of frequency distribution of current direction and velocity for Seraya Area (5/10)

AREA : SINGAPORE
STATION NUMBER : SC5

SAMPLING PERIOD : 1981 2 26 14 0 - 1981 3 13 13 10

(RANGE)/(CODE)	(N)	(NNE)	(NE)	(ENE)	(E)	(ESE)	(SE)	(SSE)	(S)	(SSW)	(SW)	(WSW)	(W)	(WNW)	(NW)	(NNW)	TOTAL
0. - 9.9	34 (0.73%)	35 (0.73%)	17 (0.42%)	26 (0.56%)	22 (0.53%)	52 (1.13%)	114 (2.53%)	66 (1.43%)	79 (1.73%)	78 (1.70%)	86 (1.42%)	99 (2.20%)	103 (2.31%)	72 (1.61%)	34 (0.73%)	29 (0.63)	926 20.1
10.0 - 19.9	11 (0.23%)	26 (0.61%)	94 (2.03%)	206 (4.53%)	106 (2.31%)	174 (3.83%)	124 (2.73%)	10 (0.21%)	13 (0.28%)	43 (0.93%)	141 (3.11%)	152 (3.33%)	210 (4.61%)	230 (5.03%)	26 (0.61%)	18 (0.4)	1584 34.5
20.0 - 29.9	0 (- %)	0 (- %)	0 (- %)	104 (2.19%)	123 (2.71%)	110 (2.40%)	7 (0.21%)	7 (0.21%)	14 (0.30%)	0 (- %)	55 (1.23%)	107 (2.33%)	336 (7.31%)	32 (0.73%)	0 (- %)	0 (-)	895 19.5
30.0 - 39.9	0 (- %)	0 (- %)	0 (- %)	10 (0.22%)	147 (3.11%)	7 (0.22%)	0 (- %)	13 (0.31%)	0 (- %)	0 (- %)	46 (1.05%)	175 (3.81%)	236 (5.14%)	5 (0.11%)	0 (- %)	0 (-)	632 13.8
40.0 - 49.9	0 (- %)	0 (- %)	0 (- %)	0 (- %)	7 (0.23%)	0 (- %)	0 (- %)	0 (- %)	0 (- %)	0 (- %)	32 (0.71%)	312 (6.85%)	27 (0.63%)	0 (- %)	0 (- %)	0 (-)	378 8.2
50.0 - 59.9	0 (- %)	0 (- %)	0 (- %)	0 (- %)	0 (- %)	0 (- %)	0 (- %)	0 (- %)	0 (- %)	0 (- %)	0 (- %)	165 (1.69%)	0 (- %)	0 (- %)	0 (- %)	0 (-)	165 3.6
60.0 - 69.9	0 (- %)	0 (- %)	0 (- %)	0 (- %)	0 (- %)	0 (- %)	0 (- %)	0 (- %)	0 (- %)	0 (- %)	0 (- %)	10 (0.21%)	0 (- %)	0 (- %)	0 (- %)	0 (-)	10 0.2
70.0 - 79.9	0 (- %)	0 (- %)	0 (- %)	0 (- %)	0 (- %)	0 (- %)	0 (- %)	0 (- %)	0 (- %)	0 (- %)	0 (- %)	0 (- %)	0 (- %)	0 (- %)	0 (- %)	0 (-)	0 0.
80.0 - 89.9	0 (- %)	0 (- %)	0 (- %)	0 (- %)	0 (- %)	0 (- %)	0 (- %)	0 (- %)	0 (- %)	0 (- %)	0 (- %)	0 (- %)	0 (- %)	0 (- %)	0 (- %)	0 (-)	0 0.
90.0 - 99.9	0 (- %)	0 (- %)	0 (- %)	0 (- %)	0 (- %)	0 (- %)	0 (- %)	0 (- %)	0 (- %)	0 (- %)	0 (- %)	0 (- %)	0 (- %)	0 (- %)	0 (- %)	0 (-)	0 0.
100.0 -	0 (- %)	0 (- %)	0 (- %)	0 (- %)	0 (- %)	0 (- %)	0 (- %)	0 (- %)	0 (- %)	0 (- %)	0 (- %)	0 (- %)	0 (- %)	0 (- %)	0 (- %)	0 (-)	0 0.
* SUBTOTAL	45 (1.03%)	59 (1.31%)	111 (2.61%)	346 (7.53%)	402 (8.81%)	361 (7.51%)	265 (5.33%)	96 (2.11%)	106 (2.31%)	121 (2.61%)	340 (7.41%)	1020 (22.21%)	910 (19.81%)	339 (7.41%)	60 (1.31%)	47 (1.03)	
MEAN(VELOCITY)	7.96	8.01	11.79	17.85	25.72	17.40	10.62	12.96	10.01	8.98	20.08	34.70	25.53	14.17	9.62	7.98	21.74
MAX VELOCITY	19.80	12.39	16.38	31.90	40.66	36.78	28.23	31.27	28.51	19.26	46.32	63.76	46.93	30.33	18.01	12.05	63.76
DIRECTION	10.	33.	55.	78.	97.	102.	166.	150.	170.	195.	235.	246.	260.	286.	304.	328.	246.
DATE	3/13 12110	3/13 11027	1/ 5 161 5	3/ 6 14130	3/ 6 11125	3/ 6 11110	2/27 8110	2/27 8115	2/27 9150	2/27 111 5	3/ 5 0340	3/ 9 22115	3/ 8 10 0	3/11 10155	3/12 11140	3/ 2 16120	3/ 9 22115
DIRECTION	45 (1.03%)	59 (1.31%)	111 (2.61%)	346 (7.51%)	402 (8.81%)	361 (7.51%)	265 (5.33%)	96 (2.11%)	106 (2.31%)	121 (2.61%)	340 (7.41%)	1020 (22.21%)	910 (19.81%)	339 (7.41%)	60 (1.31%)	47 (1.03)	4588 100.00

SOKUSOKU ALTSUGEBA.ONLY? 93.91 +KESSOKU 299 +SLACK 0 0. 1

VECTOR MEAN

DIR.	VEL.	N-COMP	E-COMP
246.	9.59	-3.95	-8.74

* TOTAL 4587

Table II-1-5-(17) Calculation results of frequency distribution of current direction and velocity for Seraya Area (6/10)

AREA : SINGAPORE
STATION NUMBER : SC6

SAMPLING PERIOD : 1981 2 26 14 0 - 1981 3 13 13 55

(RANGE)/(DIR.)	(N)	(NNE)	(NE)	(ENE)	(E)	(ESE)	(SE)	(SSE)	(S)	(SSW)	(SW)	(WSW)	(W)	(WNW)	(NW)	(NNW)	TOTAL
0. - 9.9	21 (0.43)	104 (2.13)	93 (1.91)	43 (0.93)	12 (0.25)	19 (0.43)	16 (0.33)	15 (0.31)	20 (0.43)	45 (0.93)	103 (2.13)	43 (0.93)	26 (0.53)	21 (0.43)	21 (0.43)	12 (0.25)	611 12.5
10.0 - 19.9	7 (0.14)	9 (0.23)	250 (5.11)	7 (0.14)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	4 (0.11)	336 (6.87)	27 (0.62)	1 (0.02)	0 (-)	1 (0.02)	5 (0.11)	645 13.2
20.0 - 29.9	0 (-)	43 (0.93)	210 (4.31)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	445 (9.53)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	718 14.7
30.0 - 39.9	0 (-)	0 (-)	157 (3.23)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	450 (9.23)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	602 12.4
40.0 - 49.9	0 (-)	0 (-)	141 (2.91)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	443 (9.03)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	584 11.9
50.0 - 59.9	0 (-)	0 (-)	251 (5.11)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	309 (6.31)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	560 11.4
60.0 - 69.9	0 (-)	0 (-)	92 (1.91)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	310 (6.31)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	402 8.2
70.0 - 79.9	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	325 (6.61)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	325 6.6
80.0 - 89.9	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	376 (7.71)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	376 7.7
90.0 - 99.9	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	68 (1.41)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	68 1.4
100.0 -	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 0.
* SUBTOTAL	28 (0.61)	157 (3.21)	1196 (24.41)	50 (1.01)	12 (0.21)	19 (0.41)	14 (0.31)	11 (0.21)	20 (0.41)	49 (1.01)	3183 (65.01)	70 (1.41)	27 (0.61)	21 (0.41)	22 (0.41)	17 (0.31)	
MEAN(VELOCITY)	7.58	12.16	36.74	6.58	3.58	3.26	3.05	2.75	3.27	6.37	48.06	8.83	5.79	5.14	5.12	6.94	40.58
MAX VELOCITY	19.71	29.55	66.71	15.16	5.48	5.50	6.37	3.76	5.02	12.92	92.86	18.49	10.15	8.36	13.28	16.70	92.86
DIRECTION	9.	28.	44.	59.	82.	106.	129.	150.	182.	210.	227.	239.	260.	282.	323.	348.	227.
DATE	2/27 11: 0	2/21 8:40	3/ 2 11:55	3/ 2 15:30	3/ 2 15:50	3/ 9 2:45	3/ 9 3: 5	3/ 9 3:20	3/11 8:45	3/13 9: 0	2/26 21:30	3/ 4 18: 0	2/25 13:50	2/21 16:15	2/27 12: 0	2/23 11:35	2/26 21:30
**DIR(ONLY)	28 (0.61)	157 (3.21)	1196 (24.41)	50 (1.01)	12 (0.21)	19 (0.41)	14 (0.31)	11 (0.21)	20 (0.41)	49 (1.01)	3183 (65.01)	70 (1.41)	27 (0.61)	21 (0.41)	22 (0.41)	17 (0.31)	4896 100.00

SOKUIDKU KEISU(DIR.ONLY) 100.0% /KESSOKU 0 /SLACK 0 0.)

VECTOR MEAN
DIR. VEL. N-COMP E-COMP
231. 22.59 -14.08 -17.66

* TOTAL 4896

Table II-1-5-(17) Calculation results of frequency distribution of current direction and velocity for Seraya Area (7/10)

AREA : SINGAPORE
STATION NUMBER : TC1

SAMPLING PERIOD : 1981 2 26 13 0 - 1981 3 17 9 25

(RANGE)/(DIR.)	(N)	(NNE)	(NE)	(ENE)	(E)	(ESE)	(SE)	(SSE)	(S)	(SSW)	(SW)	(WSW)	(W)	(WNW)	(NW)	(NNW)	TOTAL
0. - 9.9	159 (2.9)	51 (0.9)	34 (0.6)	54 (1.0)	80 (1.5)	73 (1.3)	93 (1.7)	80 (1.5)	55 (1.0)	42 (0.8)	35 (0.6)	39 (0.7)	41 (0.8)	69 (1.3)	53 (1.0)	157 (2.9)	1115 20.5
10.0 - 19.9	87 (1.6)	4 (0.1)	0 (-)	0 (-)	8 (0.1)	56 (1.0)	202 (3.7)	235 (4.3)	55 (1.0)	14 (0.3)	21 (0.4)	0 (-)	1 (0.0)	24 (0.4)	268 (4.9)	524 (9.7)	1499 27.6
20.0 - 29.9	13 (0.2)	0 (-)	0 (-)	0 (-)	0 (-)	20 (0.4)	169 (3.1)	240 (4.4)	15 (0.3)	8 (0.1)	0 (-)	0 (-)	0 (-)	0 (-)	101 (1.9)	674 (12.4)	1240 22.8
30.0 - 39.9	6 (0.1)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	55 (1.0)	220 (4.1)	1 (0.0)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	5 (0.1)	447 (8.2)	732 13.5
40.0 - 49.9	1 (0.0)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	175 (3.2)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	373 (6.9)	549 10.1
50.0 - 59.9	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	148 (2.7)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	100 (1.8)	248 4.6
60.0 - 69.9	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	42 (0.8)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	5 (0.1)	47 0.9
70.0 - 79.9	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 0.
80.0 - 89.9	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 0.
90.0 - 99.9	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 0.
100.0 -	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 0.
* SUBTOTAL	264 (4.9)	55 (1.0)	34 (0.6)	54 (1.0)	88 (1.6)	149 (2.7)	519 (9.6)	1140 (21.0)	126 (2.3)	64 (1.2)	56 (1.0)	39 (0.7)	42 (0.8)	93 (1.7)	427 (7.9)	2280 (42.0)	
MEAN(VELOCITY)	10.18	4.83	3.77	4.09	5.75	10.85	18.44	31.84	11.46	10.20	8.13	5.40	6.21	7.90	16.37	28.09	23.24
MAX VELOCITY	40.12	12.66	7.55	9.87	15.94	25.08	37.21	64.68	32.90	22.11	15.72	8.78	11.00	14.96	34.83	60.65	64.68
DIRECTION	349.	12.	42.	77.	100.	123.	133.	152.	169.	192.	214.	252.	278.	300.	326.	343.	152.
DATE	3/ 8 12:10	2/26 15:25	2/26 15:40	3/ 1 11:40	3/ 1 11: 0	3/16 11:45	3/14 8:20	3/ 9 15:15	2/27 6:15	2/28 8:20	2/28 9:15	3/ 4 15:45	3/10 7:40	3/ 8 6:20	3/ 4 18: 0	3/10 12:45	3/ 9 15:15
**DIR(ONLY)	264 (4.9)	55 (1.0)	34 (0.6)	54 (1.0)	88 (1.6)	149 (2.7)	519 (9.6)	1140 (21.0)	126 (2.3)	64 (1.2)	56 (1.0)	39 (0.7)	42 (0.8)	93 (1.7)	427 (7.9)	2280 (42.0)	5430 100.00

SOKUTOKU RITSU(DIR.ONLY) 100.0% ,KESSOKU 0 ,SLACK 0 0. %

VECTOR MEAN	DIR.	VEL.	N-COMP	E-COMP
	345.	4.68	4.51	-1.25

* TOTAL 5430

Table II-1-5-(17) Calculation results of frequency distribution of current direction and velocity for Seraya Area (8/10)

AREA : SINGAPORE
STATION NUMBER : YC2

SAMPLING PERIOD : 1981 2 26 14 0 - 1981 3 17 11 5

(RANGE)/(DIR.)	(N)	(NNE)	(NE)	(ENE)	(E)	(ESE)	(SE)	(SSE)	(S)	(SSW)	(SW)	(WSW)	(W)	(WNW)	(NW)	(NNW)	TOTAL
0. - 9.9	2 (0.0)	2 (0.0)	3 (0.1)	3 (0.1)	14 (0.3)	119 (2.2)	154 (2.8)	46 (0.8)	32 (0.6)	23 (0.4)	32 (0.6)	112 (2.1)	240 (4.4)	85 (1.6)	10 (0.2)	3 (0.1)	880 16.2
10.0 - 19.9	0 (-)	0 (-)	0 (-)	0 (-)	2 (0.0)	237 (4.4)	69 (1.3)	1 (0.0)	0 (-)	0 (-)	0 (-)	13 (0.2)	455 (8.4)	318 (5.8)	0 (-)	0 (-)	1095 20.1
20.0 - 29.9	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	331 (6.1)	31 (0.6)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	81 (1.5)	495 (9.1)	0 (-)	0 (-)	938 17.2
30.0 - 39.9	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	341 (6.3)	14 (0.3)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	45 (0.8)	503 (9.2)	0 (-)	0 (-)	903 16.6
40.0 - 49.9	0 (-)	0 (-)	0 (-)	0 (-)	13 (0.2)	259 (4.8)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	9 (0.2)	418 (7.7)	0 (-)	0 (-)	699 12.9
50.0 - 59.9	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	163 (3.0)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	221 (4.1)	0 (-)	0 (-)	384 7.1
60.0 - 69.9	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	176 (3.2)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	176 3.2
70.0 - 79.9	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	145 (2.7)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	145 2.7
80.0 - 89.9	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	146 (2.7)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	146 2.7
90.0 - 99.9	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	62 (1.1)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	62 1.1
100.0 -	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	10 (0.2)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	10 0.2
* SUBTOTAL	2 (0.0)	2 (0.0)	3 (0.1)	3 (0.1)	29 (0.5)	1989 (36.6)	268 (4.9)	47 (0.9)	32 (0.6)	23 (0.4)	32 (0.6)	125 (2.3)	830 (15.3)	2040 (37.5)	10 (0.2)	3 (0.1)	
MEAN(VELOCITY)	0.58	1.51	0.97	1.92	22.21	43.51	11.72	5.94	2.74	2.76	2.98	5.68	14.37	32.30	3.27	1.99	31.14
MAX VELOCITY	0.63	1.53	1.54	3.27	44.22	103.43	34.81	10.56	6.69	4.69	5.80	12.68	42.23	55.97	7.17	3.07	103.43
DIRECTION	358.	24.	53.	64.	97.	114.	125.	147.	171.	196.	215.	238.	280.	286.	306.	328.	114.
DATE	3/16 22: 5	3/11 15: 0	3/ 4 11: 5	3/ 5 12:35	3/16 10:25	3/ 9 15:25	3/ 2 11:35	3/ 2 12:45	3/ 8 5:45	3/ 3 1:35	3/ 8 5:50	3/ 1 0:20	3/13 13:40	3/ 8 7:35	3/ 8 12:25	3/ 8 12:30	3/ 9 15:25
**DIR(ONLY)	2 (0.0)	2 (0.0)	3 (0.1)	3 (0.1)	29 (0.5)	1989 (36.6)	268 (4.9)	47 (0.9)	32 (0.6)	23 (0.4)	32 (0.6)	125 (2.3)	830 (15.3)	2040 (37.5)	10 (0.2)	3 (0.1)	5438 100.00

SOKUTOKU RITSU(DIR.ONLY) 100.0% ,KESSOKU 0 ,SLACK 0 0. %

VECTOR MEAN	DIR.	VEL.	N-COMP	E-COMP
	162.	3.61	-3.43	1.13

* TOTAL 5438

Table II-1-5-(17) Calculation results of frequency distribution of current direction and velocity for Seraya Area (9/10)

AREA : SINGAPORE
STATION NUMBER : TC3

SAMPLING PERIOD : 1981 2 26 16 0 - 1981 3 17 11 30

(RANGE)/(DIR.)	(N)	(NNE)	(NE)	(ENE)	(E)	(ESE)	(SE)	(SSE)	(S)	(SSW)	(SW)	(WSW)	(W)	(WNW)	(NW)	(NNW)	TOTAL
0. - 9.9	97 (1.8)	18 (0.3)	2 (0.0)	3 (0.1)	1 (0.0)	2 (0.0)	3 (0.1)	9 (0.2)	51 (0.9)	142 (2.6)	65 (1.2)	47 (0.9)	35 (0.6)	44 (0.8)	64 (1.2)	187 (3.5)	770 14.2
10.0 - 19.9	522 (9.6)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	1 (0.0)	11 (0.2)	268 (4.9)	120 (2.2)	10 (0.2)	0 (-)	0 (-)	2 (0.0)	11 (0.2)	132 (2.4)	1077 19.9
20.0 - 29.9	475 (8.8)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	3 (0.1)	305 (5.6)	23 (0.4)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	61 (1.1)	867 16.0
30.0 - 39.9	476 (8.8)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	1 (0.0)	314 (5.8)	3 (0.1)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	21 (0.4)	815 15.0
40.0 - 49.9	496 (9.1)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	183 (3.4)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	677 12.5
50.0 - 59.9	454 (8.4)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	171 (3.2)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	625 11.5
60.0 - 69.9	173 (3.2)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	149 (2.7)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	322 5.9
70.0 - 79.9	7 (0.1)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	167 (3.1)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	174 3.2
80.0 - 89.9	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	92 (1.7)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	92 1.7
90.0 - 99.9	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 0.
100.0 -	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 0.
* SUBTOTAL	2698 (49.8)	18 (0.3)	2 (0.0)	3 (0.1)	1 (0.0)	2 (0.0)	4 (0.1)	24 (0.4)	1700 (31.4)	288 (5.3)	75 (1.4)	47 (0.9)	35 (0.6)	46 (0.8)	75 (1.4)	401 (7.4)	
MEAN(VELOCITY)	35.64	4.62	3.65	2.50	3.76	3.55	7.20	13.82	41.48	11.20	6.01	4.36	4.26	4.37	6.02	12.70	32.63
MAX VELOCITY	71.54	8.42	4.83	3.83	3.76	4.94	10.12	30.78	89.56	32.19	13.74	9.50	9.36	10.48	15.43	37.30	89.56
DIRECTION	355.	12.	43.	66.	96.	120.	145.	168.	179.	193.	218.	242.	273.	297.	324.	348.	179.
DATE	3/ 9 11:25	3/ 2 13:25	3/ 2 13: 5	3/ 2 13: 0	3/ 2 12:55	3/ 2 12:50	3/ 2 12:35	3/13 18:30	3/ 9 15:25	3/ 8 1:20	3/ 9 1:35	3/ 4 23:20	3/ 5 23:40	3/ 5 23:35	3/ 5 23:25	3/ 6 22: 0	3/ 9 15:25
**DIR(ONLY)	2698 (49.8)	18 (0.3)	2 (0.0)	3 (0.1)	1 (0.0)	2 (0.0)	4 (0.1)	24 (0.4)	1700 (31.4)	288 (5.3)	75 (1.4)	47 (0.9)	35 (0.6)	46 (0.8)	75 (1.4)	401 (7.4)	5419 100.00

SOKUTOKU RITSU(DIR,ONLY) 100.0% ,KESSOKU 0 ,BLACK 0 0. %

VECTOR MEAN	DIR.	VEL.	N-COMP	E-COMP
	340.	5.30	4.97	-1.83

* TOTAL 5419

Table II-1-5-(17) Calculation results of frequency distribution of current direction and velocity for Seraya Area (10/10)

AREA : SINGAPORE
STATION NUMBER : TC4

SAMPLING PERIOD : 1981 2 27 13 0 - 1981 3 17 12 30

(RANGE)/(DIR.)	(N)	(NNE)	(NE)	(ENE)	(E)	(ESE)	(SE)	(SSE)	(S)	(SSW)	(SW)	(WSW)	(W)	(WNW)	(NW)	(NNW)	TOTAL
0. - 9.9	29	33	46	35	29	14	8	7	9	21	30	22	15	20	20	31	369
	(0.6)(	0.6)(	0.9)(	0.7)(	0.6)(	0.3)(	0.2)(	0.1)(	0.2)(	0.4)(	0.6)(	0.4)(	0.3)(	0.4)(	0.4)(	0.6)	7.1
10.0 - 19.9	39	16	13	36	99	68	22	21	56	43	33	74	119	86	136	127	988
	(0.8)(	0.3)(	0.3)(	0.7)(	1.9)(	1.3)(	0.4)(	0.4)(	1.1)(	0.8)(	0.6)(	1.4)(	2.3)(	1.7)(	2.6)(	2.5)	19.1
20.0 - 29.9	0	0	0	0	35	149	46	44	26	0	0	0	15	123	403	113	952
	(-)(	-)(	-)(	-)(	0.7)(	2.9)(	0.9)(	0.8)(	0.5)(	-)(	-)(	-)(	0.3)(	2.4)(	7.8)(	2.2)	18.4
30.0 - 39.9	0	0	0	0	0	147	57	42	0	0	0	0	0	74	723	55	1098
	(-)(	-)(	-)(	-)(	-)(	2.8)(	1.1)(	0.8)(	-)(	-)(	-)(	-)(	-)(	1.4)(	14.0)(	1.1)	21.2
40.0 - 49.9	0	0	0	0	0	103	75	16	0	0	0	0	0	33	389	15	631
	(-)(	-)(	-)(	-)(	-)(	2.0)(	1.4)(	0.3)(	-)(	-)(	-)(	-)(	-)(	0.6)(	7.5)(	0.3)	12.2
50.0 - 59.9	0	0	0	0	0	71	73	0	0	0	0	0	0	0	374	0	518
	(-)(	-)(	-)(	-)(	-)(	1.4)(	1.4)(	-)(	-)(	-)(	-)(	-)(	-)(	-)(	7.2)(	-)	10.0
60.0 - 69.9	0	0	0	0	0	34	127	0	0	0	0	0	0	0	192	0	353
	(-)(	-)(	-)(	-)(	-)(	0.7)(	2.5)(	-)(	-)(	-)(	-)(	-)(	-)(	-)(	3.7)(	-)	6.8
70.0 - 79.9	0	0	0	0	0	31	130	0	0	0	0	0	0	0	20	0	181
	(-)(	-)(	-)(	-)(	-)(	0.6)(	2.5)(	-)(	-)(	-)(	-)(	-)(	-)(	-)(	0.4)(	-)	3.5
80.0 - 87.9	0	0	0	0	0	1	88	0	0	0	0	0	0	0	0	0	89
	(-)(	-)(	-)(	-)(	-)(	0.0)(	1.7)(	-)(	-)(	-)(	-)(	-)(	-)(	-)(	-)(	-)	1.7
90.0 - 99.9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	(-)(	-)(	-)(	-)(	-)(	-)(	-)(	-)(	-)(	-)(	-)(	-)(	-)(	-)(	-)(	-)	0.
100.0 -	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	(-)(	-)(	-)(	-)(	-)(	-)(	-)(	-)(	-)(	-)(	-)(	-)(	-)(	-)(	-)(	-)	0.
* SUBTOTAL	68	49	59	71	163	618	626	130	89	64	63	96	149	336	2257	341	
	(1.3)(	0.9)(	1.1)(	1.4)(	3.1)(	11.9)(	12.1)(	2.5)(	1.7)(	1.2)(	1.2)(	1.9)(	2.9)(	6.5)(	43.6)(	6.6)	
MEAN(VELOCITY)	10.17	8.35	7.83	9.86	15.54	37.04	5A-32	27.86	16.12	11.78	10.47	11.62	14.83	25.62	39.51	21.67	34.60
MAX VELOCITY	17.15	11.50	12.89	16.57	27.55	80.19	89.75	48.05	24.37	16.19	14.93	16.24	26.50	48.90	76.76	47.00	89.75
DIRECTION	351.	16.	45.	79.	101.	124.	127.	147.	167.	204.	223.	256.	280.	303.	311.	327.	127.
DATE	3/12	3/11	3/11	3/10	3/ 8	3/ 6	3/ 8	3/ 8	3/13	3/14	3/14	3/14	3/ 1	3/ 3	3/ 9	3/11	3/ 8
	9:15	20:30	20:20	19:25	17:55	14:40	15:20	2:10	19:25	21: 5	20:15	19:35	20:25	21: 0	10:55	10:30	15:20
**DIR(ONLY)	68	49	59	71	163	618	626	130	89	64	63	96	149	336	2257	341	5179
	(1.3)(	0.9)(	1.1)(	1.4)(	3.1)(	11.9)(	12.1)(	2.5)(	1.7)(	1.2)(	1.2)(	1.9)(	2.9)(	6.5)(	43.6)(	6.6)	100.00

SOKUTOKU RITSU(DIR.ONLY) 100.0% ,KESSOKU .0 ,SLACK 0 0. %

VECTOR MEAN

DIR.	VEL.	N-COMP	E-COMP
323.	8.16	6.47	-4.96

* TOTAL 5179

(2) As same with the previous paragraph (1), the scattering plots are given in which 1 hour running mean of current direction and velocity of the survey period is plotted on the direction coordinates. From this, it can be seen what velocity values are distributing in the each directions.

The plottig is performed for each survey point and those scattering plots are replaced on the survey map which makes the horizontal distribution map. These figures are shown in later paragraph, II-1-7 typical pattern of survey areas.

(3) Current condition chart based on the results of harmonic analysis of tidal current

By the harmonic analysis of the tidal current, the major dominant constituents of the survey area can be obtained. The dominant constituent can be considered as the typical current of the survey area.

The processes of compiling curret conditions map are (1) to draw or replace the current ellipse on the survey point chart, and (2) to express with vectors on the survey points chart. From the above (1) and (2), the current patterns can be obtained. And by the constant current map (mean current of the total survey duration), the averaged current pattern can be obtained. These figures are also described in later paragraph, II-1-7.

(4) Current condition chart based on the vector time series is compiled which shows the variation of spatial pattern of lower frequency fluctuation components of tide.

The process for compiling the current condition map of vector time series is to select the current pattern which is the highest in appearance frequency from the current condition map of vectors after removing the tidal components by 25 hours running mean after cutting the component of less than 1 day.

In this study conducted in the Republic of Singapore, the current condition map has not been compiled as the component of the tidal current is dominant.

However, as for the current condition of the survey period related to the water temperature, salinity and water quality, the current condition map has been compiled based on the current velocity vector of 1 hour running mean in order to examine the detailed current pattern. The figure is described in the later paragraph, II-4 Temperature Survey.

II-1-6 Analysed Results of Past Survey Data

II-1-6-1 Current survey around Pulau Ayer Merbau

The survey has been conducted for the purpose of environmental impact assessment prior to the construction of petrochemical complex on Pulau Ayer Merbau (the island near to Pulau Seraya).

The survey area was the surrounding sea areas of Pulau Ayer Merbau and the survey has been conducted in August 1979. Table II-1-6-(1) shows the scope of the survey and Fig. II-1-6-(1) shows the survey point chart, and Fig. II-1-6-(2) shows the survey methods.

Table II-1-6-(1) Scope of current survey at surrounding area of Pulau Ayer Merbau

Survey Items	Survey point	Layers	Peiod	Methods
(1) 15 day current meter observation	St1-St5 (CM1-CM5)	-3m from low tide level	Aug. 7 – 25, 1979	CT/3 current meter Observation by Δt 30 minutes
(2) 12-hour current meter observation	St6 (CM6)	-0.5m depth x 1/2 bottom + 1m	Aug. 8, 16, 23, 1979	ENDECO type 110 current meter Observation by hanging down current meter

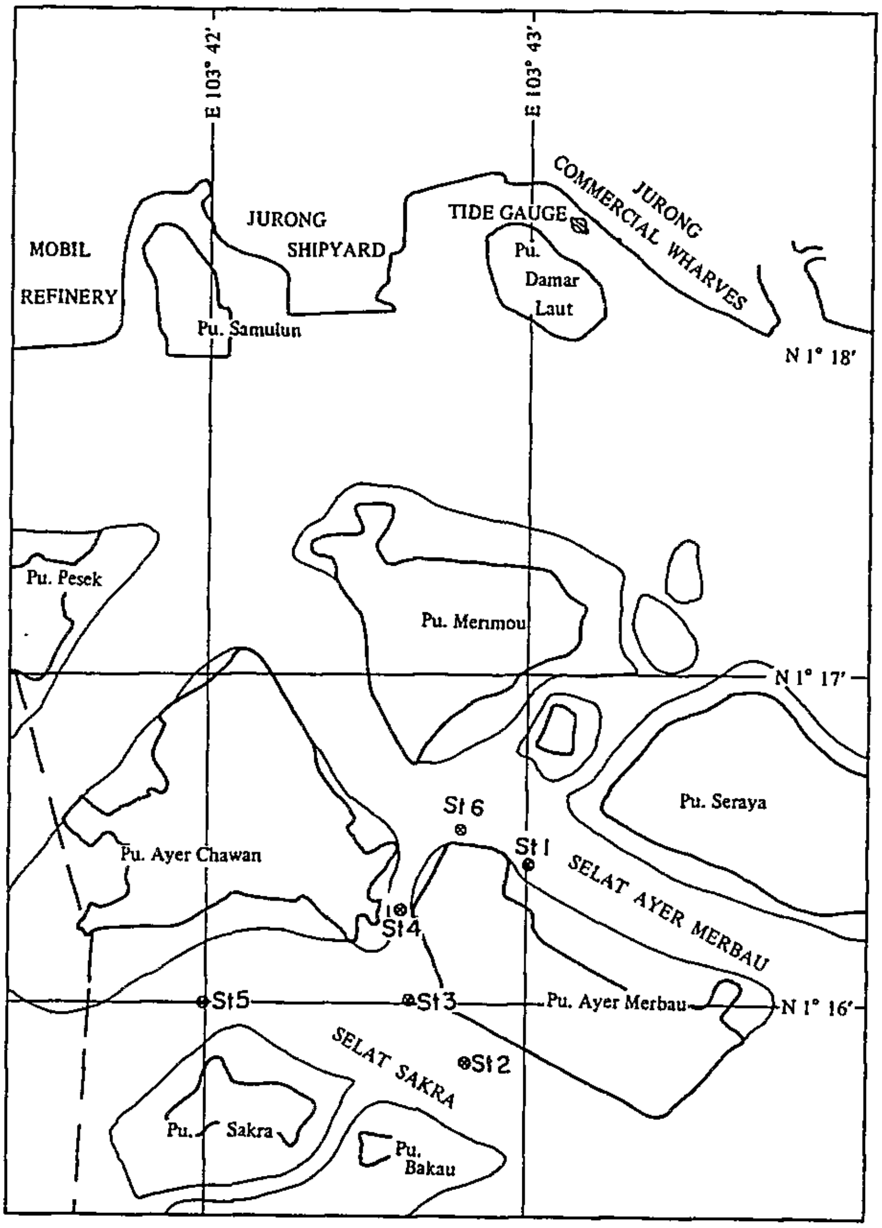
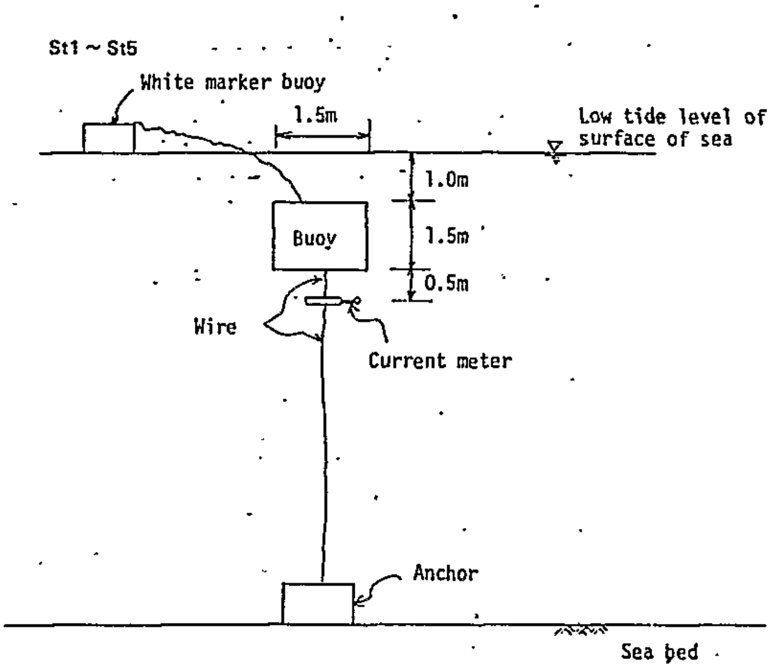


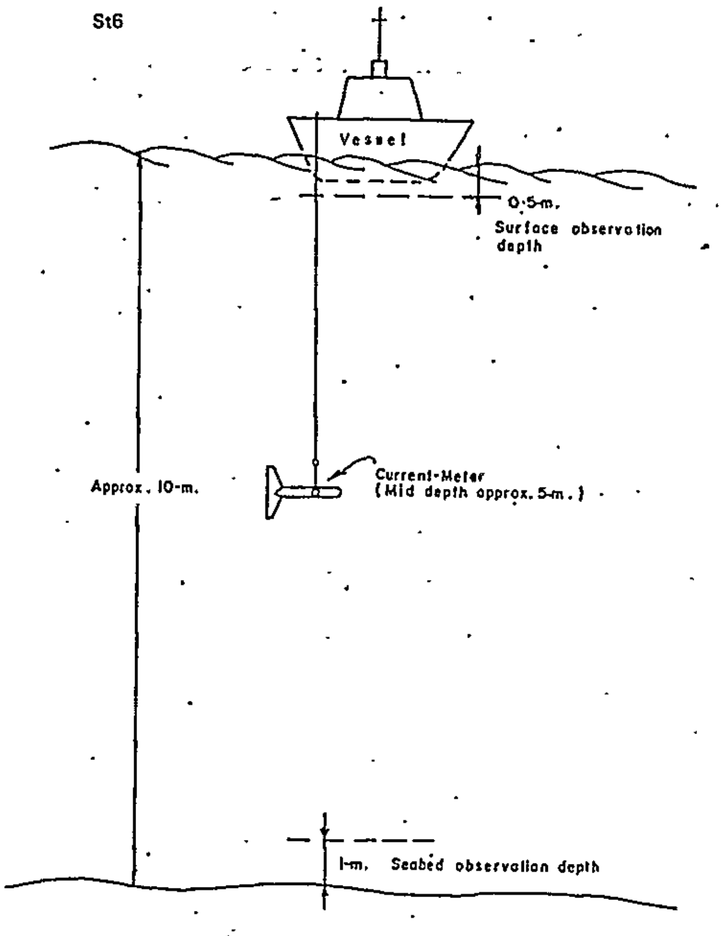
Fig. II-1-6-(1) Survey point chart of current survey at Pulau Ayer Merbau Area

Table II-1-6-(1) Location table of survey points

St1 (CM1)	01°16'30"N	103°43'00"E
St2 (CM2)	01°16'00"N	103°42'50"E
St3 (CM3)	01°16'00"N	103°42'40"E
St4 (CM4)	01°16'20"N	103°42'40"E
St5 (CM5)	01°16'00"N	103°42'00"E
St6 (CM6)	01°16'40"N	103°42'50"E



(1) Sketch of the Setting Condition of Current Meter



(2) Deployment of Equipment in 12-Hour Current Observ

Fig. II-1-6-(2) Survey methods of current survey at Pulau Ayer Merbau Area

1) Time series plots of current direction and velocity

The time series plots of current direction and velocity are shown in Fig. II-1-6-(3).

At the survey points, St1, 2 and 5, the velocity is fast and 1 day cycle period is observed.

2) Time series plots of current velocity components

The time series plots of velocity component are shown in Figs. II-1-6-(4) and II-1-6-(5).

At all the survey points, the clear oscillation with about 1 day period are seen. The current pattern is same with the results of Seraya Area which is described in the previous paragraph.

3) Vector time series

The vector time series are shown in Fig. II-1-6-(6). At all the survey points, it is recognized that the duration of slack water is short and the current direction turns within short time by 180°.

Fig. II-1-6-(7) shows the general current conditions of all survey points which extracted from the vector diagram.

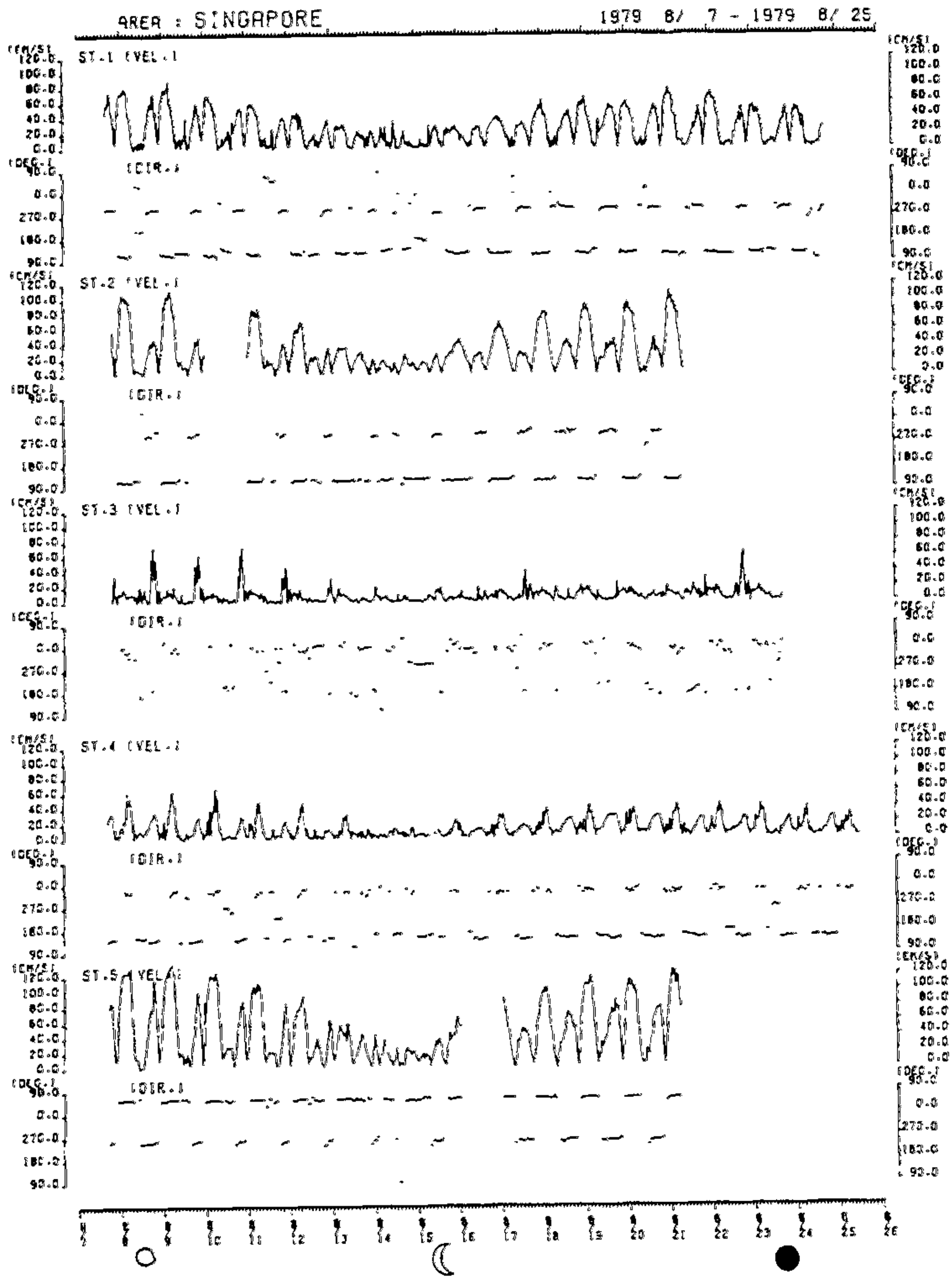


Fig. II-1-6-(3) Time series of current direction and velocity of Pulau Ayer Merbau

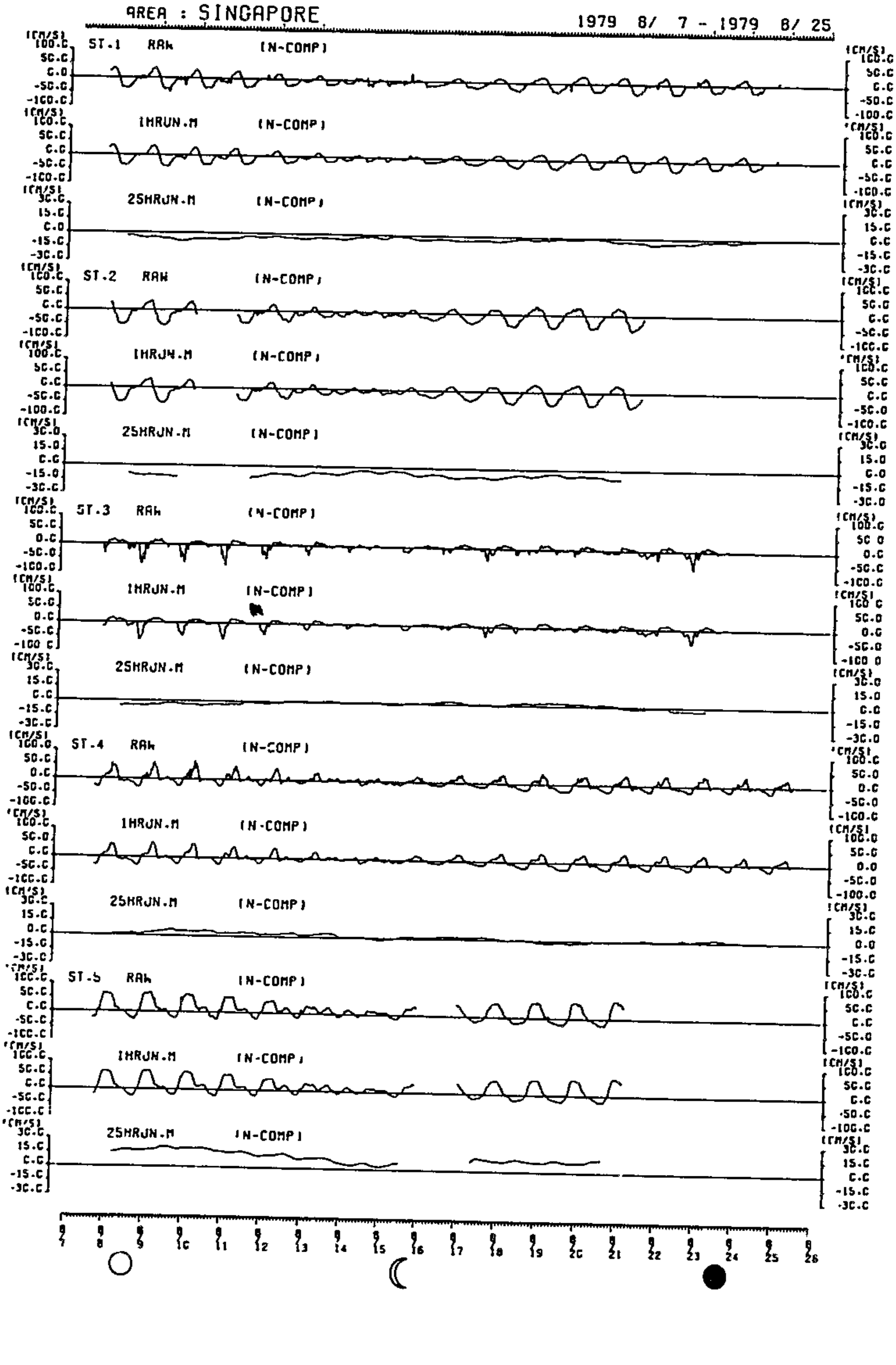


Fig. II-1-6-(4) Time series component current (N-comp.) of Pulau Ayer Merbau

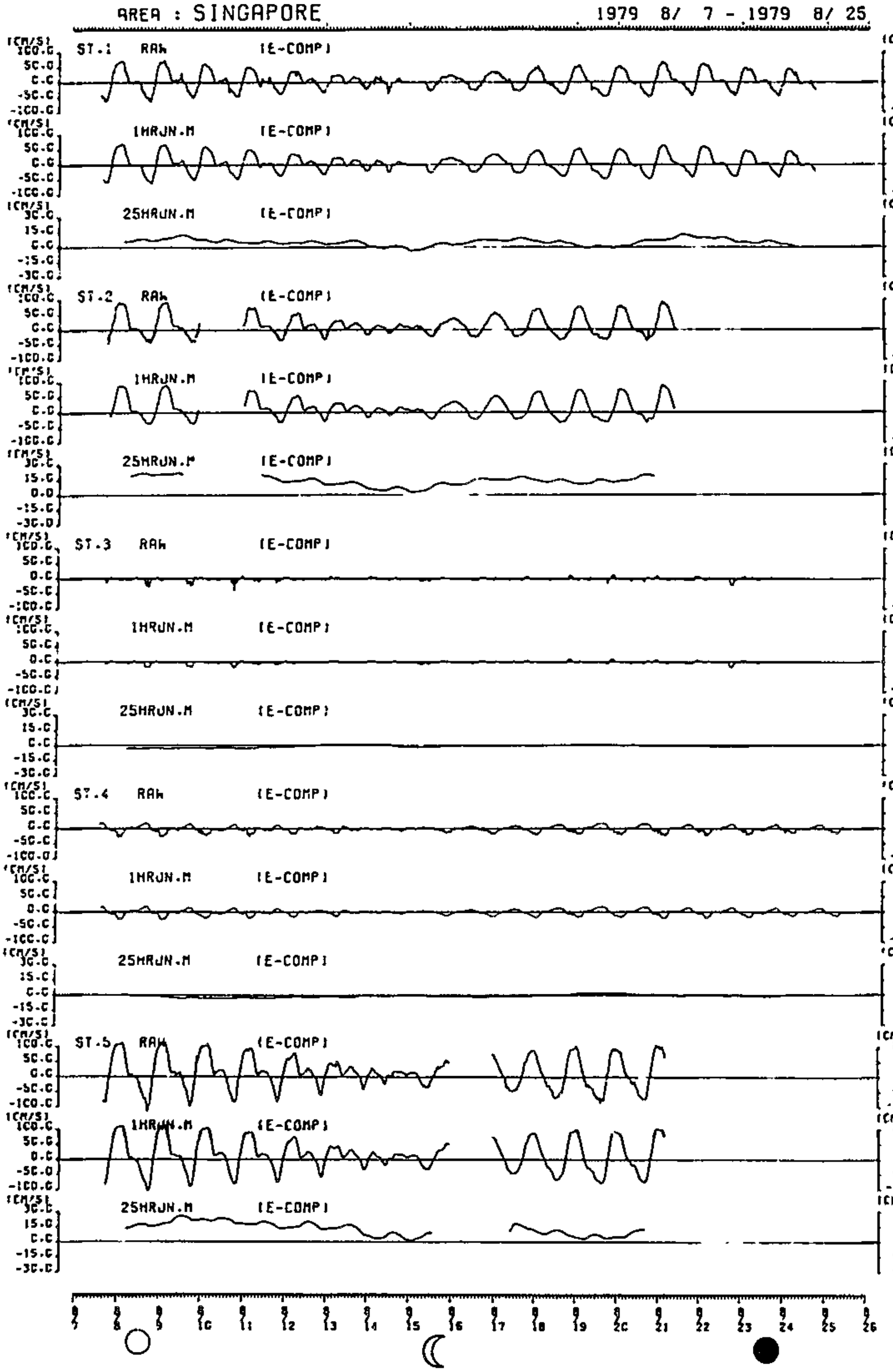


Fig. II-1-6-(5) Time series of component current (E-comp.) of Pulau Ayer Merbau

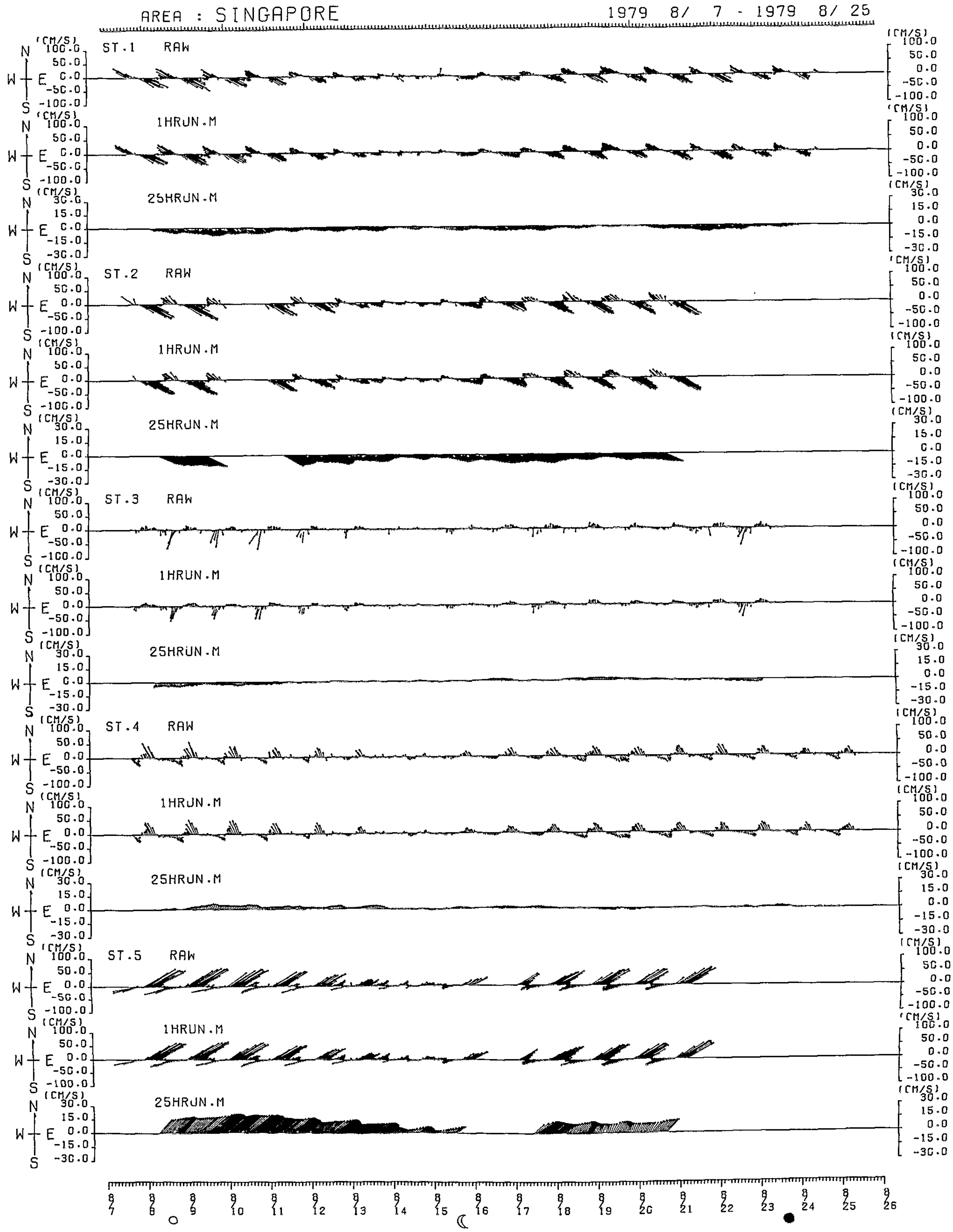


Fig. II-1-6-(6) Time series of tidal current vectors of Pulau Ayer Merbau

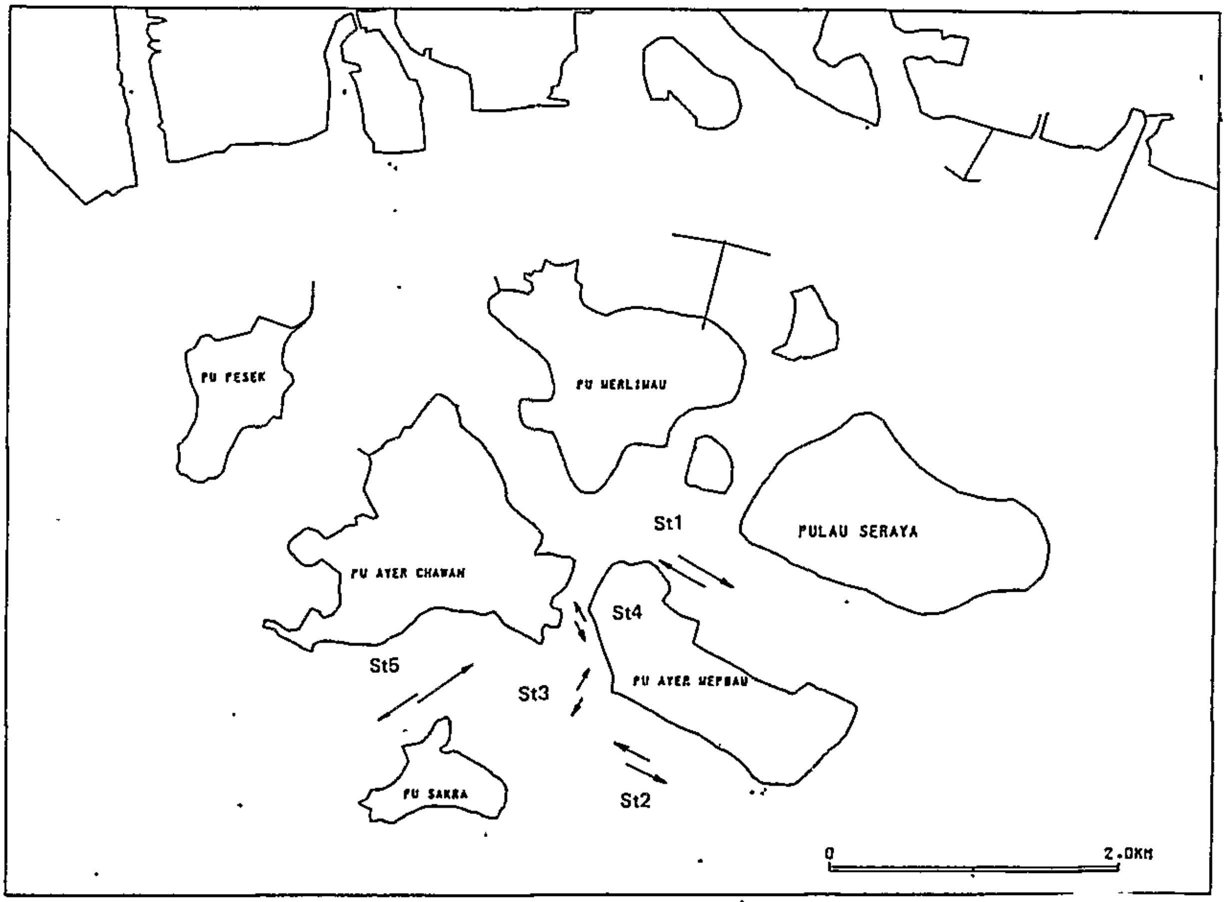


Fig. II-1-6-(7) Current fluctuation of Pulau Ayer Merbau Area

4) Harmonic analysis of tidal current

Table II-1-6-(2) shows the results of harmonic analysis. From this table, the most dominant tidal constituent and the next dominant constituent of all the survey points are extracted, and shown in Table II-1-6-(3).

Table II-1-6-(3) List of dominant tidal current constituents at all survey points near Pulau Ayer Merbau

Survey point	The First Dominant N-comp.	Component Current E-comp.	The Second Dominant N-comp.	Comp. Current E-comp
St 1	O_1 (10.35)	M_2 (2.56)	K_1 (8.13)	O_1 (2.05)
St 2	O_1 (14.11)	O_2 (8.36)	K_1 (12.95)	K_1 (7.57)
St 3	K_1 (14.15)	K_1 (26.16)	O_1 (13.28)	O_1 (24.80)
St 4	K_1 (21.58)	K_1 (33.70)	O_1 (18.54)	O_1 (29.49)
St 5	K_1 (23.87)	K_1 (47.03)	O_1 (21.39)	O_1 (46.79)

From the above table, at all the survey points (except St1 E-comp) K_1 and O_1 constituents are dominant and these current are called as diurnal tidal current.

The same results are found in the current survey conducted at around Pulau Seraya. Fig. II-1-6-(8) shows the current ellipIse.

Table II-1-6-(2) Results of harmonic analysis of Tidal current of Pulau Ayer Merbau (1/3)

St–1	Position		Lat. 1°16'30"N Long. 103°43'00"E		From : To		Aug. 8 1979 00:00 Aug. 23 1979 00:00			Observation Layer		– 3 m
Constituents	N-Comp.		E-Comp.		Elements of Ellipse						Main Dir.	
					Major Axis			Minor Axis				
	V (cm/s)	S (°)	V (cm/s)	S (°)	Dir. (°)	V (cm/s)	*k* (°)	Dir. (°)	V (cm/s)	*k* (°)	V (cm/s)	*k* (°)
K_1	14.15	59	26.16	239	298	29.74	59	28	0.03	149	29.74	59
O_1	13.28	25	24.80	204	298	28.13	24	28	0.30	114	28.13	24
Q_1	2.69	339	5.22	170	117	5.86	167	27	0.45	257	5.85	347
M_2	9.55	200	16.62	23	119	19.16	22	29	0.46	112	19.16	202
S_2	4.20	206	7.88	30	118	8.93	29	28	0.24	119	8.93	209
N_2	1.76	262	2.33	83	127	2.92	83	37	0.02	173	2.89	263
M_4	1.08	96	1.34	280	308	1.72	99	218	0.05	189	1.70	99
MS_4	0.86	102	1.58	294	298	1.80	111	208	0.15	201	1.80	111
K_2	1.14	206	2.14	30	118	2.42	29	28	0.06	119	2.42	209
P_1	4.68	59	8.66	239	298	9.84	59	28	0.01	149	9.84	59
V_0	–3.72 cm/s		5.49 cm/s			6.64 cm/s			124°		–6.61 cm/s 298°	

Table II-1-6-(2) Results of harmonic analysis of Tidal current of Pulau Ayer Merbau (2/3)

St-2	Position		From : To		Observation Layer
	Lat.	1°16'00"N	Aug. 7 1979	20:00	- 3 m
	Long.	103°42'50"E	Aug. 21 1979	07:30	

Constituents	N-Comp.		E-Comp.		Elements of Ellipse: Major Axis			Elements of Ellipse: Minor Axis			Main Dir.	
	V (cm/s)	k (°)	V (cm/s)	k (°)	Dir. (°)	V (cm/s)	k (°)	Dir. (°)	V (cm/s)	k (°)	V (cm/s)	k (°)
K_1	21.58	63	33.70	239	302	40.00	60	32	1.26	150	40.00	60
O_1	18.54	28	29.49	198	302	34.74	21	32	2.55	111	34.74	21
Q_1	4.92	338	8.77	174	118	9.99	170	28	1.14	260	9.97	350
M_2	9.12	208	12.68	38	125	15.56	35	35	1.29	125	15.54	215
S_2	4.85	220	8.80	47	118	10.03	45	28	0.53	135	10.01	225
N_2	1.52	277	1.39	41	139	1.82	73	229	0.96	163	1.76	243
M_4	0.99	86	0.80	278	320	1.27	91	230	0.13	181	1.20	93
MS_4	1.60	133	2.16	320	306	2.68	137	216	0.14	227	2.68	137
K_2	1.32	220	2.39	47	118	2.73	45	28	0.14	135	2.72	225
P_1	7.14	63	11.15	239	302	13.24	60	32	0.41	150	13.24	60
V_0	−7.91 cm/s		14.80 cm/s			16.78 cm/s			118°		−16.72 cm/s 302°	

St-3	Position		From : To		Observation Layer
	Lat.	1°16'30"N	Aug. 8 1981	00:00	- 3 m
	Long	103°42'40"E	Aug 23 1981	00:00	

Constituents	N-Comp.		E-Comp.		Elements of Ellipse: Major Axis			Elements of Ellipse: Minor Axis			Main Dir.	
	V (cm/s)	k (°)	V (cm/s)	k (°)	Dir. (°)	V (cm/s)	k (°)	Dir. (°)	V (cm/s)	k (°)	V (cm/s)	k (°)
K_1	8.13	249	0.87	223	185	8.17	69	95	0.37	159	8.08	69
O_1	10.25	191	2.05	185	191	10.45	11	101	0.22	101	10.44	11
Q_1	3.44	247	0.89	301	189	3.48	69	279	0.70	159	3.47	70
M_2	5.20	356	2.56	325	204	5.67	171	114	1.22	261	5.59	173
S_2	2.35	25	1.07	341	19	2.48	20	289	0.71	110	2.47	201
N_2	3.32	20	0.95	53	13	3.42	22	103	0.50	112	3.42	202
M_4	0.56	142	0.70	225	254	0.71	33	344	0.55	123	0.59	339
MS_4	0.86	240	0.50	219	209	0.98	55	119	0.16	145	0.95	57
K_2	0.63	25	0.29	341	19	0.67	20	289	0.19	110	0.67	201
P_1	2.69	249	0.29	223	185	2.70	69	95	0.12	159	2.67	69
V_0	−0.46 cm/s		−0.76 cm/s			0.89 cm/s			238°		0.63 cm/s 193°	

Table II-1-6-(2) Results of harmonic analysis of Tidal current of Pulau Ayer Merbau (3/3)

St-4	Position				From : To						Observation Layer	
	Lat. 1°16'20"N Long. 103°42'40"E				Aug. 8 1979 00:00 Aug. 23 1979 00:00						- 3 m	
Constituents	N-Comp.		E-Comp.		Elements of Ellipse						Main Dir.	
					Major Axis			Minor Axis				
	V (cm/s)	k (°)	V (cm/s)	k (°)	Dir. (°)	V (cm/s)	k (°)	Dir. (°)	V (cm/s)	k (°)	V (cm/s)	k (°)
K_1	12.95	236	7.57	58	149	15.00	57	59	0.13	147	9.71	56
O_1	14.11	201	8.36	32	149	16.35	24	59	1.31	114	10.61	19
Q_1	2.36	178	0.88	327	341	2.48	175	71	0.43	265	1.98	3
M_2	6.32	56	3.52	218	331	7.18	52	61	0.93	142	4.87	240
S_2	2.72	74	1.30	235	335	2.99	71	65	0.38	161	2.16	258
N_2	1.83	110	1.18	266	328	2.14	103	58	0.40	193	1.38	297
M_4	3.55	239	1.43	43	158	3.81	57	248	0.36	147	2.90	62
MS_4	3.02	264	1.27	67	157	3.26	82	247	0.35	172	2.45	87
K_2	0.74	74	0.35	235	335	0.81	71	65	0.10	161	0.58	258
P_1	4.28	236	2.50	58	149	4.96	57	59	0.04	147	3.21	56
V_0	1.66 cm/s		-0.56 cm/s			1.75 cm/s			341°		-1.38 cm/s 199°	

St-5	Position				From : To						Observation Layer	
	Lat. 1°16'40"N Long. 103°42'50"E				Aug. 7 1979 18:00 Aug. 21 1979 04:30						- 3 m	
Constituents	N-Comp		E-Comp.		Elements of Ellipse						Main Dir.	
					Major Axis			Minor Axis				
	V (cm/s)	k (°)	V (cm/s)	k (°)	Dir. (°)	V (cm/s)	k (°)	Dir. (°)	V (cm/s)	k (°)	V (cm/s)	k (°)
K_1	23.87	225	47.03	233	243	52.67	51	333	2.76	141	52.65	52
O_1	21.39	191	46.79	200	245	51.37	19	335	2.85	109	51.36	18
Q_1	6.10	160	10.75	158	60	12.37	158	330	0.19	248	12.33	338
M_2	8.88	25	20.76	10	67	22.48	12	337	2.15	102	22.46	193
S_2	5.36	29	10.20	22	62	11.51	24	332	0.58	114	11.50	203
N_2	1.08	351	4.37	34	79	4.45	33	169	0.72	123	4.31	210
M_4	1.70	299	3.68	229	258	3.74	54	168	1.57	144	3.65	60
MS_4	1.64	284	4.08	263	249	4.36	86	159	0.54	176	4.35	87
K_2	1.45	29	2.77	22	62	3.13	24	332	0.15	114	3.12	203
P_1	7.90	225	15.57	233	243	17.43	51	333	0.91	141	17.42	52
V_0	13.19 cm/s		13.66 cm/s			18.99 cm/s			46°		-17.96 cm/s 245°	

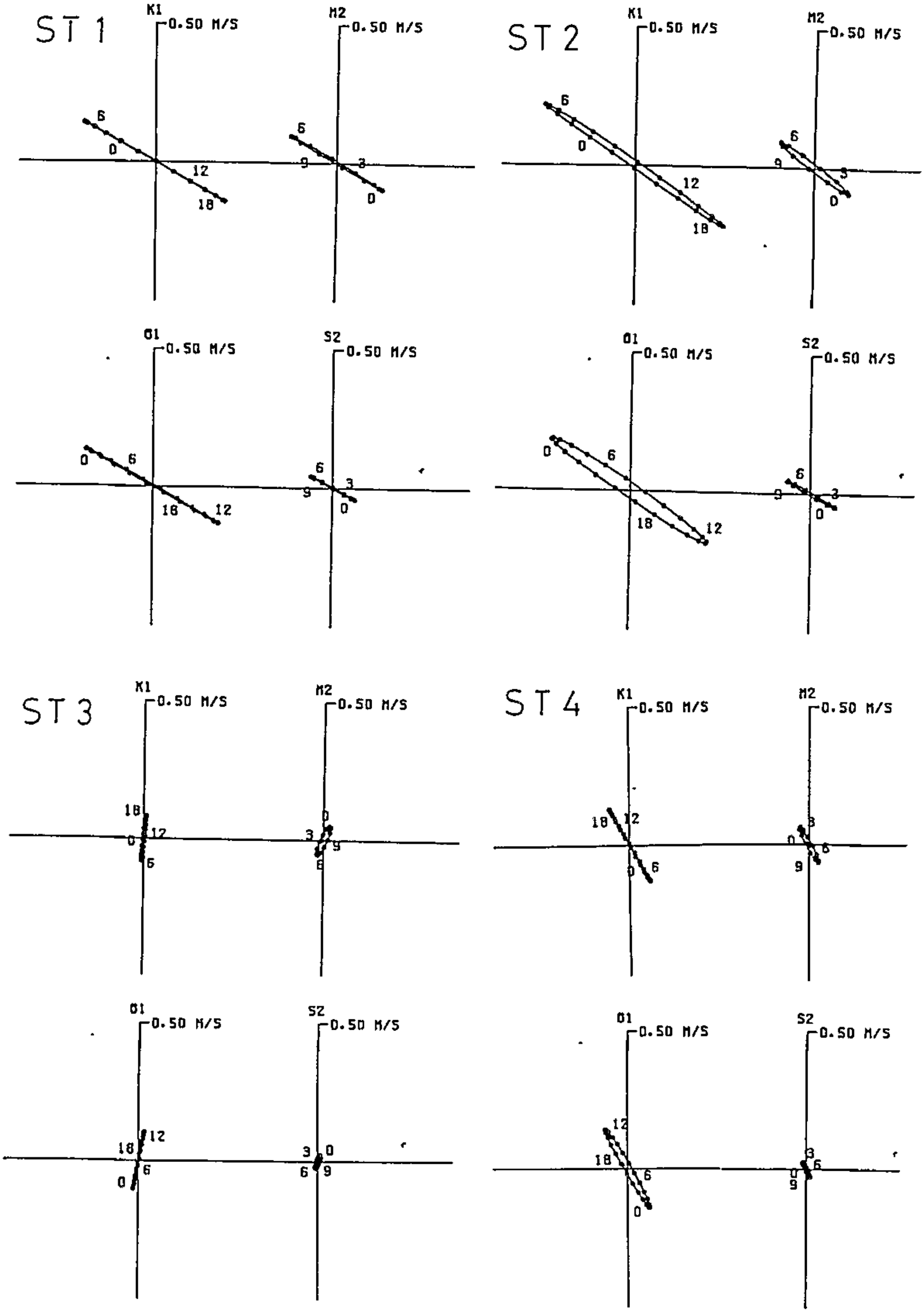


Fig. II-1-6-(8) Current ellipse of current survey at Pulau Ayer Merbau (1)

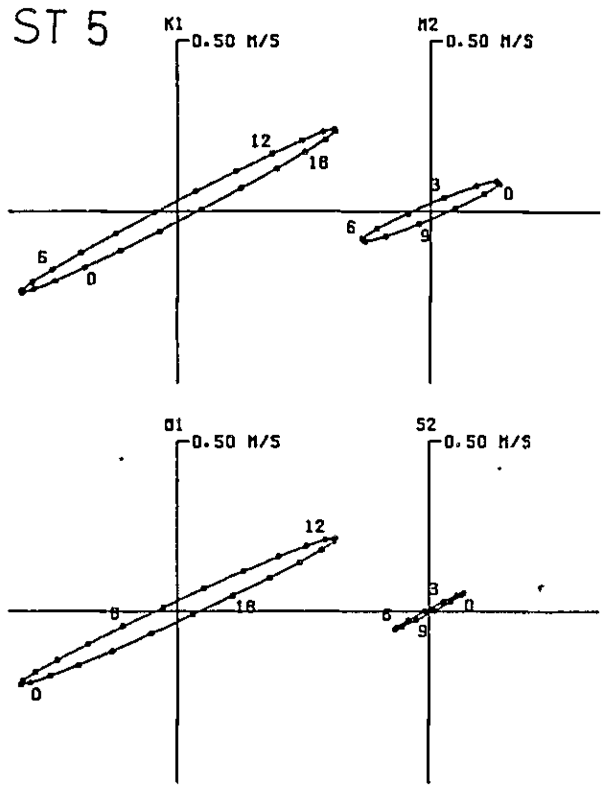


Fig. II-1-6-(8) Current ellipse of current survey at Pulau Ayer Merbau (2)

5) Mean velocity and standard deviation

Table II-1-6-(4) shows the statistics of current fluctuation.

Table II-1-6-(4) Statistics of current fluctuation of current survey at Pulau Ayer Merbau

Station	Average	Velocity (cm/sec)	Standard	Deviation (cm/s)	Dominant	Period (hour)
	N-comp	E-comp.	N-comp	E-comp.	N-comp.	E-comp.
St 1	-3.5	5.3	15.6	28.3	24.74 12.48	24.74 12.30
St 2	-8.3	15.0	19.1	29.6	25.09 12.13	24.74 12.30
St 3	-0.2	-0.7	11.1	3.5	25.09 12.66	24.04 12.48
St 4	1.7	-0.6	14.7	8.5	24.74 12.30	24.74 12.30
St 5	14.3	16.6	22.7	46.9	24.74 12.30	25.09 12.48

Fig. II-1-6-(9) shows the average velocity pattern at survey points based on N-comp. and E-comp. of the above table.

From this diagram, it is found that the sea area of Pulau Ayer Merbau is mainly covered by the eastward current when the current survey conducted in August 1979. This is quite opposite results compared with the results of the current survey conducted at Pulau Seraya Area. For the reasons of this difference, it will be described in the later paragraph, II-1-7.

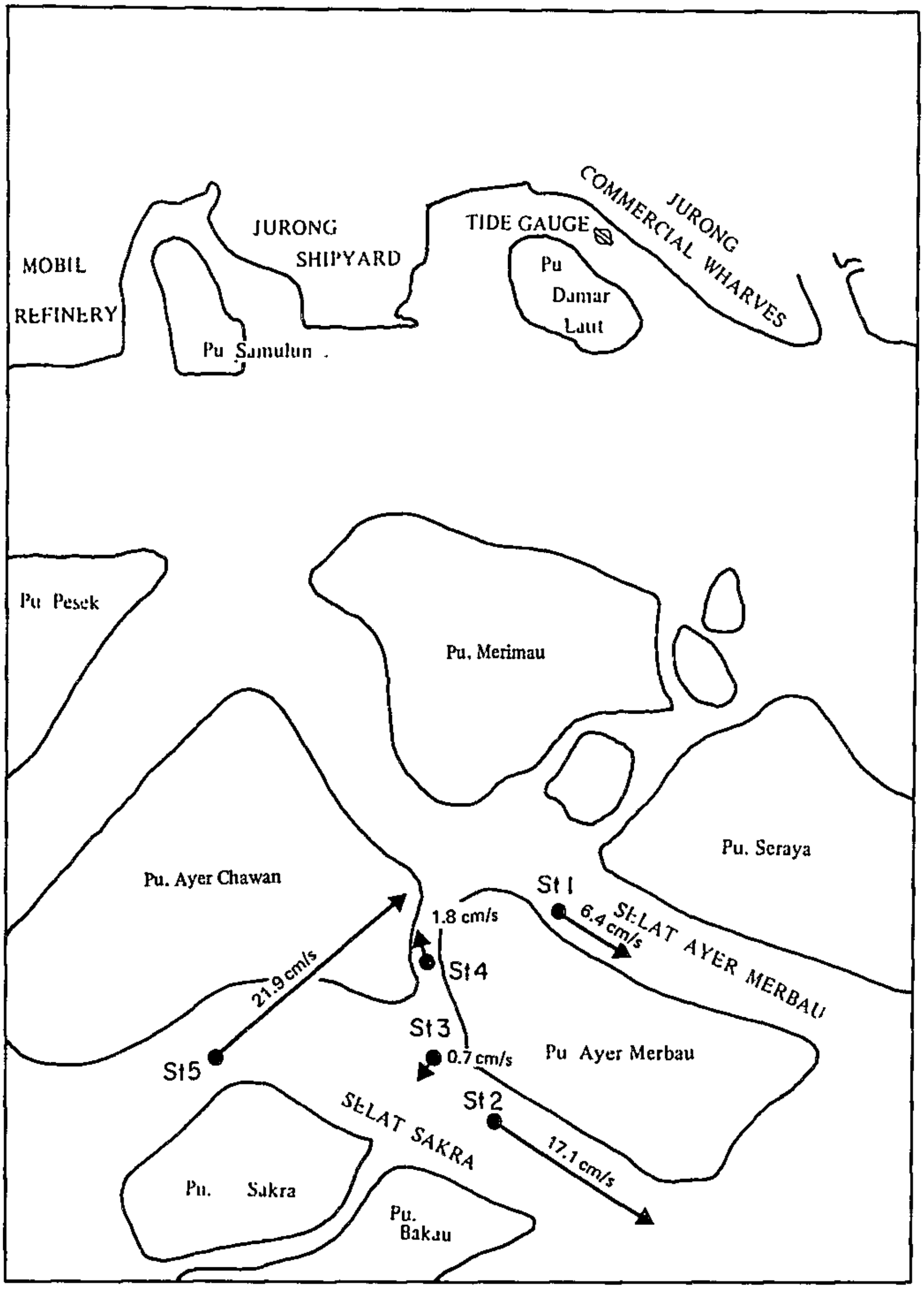


Fig. II-1-6-(9) Mean current of Pulau Ayer Merbau Area (August 1979)

6) Power spectrum

Fig. II-1-6-(10) shows the results of power spectrum. The detailed dominant frequency at all the survey points are shown in Table II-1-6-(4). From these, the fluctuation with about 1 day period is found dominant.

7) Auto correlation

Fig. II-1-6-(11) shows the results of auto correlation. From this figure, it is recognized that the oscillation of about 1 day period is dominant on the time domain at all survey points.

8) Frequency distribution of current direction and velocity

Fig. II-1-6-(12) shows the frequency distribution of the current direction and velocity.

As for the velocity distribution, the differences among survey points are observed, and the velocity around 0-20.0 cm/sec are the most often in frequency at St3 and St4.

As for the current direction, it is distributed as directed to the coastal line, which is clear from Fig. II-1-6-(6).

9) Current condition chart based on the results of scattering plots and harmonic analysis of tidal current

For these, it is described in the later paragraph, II-1-7.

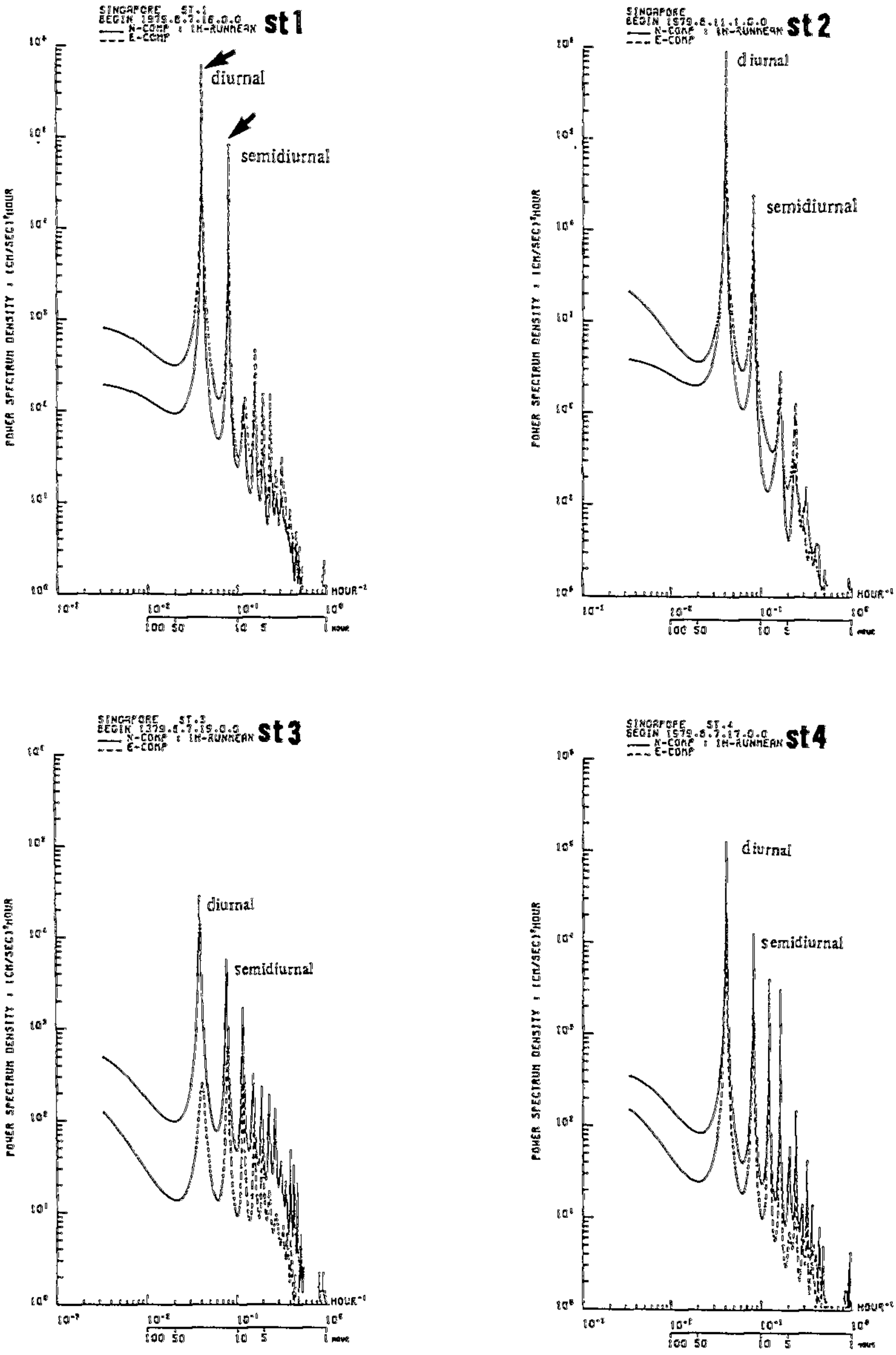


Fig. II-1-6-(10) Power spectrum of current survey at Pulau Ayer Merbau Area (1)

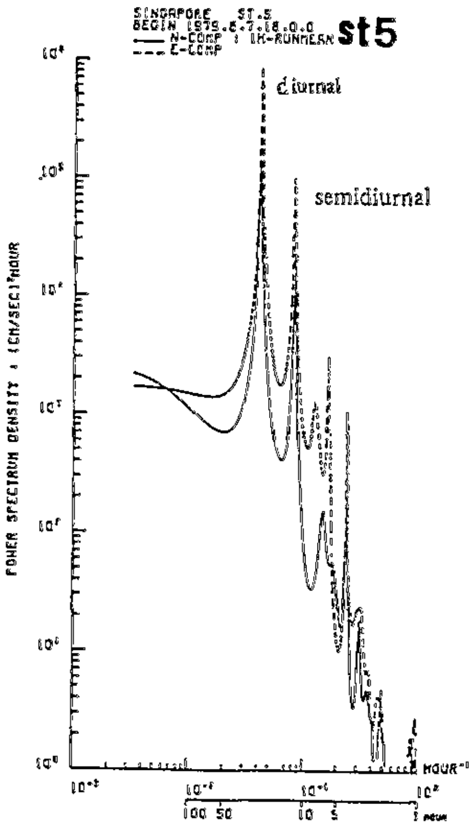
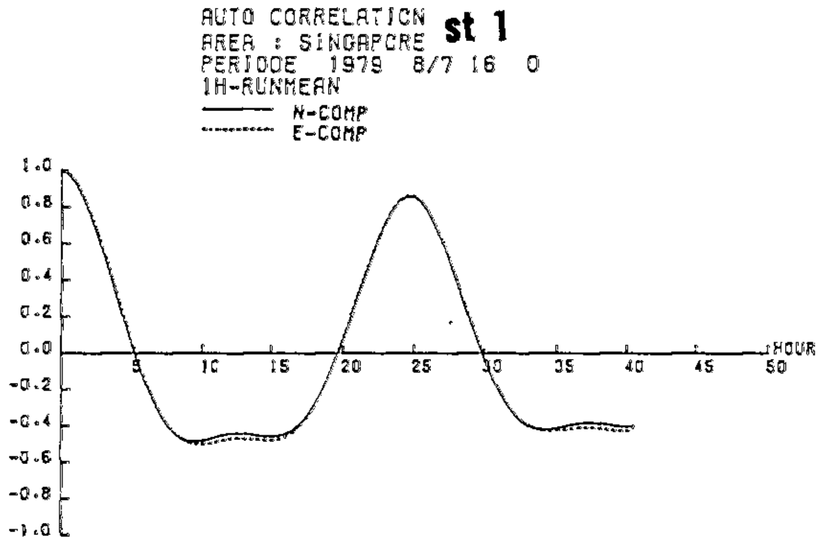
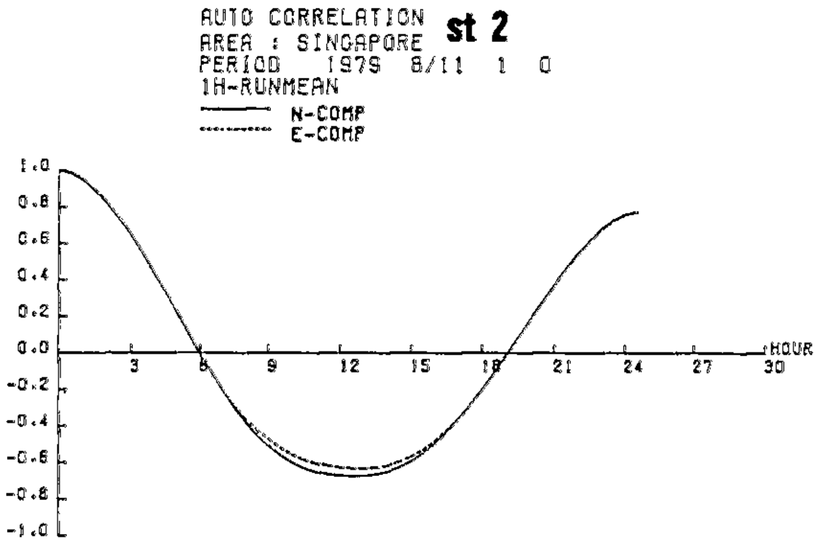


Fig. II-1-6-(10) Power spectrum of current survey at Pulau Ayer Merbau Area (2)





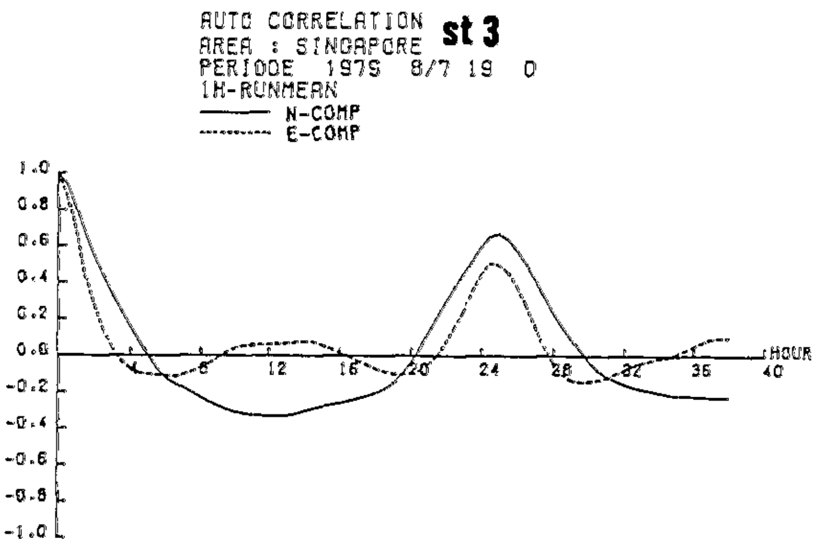
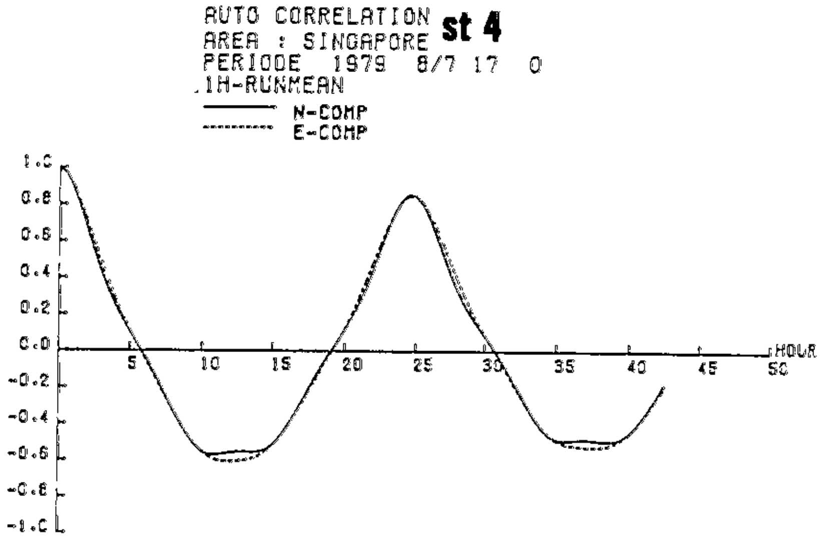


Fig. II-1-6-(11) Auto correlogram for Merbau Area (1)



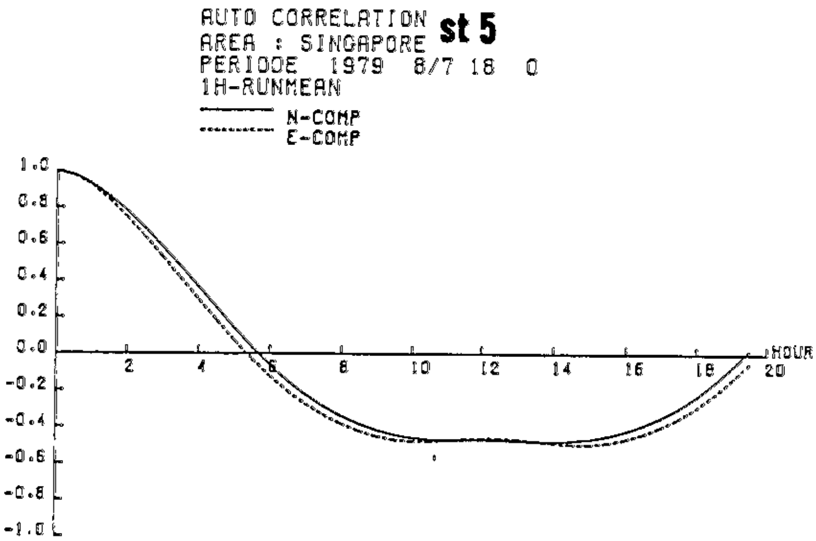
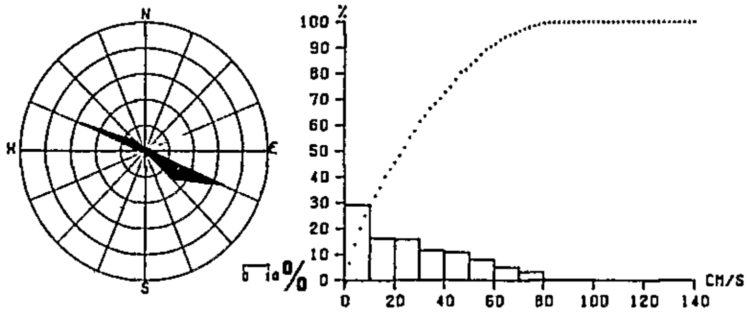
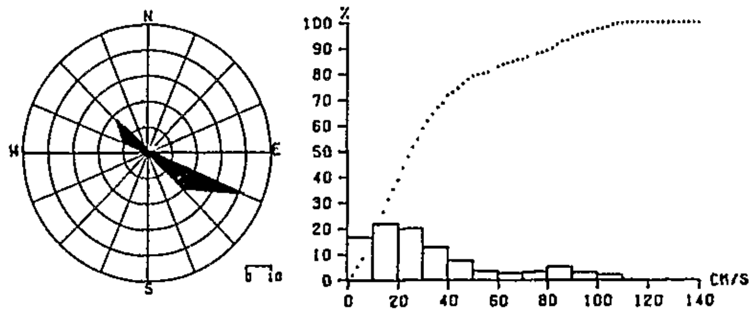


Fig. II-1-6-(11) Auto correlogram for Merbau Area (2)

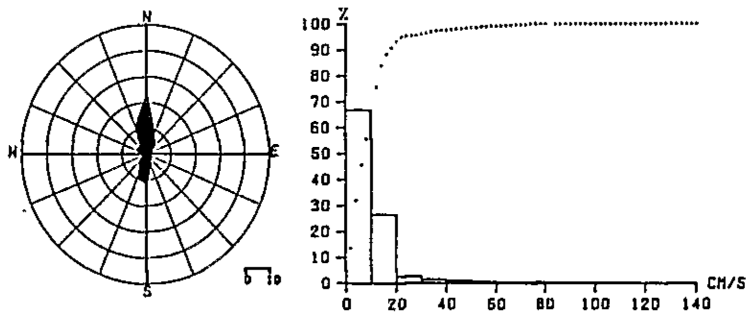
AREA : SINGAPORE STATION : st1
PERIOD : 1979. 8. 7.15.30 - 1979. 8.24.17. 0



AREA : SINGAPORE STATION : st2
PERIOD : 1979. 8. 7.19. 0 - 1979. 8.21. 8. 0



AREA : SINGAPORE STATION : st3
PERIOD : 1979. 8. 7.18.30 - 1979. 8.23.16. 0



AREA : SINGAPORE STATION : st4
PERIOD : 1979. 8. 7.16. 0 - 1979. 8.25.10.30

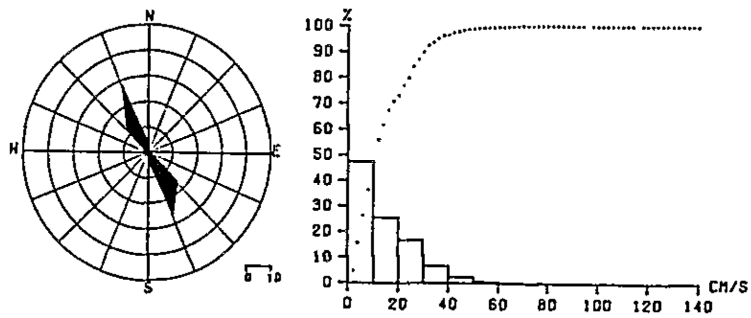


Fig. II-1-6-(12) Frequency distribution of current direction and velocity at Pulau Ayer Merbau Area (1)

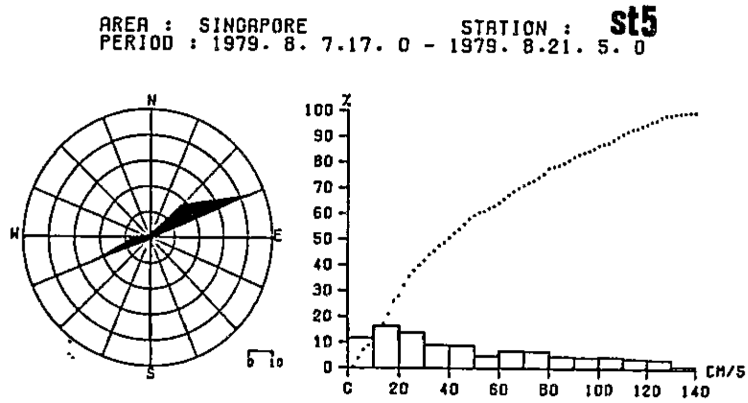


Fig. II-1-6-(12) Frequency distribution of current direction and velocity at Pulau Ayer Merbau Area (2)

II-1-6-2 Tide and tidal current survey of the straits of Malacca and Singapore

The survey has been conducted at 5 existing tide stations located in the Straits of Malacca and Singapore and also at 12 newly established tide stations for 14 months simultaneously and except that, two simultaneous survey for 35 days respectively have been conducted for investigating the characteristics of the tide and tidal current, and also for the prediction of the tide and tidal current.

The survey area has been extended to the total areas of the Straits of Malacca and Singapore and the survey has been conducted during March to April 1979.

Table II-1-6-(5) shows the scope of survey, Fig. II-1-6-(14) shows the survey point chart and Fig. II-1-6-(15) shows the survey methods.

Table II-1-6-(5) Scope of survey at the Sraits of Malacca and singapore

Survey Items	Survey Point	Layer	Period	Methods
Tidal current observation	1 – 6		(Fisrt Survey) July 10-August 20, 1979 (Second Survey) Nov. 9 – Dec. 20, 1979	Setting NC-type current meters for observation (fixed point continuous measurement)
	1	-2.5m	Augt. 5, Augt. 24, Nov. 16, & Dec. 4	Hanging down DCM-2 current meters from the survey boat for observation (series layers)
	2	-5.0m	July 22, 23, & Dec. 2	
	3	-10m -15m	July 21, & Dec. 2	
	4	–	July 26, 27, Nov. 14 & Dec. 1	
		–		
	6	(each 5m)	Nov. 17 & Dec. 1	
		–	1979	1979
Tide observation	17 points		From March - April 1979	Setting tidal guage at tidal stations

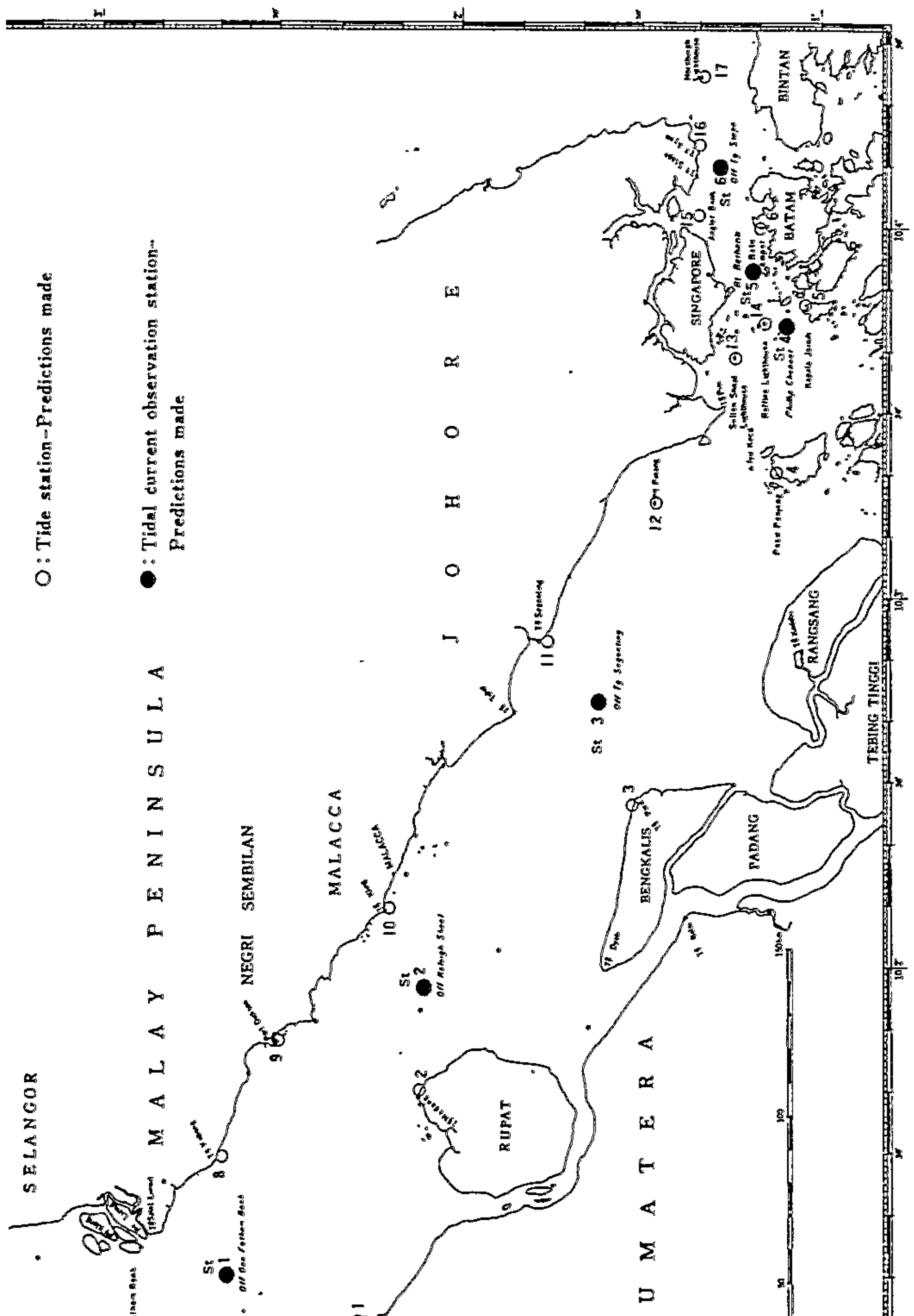
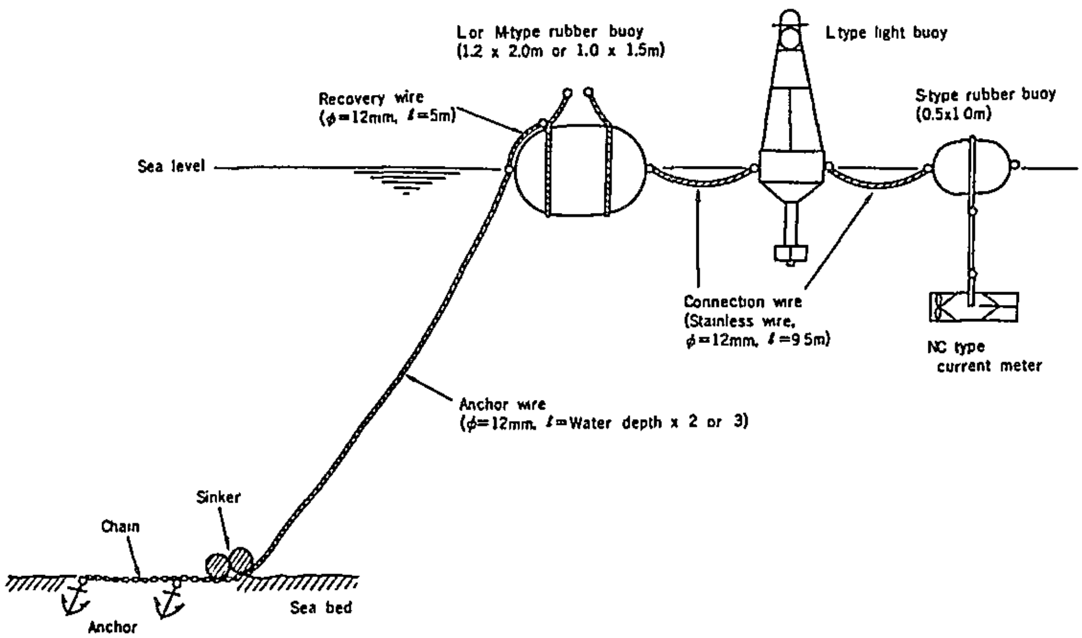


Fig. II-1-6-(14) Servey point chart of current survey at the straits of Malacca and Singapore

Table II-1-6-(6) Location table of survey points

	Current Survey Point	
St1	Off One Fathom Bank	02° 40.0' N - 101° 10.0' E
St2	Off Raleigh Shoal	02° 06.7' N - 101° 56.8' E
St3	Off Tg. Segenting	01° 37.7' N - 102° 43.0' E
St4	Phillip Channel	01° 05.8' N - 103° 44.0' E
St5	Batu Berhanti	01° 11.8' N - 103° 52.5' E
St6	Off Tg. Stapa	01° 17.3' N - 104° 09.5' E

LAYOUT OF MOORING SYSTEM (A) AT STATIONS 1,2,3 AND 6



LAYOUT OF MOORING SYSTEM (B) AT STATIONS 4 AND 5

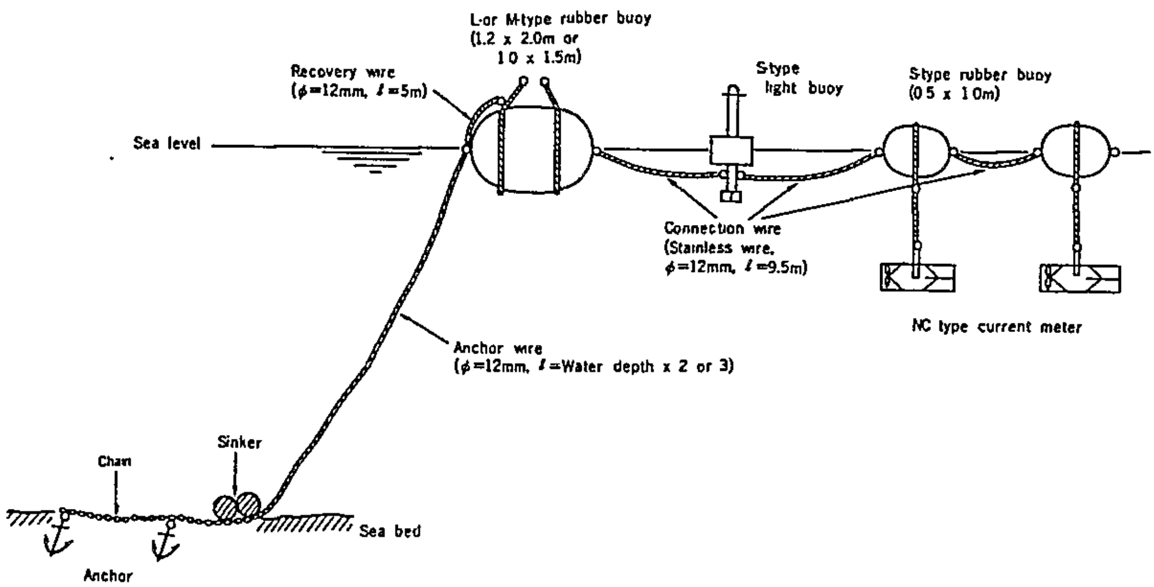


Fig. II-1-6-(15) Survey methods of current survey at the Straits of Malacca and Singapore

The data for St4, 5 and 6 have been extracted from the report for harmonic analysis of the tidal current as these 3 survey points are located most near to the survey area (Seraya and Tekong Area).

The results of such analysis are shown in Tables II-1-6-(7) and II-1-6-(8). Table II-1-6-(7) is referred to the first survey and Table II-1-6-(8) is referred to the second survey. The unit of velocity in these tables are based on knot (kn) and 1 kn = 51.4 cm/sec. From these tables, the dominant tidal current constituent of the respective survey points are;

— First survey

St 4 (Phillip Channel)	K_1 (0.950 kn)	O_1 (0.713 kn)
St 5 (Batu Berhanti)	K_1 (0.916 kn)	O_1 (0.839 kn)
St 6 (Off Tg Stapa)	K_1 (0.268 kn)	O_1 (0.205 kn)

— Second survey

St 4	K_1 (0.989 kn)	O_1 (0.751 kn)
St 5	O_1 (0.906 kn)	K_1 (0.861 kn)
St 6	K_1 (0.144 kn)	O_1 (0.128 kn)

From the above, it is observed that K_1 and O_1 constituents are dominant at these survey points.

The report is describing that the direction of tidal current in the straits of Malacca is directed to North/West or South/East, and the direction in the west exit of the Straits of Singapore (Phillip Channel) is South/South/West or North/North/East and at the east exit it is directed to West/South/West or East/North/East.

The ratio between diurnal tidal current and semidiurnal tidal current in the straits of Malacca is 0.26 to 0.33 and the tidal current is generally fluctuating by semidiurnal cycle period. In the straits of Singapore, on the contrary, the ratio between dirunal and semidiurnal tidal current is 1.35 to 2.19 and the diurnal current is dominant.

When the appearing time of the maximum velocity is compared with 6 survey points, it is found that in the straits of Malacca, St1 is the fastest and getting slow towards the east. The time difference between St1 and St3 is about 2.7 hours under the average condition of the spring tide. Further, at St1 the south/east flow comes fastest at around the time of high tide. In the straits of Singapore, the appearing time of the maximum velocity is the fastest at the eastward flow and getting slow towards the west. The time difference between St5 and St4 is about 1.8 hours under the average condition of the spring tide. Futher, at St6 the west/south/west flow comes fastest 2.2 hours before the high tide. but in the straits of Singapore, these time difference comes very small when the current is the diurnal tidal current.

The total of 4 major component current is 1.9 to 2.2 kn in the straits of Malacca and in the straits of Singapore, 2.9 kn at St4, 4.8 kn at St5, and 2.7 kn at St6.

From the results of current survey conducted at the various layers, the velocity and direction of each depths are found within the rane of $\pm$25% for velocity and $\pm$15% for direction compared with the values of -10 m.

Fig II-1-6-(16) shows the diagram showing the ratios of the maximum current velocity at various depths to that at 10 m depth.

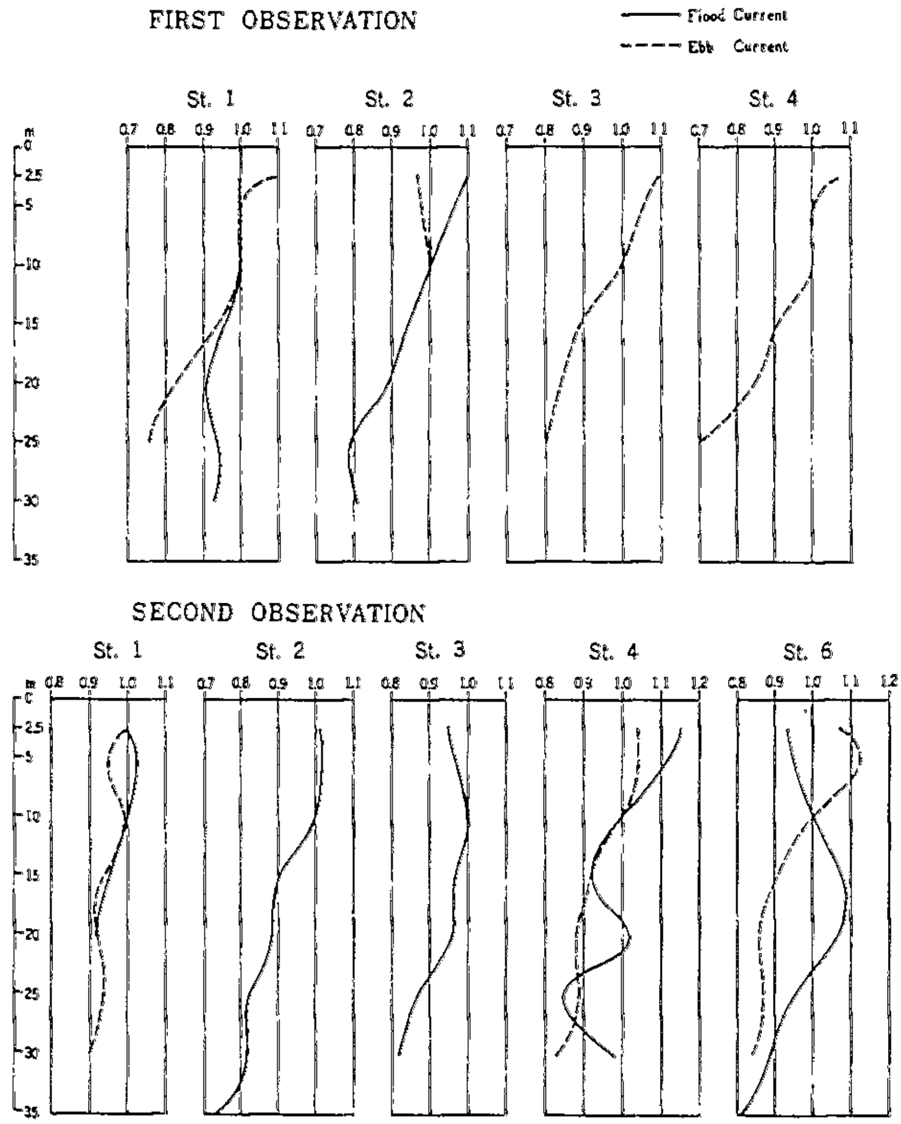


Fig. II-1-6-(16) Diagram showing the ratios of the maximum current velocity at various depths to that at 10 m depth

Table II-1-6-(7) Results of harmonic analysis of tidal current survey of the Straits of Malacca and Singapore (first survey) (1/2)

Table 4-4 HARMONIC CONSTANTS OF TIDAL CURRENT St. 4 (Phillip Channel)

Position: Lat. 1°05'46" N Long. 103°44'03" E
Time kept at the Place: −07 30
Depth 10 m
Duration: July 16 ~ Aug. 16, 1978

Constituents	N-Comp.		E-Comp.		Elements of Ellipse						Main Dir. 25°		
					Major Axis			Minor Axis					
	V (kn)	κ (°)	V (kn)	κ (°)	Dir. (°)	V (kn)	κ (°)	Dir. (°)	V (kn)	κ (°)	V (kn)	κ (°)	g (°)
Mm	0.058	257.0	0.041	201.2	30	0.065	242.2	120	0.030	152.2	0.065	244.4	248.5
MS'	0.234	162.0	0.193	186.0	24	0.257	166.2	114	0.042	256.2	0.257	166.3	173.9
Q1	0.138	152.8	0.072	139.4	26	0.153	159.0	116	0.028	249.0	0.152	158.8	155.5
O1	0.713	182.9	0.477	207.7	33	0.842	191.0	123	0.163	281.0	0.835	189.5	190.3
M1	0.033	189.4	0.035	120.1	50	0.039	147.8	140	0.027	59.8	0.038	167.7	172.7
K1	0.950	231.0	0.533	248.6	29	1.082	236.3	119	0.125	326.1	1.079	236.1	245.3
J1	0.029	48.5	0.019	178.9	341	0.041	41.9	71	0.013	131.9	0.031	59.7	72.9
OO1	0.153	339.6	0.148	340.6	44	0.213	340.1	134	0.002	70.1	0.201	339.9	357.2
P1	0.312	232.1	0.175	247.7	29	0.355	235.8	119	0.041	325.8	0.354	235.3	243.8
μ2	0.029	34.8	0.042	38.5	55	0.050	37.3	145	0.001	127.3	0.044	36.3	38.6
N2	0.187	86.7	0.050	82.9	15	0.194	86.4	105	0.003	356.4	0.191	86.2	92.1
ν2	0.036	85.8	0.010	81.2	15	0.037	85.5	105	0.001	355.5	0.037	85.3	91.7
M2	0.647	110.4	0.186	84.4	15	0.669	108.6	105	0.079	18.6	0.658	107.4	117.3
L2	0.016	63.2	0.015	112.4	43	0.020	86.1	133	0.009	176.1	0.020	77.8	91.8
S2	0.174	150.0	0.072	65.1	3	0.175	148.9	93	0.073	58.9	0.164	139.1	156.6
K2	0.047	150.0	0.020	65.1	3	0.048	148.9	93	0.020	58.9	0.045	138.9	157.1
2SM2	0.012	60.2	0.027	284.0	290	0.028	98.1	20	0.008	8.1	0.008	350.9	16.0
MO3	0.025	305.8	0.078	62.6	279	0.079	246.1	9	0.023	336.1	0.030	22.6	37.1
M3	0.016	220.9	0.012	229.3	53	0.027	226.3	143	0.003	316.3	0.024	234.2	239.0
MK3	0.007	182.3	0.092	135.9	87	0.092	136.1	177	0.005	46.1	0.044	142.2	161.2
MN4	0.016	52.7	0.017	347.1	49	0.019	16.7	139	0.012	286.2	0.018	32.2	48.0
M4	0.055	15.3	0.031	34.5	29	0.063	19.9	119	0.009	109.9	0.063	19.3	39.2
SN4	0.009	340.2	0.038	297.6	79	0.039	299.3	169	0.006	209.3	0.033	312.0	335.3
MS4	0.349	14.6	0.017	10.0	37	0.061	12.9	127	0.007	282.9	0.060	13.4	40.8
2MN6	0.016	271.2	0.015	303.5	44	0.021	312.4	134	0.003	222.4	0.020	215.6	341.3
M6	0.024	266.8	0.018	230.3	35	0.029	254.3	125	0.009	164.2	0.028	253.2	286.9
MSN6	0.010	286.9	0.014	310.9	68	0.015	328.4	158	0.010	238.4	0.012	258.2	293.5
2MS6	0.017	326.9	0.015	13.0	41	0.021	346.7	131	0.009	76.3	0.020	340.1	17.4
2SM6	0.005	221.0	0.006	135.0	79	0.006	144.2	169	0.005	54.2	0.005	194.6	239.6
Non-Tidal Current	−0.160		0.092		150.1	0.184					−0.106		

Table 4-5 HARMONIC CONSTANTS OF TIDAL CURRENT St. 5 (Batu Berhanti)

Position Lat 1°11'46" N Long. 103°52'42" E
Time kept at the Place. −07 30
Depth. 10 m
Duration July 16 ~ Aug 16, 1978

Constituents	N-Comp.		E-Comp.		Elements of Ellipse						Main Dir. 59°		
					Major Axis			Minor Axis					
	V (kn)	κ (°)	V (kn)	κ (°)	Dir. (°)	V (kn)	κ (°)	Dir. (°)	V (kn)	κ (°)	V (kn)	κ (°)	g (°)
Mm	0.119	264.0	0.180	189.8	74	0.185	199.7	164	0.111	109.7	0.180	209.0	213.1
MSf	0.191	145.1	0.195	200.8	46	0.242	173.4	136	0.128	263.4	0.237	180.4	188.1
Q1	0.192	112.5	0.271	179.6	55	0.333	181.0	145	0.013	91.0	0.337	180.9	177.5
O1	0.839	200.0	1.363	206.5	59	1.618	206.2	149	0.003	296.2	1.608	206.1	207.0
M1	0.096	238.7	0.080	198.5	38	0.117	222.9	128	0.042	132.9	0.111	215.4	220.2
K1	0.916	250.2	1.436	246.2	58	1.736	247.2	148	0.054	157.2	1.736	247.3	256.2
J1	0.020	233.1	0.064	177.1	77	0.063	181.7	167	0.070	91.1	0.062	186.7	199.8
OO1	0.198	351.1	0.393	22.1	65	0.431	14.9	155	0.088	104.9	0.428	13.6	30.7
P1	0.300	249.3	0.486	245.3	58	0.530	246.4	148	0.018	156.4	0.530	246.4	254.7
μ2	0.034	13.5	0.082	26.6	48	0.100	22.6	138	0.009	113.4	0.109	23.1	25.3
N2	0.140	65.0	0.190	61.6	54	0.236	62.8	144	0.007	332.8	0.219	62.7	68.2
ν2	0.027	63.7	0.037	59.7	54	0.046	61.1	144	0.002	330.1	0.045	61.0	67.0
M2	0.519	50.0	0.792	55.8	57	0.946	54.0	147	0.044	144.0	0.945	54.1	63.8
L2	0.027	35.6	0.102	74.4	72	0.108	68.6	162	0.036	158.6	0.115	64.5	78.2
S2	0.172	78.8	0.351	76.2	64	0.392	76.3	154	0.007	346.3	0.390	76.8	94.0
K2	0.047	78.8	0.097	76.2	64	0.108	76.7	154	0.002	346.3	0.107	76.8	94.6
2SM2	0.038	203.2	0.041	282.9	50	0.046	253.3	140	0.031	343.3	0.046	259.4	284.2
MO3	0.056	109.6	0.143	36.3	83	0.144	39.0	173	0.053	309.0	0.133	46.3	58.7
M3	0.003	321.5	0.032	334.6	85	0.032	334.5	175	0.001	64.5	0.029	334.0	348.4
MK3	0.016	186.4	0.082	125.5	84	0.082	126.5	174	0.014	36.5	0.075	131.2	149.7
MN4	0.013	146.7	0.011	237.1	359	0.015	145.8	89	0.011	235.8	0.012	200.1	215.3
M4	0.026	131.0	0.005	292.5	349	0.027	111.2	79	0.000	21.2	0.009	110.5	129.7
SN4	0.035	329.4	0.052	309.0	37	0.062	315.7	147	0.010	225.2	0.062	314.9	337.7
MS4	0.006	140.4	0.086	347.9	273	0.086	167.8	3	0.003	77.8	0.071	348.9	19.8
2MN6	0.013	332.4	0.017	93.9	299	0.019	289.6	29	0.010	19.6	0.013	61.8	93.6
M6	0.021	39.6	0.027	186.2	307	0.033	18.6	37	0.010	108.6	0.015	162.3	191.2
MSN6	0.014	326.5	0.036	208.2	281	0.037	24.6	11	0.003	294.6	0.028	221.0	253.4
2MS6	0.013	46.4	0.041	117.3	84	0.041	115.7	174	0.001	205.3	0.037	108.4	144.9
2SM6	0.015	168.9	0.026	223.2	68	0.028	213.2	158	0.011	303.2	0.028	209.5	253.6
Non Tidal Current	0.207		0.415		63.4	0.464					0.462		

Table II-1-6-(7) Results of harmonic analysis of tidal current survey of the Straits of Malacca and Singapore (first survey) (2/2)

Table 4-6 HARMONIC CONSTANTS OF TIDAL CURRENT St. 6 (Off Tg. Stapa)

Position: Lat 1°17'25" N Long 104°10'20" E
Time kept at the Place −07 30
Depth. 10 m
Duration: July 16 ~ Aug. 16, 1978

Constituents	N-Comp.		E-Comp.		Elements of Ellipse: Major Axis			Elements of Ellipse: Minor Axis			Max Dir. 76°		
	V (kn)	κ (°)	V (kn)	κ (°)	Dir. (°)	V (kn)	κ (°)	Dir. (°)	V (kn)	κ (°)	V (kn)	κ (°)	ξ (°)
Mm	0.037	172.6	0.146	194.0	84	0.147	193.7	174	0.006	281.7	0.145	193.4	197.5
MSf	0.029	297.4	0.176	165.2	277	0.177	344.4	7	0.022	254.4	0.166	167.0	174.7
Q1	0.037	176.6	0.147	180.2	76	0.151	179.9	166	0.002	265.9	0.151	179.9	176.3
O1	0.205	176.0	0.742	208.2	77	0.767	206.3	167	0.107	296.3	0.763	206.2	206.6
M1	0.015	196.5	0.099	188.8	81	0.102	189.7	161	0.004	99.7	0.104	189.4	194.0
K1	0.266	212.8	0.821	246.1	74	0.852	243.6	164	0.142	213.4	0.851	243.7	222.2
J1	0.019	329.9	0.050	135.5	290	0.054	327.2	20	0.002	47.8	0.044	135.8	346.5
OO1	0.033	9.9	0.078	12.1	47	0.106	11.3	137	0.001	101.3	0.093	11.7	78.6
P1	0.088	212.0	0.269	245.2	74	0.279	242.3	164	0.046	332.5	0.279	242.8	230.8
μ2	0.015	244.7	0.047	53.0	288	0.050	334.1	18	0.003	324.1	0.042	52.0	53.4
N2	0.064	54.6	0.167	50.8	69	0.179	51.7	159	0.004	321.3	0.177	51.1	56.1
ν2	0.017	51.6	0.013	49.3	69	0.032	49.9	159	0.001	319.9	0.032	49.7	51.2
M2	0.150	59.2	0.729	50.7	78	0.744	51.1	168	0.022	321.1	0.741	51.2	60.3
L2	0.025	89.3	0.036	74.3	32	0.044	75.8	162	0.006	345.8	0.039	75.3	88.6
S2	0.077	104.6	0.291	95.0	75	0.300	95.6	165	0.012	5.6	0.300	95.5	102.2
K2	0.021	104.6	0.080	95.0	75	0.082	95.6	165	0.003	5.6	0.082	95.5	102.8
2SM2	0.029	316.2	0.033	221.4	286	0.034	28.0	16	0.029	298.0	0.032	233.8	258.0
MO3	0.024	322.5	0.041	158.1	299	0.049	334.5	29	0.006	244.5	0.036	160.6	170.0
M3	0.017	107.0	0.024	259.4	304	0.028	88.3	34	0.006	178.3	0.019	253.8	267.3
MK3	0.009	51.6	0.055	212.9	279	0.055	33.4	9	0.003	123.4	0.051	212.1	239.8
MN4	0.011	33.9	0.007	308.2	13	0.011	26.5	103	0.006	296.5	0.007	338.0	351.9
M4	0.024	96.0	0.015	277.4	328	0.028	96.4	58	0.000	6.4	0.008	278.2	296.3
SN4	0.010	358.8	0.029	354.7	72	0.031	355.1	162	0.001	265.1	0.031	355.0	16.6
MS4	0.013	337.0	0.011	309.2	22	0.014	248.3	112	0.010	338.3	0.011	293.2	319.0
2MN6	0.006	212.3	0.008	103.9	294	0.009	268.1	24	0.006	178.1	0.008	114.6	133.6
M6	0.006	34.0	0.018	103.3	83	0.018	101.1	173	0.005	191.1	0.018	99.0	126.1
MSN6	0.003	80.4	0.004	77.5	56	0.005	78.4	146	0.000	348.4	0.005	77.9	108.5
2MS6	0.001	191.9	0.019	206.9	87	0.019	206.9	177	0.000	296.9	0.019	206.8	241.5
2SM6	0.010	208.0	0.009	207.0	43	0.013	207.5	133	0.000	117.5	0.011	207.2	249.5
Non Tidal Current	0.107		0.383		74.5	0.402					0.402		

Table II-1-6-(8) Results of harmonic analysis of tidal current survey of the Straits of Malacca and Singapore (second survey) (1/2)

Table 5-4 HARMONIC CONSTANTS OF TIDAL CURRENT St. 4 (Phillip Channel)

Position Lat 1°05'40" N Long 103°43'50" E
Time kept at the Place. −07 30
Depth: 10 m
Duration: Nov 12 ~ Dec. 13, 1978

Constituents	N-Comp.		E-Comp.		Elements of Ellipse: Major Axis			Elements of Ellipse: Minor Axis			Max Dir. 27°		
	V (kn)	κ (°)	V (kn)	κ (°)	Dir. (°)	V (kn)	κ (°)	Dir. (°)	V (kn)	κ (°)	V (kn)	κ (°)	ξ (°)
Mm	0.170	179.4	0.098	156.1	29	0.194	173.8	119	0.034	83.8	0.193	174.1	178.2
MSf	0.098	29.3	0.133	26.0	54	0.165	27.2	144	0.004	297.2	0.148	27.9	33.6
Q1	0.079	193.7	0.082	169.9	46	0.111	181.3	136	0.023	91.3	0.106	185.4	183.2
O1	0.731	191.3	0.613	212.9	37	0.951	199.8	129	0.179	289.8	0.915	197.6	198.5
M1	0.056	20.0	0.017	303.4	7	0.057	18.0	97	0.019	288.0	0.054	18.4	17.4
K1	0.989	234.5	0.545	242.5	29	1.127	236.3	119	0.067	326.3	1.126	236.2	245.2
J1	0.094	106.8	0.026	135.1	14	0.097	108.5	104	0.012	198.5	0.094	110.2	123.3
OO1	0.262	241.3	0.011	25.1	358	0.263	242.9	88	0.019	332.9	0.232	242.6	262.9
P1	0.333	232.8	0.180	240.8	29	0.373	234.7	119	0.022	324.7	0.373	234.6	243.0
μ2	0.024	253.6	0.020	10.5	326	0.027	231.8	56	0.016	321.8	0.019	279.2	281.5
N2	0.139	88.5	0.058	52.6	15	0.145	85.7	105	0.011	355.7	0.141	83.3	89.4
ν2	0.034	88.8	0.081	50.6	15	0.035	85.9	105	0.003	355.9	0.035	83.3	89.9
M2	0.728	106.4	0.262	67.0	16	0.757	102.9	106	0.160	12.9	0.744	100.5	110.4
L2	0.045	109.5	0.013	59.5	11	0.045	107.0	101	0.010	17.0	0.044	103.6	117.4
S2	0.255	126.7	0.072	95.3	14	0.262	124.7	104	0.037	34.7	0.253	122.6	140.4
K2	0.070	127.3	0.020	97.0	14	0.072	125.8	104	0.010	35.8	0.071	123.9	147.1
2SM2	0.030	358.3	0.029	148.0	317	0.040	344.2	47	0.021	74.2	0.017	21.4	46.3
MO3	0.070	271.0	0.072	82.8	343	0.074	270.2	73	0.002	0.2	0.052	272.6	285.4
M3	0.001	45.7	0.012	182.5	305	0.014	14.9	35	0.005	104.9	0.005	92.9	108.6
MK3	0.046	128.6	0.059	78.7	55	0.068	95.8	145	0.030	5.8	0.062	109.1	128.1
MN4	0.051	335.0	0.017	241.5	353	0.071	340.9	83	0.019	250.9	0.020	312.1	327.8
M4	0.040	354.4	0.019	302.1	31	0.047	348.1	121	0.012	258.1	0.042	346.4	6.2
SN4	0.005	113.2	0.008	9.1	282	0.008	182.7	12	0.004	92.7	0.005	65.5	81.9
MS4	0.034	77.2	0.024	114.0	35	0.040	88.6	125	0.012	178.6	0.040	86.8	114.3
2MN6	0.011	234.7	0.004	104.8	345	0.011	238.9	75	0.003	148.9	0.009	224.7	150.3
M6	0.010	252.3	0.023	110.0	289	0.025	290.7	19	0.007	200.7	0.008	172.0	201.7
MSN6	0.009	319.5	0.003	338.6	351	0.009	316.7	81	-0.003	306.7	0.007	231.8	265.5
2MS6	0.013	327.0	0.022	85.8	292	0.023	276.7	22	0.011	6.7	0.011	18.3	35.6
2SM6	0.009	208.8	0.012	51.3	306	0.015	223.6	36	0.003	133.6	0.004	171.2	216.2
Non-Tidal Current	-0.634		-0.135		195.5	0.656					-0.644		

Table II-1-6-(8) Results of harmonic analysis of tidal current survey of the Straits of Malacca and Singapore (second survey) (2/2)

Table 5-5 HARMONIC CONSTANTS OF TIDAL CURRENT St. 5 (Batu Berhanti)

Position. Lat 1°11'38" N Long. 103°52'42" E
Time kept at the Place. −07 30
Depth: 10 m
Duration Nov 12 ~ Dec 13, 1978

Constituents	N-Comp.		E-Comp.		Elements of Ellipse: Major Axis			Minor Axis			Main Dir. 57°		
	V (kn)	κ (°)	V (kn)	κ (°)	Dir. (°)	V (kn)	κ (°)	Dir. (°)	V (kn)	κ (°)	V (kn)	κ (°)	ξ (°)
Mm	0.173	186.4	0.239	166.3	55	0.290	173.0	145	0.049	83.0	0.291	172.6	136.6
MSf	0.190	66.0	0.394	61.8	54	0.489	63.2	144	0.017	332.2	0.488	63.0	70.7
Q1	0.113	137.9	0.224	169.7	63	0.245	163.7	153	0.055	253.7	0.243	162.0	138.6
O1	0.906	201.2	1.373	199.3	57	1.645	199.9	147	0.026	109.9	1.644	199.9	200.5
M1	0.020	276.1	0.080	252.2	77	0.082	253.4	167	0.008	163.4	0.078	255.4	360.2
K1	0.862	227.9	1.384	232.9	58	1.629	234.5	148	0.064	144.5	1.621	234.3	243.3
J1	0.080	57.6	0.115	123.5	66	0.132	109.7	156	0.069	199.7	0.131	104.7	117.7
OO1	0.211	209.8	0.067	224.7	17	0.221	211.1	107	0.017	301.1	0.169	214.7	231.9
P1	0.265	236.3	0.458	231.2	58	0.529	237.6	148	0.026	142.6	0.529	232.7	340.0
μ2	0.063	099.2	0.095	108.9	39	0.096	155.8	069	0.061	55.8	0.092	140.0	043.0
N2	0.147	52.4	0.298	54.3	64	0.332	54.1	154	0.002	144.0	0.330	54.0	55.6
ν2	0.028	52.3	0.053	54.3	64	0.064	54.0	154	0.001	144.0	0.064	53.9	60.0
M2	0.645	64.5	1.054	62.6	59	1.236	62.9	149	0.018	312.9	1.236	62.9	32.5
L2	0.069	6.3	0.018	245.2	337	0.071	17.3	67	0.013	287.3	0.035	307.9	320.6
S2	0.267	86.2	0.380	73.6	55	0.462	77.1	145	0.052	347.1	0.461	76.8	94.1
K2	0.033	87.6	0.105	74.3	55	0.127	78.6	145	0.014	348.6	0.127	78.3	96.2
2SM2	0.013	33.9	0.089	142.6	273	0.089	322.8	3	0.013	52.8	0.073	137.0	161.9
MO3	0.017	201.3	0.064	21.4	285	0.067	202.1	15	0.003	292.1	0.045	19.3	29.6
M3	0.029	149.4	0.047	183.6	61	0.053	173.1	151	0.014	263.1	0.057	174.2	188.6
MK3	0.036	0.4	0.131	48.0	75	0.137	45.9	169	0.016	135.9	0.124	41.4	60.0
MN4	0.024	249.0	0.058	268.2	69	0.062	265.6	159	0.007	355.6	0.061	264.3	279.4
M4	0.023	251.0	0.112	289.2	83	0.114	288.0	173	0.014	18.0	0.105	285.0	304.2
SN4	0.019	56.5	0.030	304.2	300	0.034	32.8	30	0.009	122.8	0.017	185.9	208.7
MS4	0.036	180.3	0.024	245.2	38	0.030	206.4	128	0.019	296.4	0.029	218.9	245.8
2MN6	0.007	234.2	0.017	34.8	292	0.018	317.6	22	0.002	307.6	0.011	28.0	37.8
M6	0.003	20.3	0.054	26.1	85	0.054	26.1	175	0.001	116.1	0.048	25.8	34.7
MSN6	0.008	169.6	0.027	206.4	73	0.028	206.1	163	0.005	296.1	0.026	202.6	215.0
2MS6	0.012	145.4	0.019	120.0	57	0.022	126.8	149	0.004	36.8	0.022	127.2	161.8
2SM6	0.016	197.6	0.020	94.4	292	0.020	258.4	22	0.015	168.4	0.017	123.3	167.4
Non-Tidal Current	−0.230		−0.461		243.5	0.515					−0.313		

Table 5-6 HARMONIC CONSTANTS OF TIDAL CURRENT St. 6 (Off Tg. Stapa)

Position Lat. 1°17'20" N Long 104°9'30" E
Time kept at the Place. −07 30
Depth: 10 m
Duration. Nov 12 ~ Dec. 13, 1978

Constituents	N-Comp.		E-Comp.		Elements of Ellipse: Major Axis			Minor Axis			Main Dir. 81°		
	V (kn)	κ (°)	V (kn)	κ (°)	Dir. (°)	V (kn)	κ (°)	Dir. (°)	V (kn)	κ (°)	V (kn)	κ (°)	ξ (°)
Mm	0.049	48.4	0.148	173.9	282	0.151	357.0	12	0.039	87.0	0.142	171.3	175.4
MSf	0.048	136.0	0.176	70.9	81	0.177	72.6	171	0.043	342.6	0.177	73.0	80.7
Q1	0.031	140.7	0.106	159.3	74	0.110	158.5	164	0.005	248.5	0.109	151.8	155.1
O1	0.128	198.7	0.719	201.4	80	0.730	201.3	170	0.007	291.3	0.730	201.2	201.7
M1	0.011	24.6	0.043	291.1	271	0.043	110.9	1	0.011	20.9	0.042	291.6	298.1
K1	0.144	218.6	0.726	233.8	79	0.739	233.2	169	0.027	323.2	0.739	233.3	242.0
J1	0.017	18.9	0.038	89.0	80	0.038	84.8	170	0.015	174.8	0.038	85.3	91.0
OO1	0.042	83.2	0.108	208.1	286	0.112	42.3	16	0.028	132.3	0.102	215.5	223.4
P1	0.048	217.0	0.240	232.1	79	0.245	231.6	169	0.017	321.6	0.245	231.7	239.7
μ2	0.039	4.5	0.019	227.6	330	0.033	14.7	60	0.010	184.7	0.015	233.5	234.9
N2	0.030	65.2	0.210	45.3	85	0.211	45.5	175	0.007	315.5	0.210	45.6	52.6
ν2	0.004	64.1	0.041	45.3	85	0.041	45.4	175	0.002	315.4	0.041	45.6	52.1
M2	0.106	69.4	0.879	54.9	83	0.885	55.1	173	0.026	325.1	0.884	55.2	64.2
L2	0.001	172.3	0.017	329.6	293	0.018	152.1	23	0.003	242.1	0.026	327.9	341.8
S2	0.058	99.4	0.347	85.2	81	0.352	85.5	171	0.014	355.5	0.337	85.5	102.2
K2	0.016	100.7	0.095	86.4	81	0.097	86.8	171	0.004	356.8	0.097	86.8	104.1
2SM2	0.009	62.0	0.023	166.2	315	0.027	347.7	5	0.008	77.7	0.076	165.2	187.6
MO3	0.011	261.0	0.029	72.2	317	0.043	256.9	47	0.003	346.9	0.026	73.1	79.8
M3	0.020	83.2	0.023	213.0	306	0.029	51.0	36	0.013	141.0	0.023	206.3	220.3
MK3	0.022	294.7	0.054	123.8	301	0.062	301.4	31	0.004	211.4	0.046	124.8	142.3
MN4	0.004	216.1	0.026	313.0	271	0.026	133.1	1	0.004	223.1	0.025	311.5	325.6
M4	0.016	143.3	0.054	358.2	285	0.056	176.1	15	0.008	86.1	0.051	359.7	13.8
SN4	0.009	216.1	0.012	90.7	302	0.014	254.1	32	0.007	164.1	0.011	96.8	116.5
MS4	0.016	144.1	0.012	50.8	236	0.012	226.0	6	0.009	136.0	0.012	50.0	81.8
2MN6	0.002	197.0	0.012	219.2	82	0.013	218.7	172	0.001	308.7	0.013	218.7	240.8
M6	0.005	231.0	0.006	344.6	290	0.007	128.0	20	0.004	218.0	0.006	338.0	5.2
MSN6	0.016	109.5	0.029	182.1	14	0.016	107.2	104	0.009	207.1	0.010	165.3	199.0
2MS6	0.009	174.2	0.014	209.0	60	0.016	199.8	150	0.004	289.8	0.015	201.9	240.7
2SM6	0.011	42.0	0.012	171.4	50	0.012	86.6	140	0.010	176.6	0.017	111.8	155.3
Non-Tidal Current	0.047		−0.266		280.1	0.272					−0.256		

II-1-7 Typical Current Conditions of Survey Area

II-1-7-1 Current character of the sea areas around the straits of Singapore

By the Tide and Tidal Current Survey of the Straits of Malacca and Singapore, it has been recognized that the tide generated in the Indian Ocean and South China Sea reaches to the Straits of Malacca and Singapore as the tidal waves and it generates the tidal current in the straits.

The peak of the tidal waves with semi-diurnal period from the Indian Ocean propagates to the eastward through the straits of Malacca and the peak of the tidal waves with semi-diurnal period from the South China Sea propagates to the westward through the straits of Singapore. These tidal waves meet at the point near to the Raffles Lighthouse located about 17 km south/east of Pulau Seraya.

From the above observation, the tidal current of the sea areas surrounding Singapore are influenced by the current from the South China Sea and from the straits of Malacca.

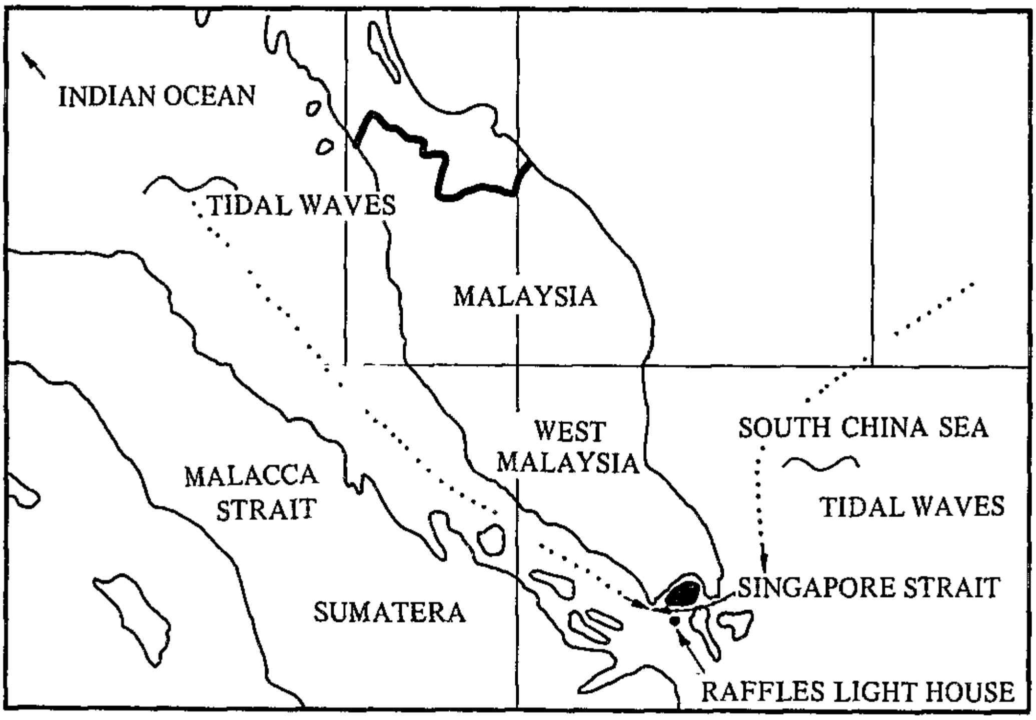


Fig. II-1-7-(1) Progress of tidal wave in the Straits of Malacca and Singapore

Fig. II-1-7-(2) shows the monthly variation of the mean sea level of the areas, the west side of the straits of Malacca (One Fathom Bank), the central part (Tg Parit), the east side (Iyu Kecil), the west side of the straits of Singapore (Sultan Shoal Lighthouse), the central part (Batu Ampar) and the east side (Horsburgh Lighthouse).

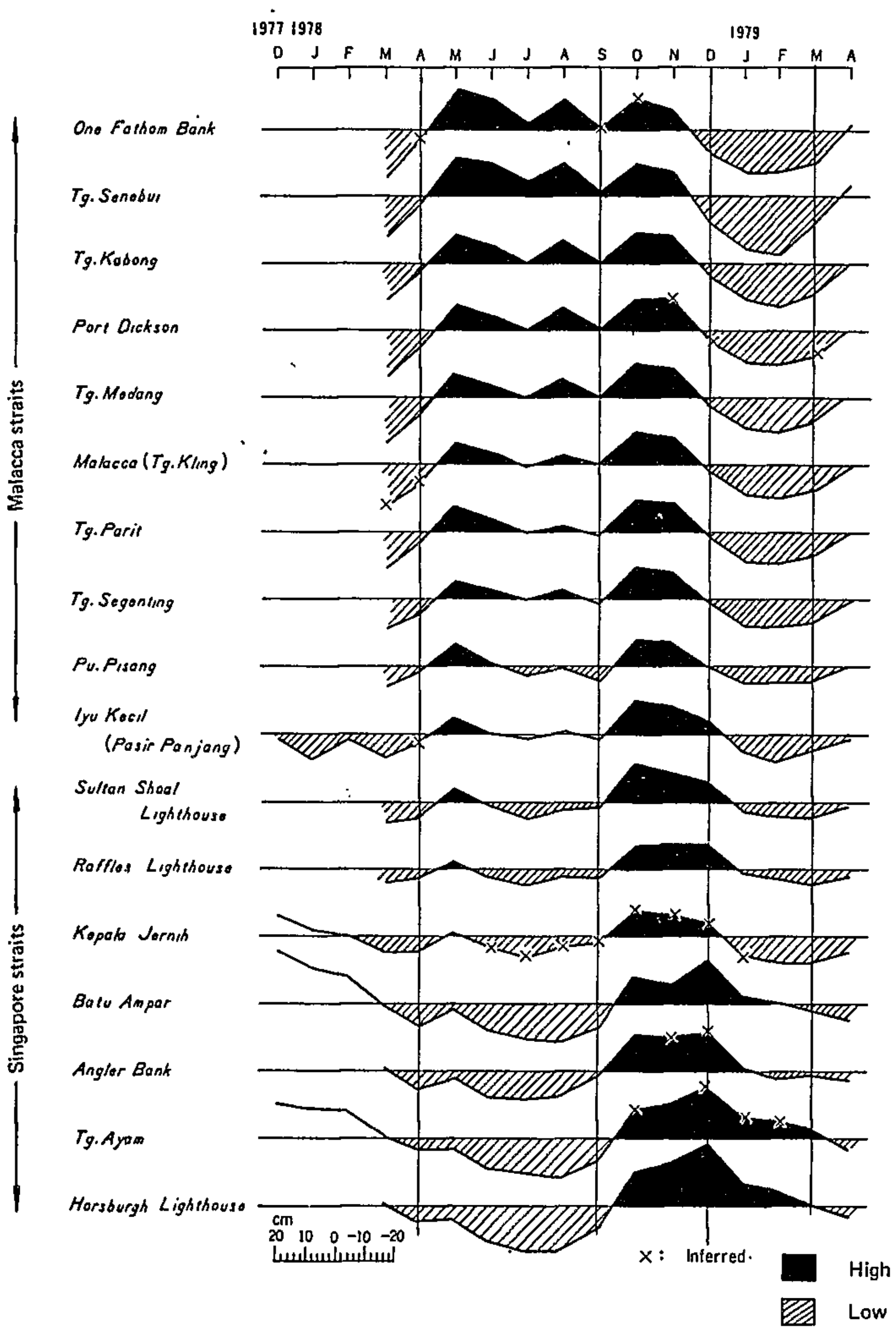


Fig. II-1-7-(2) Monthly mean sea level

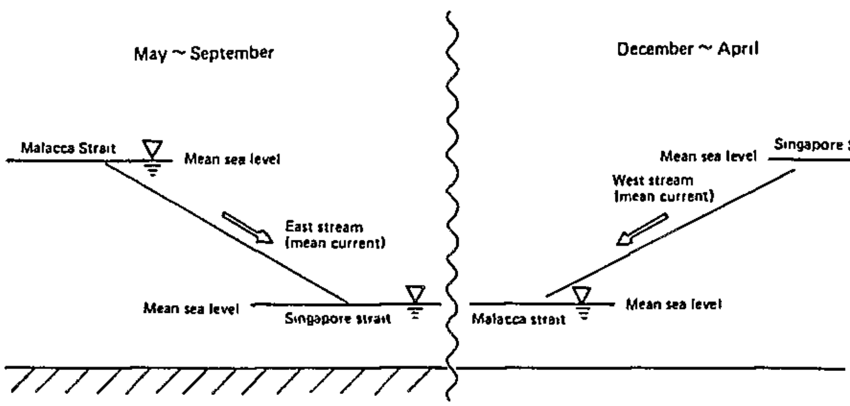
From this figure, it can be seen that the sea level conditions are different between the west side of the straits of Malacca and the east side of the straits of Singapore.

For example, in the areas from One Fathom Bank to Tg. Segenting, the sea level is higher than average during May to November and the peaks are appeared in May and October. And the sea level is lower than yearly average during December to April and the lowest peak is appeared in February.

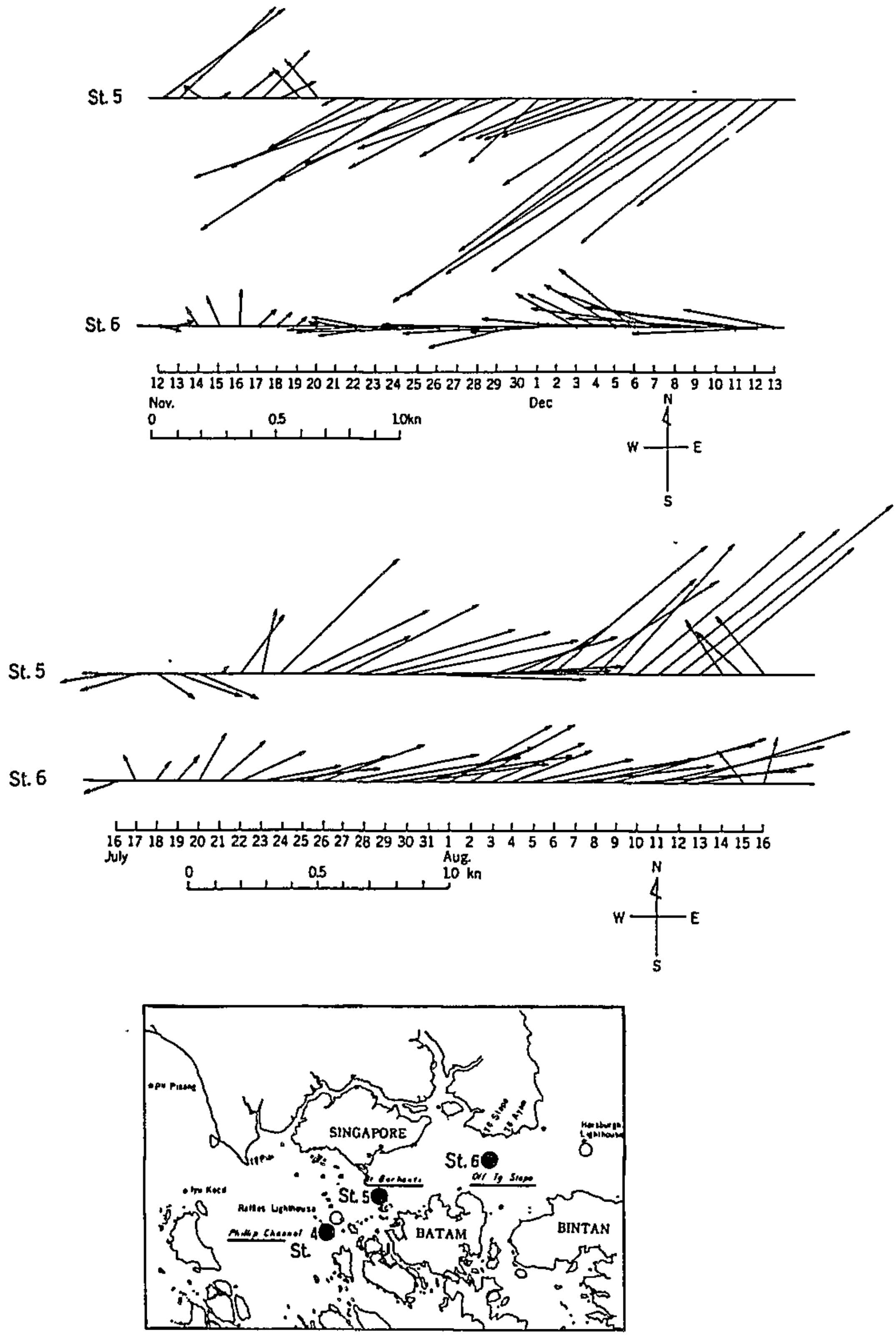
In the sea areas extending from Batu Ampar to Horsburgh Linghhouse, the monthly mean sea level is lower than the yearly mean sea level during April to September, and the lowest peak is appeared during July/August. And the sea level is higher than yearly mean level during October to March and the peak is appeared in December.

From these, it can be confirmed that the mean sea level during December to April in the side of the straits of Singapore is higher than the side of the straits of Malacca and during May to September, it is reversed.

From the above, the mean current surrounding Singapore is considered to be as shown in Fig. II-1-7-(3).



For the reference, the time variation of mean current fluctuation obtained through the Tide and Tidal Current Survey at the Straits of Malacca and Singapore are shown in Fig. II-1-7-(4).

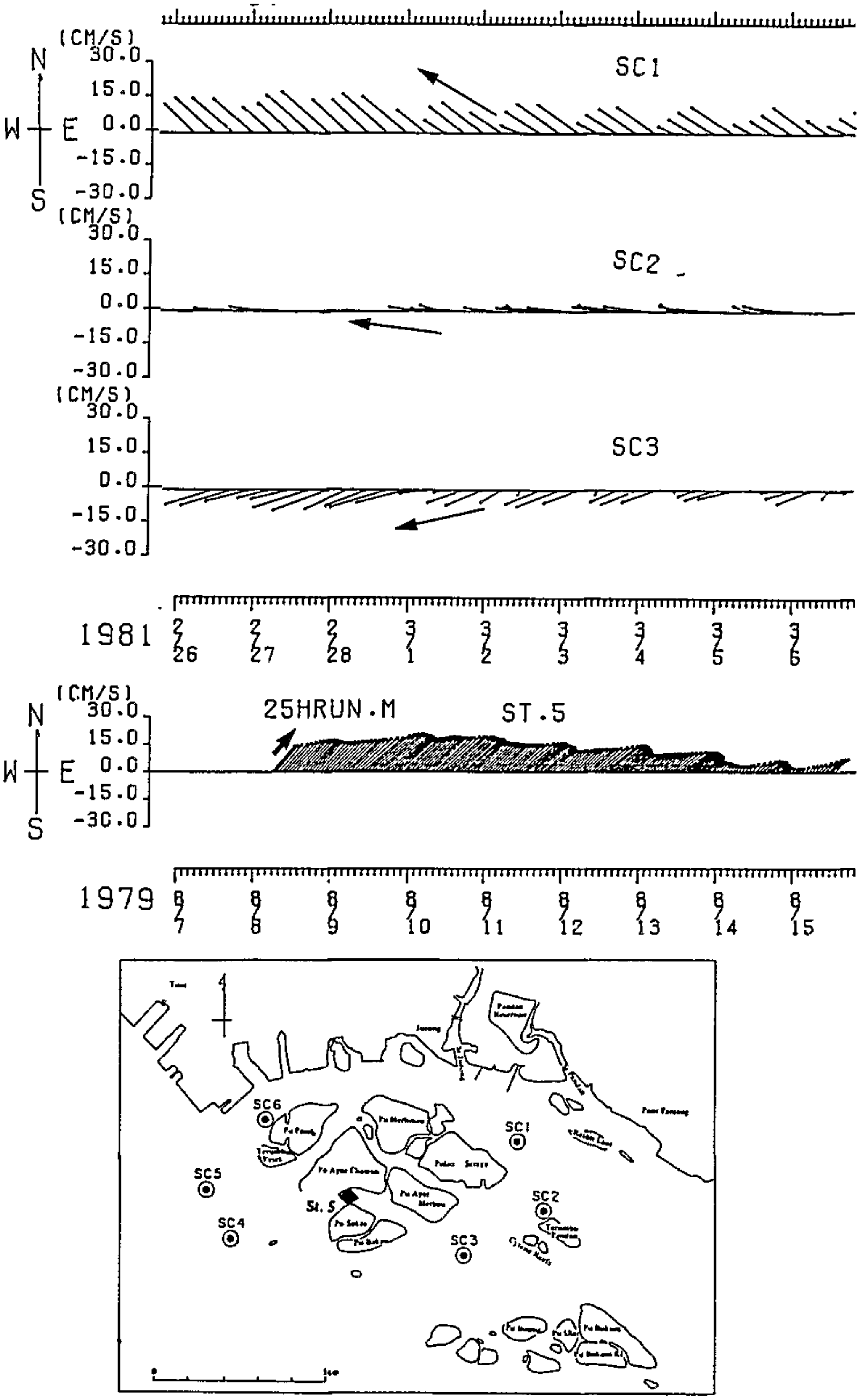


Seasonal Variation of Mean Current in the Straits of Singapore
(Comparison between Nov/Dec and July/Aug)
– Results of Tides & Tidal Current Survey at the Straits of Malacca & Singapore –

Fig. II-1-7-(4) Variation of daily mean tidal currents

And from the figure, it can be confirmed that during mid-November to mid-December illustrated in the upper part of the figure, current is the westward flow pattern and during mid-July to end-August illustrated in the down part of the figure, the current shows the eastward flow pattern.

Fig. II-1-7-(5) shows the fluctuation of the mean current of SC1, 2, 3 of Pulau Seraya Area involved in this study and St5 of the current survey conducted at Pulau Ayer Merbau Area.



Seasonal Variation of Mean Current at Seraya Area
(Comparison between Feb/Mar and August)

Fig. II-1-7-(5) Time series fluctuation of mean current

The survey at SC1, 2 and 3 has been conducted during end-Febrary to mid-March 1981 and so the current shows the westward flow pattern.

On the other hand, the survey at St5 has been conducted during August 1979 and so the current shows the eastward flow pattern. From the above, it can be confirmed that the current variation of the sea area of Singapore have the seasonal variation.

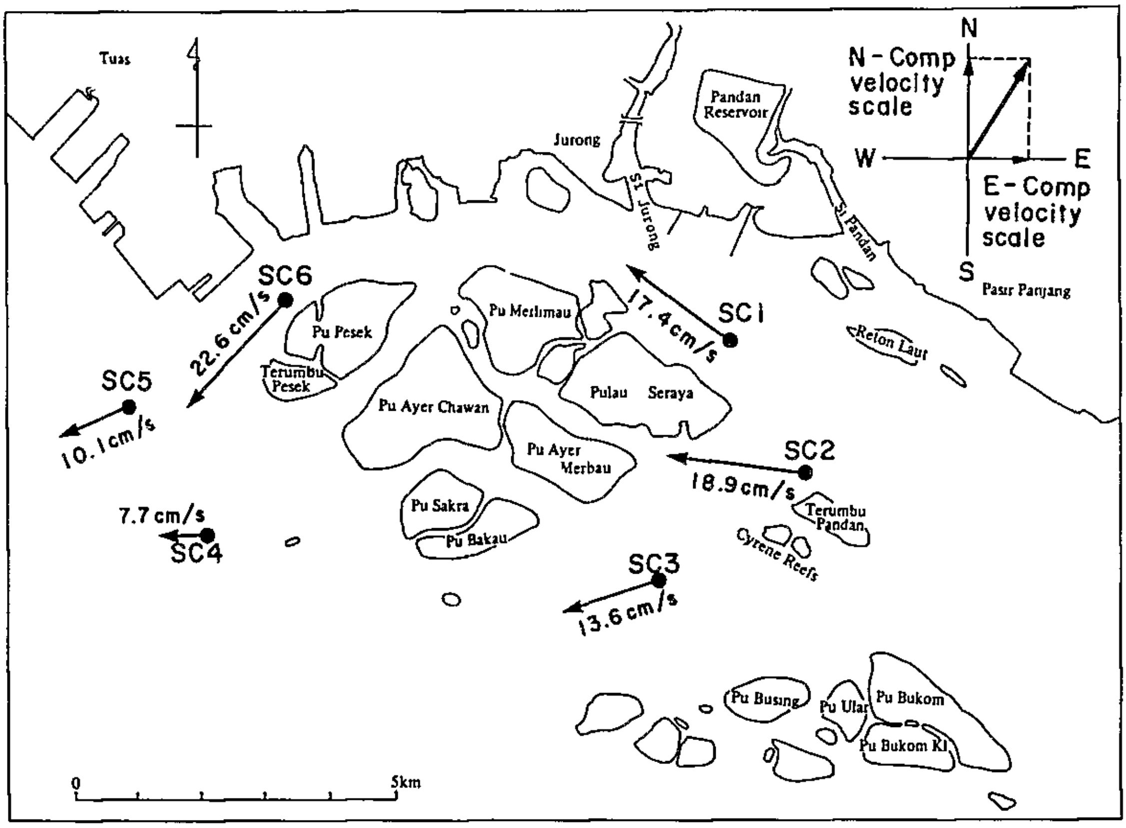


Fig. II-1-5-(16) Mean current of Seraya Area (End/Feb. to Mid/Mar. 1981)

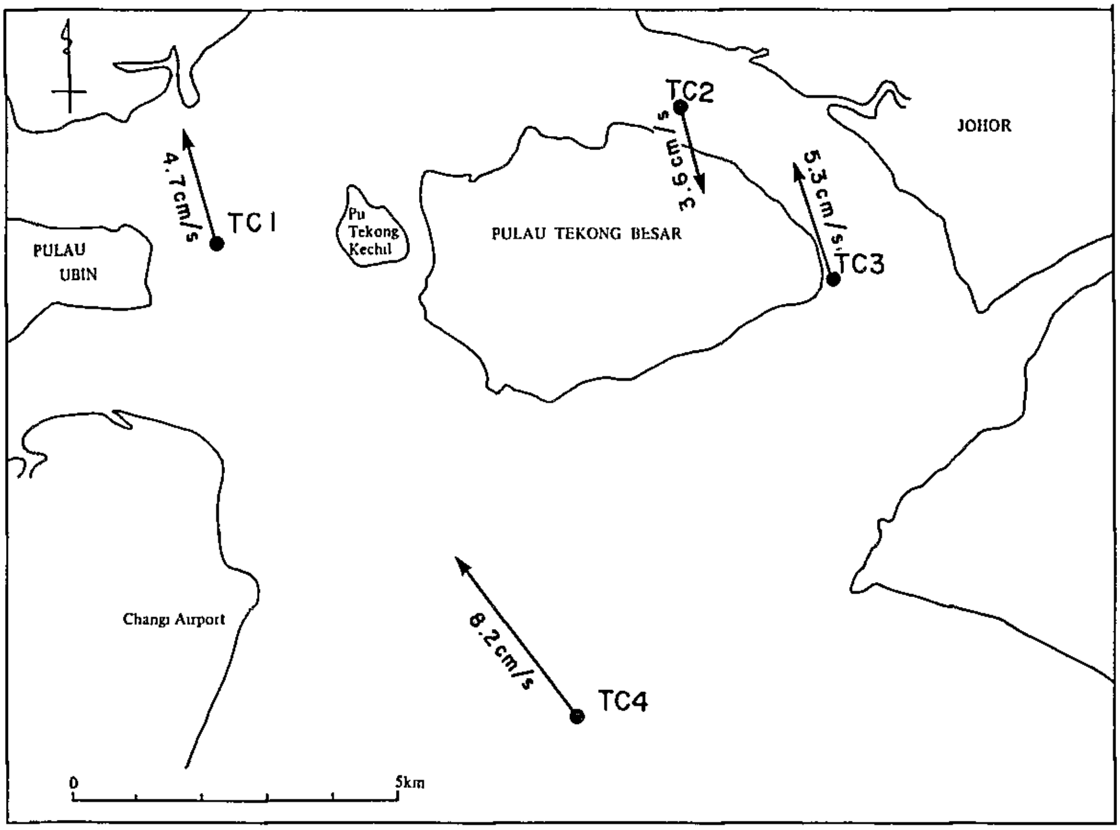


Fig. II-1-5-(17) Mean current of Tekong Area (End/Feb. to Mid/Mar. 1981)

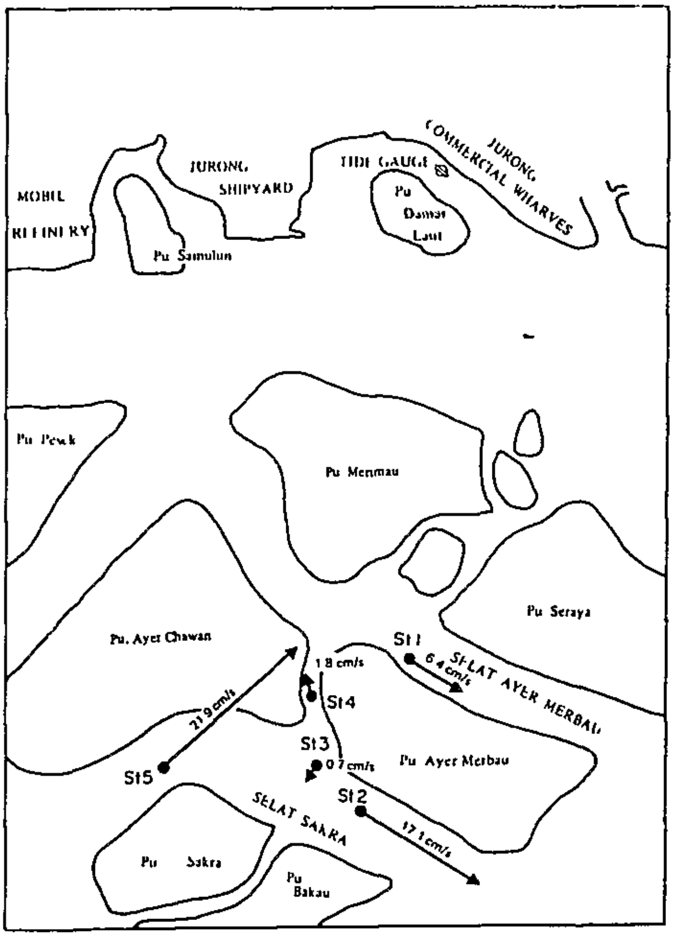


Fig. II-1-6-(9) Mean current of Pulau Ayer Merbau Area (Aug. 1979)

II-1-7-2 Tidal current pattern of Pulau Seraya Area

In the previous paragraph, II-1-7-1, the mean current (defined as constant current) of the areas surrounding Singapore has been confirmed to exist the seaonal variation in the current direction.

In this and the next paragraphs, the tidal current pattern of Pulau Seraya and Tekong Area are described.

The results of the data analysis indicate that in this area the tidal current is dominant. And at Seraya Area, the current conditions are fluctuating with about 1 day period and at Tekong Area the current conditions are fluctuating with about ½ day period.

The results of harmonic analysis of the tidal current indicate that K_1 component current of about 1 day cycle period at Seraya Area and M_2 constituent are dominant.

Based on the current condition chart of the constituent, and the results of current pattern analysis, the tidal current pattern of Seraya Area is described in this paragraph and in the next paragraph the tidal current pattern of Tekong Area is described.

1) Scattering plot

Fig. II-1-7-(6) shows the horizontal distribution chart of the scattering plots.

From the figure, the oscillating current pattern is shown, which is directing in parallel to the coastal line at all the survey points. (Refer to arrow marks in the figure.)

The scattering plot of SC4 and SC5 shape rather round and it means the current conditions of these 2 survey points are rather complicated than other points.

The plot indicates the direction to east/west except SC1 and SC6. At SC1 plots are distributing to the direction in parallel with the coastal line of Singapore main island.

From the directon of plot distribution, the dominant current direction at all survey points can be seen.

Fig. II-1-7-(7) shows the horizontal distribution chart of scattering plots of Pulau Ayer Merbau Area. In this diagram, the plot is also distributing to the direction in parallel to the coastal line of the islands.

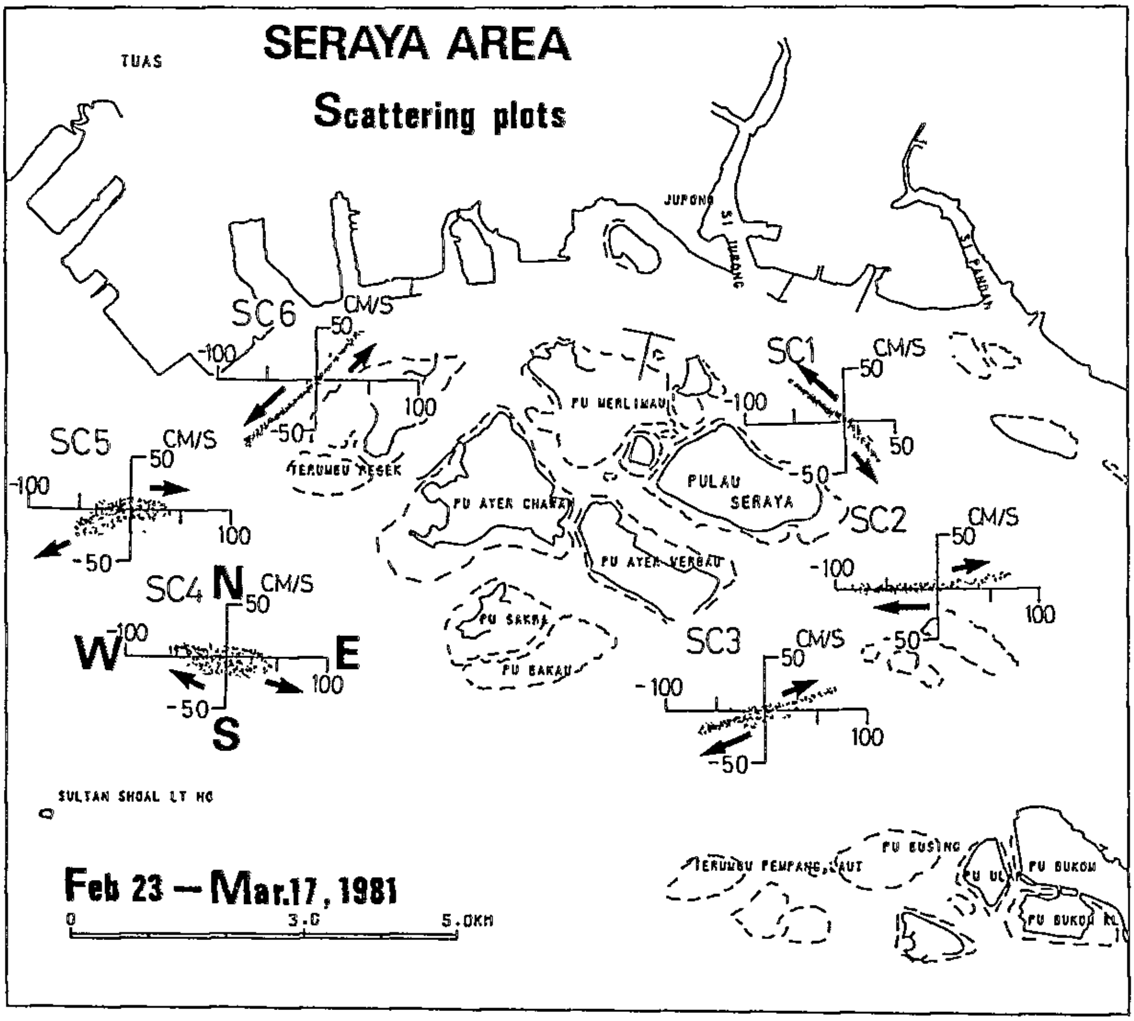


Fig. II-1-7-(6) Scattering plots of current direction and velocity of Pulau Seraya Area

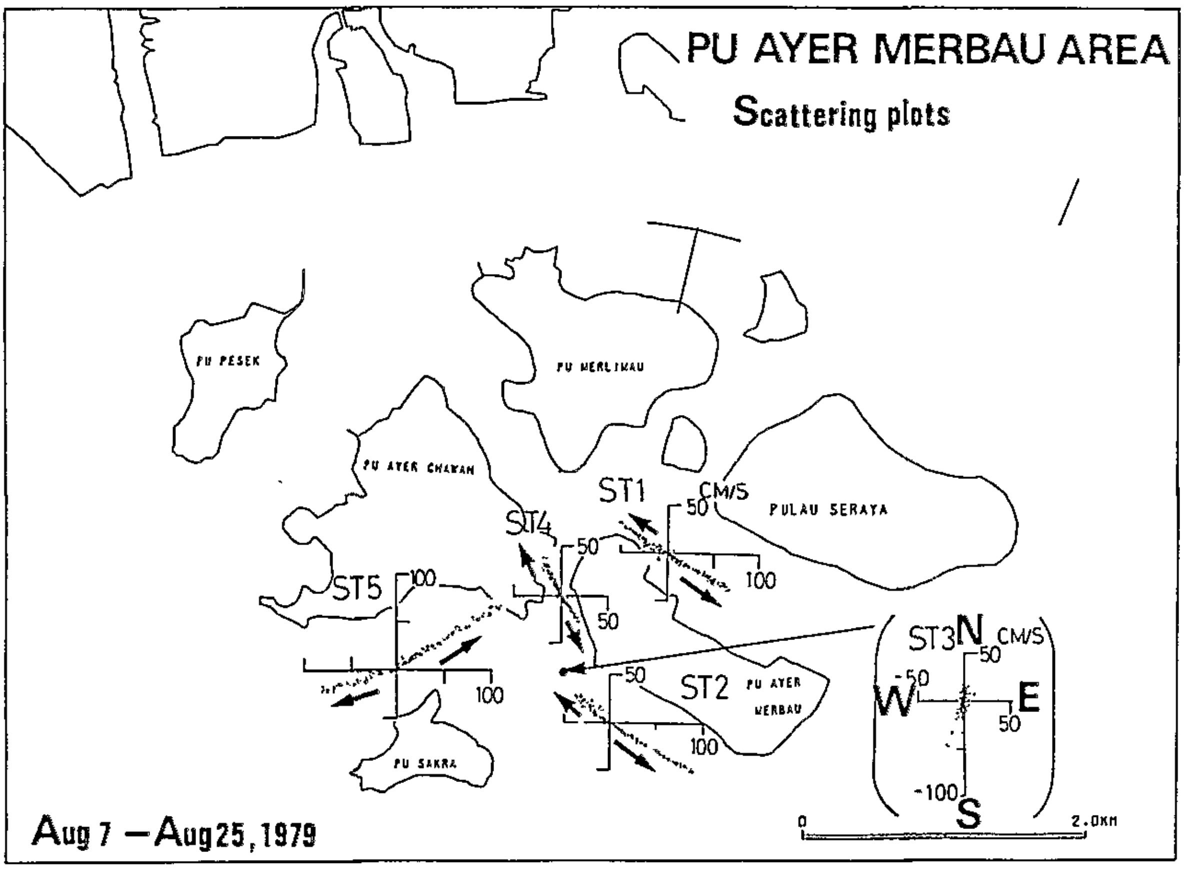
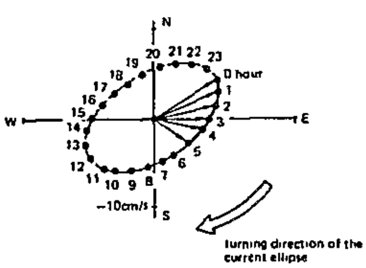


Fig. II-1-7-(7) Scattering plots of current direction and velocity of Pulau Ayer Merbau

2) Horizontal distribution chart of current ellipse and current condition chart

Fig. II-1-7-(8) shows the horizontal distribution chart of tidal current ellipse of K_1 constituent which is dominant in Seraya Area. As the period of K_1 constituent is about 1 day, the top of the velocity vectors of every hour of 0 to 23 hours are connected for illustrating the curve.

K_1 Component current



The left figure shows the velocity vectors are fluctuating with the time from North/West - East - East/South - South. The rotating sense of the current ellipse is defined as clockwise.

The maximum velocity (of K_1 component current) of 0 hour is directing to North/East (North/East stream), and at 3 hour it comes to East, and again at 12 hour the maximum velocity appears but the direction is quite opposite by 180° against 0 hour.

The actual maximum velocity of each survey point can be obtained by summing up the velocity values of the 4 major component current (K_1, O_1, M_2 & S_2) resulted from the harmonic analysis of the tidal current.

The velocity values of every hour of K_1 component current mentioned in the Fig. II-1-7-(8) are obtained from the velocity scale (indicated as 0.35 m/s) and the length of the ellipse axis of every hour.

The rotating sense of the current ellipse as mentioned in the Fig. II-1-7-(8) are clockwise in the side of Singapore main island and counterclockwise in the side of the Straits of Singapore.

The ellipse of all the survey points except SC5 are plotted in solid line which indicate what direction of current are dominant.

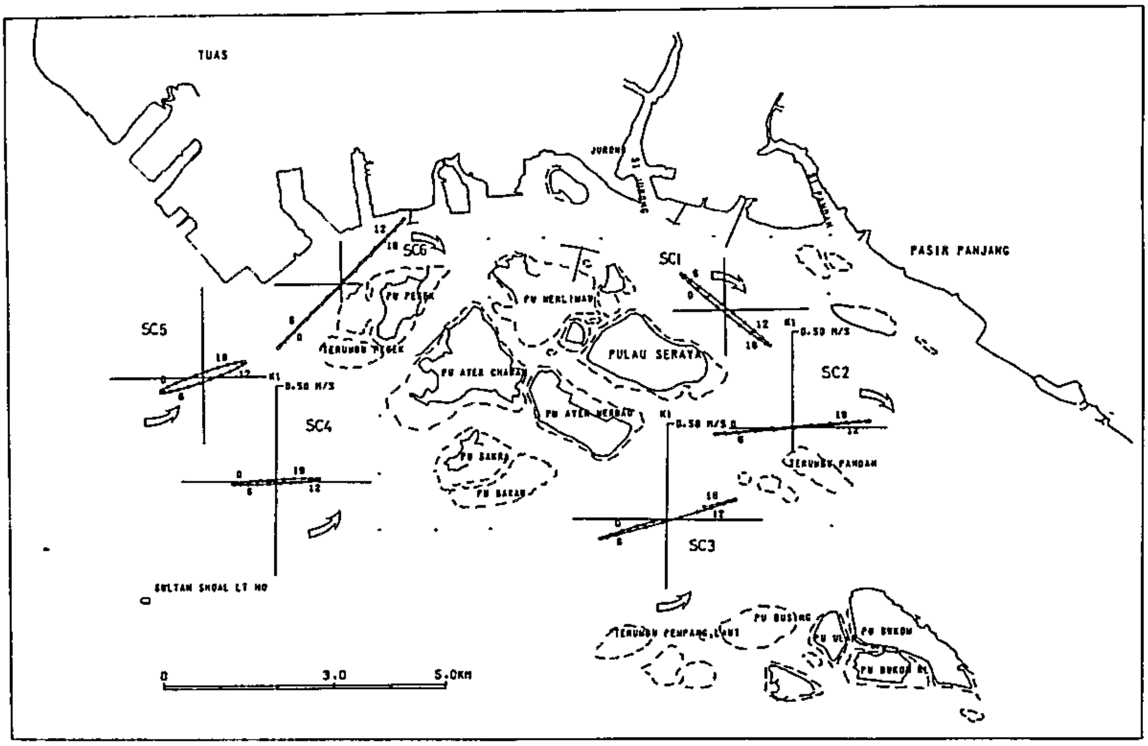
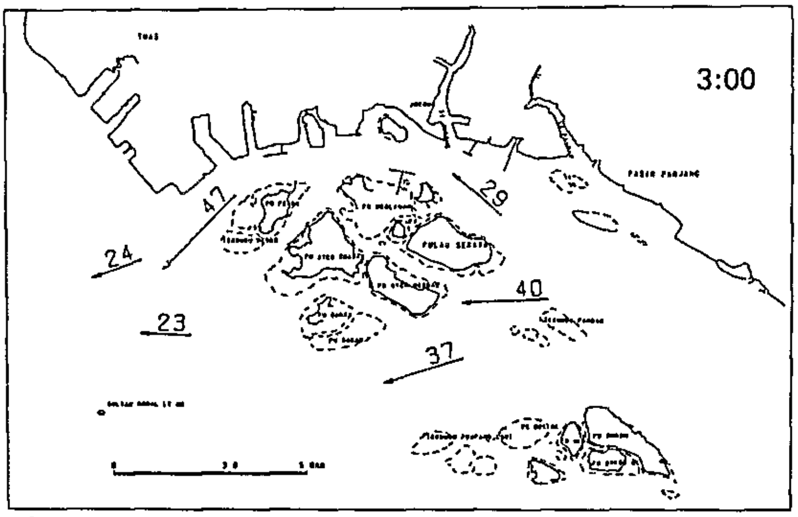


Fig. II-1-7-(8) Horizontal distribution of current ellipse of dominant component current at Seraya Area

Fig. II-1-7-(9) shows horizontal distribution of the current fluctuation mentioned in the above. These figures are usually called as Current Condition Chart or Tidal Current Chart.

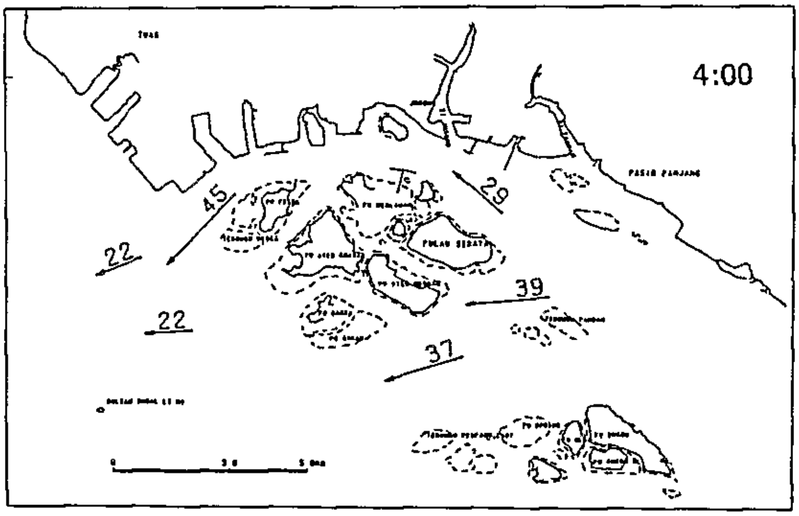
It is expressed by the horizontal distribution chart of the tidal current vector of every one hour between 0 to 23 hour which were shown in the current ellipse.

In the figure, the number indicated on the vectors is the velocity magnitude (unit-cm/sec).



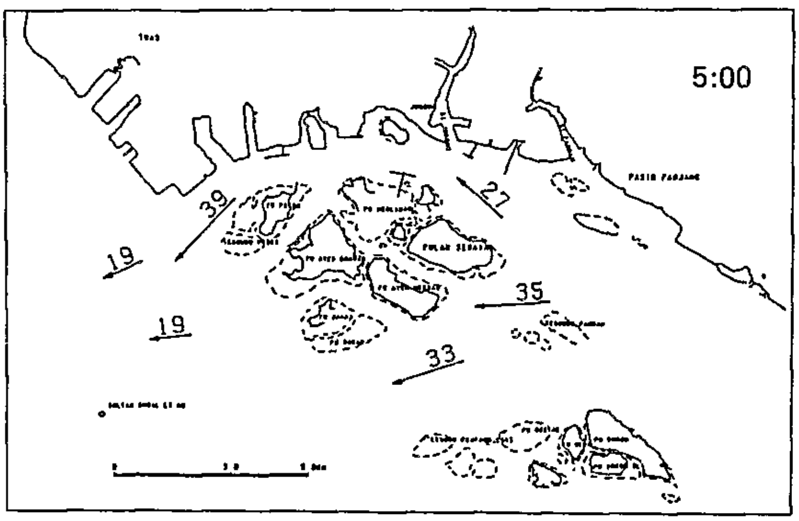
03:00 hour (high tide)

Maximum velocity time of westward flow pattern.



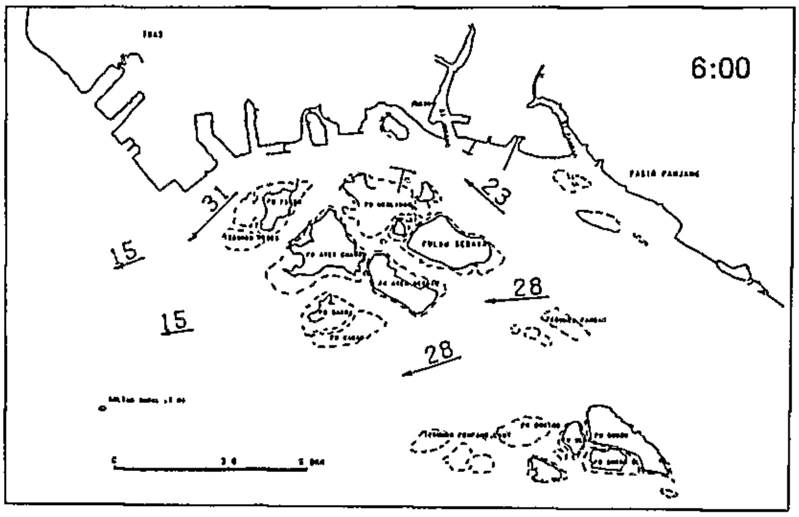
04:00 hour

Westward flow pattern



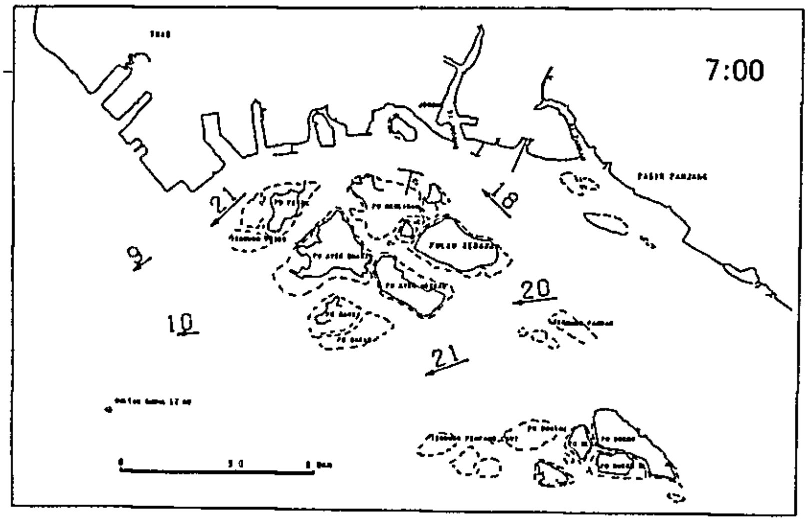
05:00 hour

Westward flow pattern



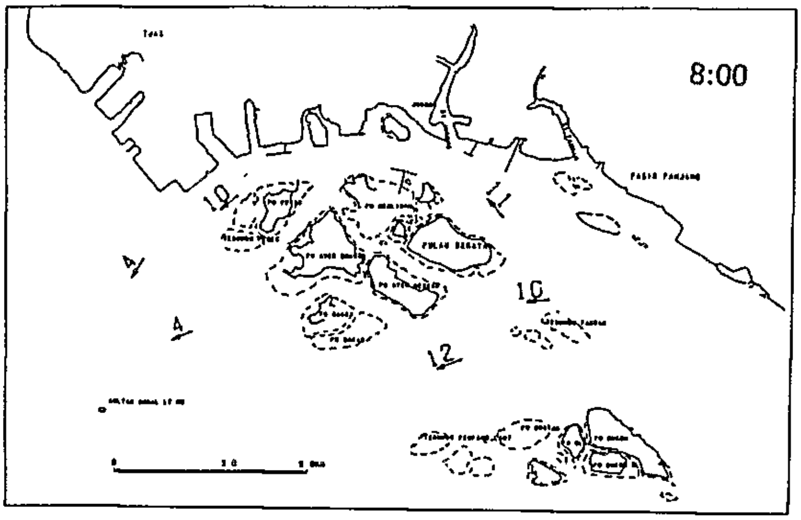
06:00 hour

Westward flow pattern



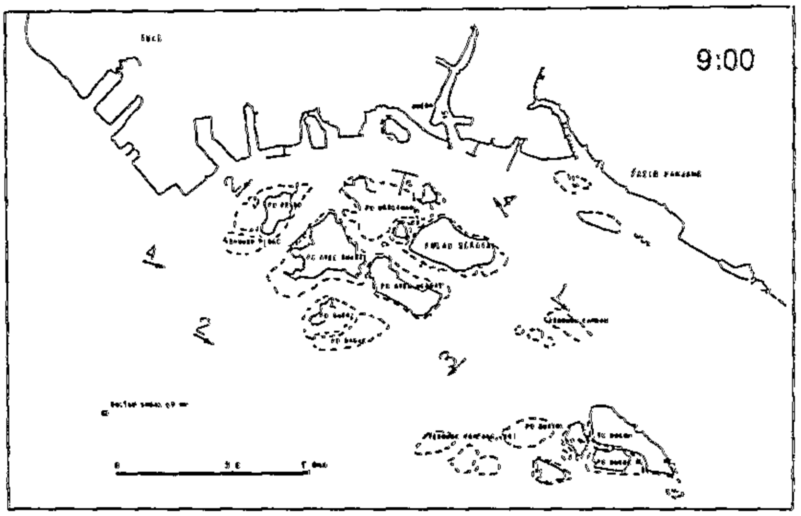
07:00 hour

Westward flow pattern



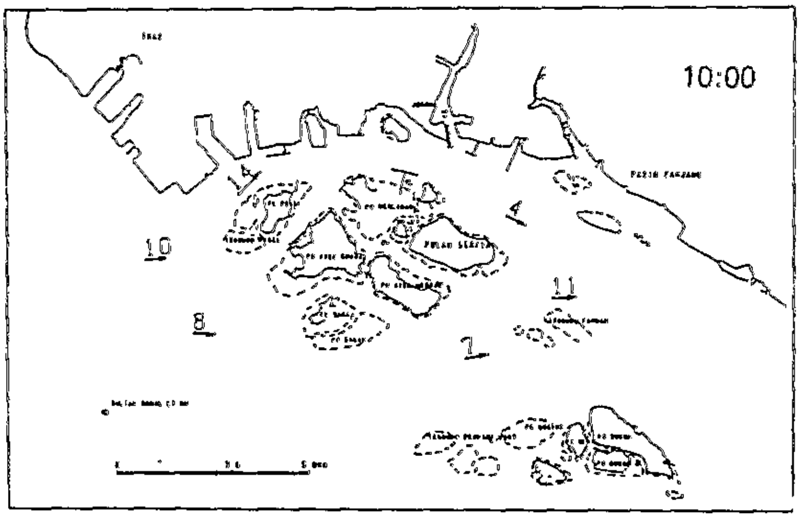
08:00 hour

Westward flow pattern



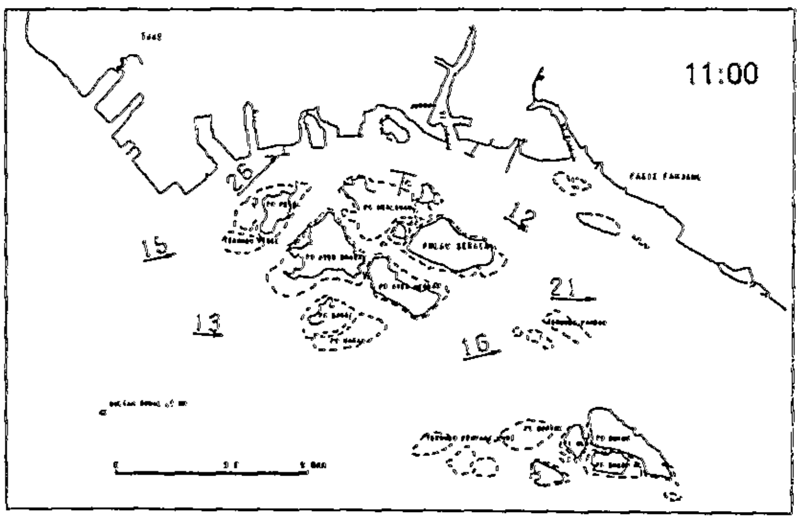
09:00 hour

The turn of current commences from the west side



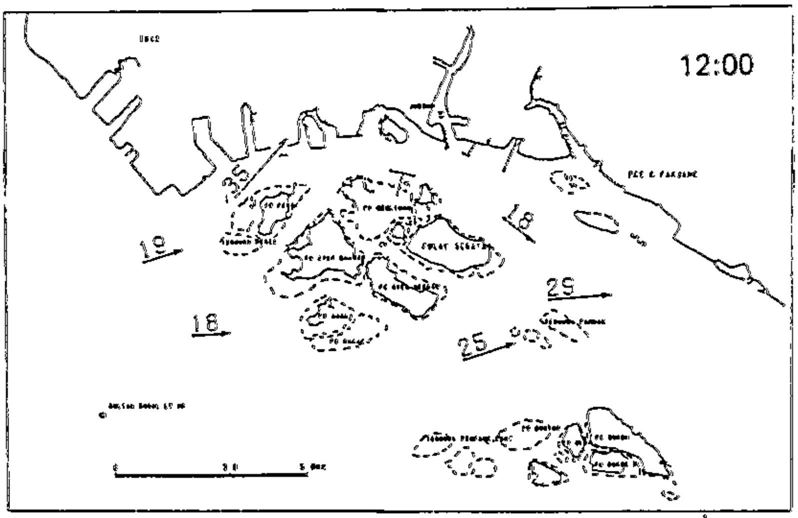
10:00 hour

Changes to eastward flow pattern



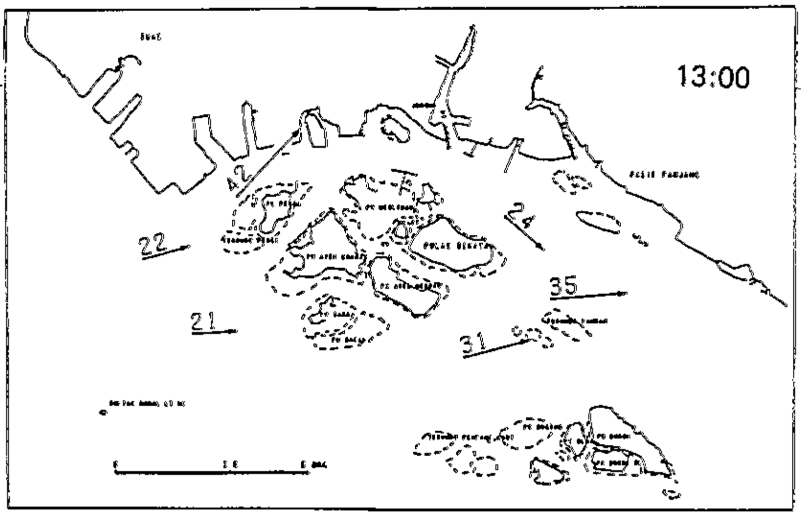
11:00 hour

Eastward flow pattern



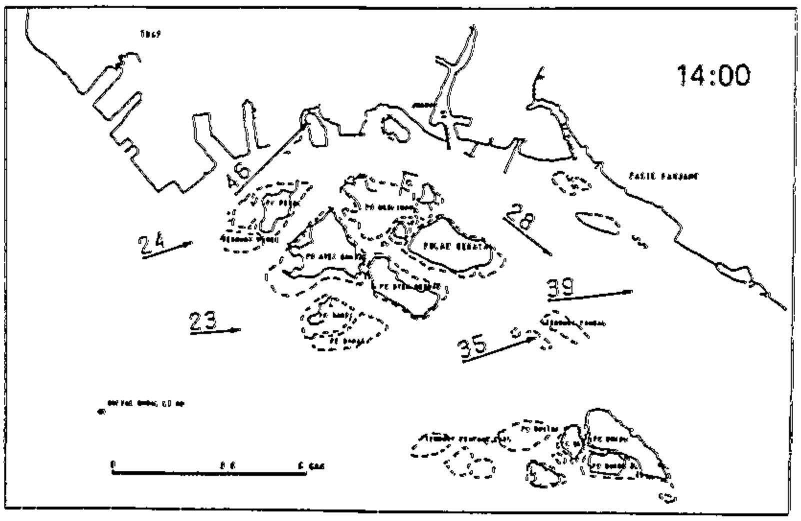
12:00 hour

Eastward flow pattern



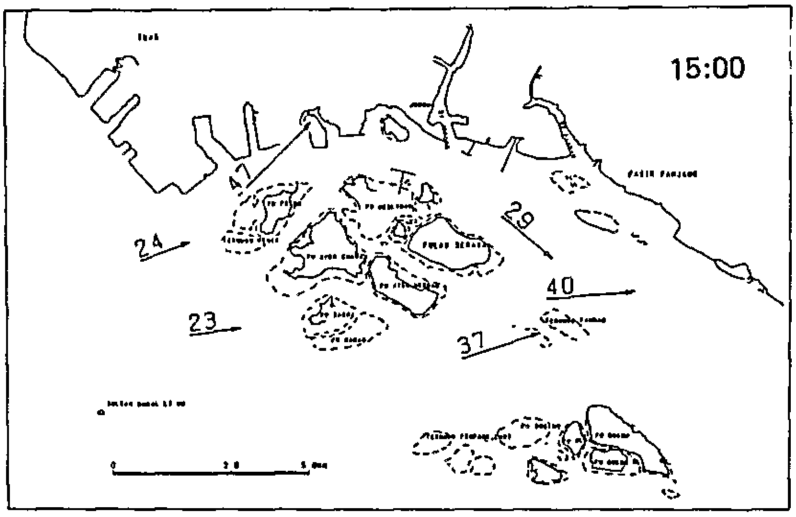
13:00 hour

Eastward flow pattern



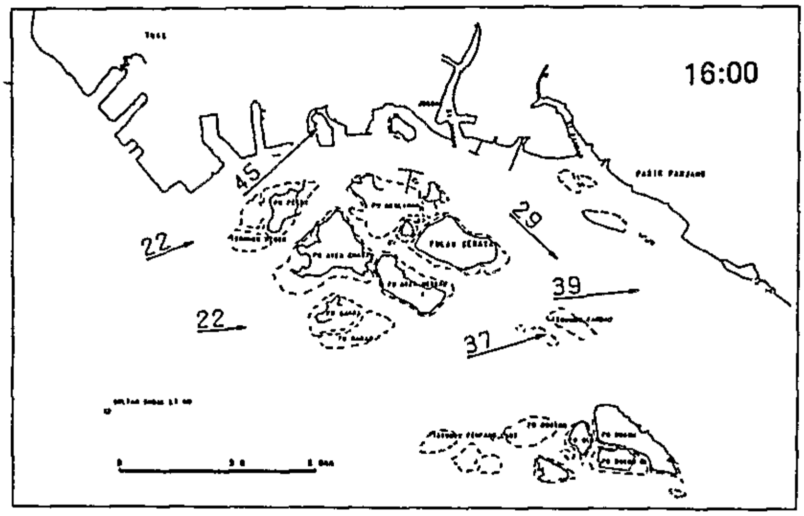
14:00 hour

Eastward flow pattern



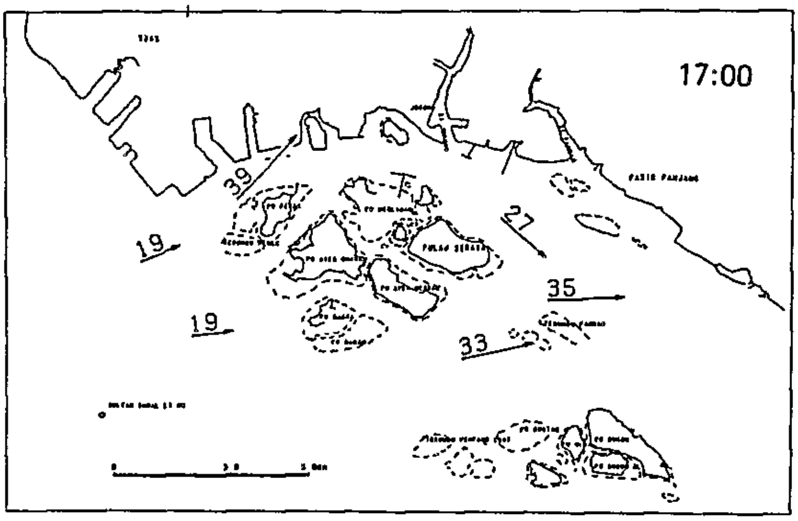
15:00 hour

The maximum velocity time of eastward flow pattern



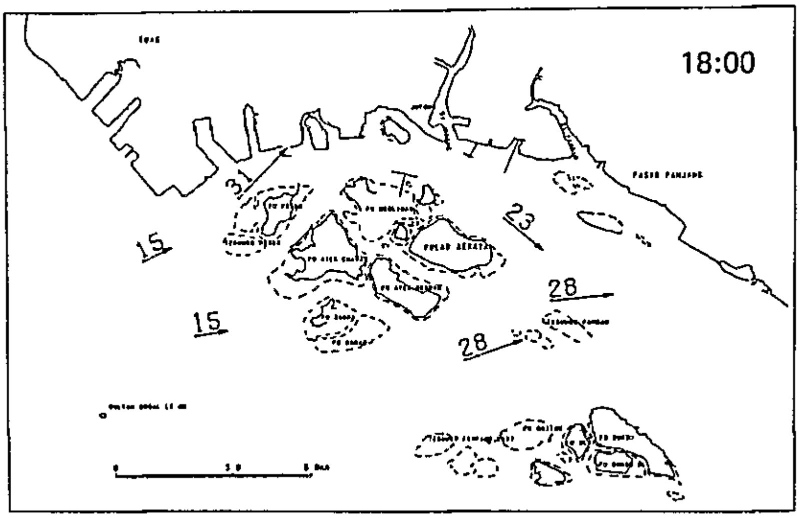
16:00 hour

Eastward flow pattern



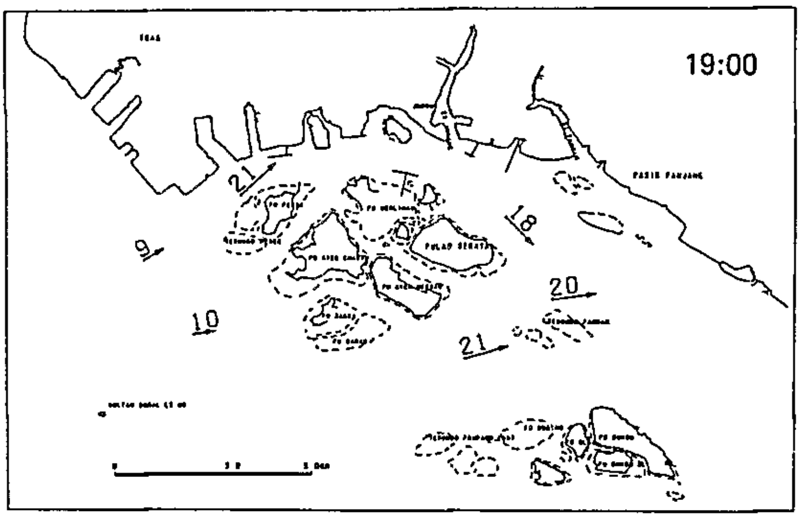
17:00 hour

Eastward flow pattern



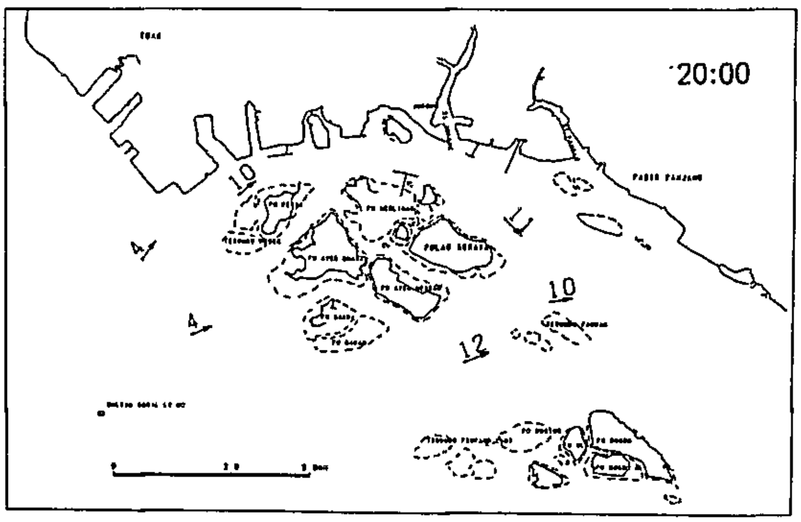
18:00 hour

Eastward flow pattern



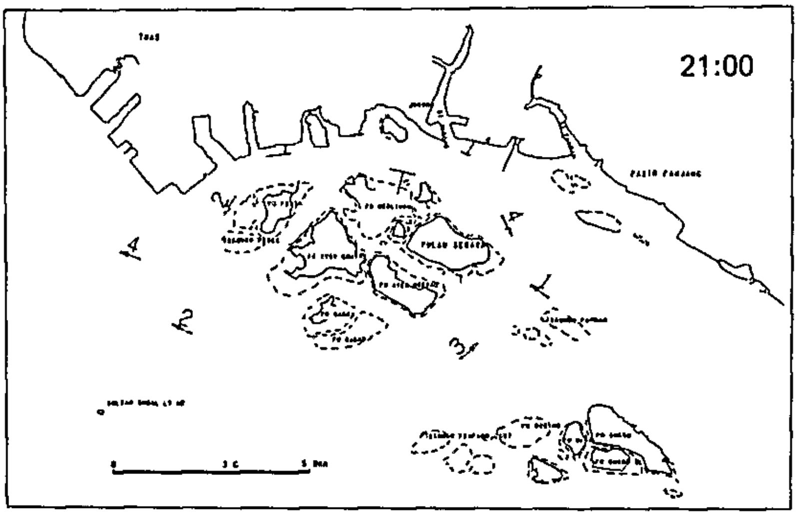
19:00 hour

Eastward flow pattern

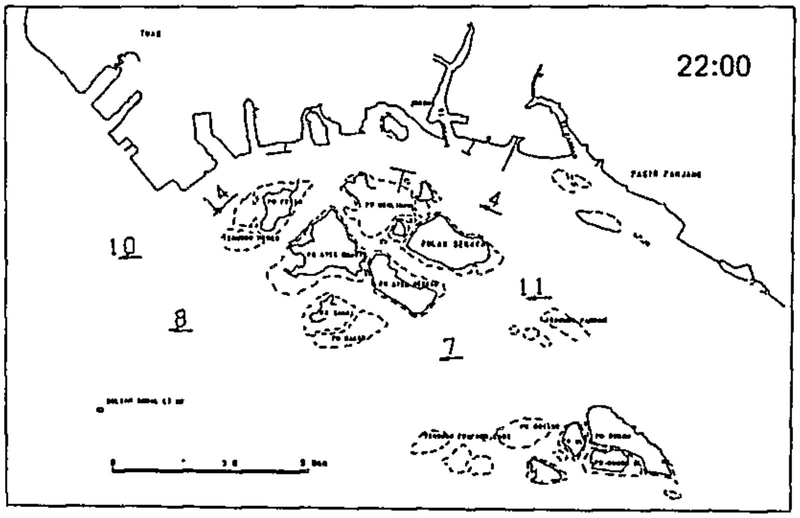


20:00 hour

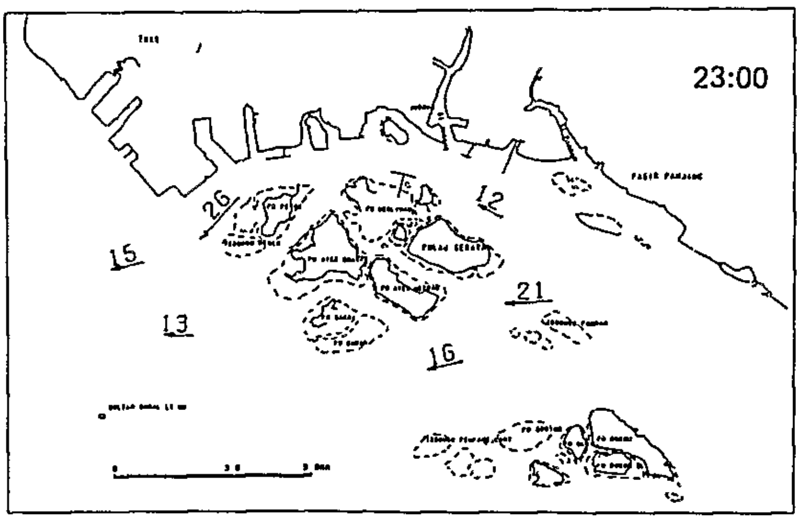
Eastward flow pattern



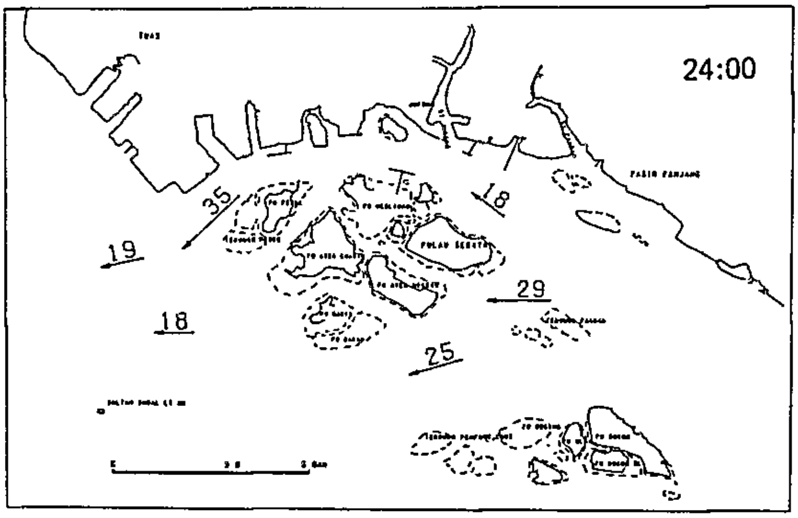
21:00 hour (low tide)
The turn of current commences



22:00 hour
Westward flow pattern

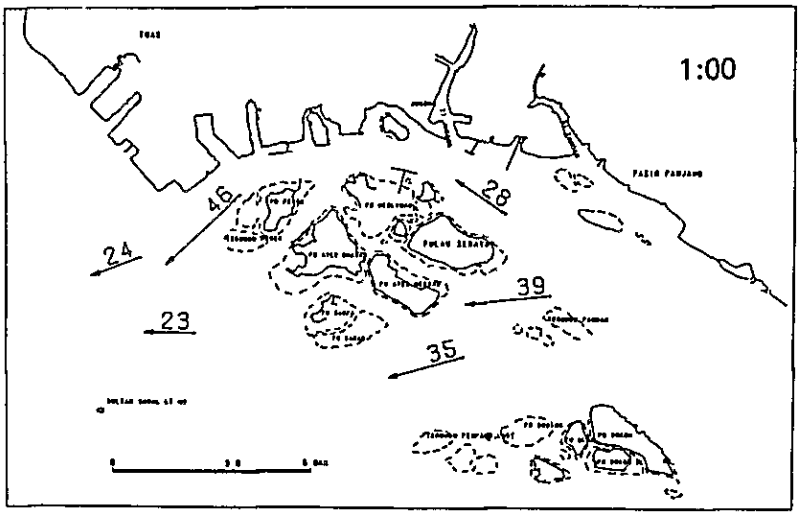


23:00 hour
Westward flow pattern



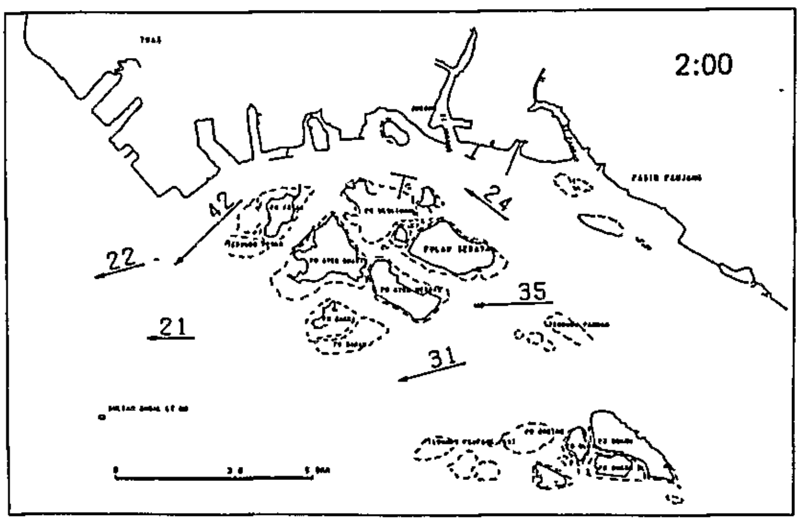
24:00 hour

Westward flow pattern



01:00 hour

Westward flow pattern



02:00 hour

Westward flow pattern

Fig. II-1-7-(10) shows the horizontal distribution chart of the tidal ellipse of the dominant constituent (K_1 component current) at Pulau Ayer Merbau Area.

This figure has been compiled for observation of current conditons of the islands surrounding Pulau Seraya.

The rotating sense of the current ellipse is counterclockwise at St3 and 4 and clockwise at St1, 2 and 5.

Fig. II-1-7-(11) shows the current condition chart of 0 to 23 hour. Same as the current condition chart of Seraya Area, the westward flow pattern and the eastward flow pattern are observed between 0 to 23 hour.

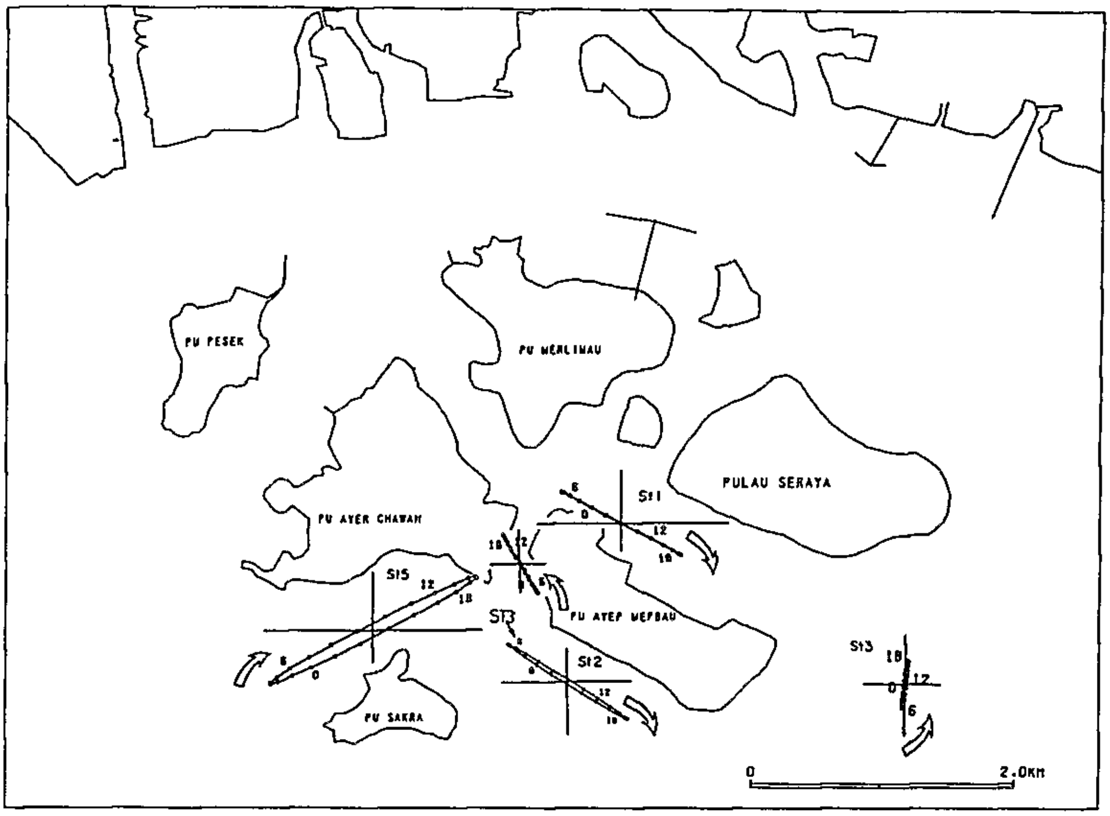


Fig. II-1-7-(10) Horizontal distribution chart of tidal ellipse of dominant constituent at Pulau Ayer Merbau

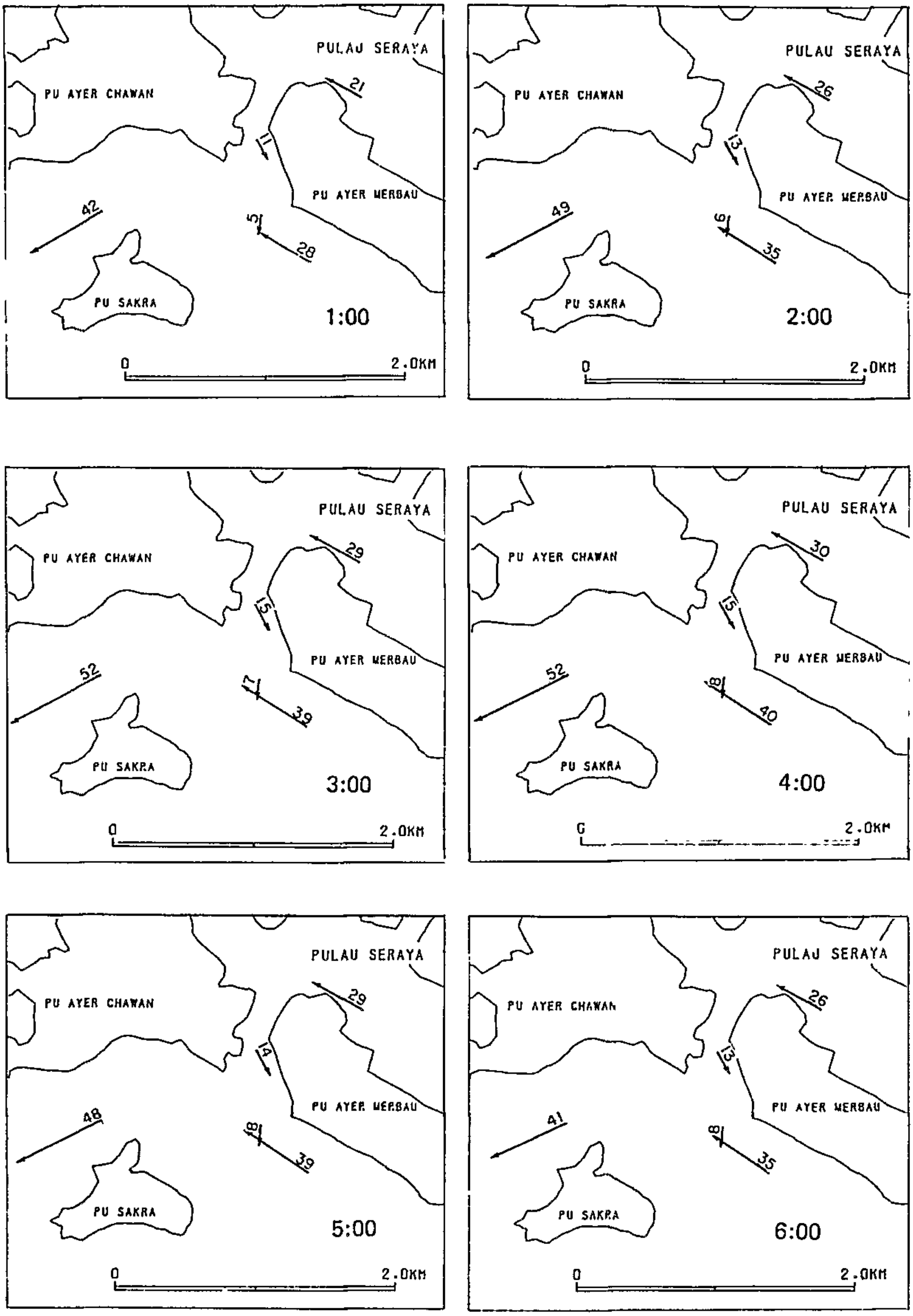


Fig. II-1-7-(11) Current condition chart (K_1 component current) of Pulau Ayer Merbau Area (1/4)

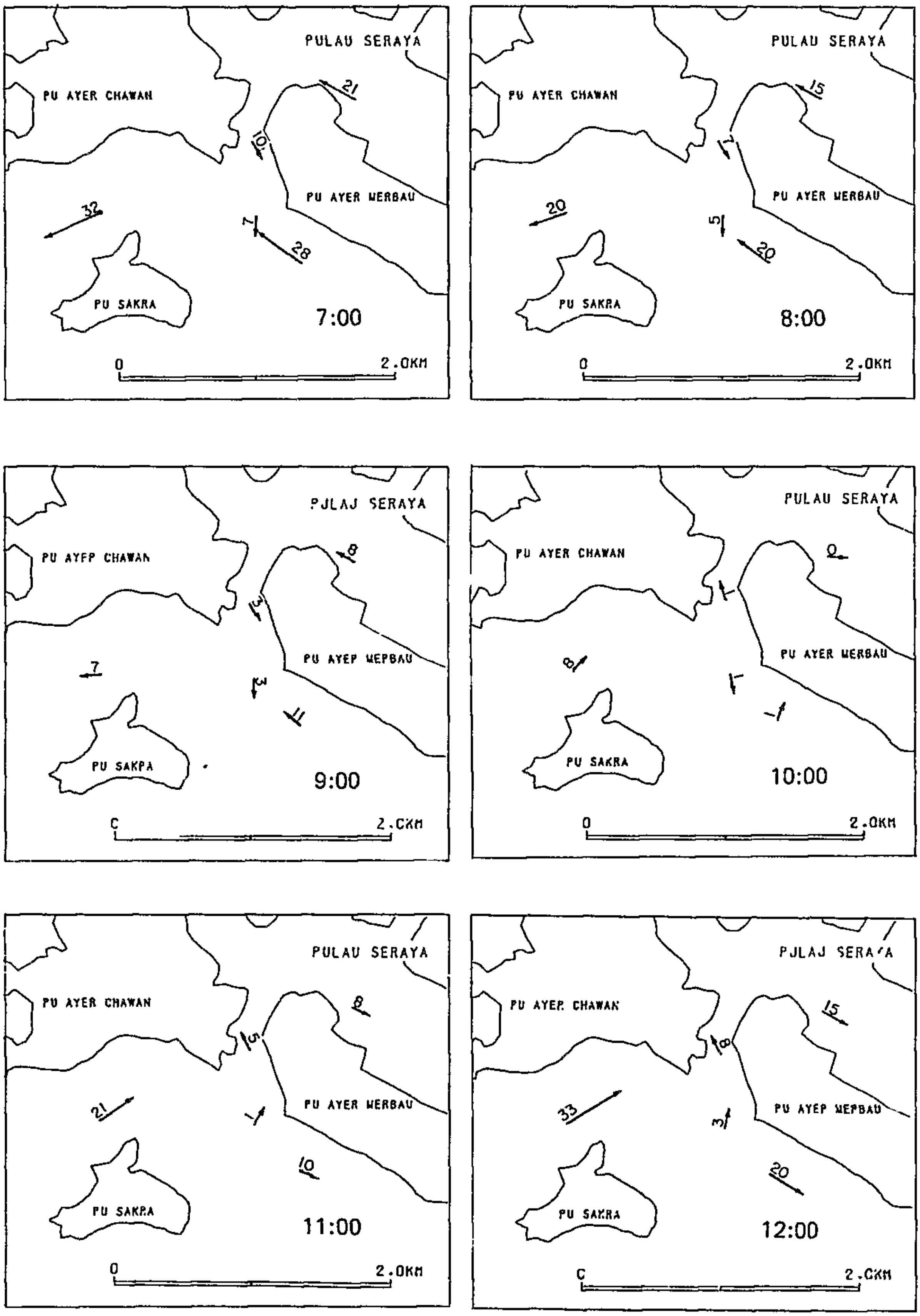


Fig. II-1-7-(11) Current condition chart (K_1 component current) of Pulau Ayer Merbau Area (2/4)

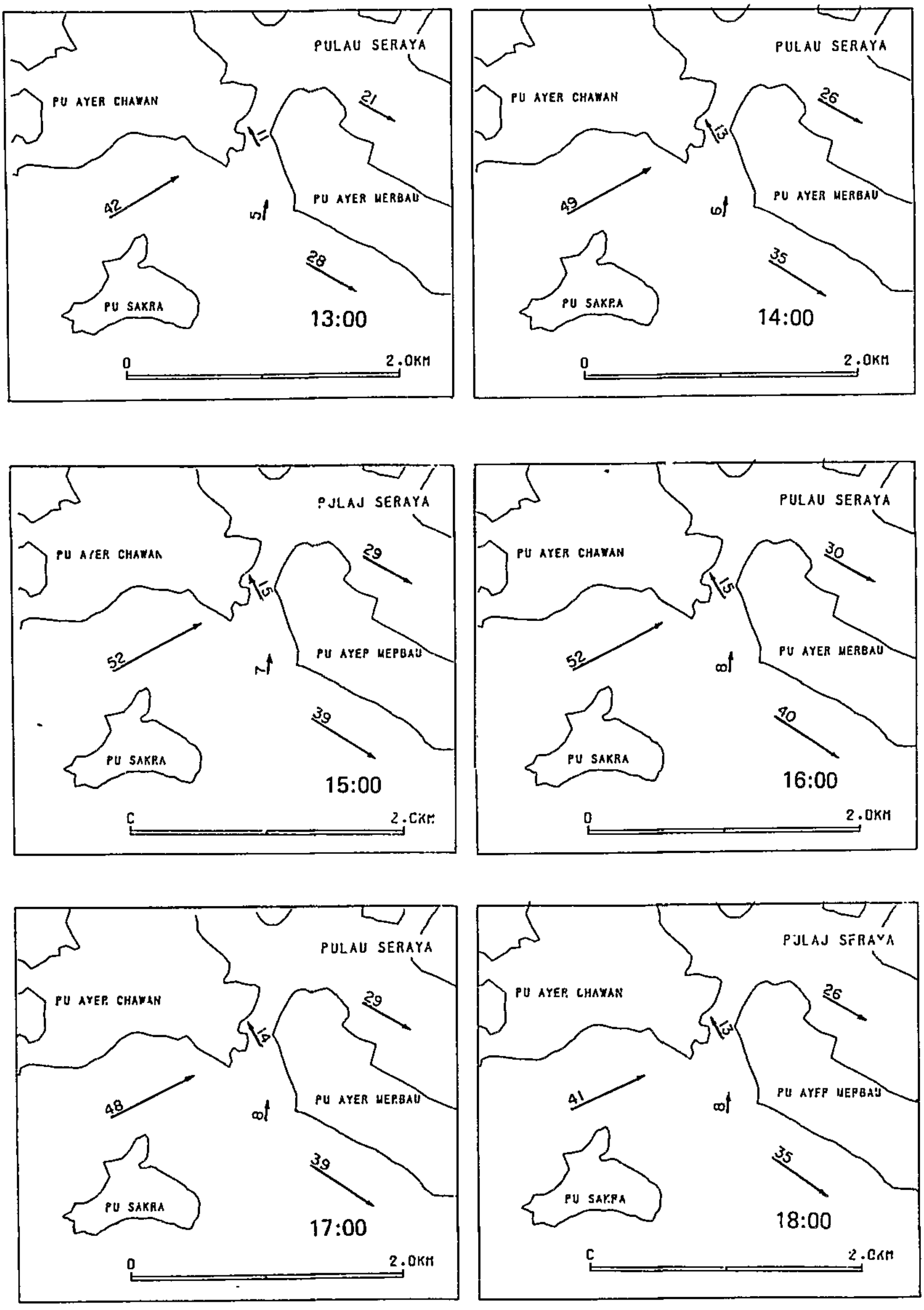


Fig. II-1-7-(11) Current condition chart (K_1 component current) of Pulau Ayer Merbau Area (3/4)

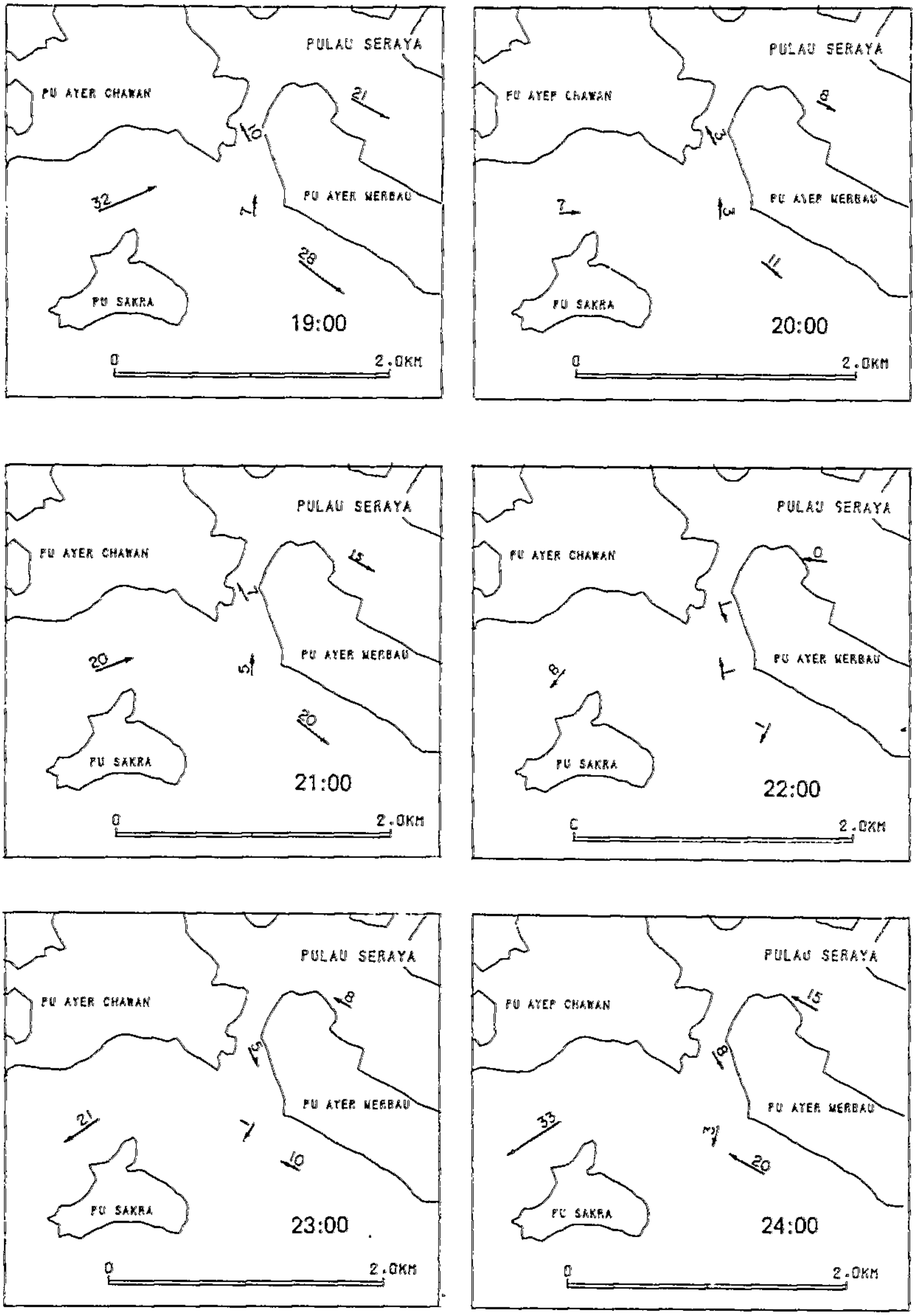


Fig. II-1-7-(11) Current condition chart (K_1 component current) of Pulau Ayer Merbau Area (4/4)

II-1-7-3 Tidal current pattern of Pulau Tekong Area

1) Scattering plot

Fig. II-1-7-(12) shows th scattering plot of the current direction and velocity.

From the figure, the plots of TC1 to TC3 are distributing to the direction parallel to the coastal line, and TC4 located at offshore is distributing towards Pulau Ubin.

2) Horizontal distribution of tidal current ellipse and current condition chart

Fig. II-1-7-(13) shows the horizontal distribution chart of current ellipse of M_2 component which is most dominant at Tekong Area.

The rotating sense of the ellipse is clockwise at TC1 and TC2, and is counterclockwise at TC3 and TC4.

M_2 component current is semi-diurnal current and the current conditions expresed by ellipse is the curent conditions of 12 hours which include 0 to 11 hour.

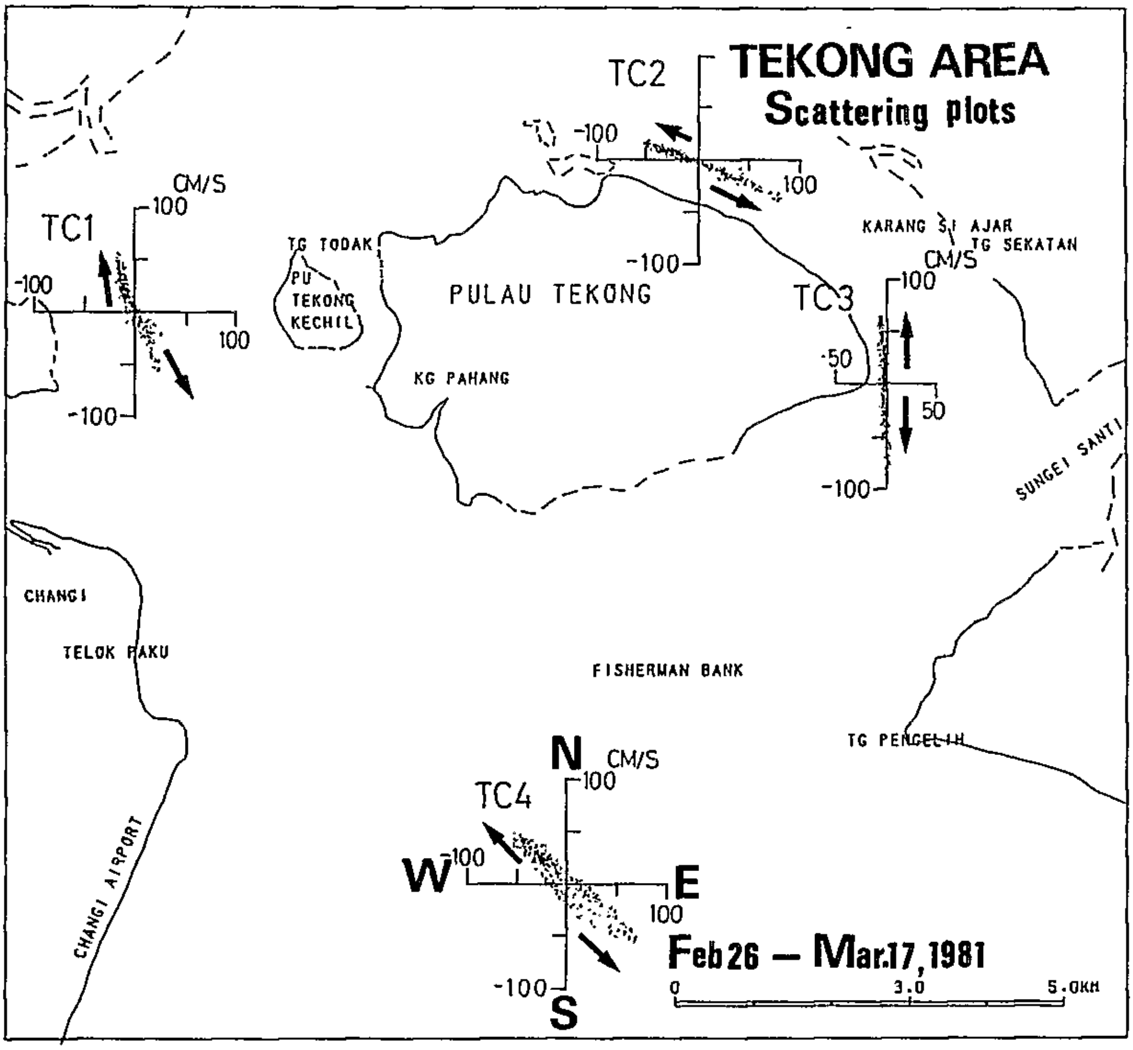


Fig. II-1-7-(12) Scattering plot of current direction and velocity of Tekong area

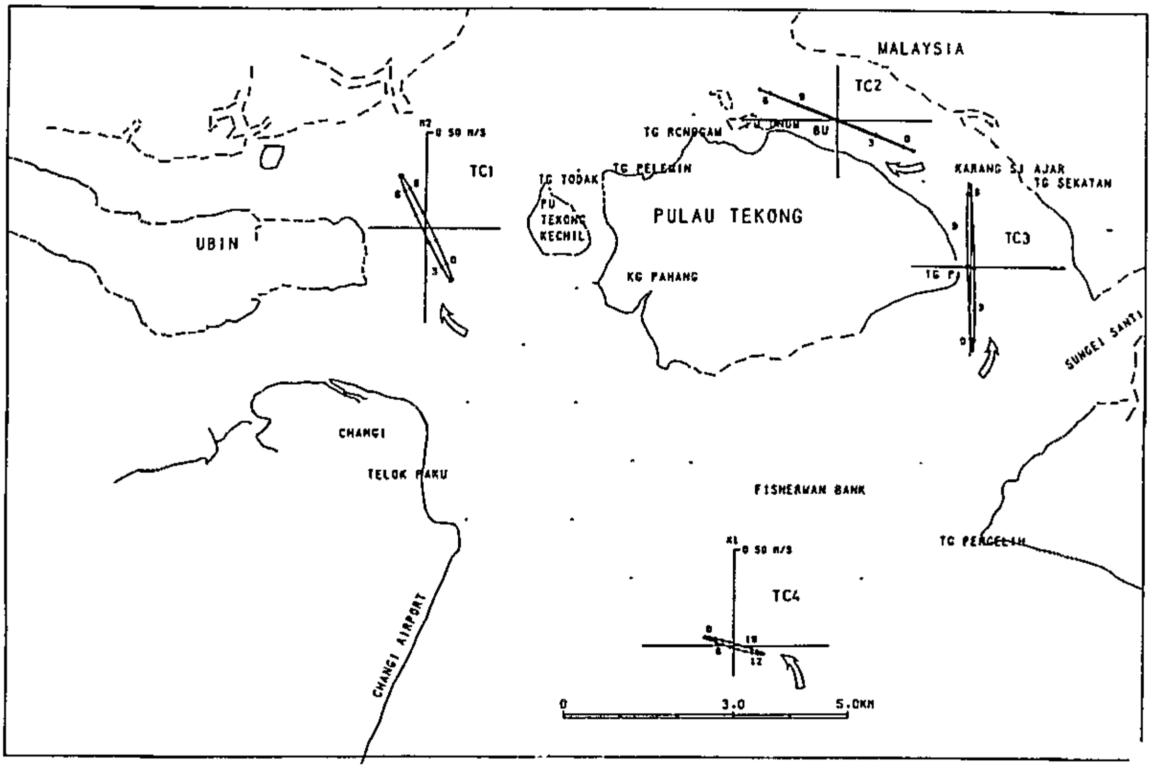
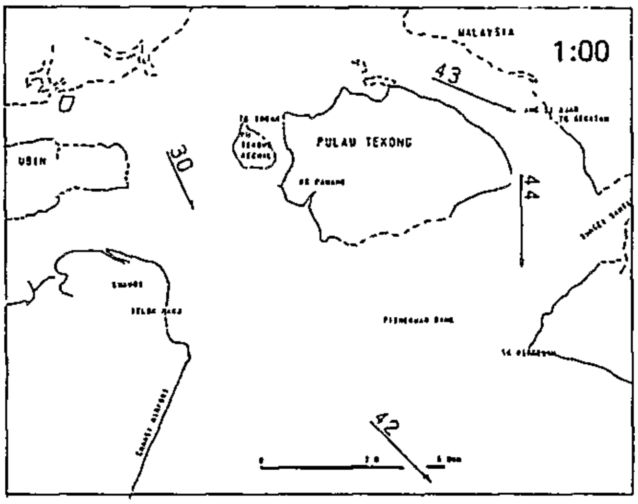
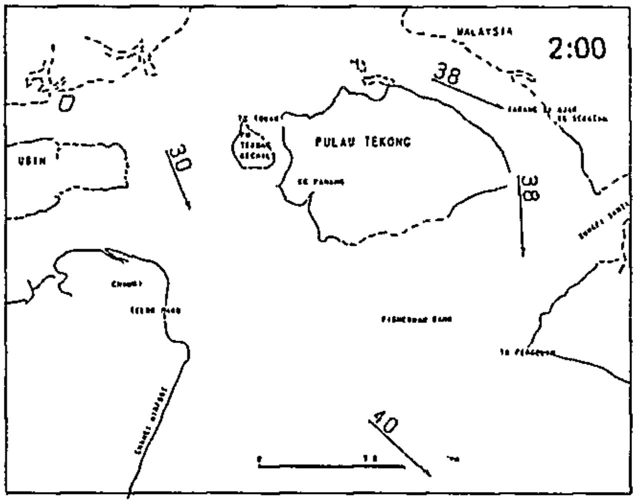


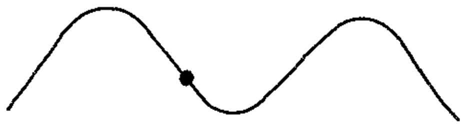
Fig. II-1-7-(13) Horizontal distribution chart of the tidal current ellipse of dominant constituent of Tekong Area

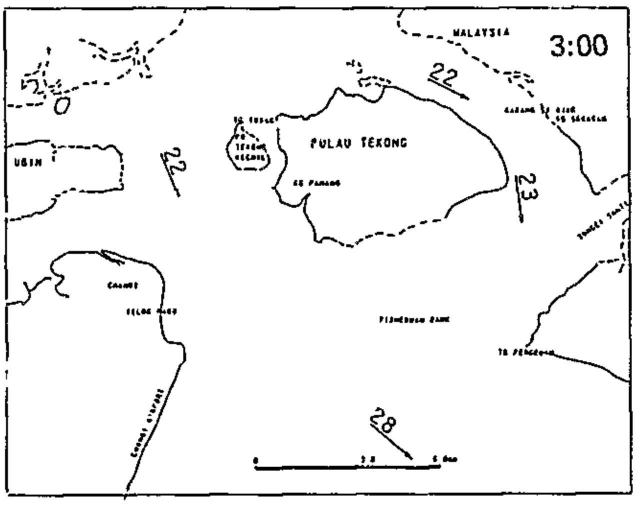


01:00 hour (3 hours after high tide)
The maximum velocity time of southward flow pattern
Velocity values of TC2, 3, 4 are more than 40 cm/sec.

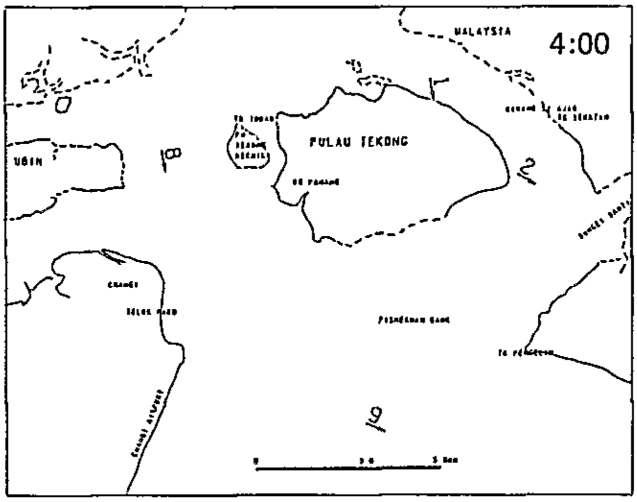


02:00 hour (4 hours after high tide)
Southward flow pattern and velocity slowing down gradually



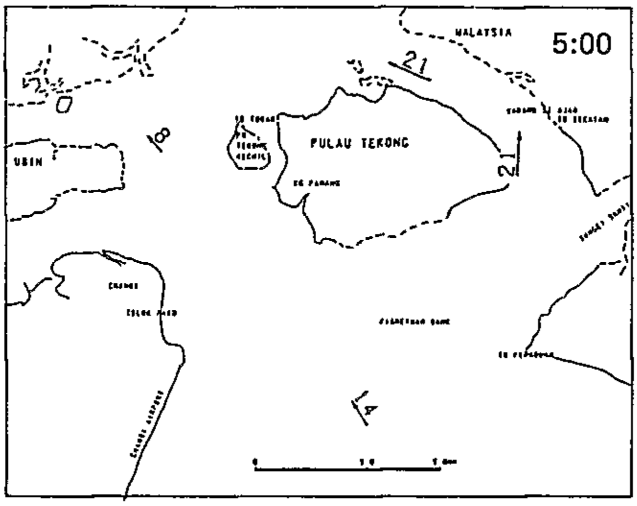


03:00 hour (5 hours after high tide)
Southward flow pattern and velocity slowing further down



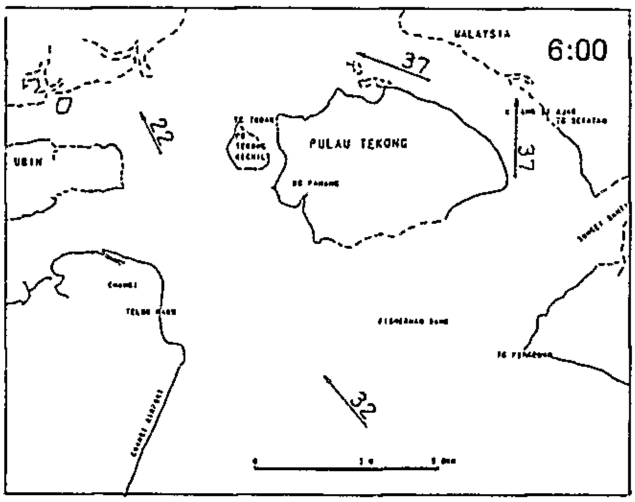
04:00 hour (slack water)

The turn of current commences



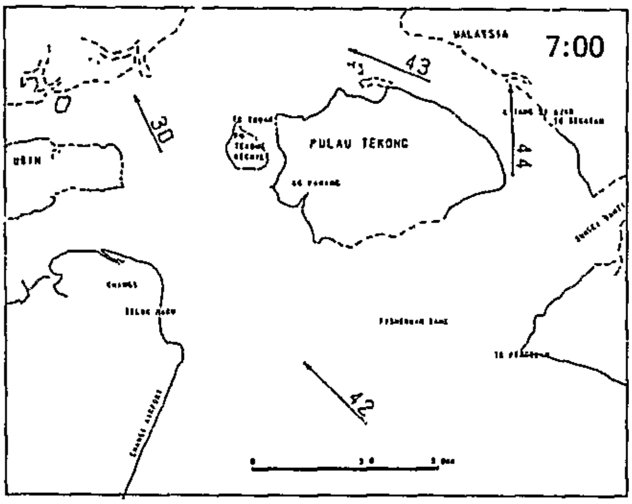
05:00 hour (1 hour after low tide)

Changing to northward flow pattern and velocity getting faster gradually



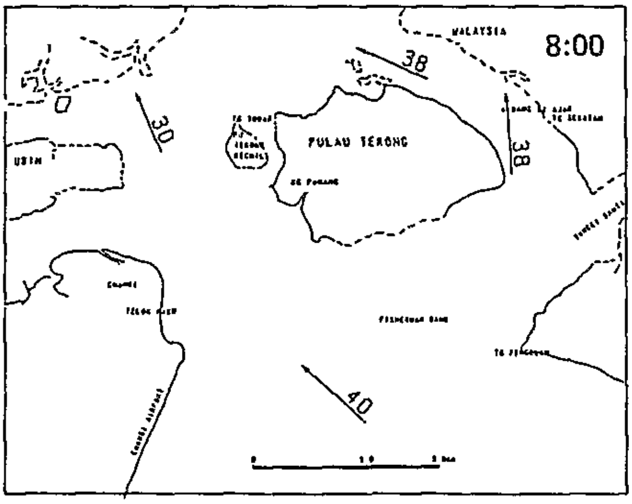
06:00 hour (2 hours after low tide)

Northward flow pattern and velocity getting faster



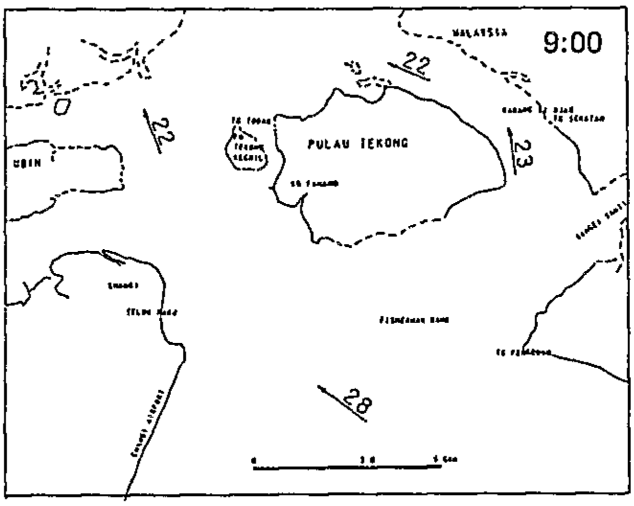
07:00 hour (3 hours after low tide)

The maximum velocity time of northward flow pattern and the velocity at TC2, 3, 4 is more than 40 cm/sec.



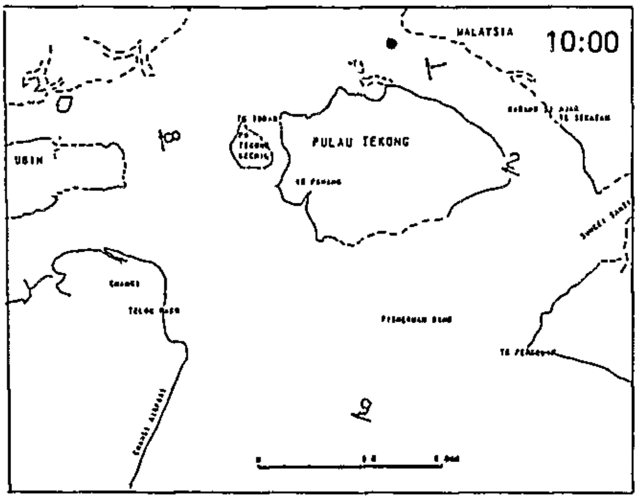
08:00 hour (4 hours after low tide)

Northward flow pattern and velocity slowing down gradually

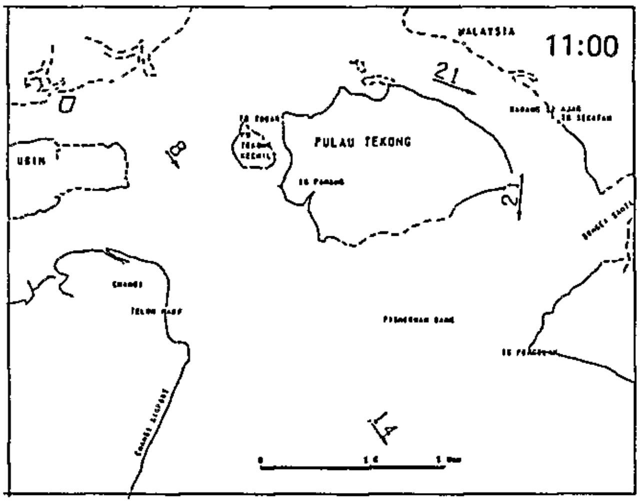


09:00 hour (5 hours after low tide)

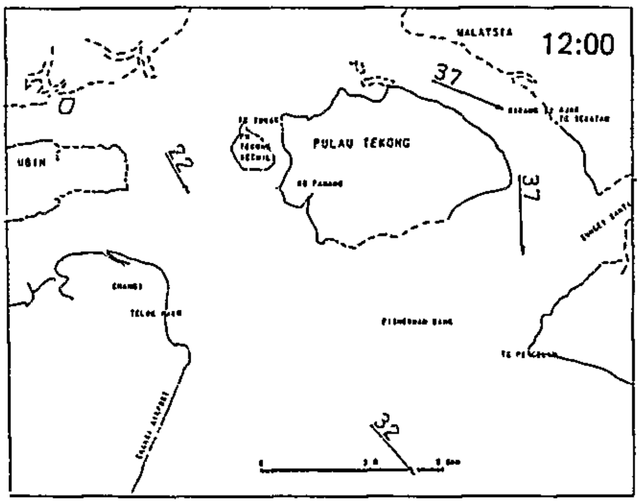
Northward flow pattern and velocity showing further down



10:00 hour (slack water & high tide)
The turn of current commences



11:00 hour (1 hour after high tide)
Changing to southward flow pattern and velocity getting fast.



12:00 hour (2 hours after high tide)
Southward flow pattern and velocity getting faster

CHAPTER 2 TIDE OBSERVATION

II-2-1 Outline

II-2-1-1 Objective of tide observation

The tide observation has been conducted for getting the information on sea level of the survey area.

The data obtained by tide observation are the basic data for setting the open boundary condition within the scope of simulation. Particularly for the simulation of coastal waters where the tides are dominant, the data of tide observation are indispensable for determination of the simulation model.

In this study, the tide observation data are important as the coastal waters near Singapore are dominated by the tides.

The tide is, as previously described, the regular fluctuation phenomena of the sea level which are generated mainly by the sun and moon.

From the general view of the tides at arbitrary points on the earth, the time of high tide propagates from the point to point and the tidal range is also observed variating from the point to point. It means the tide is a kind of wave. The wave movements propagate in the sea, and it is called as high water when the peak of the waves reach to the point and it is called as low water when the bottom of the waves reach to the point.

The tidal range is the differene between the peak and bottom of the waves in the same point. And the time required between the peak and the next peak to the waves is equal to the period of the tide.

The waves of the tides are called as the tidal waves. They are propagating to various directions as the tidal waves. The behaviours of such propagation of the tidal waves are complicated by the coastal topography, ocean depths and other hydrographic conditions.

II-2-1-2 On tide observation

The tide observation is to measure the fluctuation of the sea level continuously for long term which is changing from time to time compared with the reference level.

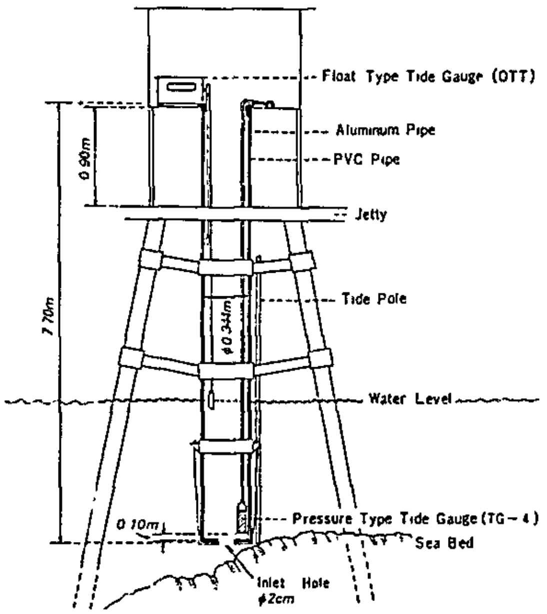
The tide observation is conducted by setting the tide gauge at the observation points. The tide gauge employed at present is shown in Table II-2-1.

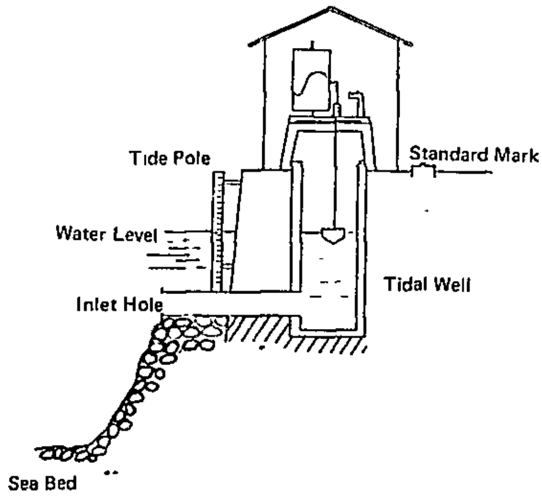
Table II-2-1 Types of tide gauge

	Name	Capacity
(1)	Float type tide gauge	Automatically record float fluctuation chart
(2)	Pressure type tide gauge	Measure fluctuation of pressure by pressure sensor and record on chart automatically

For the convenience of navigation, construction of harbours and other public works, the prediction of tide is usually conducted. The prediction of tide is compiled as Tide Table and published by the marine authorities. In Singapore, it is published by Hydrographic Department, Port of Singapore Authority (PSA). In order to obtain the necessary data for the prediction, the tide stations are established.

The tide station is usually conducting observation by the tide gauge installed in the tidal well located near to the coastal line, as shown in Fig. II-2-1. Outside of the tide station, the tide pole is installed for checking the sea level. Further, the tide station is in some cases stationed at offshore. (Refer to Fig. II-2-1)



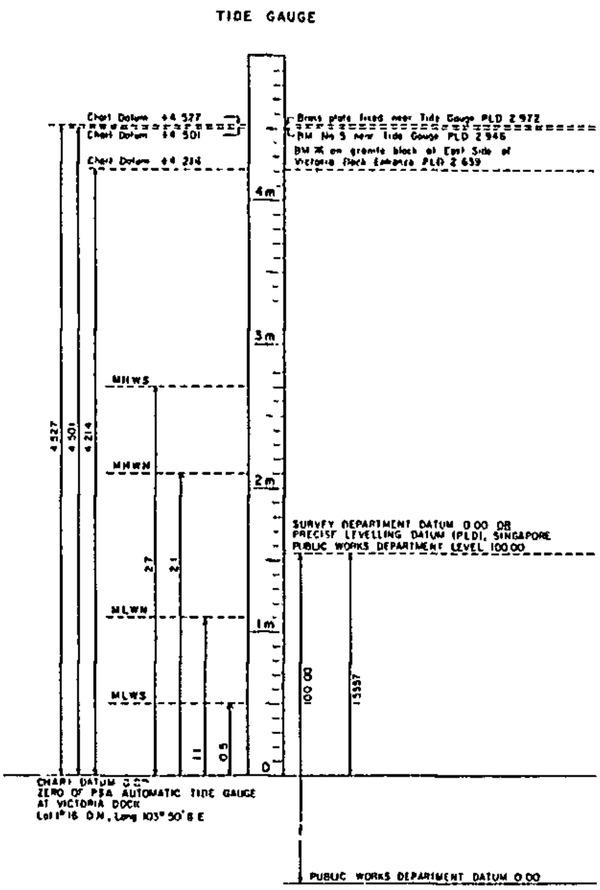


The tide observation in the environmental assessment is not conducted if the official tide stations are available in the survey areas. And the data provided by such tide stations are collected for analysis.

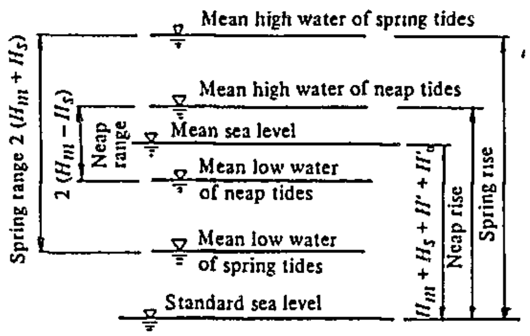
When the official tide stations are not available, the tide gauges are temporarily set for the observation of the survey period. Particulary for the data of the points distant from the coast, the pressure type and watertight type tide gauge are set on the sea bed for obtaining the data.

For the tide observation, the mean sea level is the reference level. The mean sea level is the surface level on the assumption that there are no tide fluctuation. The mean sea level fluctuates by various reasons.

Based on the data obtained by the tide observation, the relationship of the reference level is compiled. Fig. II-2-2 shows the relationship between various levels in Singapore.



HEIGHTS IN METRES



Tidal datums.

Fig. II-2-2 Relationship between various levels in Singapore

II-2-1-3 Tide observation in this study

In this study, the observation data of the official tide stations existing in the survey areas have been collected. The tide table published by PSA has also been obtained prior to the field survey and it provided the good reference for determination of various factors related to the current survey, temperature/salinity survey, and water quality survey.

II-2-1-4 On tides

In the previous chapter, the tides have been referred to and described but in this paragraph, the outline of the tides is further described. The cycle of the tidal fluctuation is usually about twice a day but in some points, it is once a day.

The tides which are oscillating regularly are the astronomical tides generated by the gravitation of the astronomic body and the meteorological tide is fluctuating unregularly which is generated by the changes of atmospheric pressure and wind directions.

The conditions of the sea surface coming highest by the tides are called as high water and the lowest conditions are called as low water. During the period from the low water to high water, the sea level is ascending gradually and such condition is called as flood. On the contrary, during the period from high water to low water, the sea level is descending gradually and such condition is called as Ebb.

Before and after the high water and low water, the fluctuation of sea level is very slow and looks like stopping. This condition is called as slack of tide.

At the point where 2 high water (or low water) are generated within a day, the time difference between 2 high water is about 12 hours and 25 minutes, and it is called as semi-diurnal tide.

At the point where only 1 high water (or low water) is generated within a day, the time difference between the next high water is about 24 hours and 50 minutes, and it is called as dirunal tide.

Therefore the time of high water or low water is slipping everyday by about 50 minutes. This fact can be found from the tide table.

The difference of height between high water and low water is called as Tidal Range. And the Mean Range is the averaged values of such tidal range of long term. Fig. II-2-3 shows the combination of semi-diurnal tide and diurnal tide.

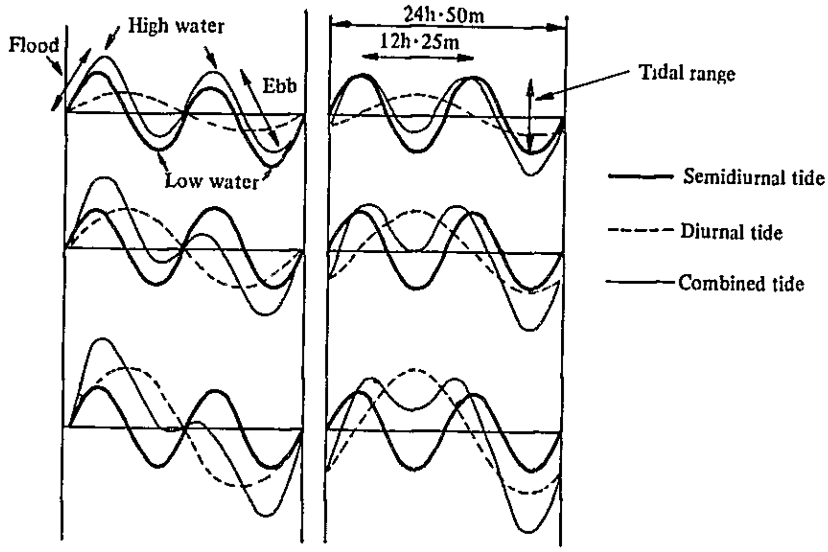


Fig. II-2-3 Combination of semidiurnal tide and diurnal tide

The major parts of the tides are the astronimical tide, which are generated by the moon and sun. As the influence of the moon is more than 2 times of the sun, the tides are almost influenced by the moon except the certain special points.

The movement of the moon is expressed by the age of moon, such as new moon, full moon, first quarter and last quarter.

The tides when the moon is on the equator are called as equatorial tide, and the tides when the moon is far away from the equator is called as tropic tide.

The tidal range comes maximum 1 or 2 days after new moon and full moon, and comes minimum 1 or 2 days after first quarter and last quarter.

The tidal range when the tidal range comes maximum is called as spring range, and when the tidal range comes minimum, it is called as neap range. These are shown in Fig. II-2-4.

The time between new moon or full moon to the spring tide is called as age of tide which is expressed by the number of days. In the coastal areas of Japna, it is usually 1 to 2 days.

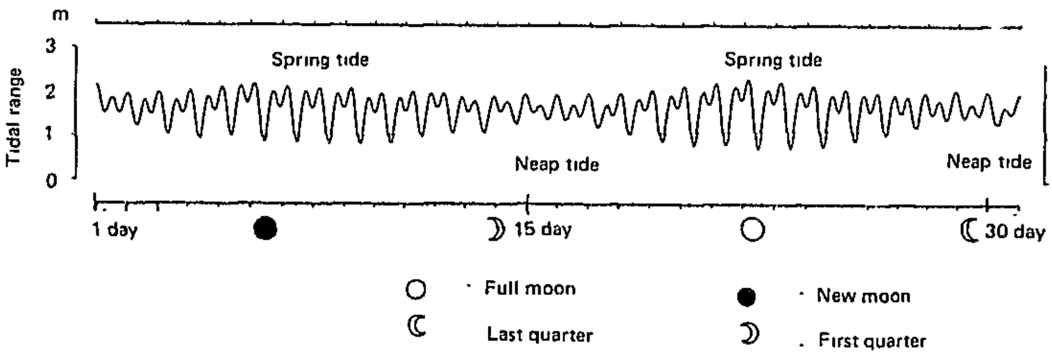


Fig. II-2-4 Spring tide and neap tide

The continuously generated 2 high water or low water are not always same in level and also the time between two high water or 2 low water is different in some cases although it is usually 12 hours and 25 minutes. These phenomena are called as diurnal inequality, and such example is found in combined tide shown in Fig. II-2-3.

Fig. II-2-5 shows the model example of the tides of the arbitrary latitudes of the earth. From this, the diurnal inequality can be observed.

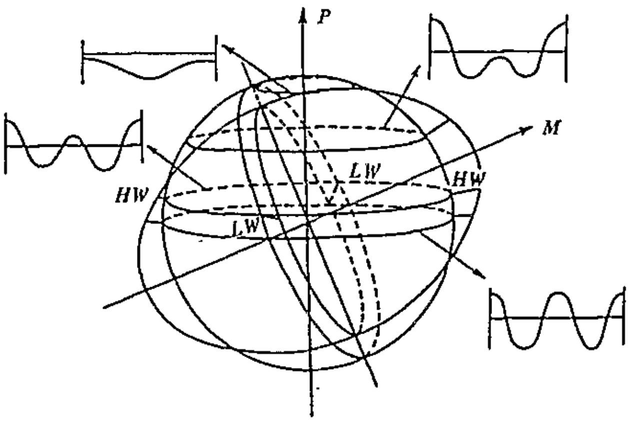


Fig. II-2-5 Model example of tides of arbitrary latitude of earth

The higher tide among continuously generated 2 high water is called as Higher High Water and lower tide is called as Lower High Tide. The lower tide among continuously generated 2 low water is called as Lower Low Water and higher tide is called as Higher Low Water. (Refer to Fig. II-2-6.)

When the diurnal inequality is dominant, lower high water and higher low water are almost disappeared and only once-a-day high water and low water are appeared. (Diurnal tide)

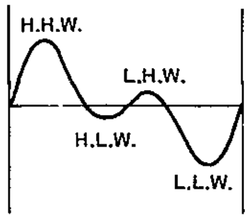


Fig. II-2-6 Diurnal inequality

As the time is different between the meridian transit of the astronimical body and the high water, the time interval between the meridian transit of the moon to the high water is called as high water interval and the time interval to the low water is called as low water interval.

The long term average of the high water and low water intervals are called as mean high water interval and mean low water interval. The average of high water interval at the time of new moon and full moon is called as High Water Full and Change, and these have the fixed values for respective harbours.

As previously described, the tidal range, high water interval and low water interval are sometimes variating and due to the diurnal inequality, there are some complicated variation during the time between high water and low water which are generated twice a day. This is due to the fact that the orbits of the moon and sun are not coincided and these orbits are not coincided with the equator of the earth, and also due to the fact that the movement velocity of the moon and sun is different from each other and the each distance to the earth and the relative position are always changing.

The tides are generated by these 2 astronomical bodies which are moving inequally but instead of analysing in this way, the tides can be considered as generated by the numberless virtual artificial stars which are moving with the fixed distance from the earth and with the respective proper velocity.

The individual tide generated is called as component tide. From the measured values of the tide of the observation points, the component tide can be obtained by calculation, and a half of tidal range of the component tides are called as Amplitude. The time between the culmination of virtual artificial stars and the component tide reaches to high water is expressed by angle and is called as Phase Lag.

The amplitude of the constituents and phase lag are called as Harmonic Constant. The process to obtain the harmonic constant from the measured data is called as Harmonic Analysis of Tide. (Refer to Fig. II-2-7)

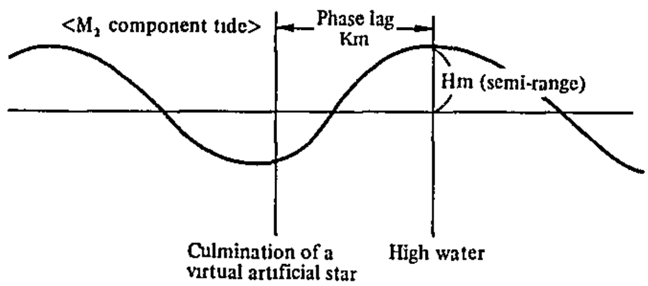


Fig. II-2-7 Amplitude and phase lag of constituent

Table II-2-2 shows the list of tidal constituent.

Table II-2-2 4 major tidal constituents

Symbols	Component Tides	Speed <360° ÷ Period>	Mean Solar Time	Symbol of Harmonic Constant	
				Semi-range	Phase Lag
M_2	Lunar Semidiurnal Tide	28°.9840	$12.^{h}42$	Hm	κm
S_2	Solar Semidiurnal Tide	30.°0000	$12.^{h}00$	Hs	κs
O_1	Lunar Diurnal Tide	13.°9430	$25.^{h}82$	H_0	κ_0
K_1	Luni-solar Diurnal Tide	15.°0410	$23.^{h}93$	H'	κ'

From the above table, the spring range is expressed by 2 x (Hm + Hs) and the neap range is 2 x (Hm - Hs).

From Fig II-2-3 and Fig. II-2-5, it is obvious that the tides are different at all the points of the earth. The types of tides are usually classified into 3 category. Table II-2-3 shows the types of the tides.

Table II-2-3 Types of tides

(1)	Semi-diurnal type	about ½ day	High & low water appear twice a day respectively. Generated by M_2 and S_2 constituents.
(2)	Diurnal type	about 1 day	High & low water appear once a day respectively. Generated by K_1 and O_1 constituents.
(3)	Combined type	about ½ day & about 1 day	

For the judgement of the type of the tide of the survey areas, it is evaluated based on the results of harmonic analysis of the tide of the tidal stations located in the survey areas.

In France, these 3 types are classified by the following references.

$F = (K_1 + O_1) / (M_2 + S_2)$ 0.25 Semi-diurnal type

0.25 $(K_1 + O_1) / (M_2 + S_2)$ 1.25 Combined type

$(K_1 + O_1) / (M_2 + S_2)$ 1.25 Diurnal type

In the United States, they are classified by

$f = (K_1 + O_1) / M_2$ 0.5 Semi-diurnal type

0.5 $(K_1 + O_1) / M_2$ 2.0 Combined type

$(K_1 + O_1) / M_2$ 2.0 Diurnal type

M_2, S_2, K_1, O_1 are amplitude of the constituents and these values are obtained by harmonic analysis of the tide (values of Hm, Hs, Ho, H^1).

II-2-2 Collection of Data for Tides

Table II-2-4 shows the list of collected data for tides.

Table II-2-4 List of collected data for tides

	Name of observation points	Data period	Kinds of data	Provided by & reference
(1)	Salve One Jurong Wharf	Jan. - June 1981	Observation data	PSA observation data
(2)	Victoria Dock Jurong Wharf	Jan. - Dec. 1981	Prediction data	PSA Singapore Tides Table and Port Facilities
(3)	17 observation points within the straits of Malacca and Singapore	Mar. 1978 - Apr. 1979	Observation & analysed data	Report on Joint Production of Common Datum Charts of the Straits of Malacca & Singapore

Fig. II-2-8 shows the location chart of Slave One, Jurong Wharf and Victoria Dock.

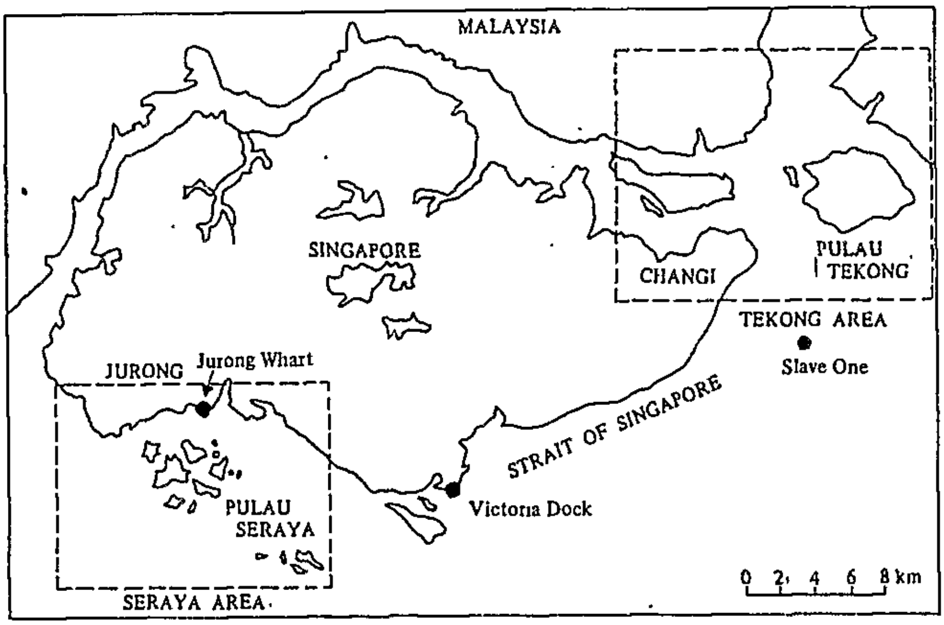


Fig. II-2-8 Location chart of Slave One, Jurong Wharf, Victoria Dock

II-2-3 Data Analysis and the Results of Analysis

II-2-3-1 Data analysis

Among the data mentioned in the Table II-2-4, (1) and (2) have been taken up for analytical calculation and the items of analysis and input into large capacity computer is limited to the data corresponding to the duration of the survey of this study.

For the process of tape punching, refer to the previous chapter.

Table II-2-5 Items of data analysis of tide observation

Items of analysis	Contents
(1) Tidal curves	Plotting the tidal fluctuation
(2) Harmonic analysis of tides	Obtaining the harmonic constant

II-2-3-2 The results of analysis

1) The tidal fluctuation of the survey period of this study

Fig. II-2-9 shows the tidal curves obtained in this study. The figure shows the tidal fluctuation plotting of the duration between February 23rd to March 17th which extracted from the data (1) of Table II-2-4. From the figure, the followings are observed.

(1) High and low water are observed twice a day.
(2) The phenomenon of diurnal inequality is observed.
(3) The spring tide is observed after March 6th (new moon)
(4) The neap tide is observed after February 27th (last quarter) and after March 13th (first quarter).
(5) The tidal range is more than about 2.5 m at the top of the spring tide.

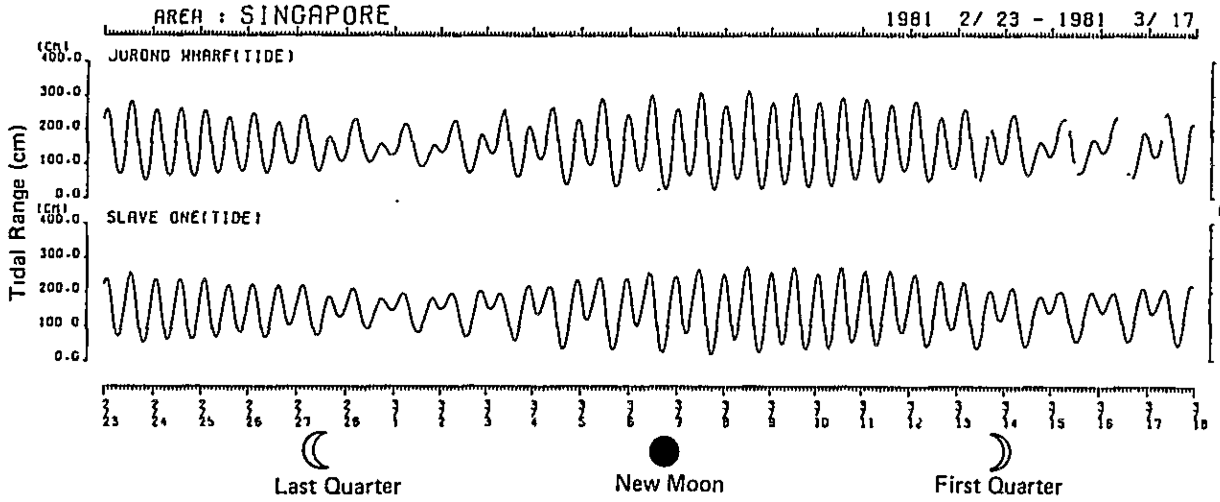


Fig. II-2-9 Tidal curves of the survey period

Fig. II-2-6 shows the results of harmonic analysis. The right hand part of the figure is the results of analysis based on the prediction data and the left hand side is the results from the measured data.

Also in the figure, K_1 to P_1 are the symbols of tidal constituent (refer to Table II-1-9 and Table II-2-2) and H represents amplitude of the constituent and K is phase lag.

Table II-2-6 Results of Harmonic analysis of tidal current

Measured Tide

Position (Jurong Wharf) Lat. 1°18'24" N Long. 103°43'12" E		
From : To Feb. 25, 1981, 00:00 Mar. 12, 1981, 00:00		
Constituents	V (cm)	k (°)
K_1	26.2	123
O_1	26.6	82
Q_1	3.7	12
M_2	81.1	303
S_2	36.1	356
N_2	12.1	313
M_4	5.0	216
MS_4	5.3	271
K_2	9.8	356
P_1	8.6	123
$\frac{k_1 + O_1}{M_2 + S_2}$	0.45	

Predicted Tide

Position (Jurong Wharf) Lat. 1°18'24" N Long. 103°43'12" E		
From : To Mar. 1, 1981 00:00 Mar. 31, 1981 23:00		
Constituents	V (cm)	k (°)
K_1	29.0	130
O_1	26.3	84
Q_1	3.8	65
M_2	82.5	307
S_2	38.8	357
N_2	12.9	299
M_4	3.7	210
MS_4	4.3	260
K_2	10.5	357
P_1	9.6	130
$\frac{k_1 + O_1}{M_2 + S_2}$	0.46	

Measured Tide

Position (Slave One) Lat. 1°20'06" N Long. 104°01'12" E		
From : To Feb. 28, 1981 00:00 Mar. 15, 1981 00:00		
Constituents	V (cm)	k (°)
K_1	29.9	76
O_1	27.0	41
Q_1	6.6	26
M_2	68.9	293
S_2	25.0	338
N_2	18.2	276
M_4	3.3	278
MS_4	3.4	336
K_2	6.8	338
P_1	9.9	76
$\frac{k_1 + O_1}{M_2 + S_2}$	0 61	

Predicted Tide

Position (Victoria Dock) Lat. 01°16'00" N Long. 103°50'36" E		
From : To Mar. 1, 1981 00:00 Mar. 31, 1981 23:00		
Constituents	V (cm)	k (°)
K_1	28.9	99
O_1	29.6	57
Q_1	5.1	36
M_2	77.3	302
S_2	34.9	351
N_2	11.8	287
M_4	1.2	231
MS_4	1.8	285
K_2	9.5	351
P_1	9.5	99
$\frac{k_1 + O_1}{M_2 + S_2}$	0.52	

Table II-2-7 has been extracted from Table II-2-6 H(amplitude) column the largest and secondary constituent and also the values of $K_1 + O_1 / M_2 + S_2$.

The constituents enumerated in Table II-2-7 are the dominant component current of the survey areas. And from the values of $K_1 + O_1 / M_2 + S_2$, the type of the tides are given.

Table II-2-7 Dominant constituent of survey areas

Point of measurement	District	First prevailing	Second prevailing	$\frac{K_1+O_1}{M_2+S_2}$	Tidal character
<Measured data>					
Slave One	Tekong district	M_2 (H = 68.9 cm)	K_1 (H = 29.9 cm)	0.61	(Mixed type)
Jurong Wharf	Seraya district	M_2 (H = 81.1 cm)	S_2 (H = 36.1 cm)	0.45	(Mixed type)
<Predicted data>					
Victoria Dock	Seraya district	M_2 (H = 77.3 cm)	S_2 (H = 34.9 cm)	0.52	(Mixed type)
Jurong Wharf	Tekong district	M_2 (H = 82.5 cm)	S_2 (H = 38.8 cm)	0.46	(Mixed type)

From Table II-2-7, it is known that M_2 constituent (Lunar-Semidiurnal Tide, cycle period 12.42 hours) is most dominant in the areas of Seraya and Tekong. Also the type of the tides is classified into the combined type.

2) Tidal character of the survey areas

Based on the results of the survey described in the previous paragraph 1) and the collected data from the Joint Survey Report on the Tides and Tidal Current of the Straits of Malacca and Singapore, the tidal character of the survey areas are described as follows:

From the survey results described in the previous paragraph 1), the tides of the survey areas are found that M_2 constituent is dominant and the type of the tides is the combined type. In the joint survey conducted in the Straits of Malacca and Singapore the tidal survey has been conducted for one year on the total areas of the Straits of Malacca and Singapore. According to that report, it is describing as "the tides generated in the Indian Sea and South China Sea reach to the Straits of Malacca and Singapore as the tidal wave and generates the tides in the straits. The peak of the tidal wave of the semi-diurnal period generated in the Indian Sea propagates to eastward passing (A) One Fathom Bank 5.1 hours after the moon transited the standard meridian (112°30' East).

On the other hand, the peak of the tidal wave of semi-diurnal cycle generated in the South China Sea propagates to westward passing (J) Horsburg Lighthouse 10.3 hours after the moon transited on the standard meridian and after 11.5 hours these two tidal waves joint at around (F) Raffles Lighthouse which is located about 17 km East/South of Pulau Seraya. (Refer to Fig. II-2-10)"

Fig. II-2-10 is the Co-Tidal Chart which shows the progress of the tides and it is also the distribution chart of the time elapse necessary for M_2 constituent (semi-diurnal) comes to high water after the moon transitted meridian (112°30' East).

From the above, the followings are confirmed.

(1) In the areas of the Straits of Singapore, the tidal wave generated in the Indian Sea and the tidal wave generated in the South China Sea joint at the point about 17 km East/South of Pulau Seraya.

The report of the joint survey also mentioned as "The character of the tides is different between the west part of the Straits of Malacca and the east part of the Straits of Singapore.

In the area around Fathom Bank diurnal inequality is small but it is getting larger to the east waterway. Between (B) Port Dickson and (D) Iyu Kecil, the inequality of the tide.level is large at the high water, and the inequality of tide level is larger at the low water. In the areas between (E) Sultan Shoal Light House to (G) Kepala Jer Jernih, the almost same inequality is seen at both high water and low water, and lower low water is generated after higher high water. In the areas between (H) Batu Ampar and Horsburgh Light House, the inequality of tide level is large at the low water.

Among the areas mentioned in the above, areas between Sultan Shoal Light House to Kepala Jer Jernih are including Seraya Area of this study. Fig. II-2-11 shows the tidal curves of the 4 seasons (vernal equinox, summer solstice, autumnal equinox and winter solstice) of Sultan Shoal which is located near Seraya Area.

In the figure, Syzygy represents the tides at new moon and full moon which is equal to the spring tide. Quadrature represents the tides at first quarter and last quarter which is equal to the neap tide.

In this study, the observation has been conducted during end/February to mid/March and so it corresponds to the tidal curves for "around the winter solstice" in the figure.

In the same way, Tekong Areas are located in the sea areas between Batu Ampar and Horsburgh Light House. The tidal curves for the four seasons of Angler Bank has been extracted from the report and shown in the lower part of the figure.

(2) In Seraya Area, the almost same inequality is seen at both high water and low water, and the lower low water is generated after higher high water.

(3) The inequality of the tide level at Tekong Area is large at low water.

The report of the Joint Survey further mentions as "The spring tide range at One Fathom Bank is about 3.7 m, about 1.8 m at around Malacca, 2.8 m at around Iyu Kecil, 1.5 m at Horsburgh Light House, and such ranges show variation among the point locations in the straits.

The neap tide range in the areas between One Fathom Bank to Malacca is about 0.5 times of the spring tide range, about 0.4 times in the sea areas between Tg. Parit to (I) Angler Bank and is about 0.5 times at around Horsburgh Light House.

In the areas between One Fathom Bank and Horsburgh Light House, the spring tide is generated about 2 days after the new moon and full moon, and the neap tide is generated about 2 days after the first quarter and last quarter.

The mean high water interval is 4 hours 18 minutes at One Fathom Bank and getting longer towards east, and 10 hours 51 minutes at Kepala Jernih."

Fig. II-2-12 is the co-range chart which shows the distribution of the points which is equal in the tide range at the time of high water.

From the figure, the distribution of tide range at the time of the spring tide is observed and the followings are confirmed.

(5) The spring range is large in the west side of the Straits of Singapore which means Seraya Area is larger than Tekong Area in the tide range. Its range is about 40 cm.

(6) The neap range is about 0.4 times of the spring range.

(7) The age of tide in both Seraya Area and Tekong Area is about 2 days.

(8) The mean high water interval is within the range of 10 hours 51 minutes and 9 hours 47 minutes in both Seraya Area and Tekong Area, and Seraya Area is longer than Tekong Area.

Table II-2-8 shows the characteristics of tides in this study which was extracted from the report of Joint Survey.

Table II-2-8 Characteritics of tides

	MHWI		$\frac{H'+H_0}{Hm+H_L}$	$\frac{H_L}{Hm}$	$\frac{H_0}{H'}$	Phase Age	Diurnal Age	Spring Range	Neap Range	$\frac{(\kappa'+\kappa_0)/2}{(\sigma'+\sigma_0)/2}$	$\frac{(\kappa'+\kappa_0)/2}{(\sigma'+\sigma_0)/2} - \frac{\kappa_m}{\sigma_m}$
	h	m				d	d	cm	cm	h	h
One Fathom Bank	4	18	0 12	0.50	0 27	1.7	−5.4	373	126	5 4	1.1
Tg Senebul	4	55	0.12	0.50	0.86	1.8	−4 5	352	119	5 6	0.7
Tg Kabong	5	4	0 14	0 50	1.59	1.7	−4.2	304	101	5 8	0 8
Port Dickson	5	39	0.18	0.50	3.66	1.7	−2 4	249	83	7 4	1.8
Tg. Medang	5	54	0.21	0.50	3 62	1.7	−1.3	224	75	8.4	2 5
Malacca (Tg Kling)	6	55	0.35	0.48	2.46	1.6	0.1	179	62	9.5	2 6
Tg. Parit	8	39	0 40	0 45	1.53	1.7	0 6	209	79	9 6	0.9
Tg Segenting	9	8	0.39	0 45	1.37	1.7	0 8	231	88	9 5	0.4
Pu Pisang	9	57	0.37	0 45	1.11	1 8	1.1	271	102	9 2	−0 7
Iyu Kecil (Pasir Panjang)	10	25	0.38	0 46	0 98	1 9	1.3	275	102	9.0	−1.4
Sultan Shoal Lighthouse	10	38	0 40	0 45	0 92	1.9	1.7	252	96	8.3	−2.3
Raffles Lighthouse	10	44	0 44	0 44	0 93	1.9	1.8	240	92	7.3	−3 3
Kepala Jernih	10	51	0 49	0 46	0 86	2 0	1.9	237	88	8 1	−2 8
Batu Ampar	10	29	0.55	0 40	1 02	2.0	1 7	213	91	5 2	−5 3
Angler Bank	10	16	0.55	0.39	1 04	2 0	1.7	209	91	4.6	−5 7
Tg Ayam	10	4	0 65	0.36	1.05	2.1	1.7	177	83	3 7	−6 4
Horsburgh Lighthouse	9	47	0 72	0.34	1 04	2.1	1.5	151	75	2 8	−7 0

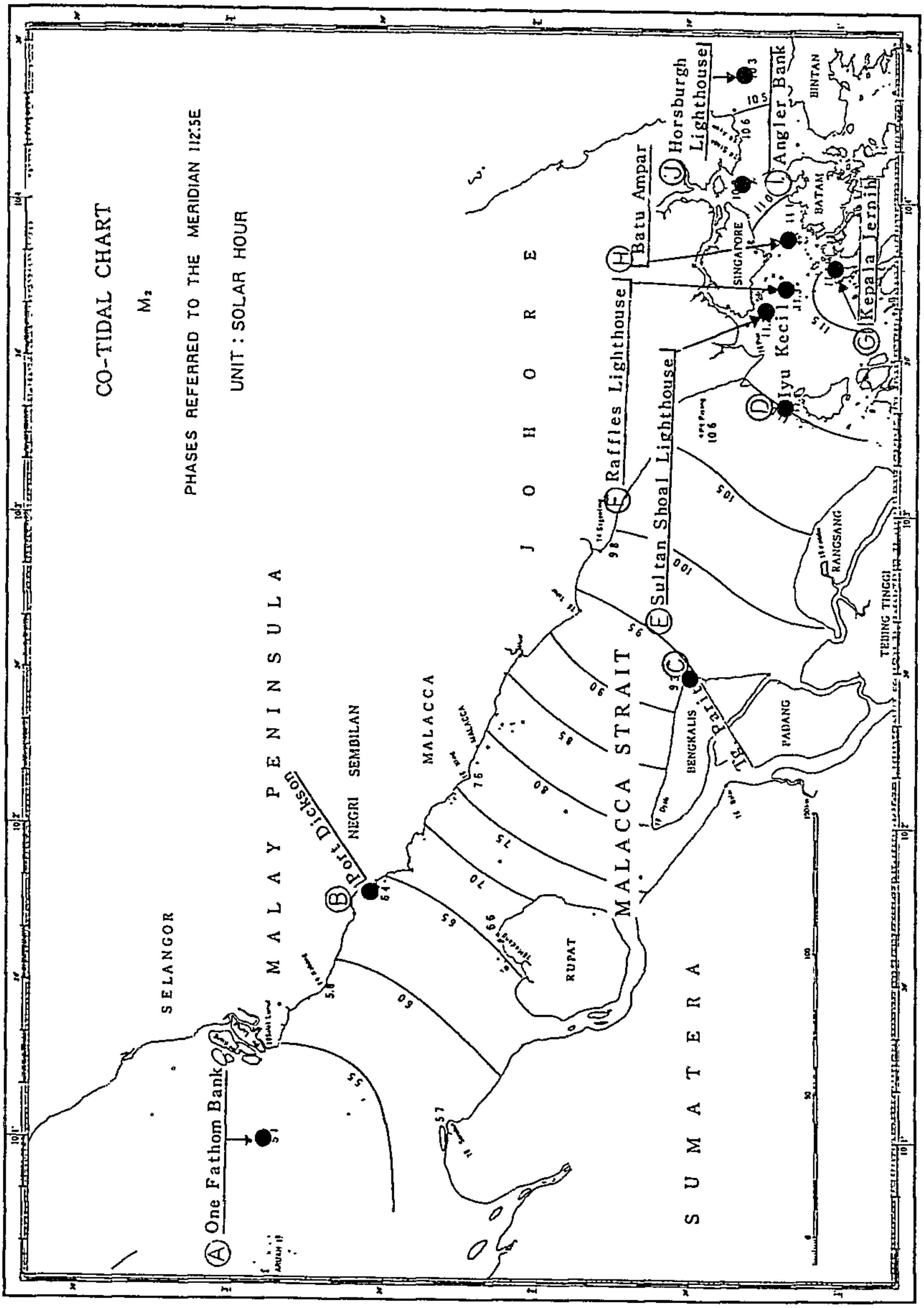
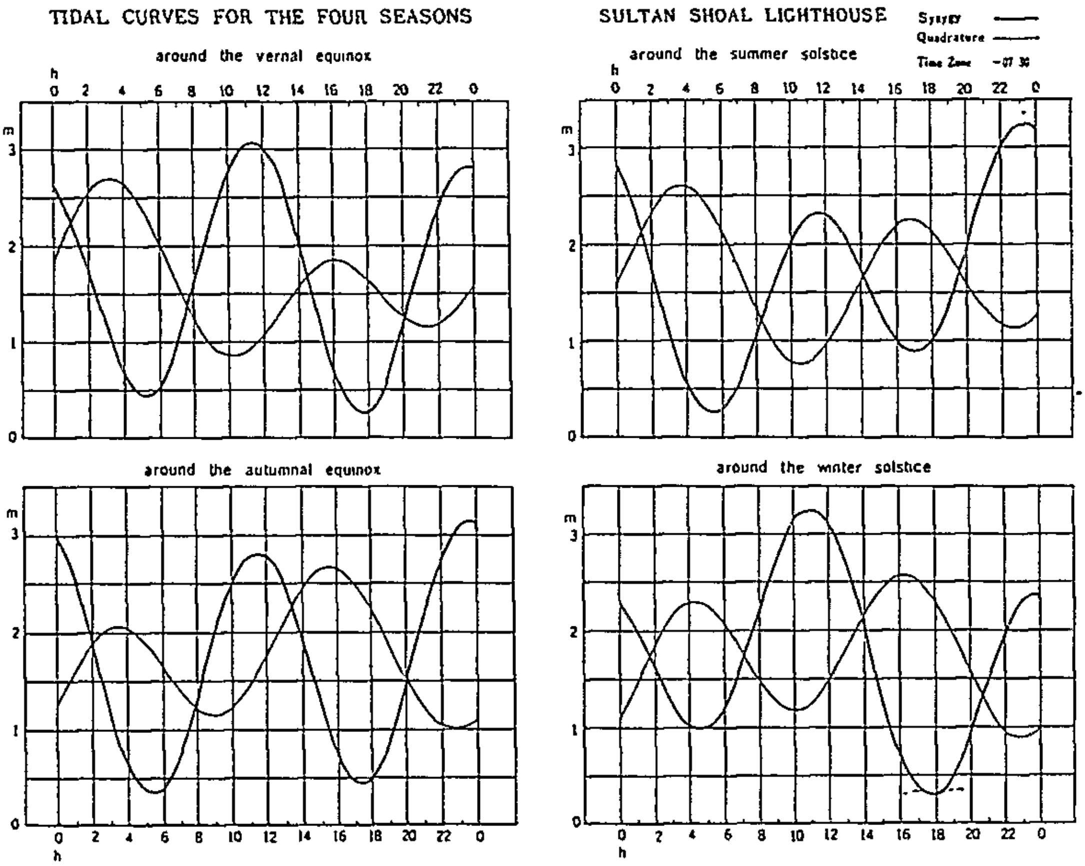


Fig. II-2-10 Co-tidal chart

<Near Seraya Area>



<Near Tekong Area>

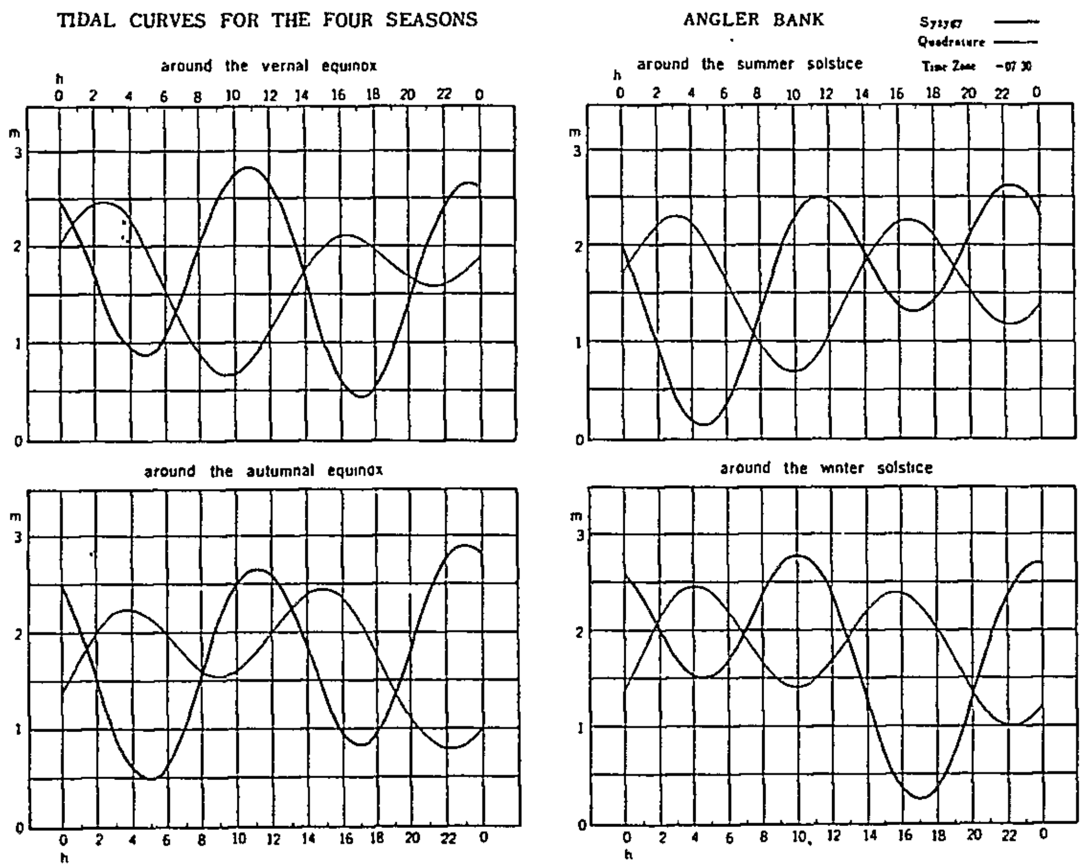


Fig. II-2-11 Tidal curves for 4 seasons

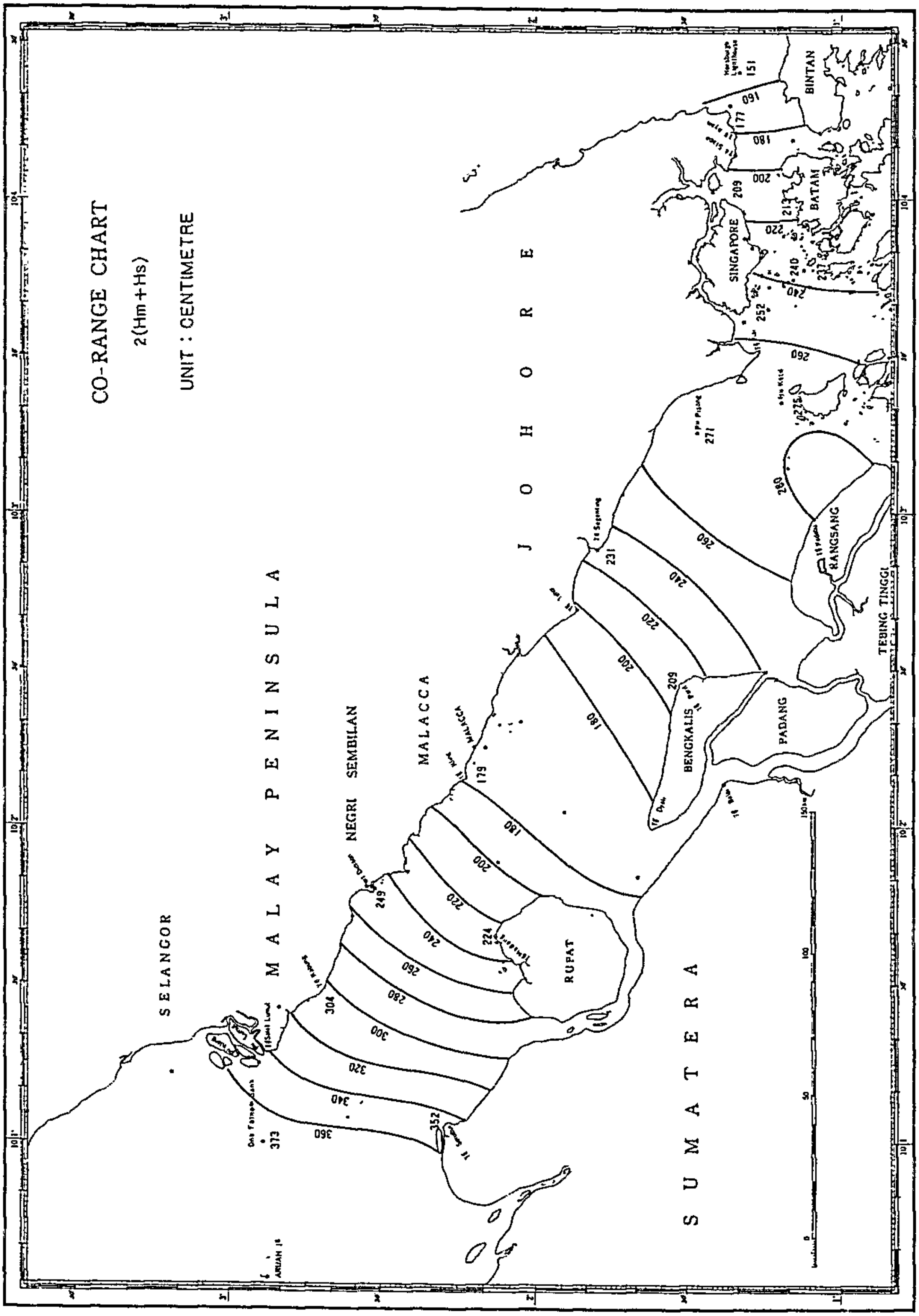


Fig. II-2-12 Co-range chart