

# REPORT ON A PRELIMINARY SURVEY IN MALACCA STRAIT AND SINGAPORE STRAIT

by a Joint Survey Team from Indonesia, Japan,  
Malaysia and Singapore

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*IHB NOTE : An article explaining the aims and organization of this same preliminary survey, written by the Chief Hydrographer of Japan, appeared in the July 1969 number of the International Hydrographic Review. In view of the volume of shipping in these regions and the importance of the survey's object — which is to decide on a traffic separation scheme — the IHB considers that an account of the methods used will interest readers.*

## OUTLINE OF PROGRESS

The survey ship *Koyo Maru* left Tokyo on 20 January 1969 and arrived in Singapore on the night of 27 January when it came under the direction of the leader of the survey team.

Prior to the commencement of sounding operations at sea seven Japanese members of the party established a tide gauge and a reflector at Tg. Telaga (Batu Pahat), and a reflector at Muar, a tide gauge at Port Dickson and a reflector at Cape Rachado.

During this time operations were conducted with the *Koyo Maru* on offshore islands, and tide gauges were installed in the grounds of Raffles Lighthouse on P. Satumu (Satumu Island), Singapore, on the 28th, and on P. Iyu Ketjil (The Brothers), Indonesia, on the 29th. It was possible to locate all the tide gauges — with the exception of the one on P. Iyu Ketjil where there was no benchmark — so that they could be easily related to the benchmarks previously used in the British survey by H.M.S. *Dampier*.

Next, sounding operations were carried out in the following three stages along the traverse lines through the Straits and in certain specified areas.

1st stage (31 January to 14 February). Two traverse lines between Singapore and Port Dickson via Phillip Channel; four traverse lines between Port Dickson and One Fathom Bank, and also in a specified area WSW of Cape Rachado. Levelling at the Tg. Telaga and Port Dickson tide stations was also carried out, as well as observations of tidal currents

at Raleigh shoal. During this period good progress was made on traverse soundings in generally favourable weather and without the squalls which had been expected. In the specified area off Cape Rachado, however, there were strong winds of 12-14 metres per second making operations with a survey boat impracticable, so instead the survey ship itself had to be used for sounding.

2nd Stage (18 to 27 February). Two traverse lines between Singapore and Port Dickson via Phillip Channel; four traverse lines in Main Strait and in a specified area NE of P. Iyu Ketjil. Levelling at the P. Iyu Ketjil tide station was carried out, and a benchmark established there. Favourable weather prevailed and operations were only suspended once, due to a squall.

3rd Stage (4 to 14 March). Soundings in certain specified areas off Buffalo Rock and in Phillip Channel, as well as on traverse lines east of Singapore.

On completion of the planned survey the participants disbanded in Singapore on 14 March. The *Koyo Maru* left Singapore on 16 March and arrived at Moji, her home port, on 23 March.

## OUTLINE OF SURVEY WORK

### Survey Control

No triangulation to establish supplementary control stations was carried out. Sounding positions on the traverse lines were controlled by objects plotted on sheets which had been produced at the scale of 1/150 000 by enlarging or contracting existing nautical charts. For the specified areas — except the one northeast of P. Iyu Ketjil — the latitudes and longitudes used for the chart construction and position plottings were adopted from the H.M.S. *Dampier* survey and from data furnished by the Port of Singapore Authority. The Indonesian data were adopted for the latitude, longitude and standard azimuth of P. Iyu Ketjil which was used for position fixing in the specified area northeast of the island.

## POSITION FIXING

### Determination of position fixing method and devices

#### *Traverse sounding area*

It was very difficult to obtain or to establish enough suitable landmarks for visual fixing throughout this whole area which is a belt of about

300 miles in length and at most about 15 miles off the coasts. Moreover, it was not at all easy for the hydrographers in Japan to anticipate good landmarks when desk planning prior to the field operations. In addition, there exists no singly effective electronic position fixing system covering the whole area. With a view to fixing positions without any gap under such field conditions it was therefore decided to use insofar as possible both radar, Loran C, sextants and gyrocompass in order to secure sufficient and accurate position fixing data.

The sole effective Loran C system covering the whole project area is the S3-Y network of the S3 chain in South Vietnam and Thailand. S3-X, the counterpart to S3-Y, can also be received and measured, but cannot be used because its position lines are almost parallel to those of S3-Y. In the survey areas of the Malacca and Singapore Straits the time difference reading of  $0.1 \mu\text{s}$  between signals arriving from the S3-Y master and slave stations corresponds to an actual distance of approximately 45 m, which is the position line interval. As an ordinary manual type Loran C receiver can scarcely measure values to within  $0.1 \mu\text{s}$ , a LR-2A type Loran receiver capable of automatically tracing and measuring signals was adopted for use, and installed on the bridge of the *Koyo Maru*.

Information on how objects effectively reflecting radar waves were distributed was collected from various vessels sailing in the Straits. As a result the necessity of increasing the number of radar targets was recognized, and the establishment of radar reflectors at three places in Malaysia and at one or two places on the coast of P. Bintan was planned. Two of the Malaysian reflectors, at Muar and Tg. Telaga, were removed at the end of operations. The one at Cape Rachado, however, was with the agreement of the Malaysian Government left in place since it was considered to be a useful aid to general navigation and likely to be well maintained. The Muar and Tg. Telaga reflectors were each made up of three elements, and the one at Cape Rachado of four, each element being an S type corner reflector of  $60 \times 60$  cm, in anti-corrosive aluminium, the radar cross section being of  $3 \times 10^7$  cm<sup>2</sup>.

As a result of field investigations, a plan to establish a reflector on Pu. Bintan was abandoned, since the existing reflector on the Horsburgh lighthouse proved effective for use in waters around Eastern Bank at the eastern extremity of the survey area.

The radar used was the one installed aboard the *Koyo Maru* for use in general navigation. An ordinary radar is not however sufficiently accurate for use in a hydrographic survey for the following reasons.

(a) A PPI type radar shows images of objects within a circle centred on the ship's position, and the distances and bearings of these objects from the ship can be measured on the PPI. However, since the directional angle of the antenna of a radar using the X waveband is about  $1^\circ$ , the degree of accuracy in the measurement of bearings was not satisfactory for our survey.

(b) Regarding distance measurements, the problem here lies not only in the PPI's non-linear distortion in directional sweeping, but also in its lack of resolution when reading distances with an indicating scale.

We found that we had to abandon measurements of bearings since there was no practical solution to this problem.

In order to solve the difficulties of measuring distances an auxiliary device — called 'RRS' (Radar Ranging Scope) — was prepared, which accurately displayed radar images for a limited area around the target on its cathode ray tube.

### *Specified areas*

In the specified areas where the suspected existence of shoal waters provides a hazard to navigation it was necessary to use a highly accurate position fixing method so that the survey could be conducted on a larger scale. The method adopted was the one-range-and-one-angle method with an Autotape and a theodolite. The two-range method with Autotape only was not suitable for this survey because it required sites for the two slave stations in a single locality. Such a locality to serve concurrently the vicinities of Phillip Channel, Cape Rachado and Pu. Iyu Ketjil was difficult to find.

### **Corrections to measured values**

#### *Loran C*

As radio waves from the S3-Y master and slave stations pass over the Malay Peninsula before reaching the Malacca Strait their propagation velocities are affected by the ground.

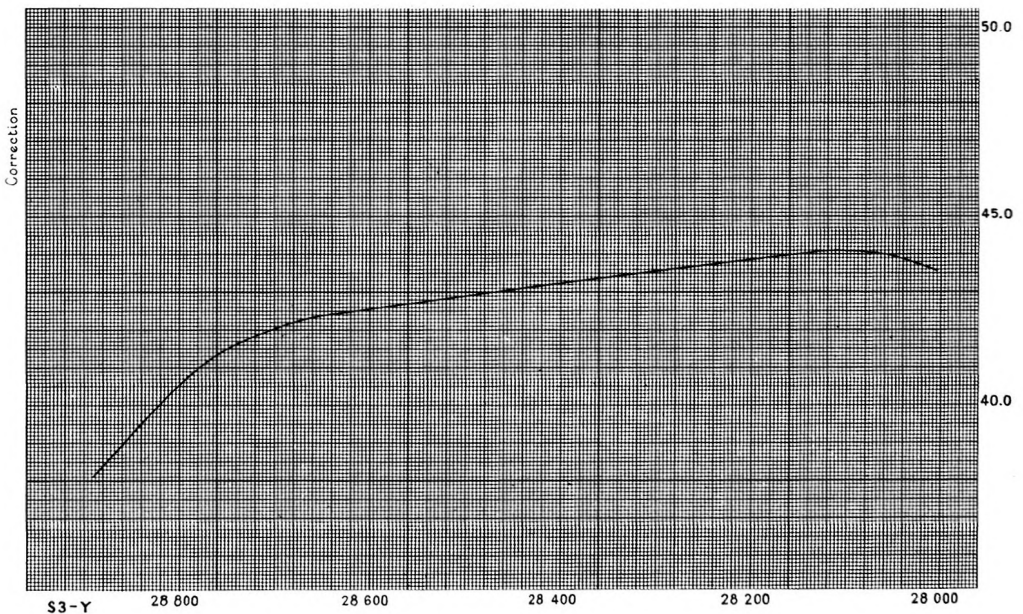


FIG. 1. — Rough correction for skywave in the Malacca Strait (in microseconds).

In the present survey, however, only sky waves have been used since the Master station is too far distant for the ground waves to reach the observation area. Consequently sky wave correction values had to be used.

Correction values were obtained from a comparison with visual fixings taken under favourable conditions, and a summary of the results is given in figure 1. As to the geographical distribution of correction values, these values tended to be smaller in the western part of the Malacca Strait while larger in the vicinity of the Singapore Strait. This tendency can be explained, since there was a correlation between these values and the length of the ground propagation paths.

### *Radar*

A series of distances measured by radar was compared with a series measured by the Autotape method in order to establish the corrections to radar measured distances for the position fixing.

## SOUNDING

### **Sounding Devices**

#### *Sounding with the Koyo Maru*

Soundings on traverse lines, and in a specified area off Cape Rachado. In choosing the type of echosounder, the following factors were taken into account.

(a) A four-beam echosounder was not absolutely necessary since the standard interval between sounding lines was 1 km on the traverse lines, and 400 metres in the specified area off Cape Rachado.

(b) As the *Koyo Maru's* speed during operations was about 13 knots, and because of considerable changes in bottom topography on account of sand waves and rocky bottom in the greater part of the survey area, a higher recording speed was considered more effective.

(c) For the same reasons a large recording range was considered more effective.

(d) The accuracy of recording had to be to within 0.1 metre in shallow passages.

The type NS-39 shallow water echosounder satisfies all these considerations and was therefore used.

#### *Sounding with the survey boat*

The survey boat carried aboard the *Koyo Maru* was used for all the sounding operations in the specified areas, except those in the area off Cape



## Correction of Soundings

### *Velocity corrections*

Bar checks were made to obtain corrections to recorded soundings. These corrections took into account variations in speed of sound due to changes in water temperature and salinity. The results showed that the correction factor for the shallow water echosounder was + 0.2 %, and for the four-beam echosounder + 0.3 % throughout the survey period.

### *Tidal corrections*

Owing to the existence of fairly large local differences in tidal conditions in the Malacca and the Singapore Straits the following difficulties were encountered in obtaining depths of water below the fixed datum.

(a) The changes in monthly sea level are not uniform throughout the Straits since differences exist in the annual change of monthly mean sea level between the Burma and the South China Seas. It is therefore impossible to determine a mean sea level for the Straits from tidal data observed over a limited period of time.

(b) Likewise, in the Straits tidal times and heights differ greatly from region to region, not only along the direction of the traverse through the Straits but also over the cross-direction between the coasts of Malaysia and Sumatra. Thus tidal values observed on the coasts cannot be directly used to correct soundings.

(c) There are only a few places for which  $Z_0$  has already been determined, so that sometimes differences between two neighbouring ports could amount to more than a metre. Consequently in certain places a new  $Z_0$  had to be determined.

For the present survey the following procedure was adopted since the methods were theoretically correct, and at the same time the datums determined would in principle coincide with those already used by the British Hydrographic Department.

(a) Tidal stations were established in the vicinities of the benchmarks previously established by the British Hydrographic Department, and mean sea levels were obtained by correlating these stations with  $Z_0$  by means of levelling.

(b) At a station established where there was no nearby benchmark, mean sea level was determined by taking daily means of tidal heights for this station and comparing them over the same period with those of an adjacent station that had been correlated with a known  $Z_0$ .

(c) By plotting  $Z_0$ 's from the Admiralty Tide Tables at intervals corresponding to the difference in distances between the places involved and by connecting these points by a curve, a diagram showing  $Z_0$ 's at every 10 cm was prepared.

(d) A chart showing the distribution of (Hm + Hs) for the coasts of Malaysia and Sumatra was prepared, plotting these data versus their distance from one another. These (Hm + Hs) sounding line values were determined as a function of the ratio of their distances from the two coasts.

(e) A distribution diagram of  $gm^\circ/29^\circ$  was prepared in the same manner,  $gm^\circ/29^\circ$  being the phase lag of  $M_2$  divided by  $29^\circ$  (the approximate value of its angular speed  $28^\circ 984$ ). This is in order to compare the differences in times of tides between the various places.

(f) Tidal corrections were made for the traverse soundings, using information obtained from the specially installed tide gauges at Port Dickson, Tg. Telaga and P. Iyu Ketjil, as well as from the Port of Singapore Authority's permanent tide station in Singapore town.

(g) For the specified area in Phillip Channel tidal corrections were obtained from the tide gauge at Raffles Lighthouse.

(h) The formula for obtaining tidal heights at the sounding stations from observed heights was as follows :

$$\text{Height of tide at sounding station} = (\text{Observed height} - \text{Daily mean}) \times \text{Ratio of tide range} + \text{Daily mean} - \text{M.S.L.} + Z_0.$$

### OBSERVATION OF TIDAL CURRENTS

Tidal currents for a layer six metres below the sea surface were observed with an Ono type automatic current meter, of 1 metre in length, weighing 25 kg in air and 16 kg in water, and moored to the Raleigh shoal light buoy. Observation data were obtained for only 30 hours because the current meter was put out of action by a fishing net entangled around the meter's buoy.

Plots were made of the direction and speed of the currents at 20-minute intervals. Computations were carried out for subsequent Harmonic Constant analysis.

The following table shows the results of a comparison between the values computed at South Sand and the predicted values taken from the Admiralty Tide Tables.

TABLE II

	Direction	Time difference	Speed ratio
Flood current	SE	+ 1.4 hours	1.0
Ebb current	NW	+ 2.8 hours	0.8

Constant currents were rarely observed.



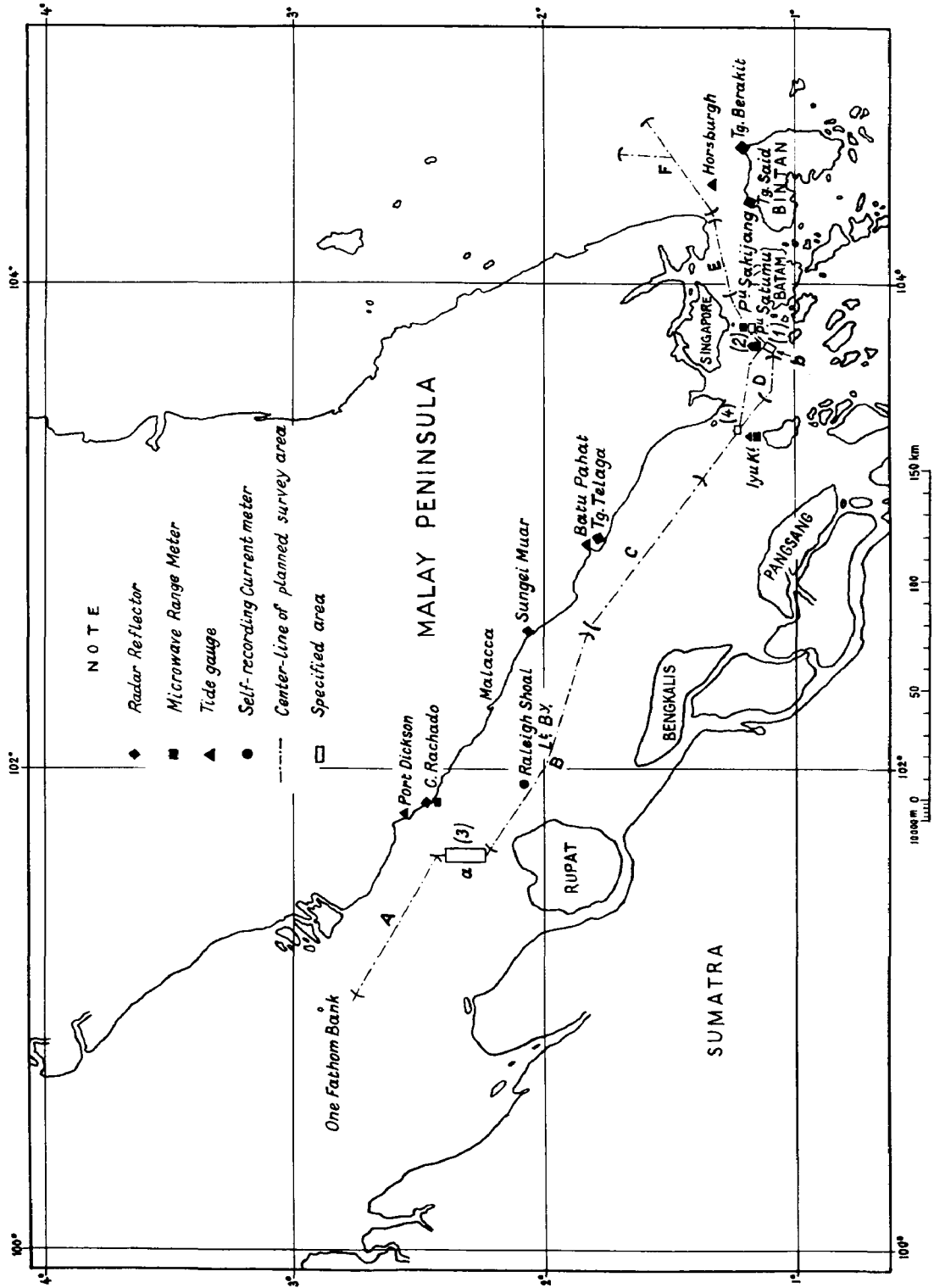


FIG. 2. — Malacca Strait

## BOTTOM SAMPLING

Sea-bottom samples were collected with a vibro-sampler capable of penetrating as deep as five metres under the surface of the sea bottom. A grab bucket was also used because the suitability of the vibro-sampler for use in the Straits was considered doubtful.

Samples were collected at 62 stations. However at only 35 stations could the vibro-sampler reach deep enough under the surface of the sea bottom. At almost all points in and around Singapore Strait the sea bottom was found to be rocky and too hard for the vibro-sampler.

## OUTLINE OF RESULTS

### Comparison with charted depths

All the areas surveyed are shown in figure 2. The soundings shown on existing nautical charts are principally taken from old surveys in which the soundings were carried out with leadlines. The vessels of those days were of considerably shallower draught than present-day large vessels, and soundings in more than 20 metres were presumably of much less importance than today.

The results of the preliminary survey show numerous soundings that are shallower than those on existing charts, especially in the areas A, B, a, and b on figure 2.

### The specified area in Phillip Channel

Great apprehension was entertained as to the safe passage of the larger deep draught vessels in this area, since only a limited number of sounding figures are shown on existing charts, and also because shallow waters of less than 20 metres have been reported by passing vessels whereas the charted least depth is 23 metres (see figure 3).

Sounding lines were run at 100-metre intervals, and in some places at 50-metre intervals.

The results of the survey of this area were :

(i) Six shallows of less than 23 metres were discovered, some of them extending over areas roughly 500 metres in diameter.

(ii) Over some of the shoal waters the character of the bottom was positively identified as rocky. The other shoals would also seem to be over rocky bottom, to judge from the bottom topography.

(iii) The bottom in the area of Phillip Channel showed the most irregular and inclined features in the entire preliminary survey area.

(iv) Newly discovered shallow waters are chiefly to the south of the parallel passing through P. Takong Kl.

(v) The width of the navigable channel with depths of more than 23 metres was narrowed down to about 700 metres near the Takong Lighthouse.

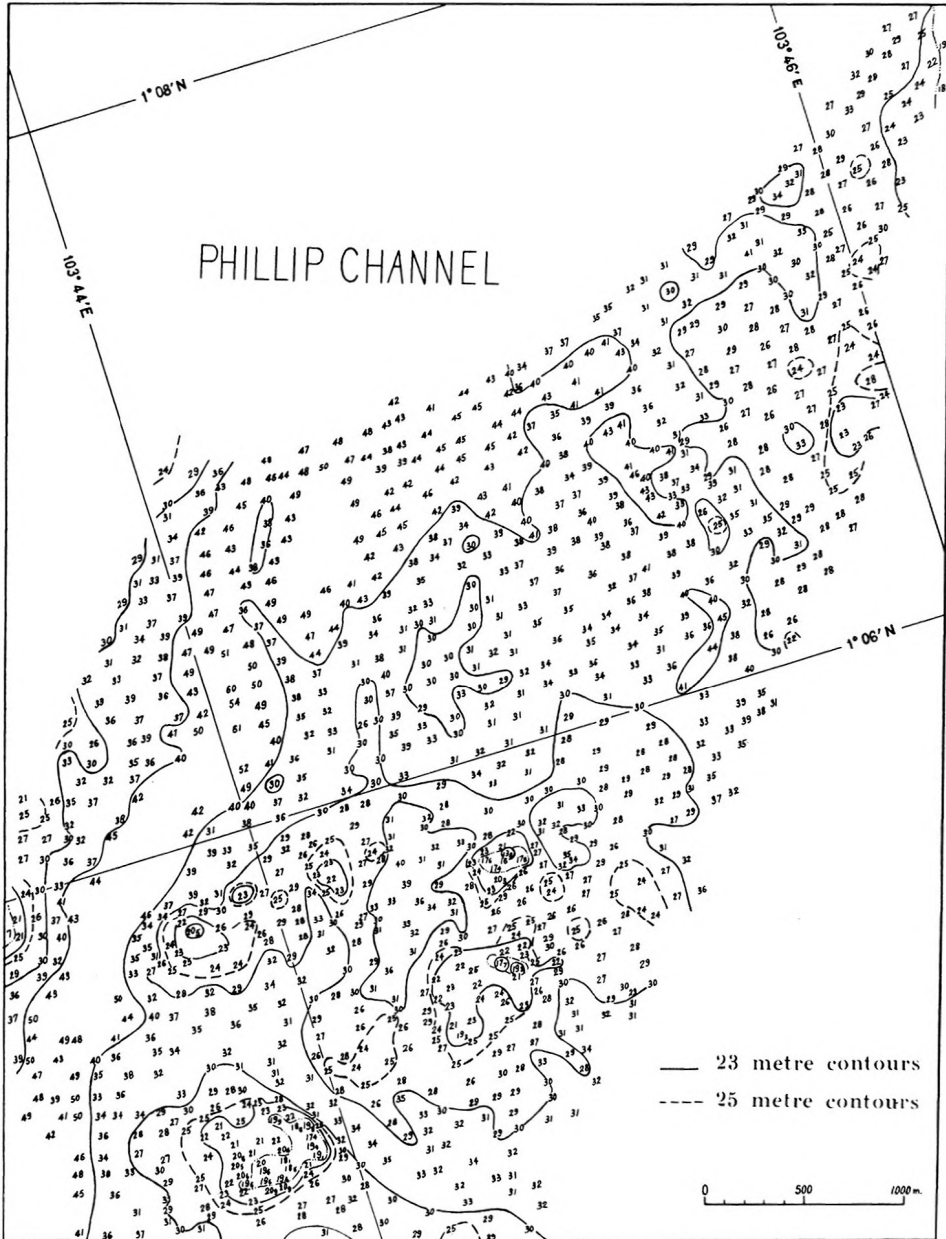


FIG. 3.

*Geographical distribution of shallow waters (see figure 4)*

(i) The mountain ranges and islands in this region are generally oriented NW - SE, and in and around Singapore three such zones can be recognized running parallel to one another in this direction. The first (Zone A) has its western border at the western extremity of Singapore Island; the second (Zone B) consists of a belt of islands near Selat Sinki, and the third (Zone C) is a belt of islands and reefs stretching from P. Nipa to P. Takong Kl.

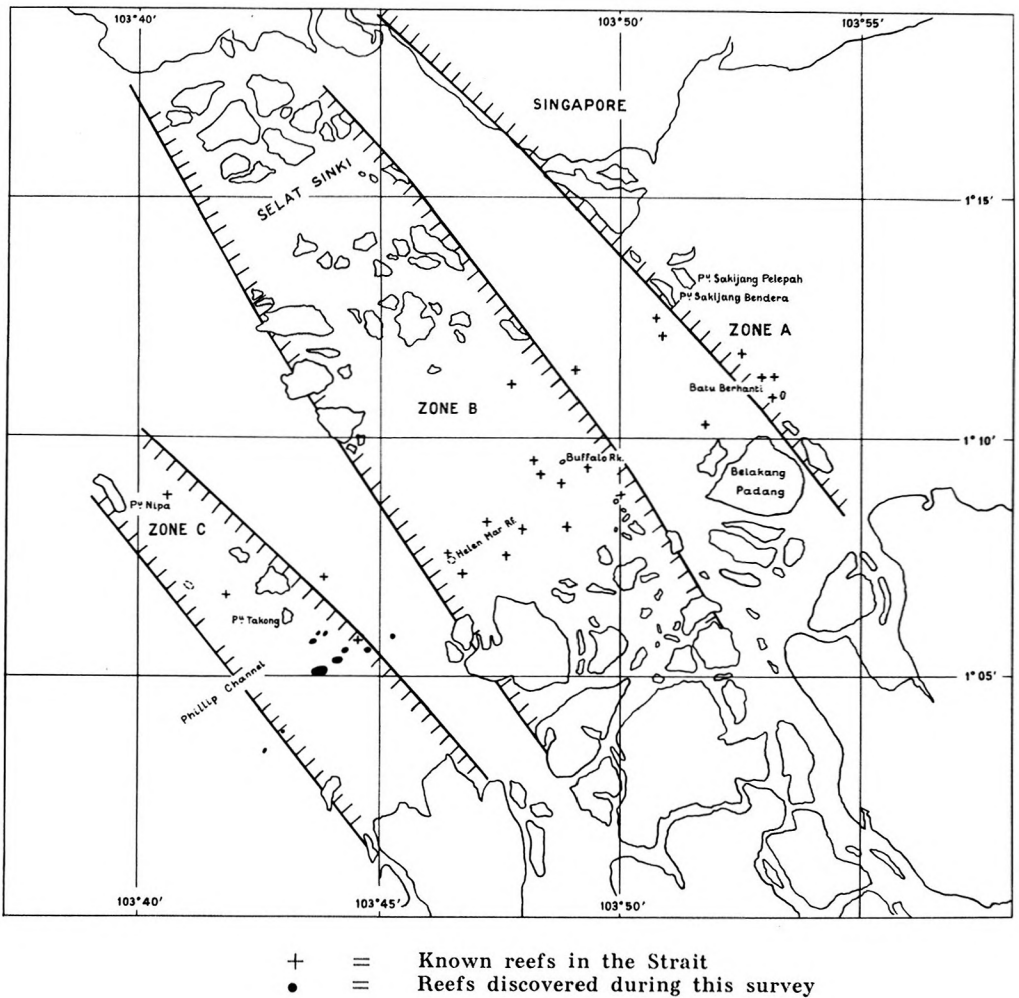


FIG. 4.

All the known shoals and reefs in Singapore Strait fall within one of these zones. Batu Berhante, for instance, is in Zone A and Buffalo Rock and Helen Mar Reef are in Zone B.

The shoal waters in Phillip Channel discovered during the present survey fall within Zone C, forming an extension to the line of islands ending at P. Takong Kl. The survey results showed that there was a sharp decrease

in the number of shoal waters in the area north of  $1^{\circ}6' N$ , an area lying between Zones B and C. As these two shallow water zones coincide with the geological structure of the area between the Malay Peninsula and Sumatra it is desirable that accurate hydrographic surveys be carried out in these particular zones.

(ii) Closer examination reveals that shallow waters exist not only on the extension of the line of islands ending at P. Takong Kl. but also are arranged in two other distinct lines. The direction of this group of shoal depths intersects the direction of the Zones B and C at an oblique angle. It is thought that this is probably due to a secondary and later geological structure. Consequently it is expected that the originally deep bottom between the lines of shallow waters has not been altered. Judging from this the possibility of finding shallow waters in these particular places may turn out to be small. Even if they do exist such shallow waters are expected rather to lie on the southern extension of the group of known shoals.

#### **Sand waves west of Raleigh Shoal**

Sand waves were observed in the area lying almost entirely between Raleigh Shoal and One Fathom Bank. Their existence in this area had been reported in 1967 by H.M.S. *Dampier* which stated that in the main area of the relevant chart the bottom was almost entirely covered with ridged sand waves, some being over 30 foot from crest to trough.

It has been demonstrated that sand waves are formed by fine sediments which have been transported in a state of saltation by currents as a consequence of a change in current after the bottom sediments first settled. Where the particles of bottom sediments are so small that they cannot resist the intensity of subsequent new currents, sand waves are formed and the bigger the diameter of sediment particles and the deeper the water, the larger the sand wave (MOGI, *Oceanic Geology*, 1962).

As a first stage in the analysis of data collected during the present survey the relation between the amplitude of sand waves and the depth of water was examined, since this is considered to have a direct effect on navigational safety.

In area A (between One Fathom Bank and Port Dickson offing) 61 stations over sand waves were selected at 2-mile intervals and amplitudes and water depths at these points were measured. Similar data were obtained in Area 'a' (specified area WSW of Cape Rachado) where 112 stations over sand waves were selected at half-mile intervals on sounding lines which were 1 mile apart. Figures 5 and 6 give the values of the amplitudes of sand waves, together with the isobaths in these areas. Table 3 shows the relation between amplitudes and depths.

In area A there are sand waves with amplitudes ranging from 1 - 9 metres. In Area 'a' sand waves of varying amplitudes (1 - 7 m) exist at shallower depths (46 - 50 m) than is the case in Area A. As regards sand waves of 4 m in amplitude, in Area A these are distributed in depths ranging between 20 and 70 m, while in Area 'a' the range is narrower, falling between

30 and 60 m. Judging from this analysis of the relation between amplitudes and depths of sand waves it is apparent that sand wave conditions in these areas are extremely complex.

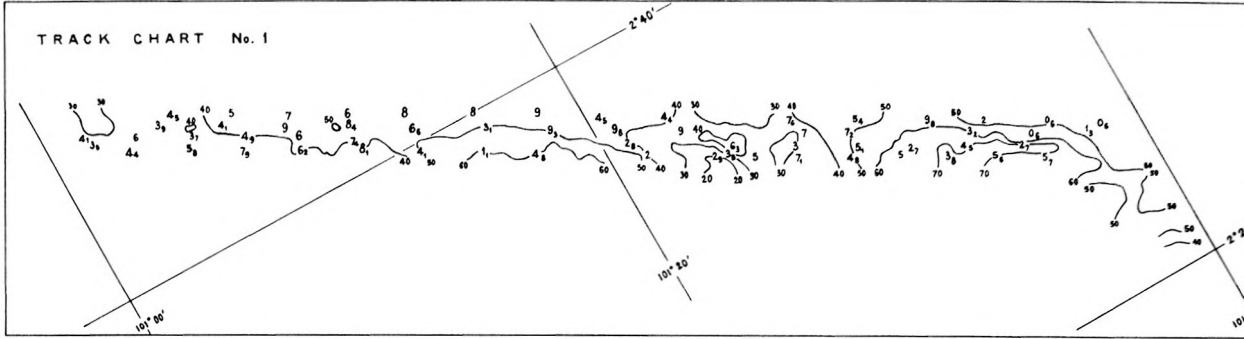


FIG. 5. — Contour lines in Zone A, with sand wave amplitudes

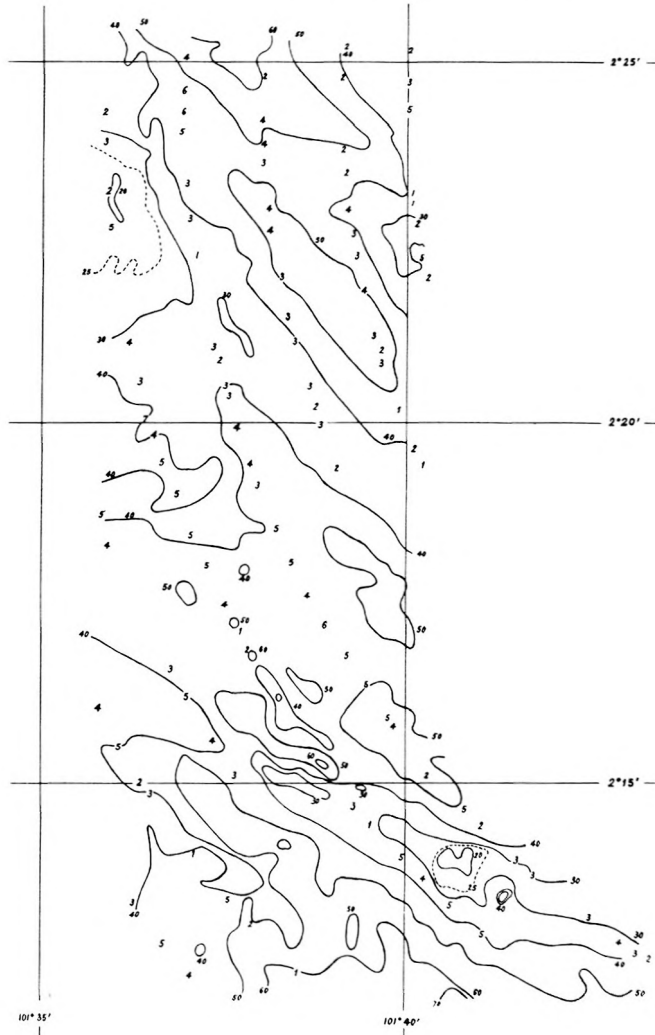


FIG. 6. — Contour lines in zone « a », with sand wave amplitudes

TABLE 3  
Area A (One Fathom Bank — Port Dickson Offing)

Depth (m) Ampli- tude (m)	16- 20	21- 25	26- 30	31- 35	36- 40	41- 45	46- 50	51- 55	56- 60	61- 65	66- 70	71- 75	76- 80	81- 85	86- 90
1							1	2			1				
2								2							
3	1							1	1			2			1
4			2			2	3	4	1				2		
5						1	1	2	1	1	2	1			
6							2	2	2				1	1	
7						1		1		3					
8							1	3		3					
9								2	1		2				
10									1						
11															

Area "a" (Specified area WSW of Cape Rachado)

Depth (m) Ampli- tude (m)	16- 20	21- 25	26- 30	31- 35	36- 40	41- 45	46- 50	51- 55	56- 60	61- 65
1				2	2	2	2	1		1
2		1	2	2	5	4	2	2	4	
3				6	6	8	4	4	2	
4				2	4	2	5	4	6	
5			1	1	2	3	11	2	2	
6							3			
7							2			

More time should be devoted to closer analysis of sand waves, and also further field surveys should be promoted.

#### Soundings between Remunia Shoals and Eastern Bank

Traverse soundings were carried out in the channel between the northern part of Remunia Shoals and Eastern Bank, in order to study the possibility of establishing a sea route with depths of more than 27 metres. The findings can be summarized as follows :

(1) Shoal waters less than 23 metres deep extend along the line connecting the positions of two charted depths of 23 metres in the northern

part of this survey area. Around this shoal there are depths of less than 27 metres, thus closing this channel.

(2) In the southern part of the channel an area of less than 27-metre depths extends eastward from Remunia Shoals, thus narrowing the channel.

(3) It is therefore considered that in this channel there is very little possibility of finding a passage with depths of more than 27 metres.

#### **Principal shoal soundings**

Twenty-one soundings of less than 23 metres, and shallower than those charted were discovered during this survey. Their description has already been given in the relevant Notices to Mariners.

#### **COMMENTS**

The existing charts compiled mainly on the basis of data from the British and Dutch surveys prior to 1936 met the navigational safety demands of those days. This is because charts compiled on the basis of lead-line soundings give valuable help provided their tolerable errors are correctly taken into account.

However, since a number of hitherto uncharted shallow waters of less than 23 metres have been discovered by this preliminary survey the existing charts now become unsatisfactory for selecting routes through depths of more than 23 metres.

Accordingly, further surveys should, in principle, be carried out over the whole area that this preliminary survey covered, in order to improve these charts and thus be able to select and mark such routes on them.

It is considered that immediate priority should be given to the area between Phillip Channel and The Brothers where there exist many reefs in less than 30 metres, as well as some abrupt depth changes in waters of 30 metres and deeper. The area between Tg. Medang Offing and One Fathom Bank where sand waves abound should also be given high priority.