REPORT
OF
HYDROGRAPHIC SURVEY
ON
THE COAST OF ABU DHABI

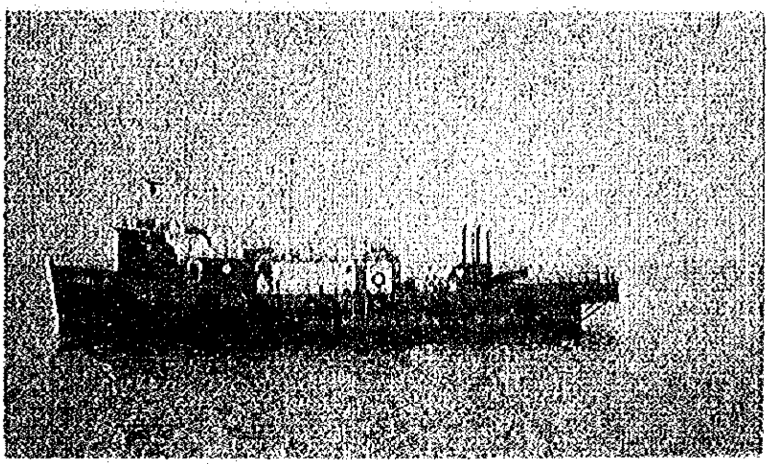
February, 1973

OVERSEAS TECHNICAL COOPERATION AGENCY
GOVERNMENT OF JAPAN

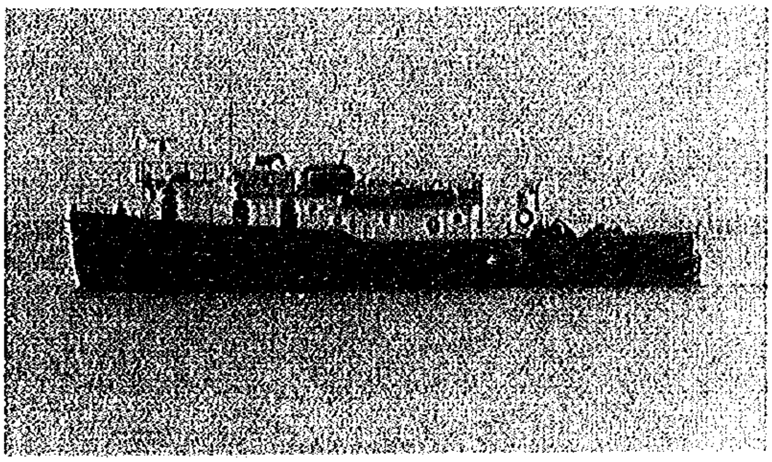
REPORT
OF
HYDROGRAPHIC SURVEY
ON
THE COAST OF ABU DHABI

February, 1973

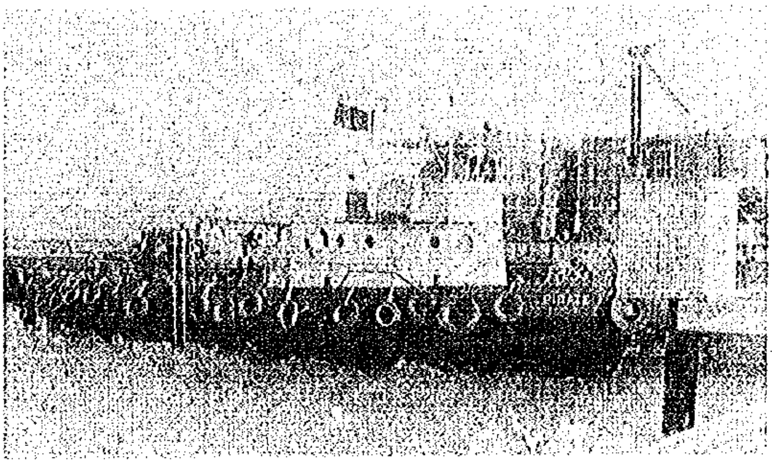
OVERSEAS TECHNICAL COOPERATION AGENCY
GOVERNMENT OF JAPAN



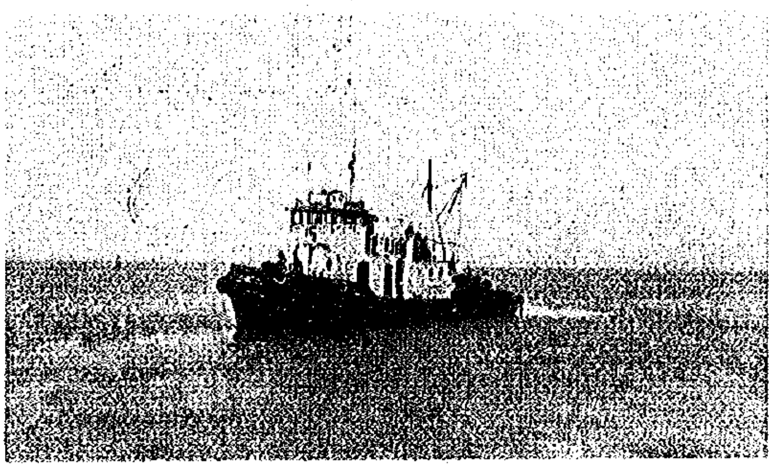
Survey Ship Jackson Creek



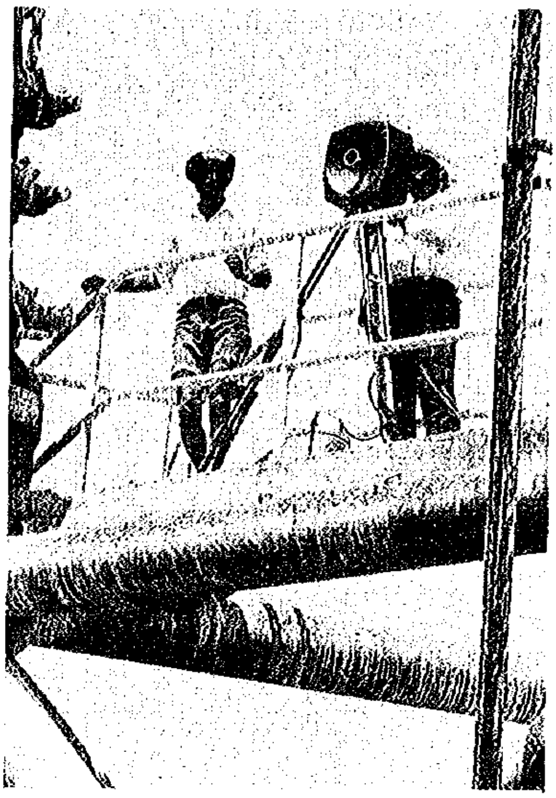
Survey Ship Creek Gal



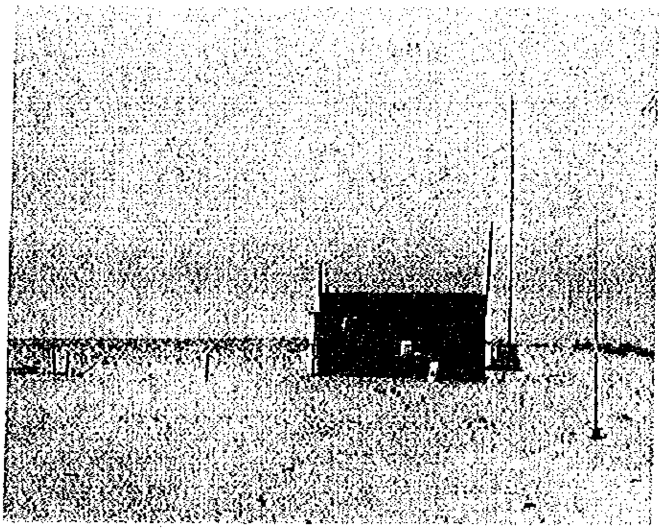
Survey Ship Pirate



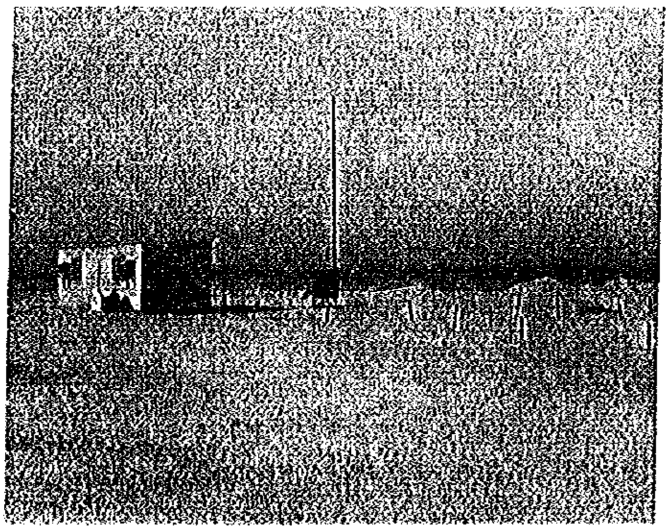
Survey Ship Lilian 16



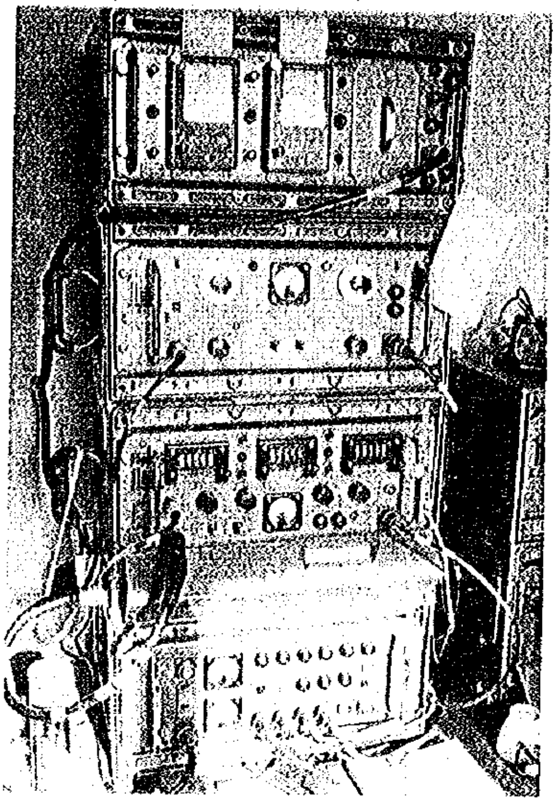
Distance measurement on an oil rig



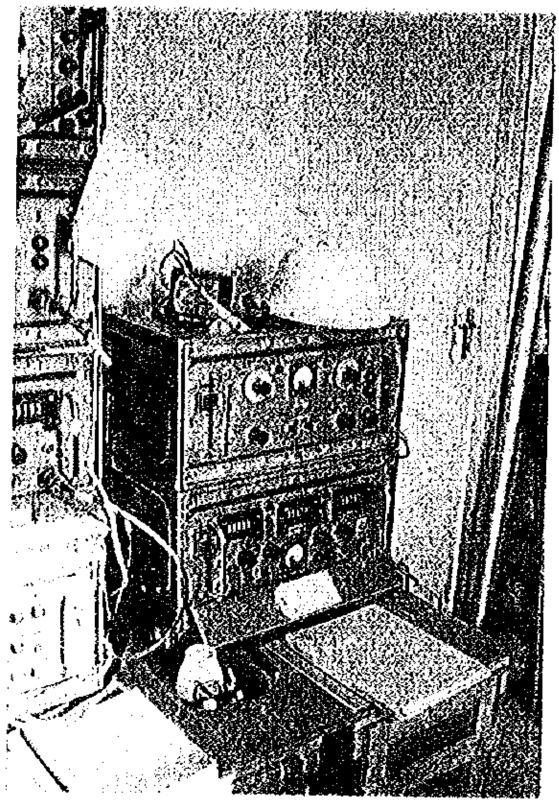
Ras Dhabiyah Hi-Fix shore station



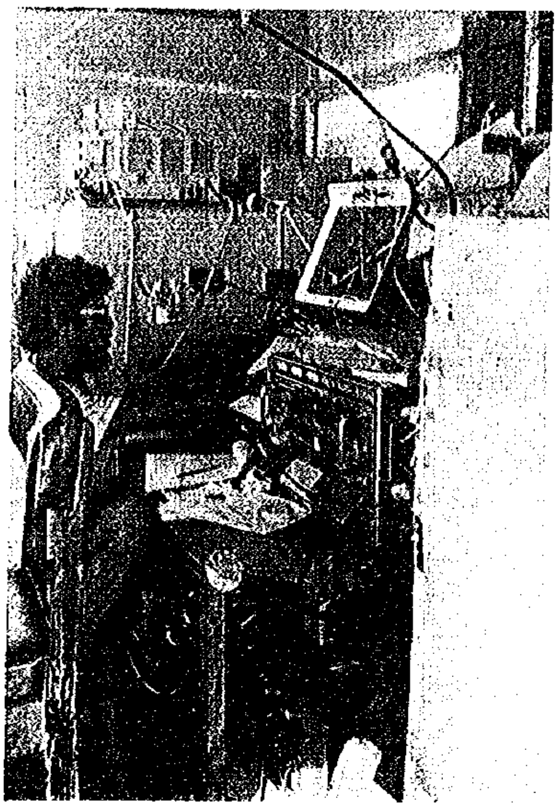
Mubarras Hi-Fix shore station



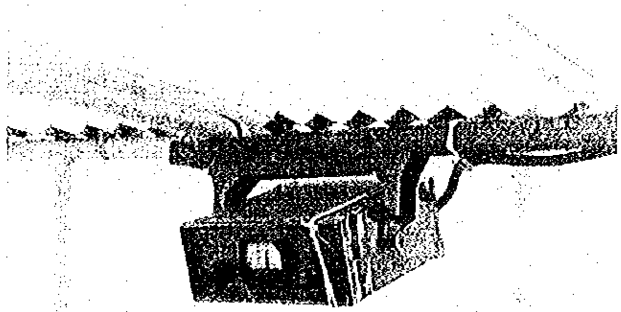
Hi-Fix eguipment in the station at Mubarras



Hi-Fix eguipment in the station at Mubarras



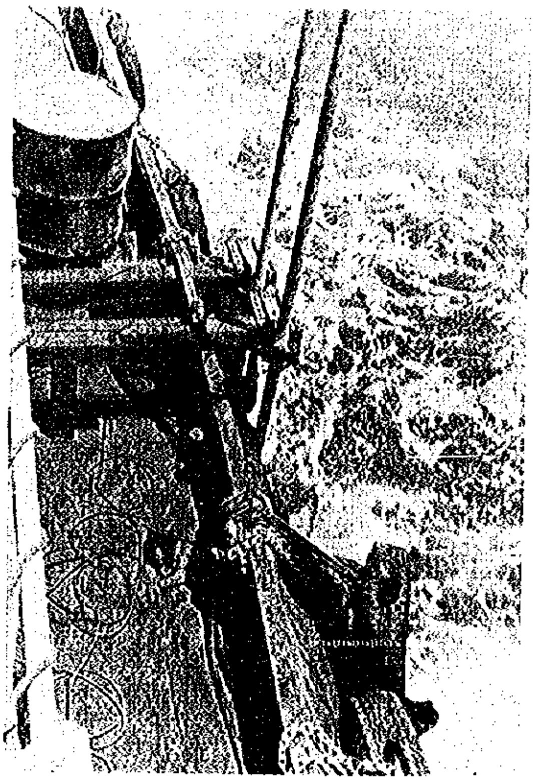
Hi-Fix operation in the bridge of a survey ship



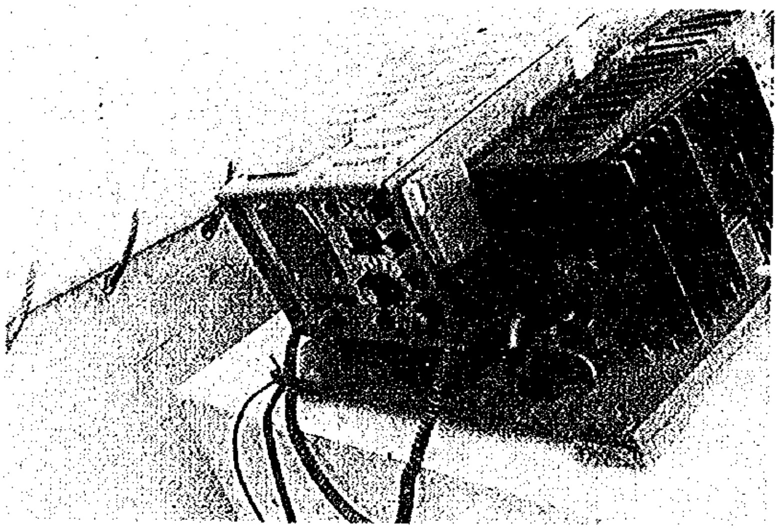
Remote indicater

Operation in the bridge of the Greek Gal

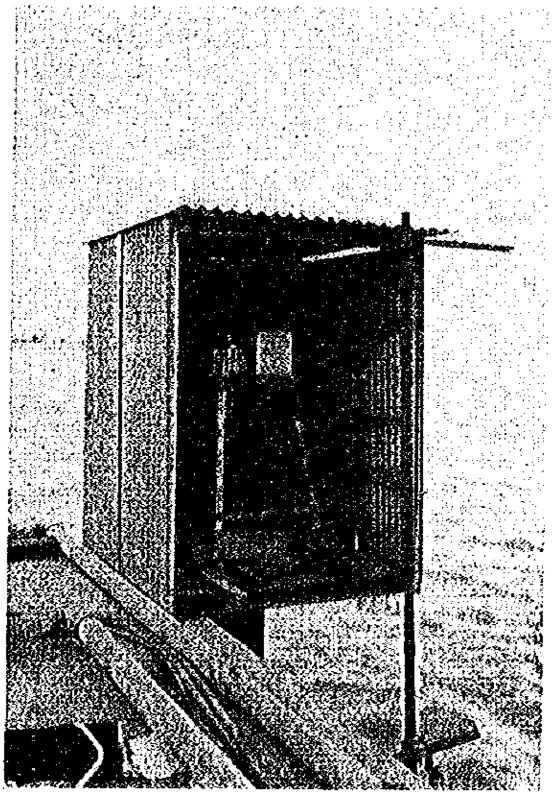
4-Beam Echo-sounder



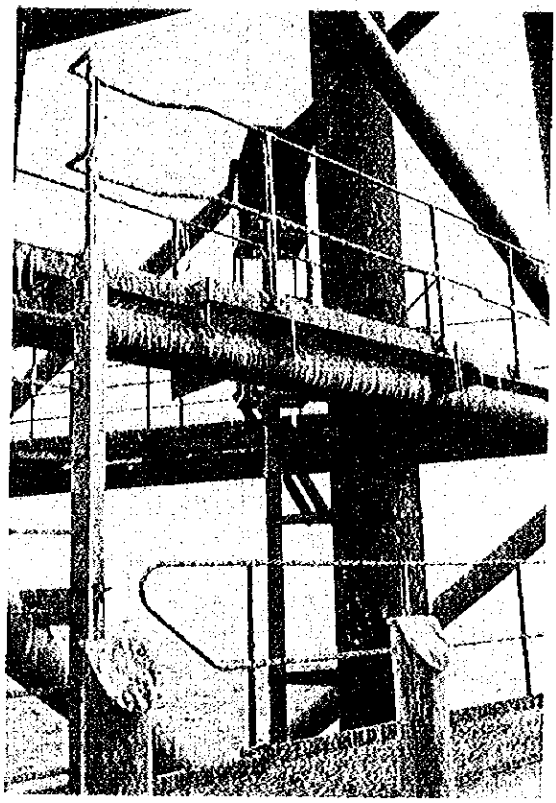
Transducers equipped to the broadside



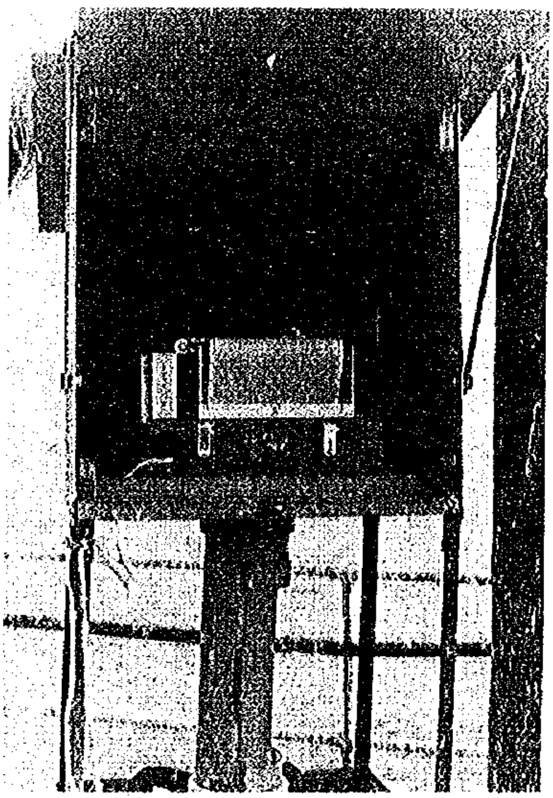
SSB transmitter-receiver



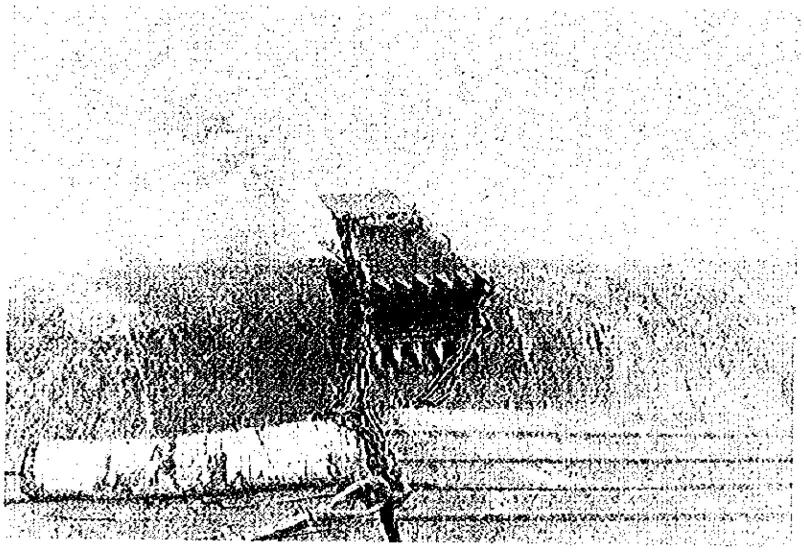
Mubarras Tide Station



Pipe 31 Tide Station



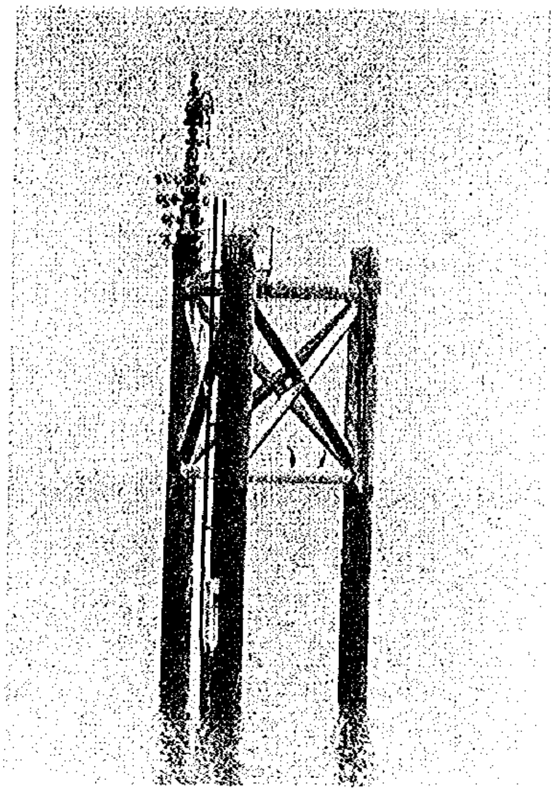
P. F. T. tide gauge(Pipe31)



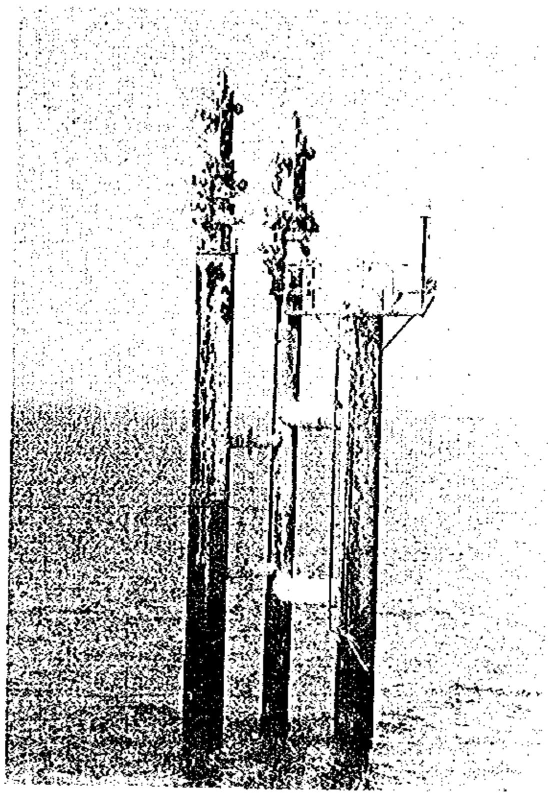
Niino type bottm sampler

The bottm sampled
(Co. Sh)

The bottm sampled(Calcareous Algae)

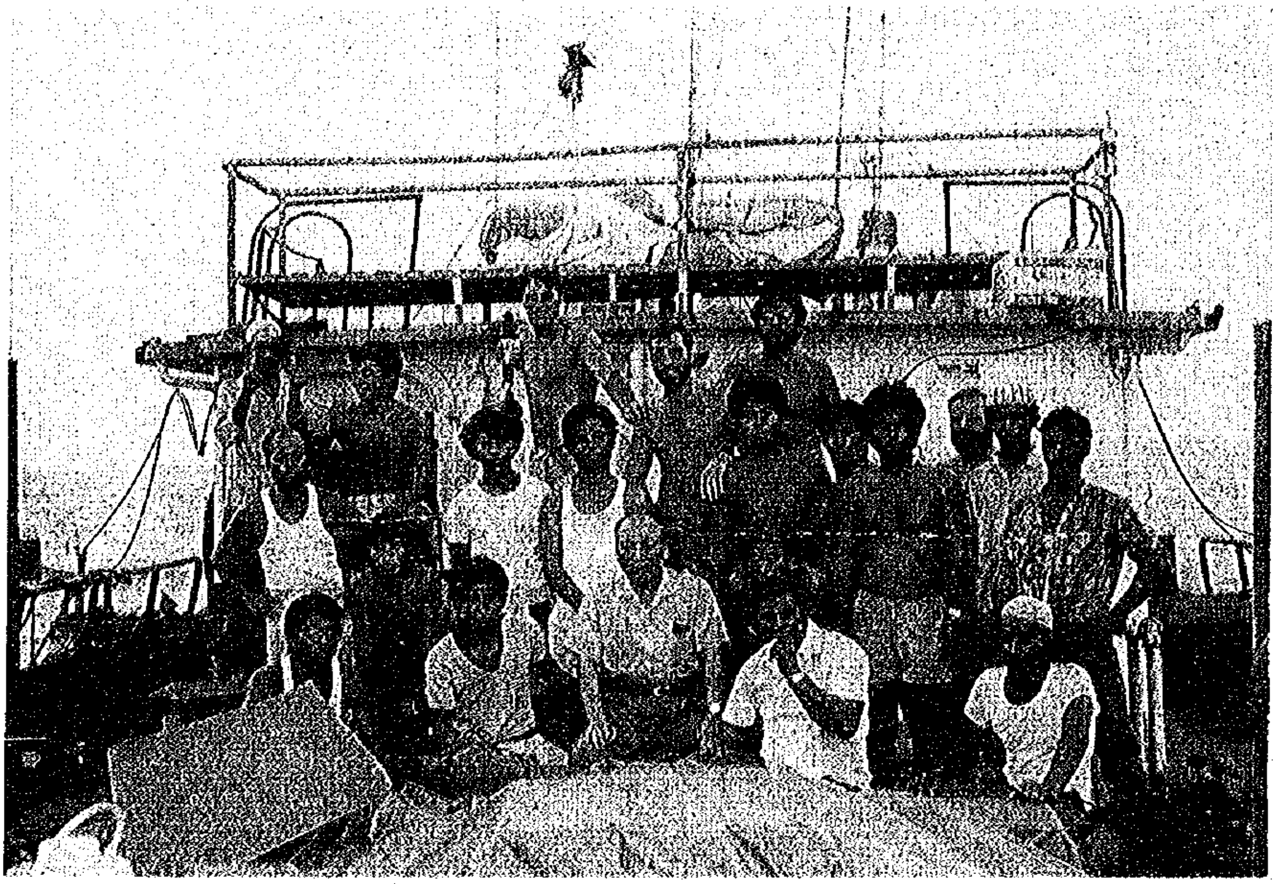


Oil Rig MR-4



Oil Rig MR-6

Setting of a current meter



Survey Team Members aboard the Jaekson Creek

CONTENTS

Page

REPORT OF HYDROGRAPHIC SURVEY ON THE COAST OF ABU DHABI

1. INTRODUCTION

As a result of the recent prospect for oil on the coast of Abu Dhabi of the (United Arab Emirates), southeastern part of the Arabian Peninsula, it is now estimated that an enormous amount of good quality oil is burried beneath the sea bottom in the vicinity of Halat al Mubarras (Mubarras island).

It is obvious that the economic condition of the country largely depends on the production and export of the oil. However, the adjacent seas to its coast have so far been not well charted for safe navigation of large-sized tankers. At present, the chart covering the waters in this locality is the British Admiralty chart at the scale of 1/330,000, which is, however, based on the survey of rather old days with a small amount of hydrographic information and consequently seemed not sufficient for assuring safe navigation of huge vessels in this particular area.

In the circumstances, the Government of Abu Dhabi made a request to the Government of Japan to carry out hydrographic survey and to prepare compatible nautical charts. In compliance with the request, the Japanese Government decided to carry out the hydrographic survey as one of its technical cooperation projects, and the Ministry of Foreign Affairs entrusted the performance of the survey to the Overseas Technical Cooperation Agency (OTCA). The OTCA then carried out this project from April to September 1972, which consisted of two stages the reconnaissance and the main survey.

2. RECONNAISSANCE

2-1. Objective

The ovjective of the reconnaissance was to make detailed explanations on the hydrographic survey to the Government of Abu Dhabi; to make necessary arrangements for smooth carrying out of the main survey; to select appropriate sites for establishment of Decca Hi-Fix stations and to fix those sites geodetically; to select suitable places for setting tide gauges; and to investigate the availability of survey ships and other necessary materials and provisions.

All of the findings are to be utilized in working out the over-all planning of the main survey.

2-2. List of Reconnaissance Hydrographic Survey Team Members

Head	: Dr. Kazuhiko Sato	Hydrographic Department, Maritime Safety Agency

Member :	Mr. Katsuyoshi Ando	Mining and Coal Bureau, Ministry of International Trade and Industry
	Mr. Yasuhiro Oyamada	Hydrographic Department, Maritime Safety Agency
	Mr. Noboru Akagi	Hydrographic Department, Maritime Safety Agency
	Mr. Kazuhisa Matsuoka	Overseas Technical Co-operation Agency
	Mr. Jun'ichi Saito	Pacific Aerosurvey Co.
	Mr. Yoshihiro Iijima	Pacific Aerosurvey Co.
	Mr. Yutaka Kyakuno	Pacific Aerosurvey Co.
	Mr. Seiji Yoshii	Pacific Aerosurvey Co.
	Mr. Toshio Machida	Pacific Aerosurvey Co.

The period of the reconnaissance was from 13 April to 9 May 1972.

2-3. Outline of the Reconnaissance

2-3-1. Contact with the Government of Abu Dhabi

The Ministry of Petroleum and Industries had been assigned in the Government of Abu Dhabi to take charge of the technical cooperation project, and the Ministry was prepared to make necessary arrangements with the other agencies concerned (Ministry of Foreign Affairs, Ministry of Defence, Ministry of the Interior and Ministry of Communications).

As the result of the talks between the reconnaissance team and the Government of Abu Dhabi on the support to be rendered by the Government for the survey, it was confirmed that the security of safe maneuvering of survey ships and the safeguard against tide gauges and current meters at sea would be under the responsibility of the Sea Wing of the Ministry of Defence, while the security of land facilities would be in charge of the Oilfield Security of the Ministry of the Interior. It was also confirmed that the Government of Abu Dhabi was fully prepared to support the smooth progress of the hydrographic survey of the present technical cooperation project, with the Ministry of Petroluem and Industries as its nucleus.

2-3-2. Selection of Hi-Fix Station Sites on Land

It was finally decided to establish the Master station on Mubarras island, the Slave 1 station on Zarqa island and the Slave 2 station on Cape Dhabiyah, after due consideration was made as to the points that propagation of radio waves over land should be avoided as far as possible and that the sites would be convenient for the maintenance, operation and logistics.

Since construction works of oil loading facilities would be in progress at the Mubarras island which would give an unfavorable condition for operation of Hi-Fix, it was proposed to establish a minitor station on one of the oil rigs in the vicinity.

2-3-3. Control Survey

(1) Method and Results

The control survey was carried out to obtain geodetic positions of the Hi-Fix land stations, i.e. Master (Mubarras), Slave 1 (Zarqa) and Slave 2 (Dhabiyah).

The surveys carried out during the reconnaissance are as shown in Figs. 1 to 3. Originally it was scheduled for the traverse to be extended from the light tower at Dhabiyah to ADOC 1 (TMS4) at Jazirat Abul al Abyyadh by way of the control point TC 69. However, the connection between TC 69 and TMS 4 was not made due to inaccessibility of the area. Computations were made to the control points on the basis of the data obtained at Abu Dhabi Oil Company in Abu Dhabi, i.e. TMS 4 for Rog-Mubarras-Zarqa and TC 69 for Slave 2 at Dhabiyah. All the data were finally recomputed to the values with reference to the control point at Zarqa and the light tower at Dhabiyah on the basis of the data received from the British Hydrographic Department at a later date. As the result, the following geographical coordinates were obtained for all antenna positions of Decca Hi-Fix stations to be established, as well as the oil rigs to be used as lane identification points:

	Lat.	Long.
Master (Mubarras)	24°27'22".904N	53°22'25".328E
Slave 1 (Zarqa)	24 51 30 .488N	53 04 46 .008E
Slave 2 (Dhabiyah)	24 19 28 .122N	54 08 28 .945E
MR 1	24 37 47 .712N	53 38 09 .432E
MR 2	24 29 29 .430N	53 42 29 .251E
MR 3	24 33 33 .645N	53 50 29 .058E
MR 4	24 26 14 .486N	53 39 54 .059E
MR 5	24 30 22 .814N	53 43 37 .171E
MR 6	24 35 39 .854N	53 43 46 .887E

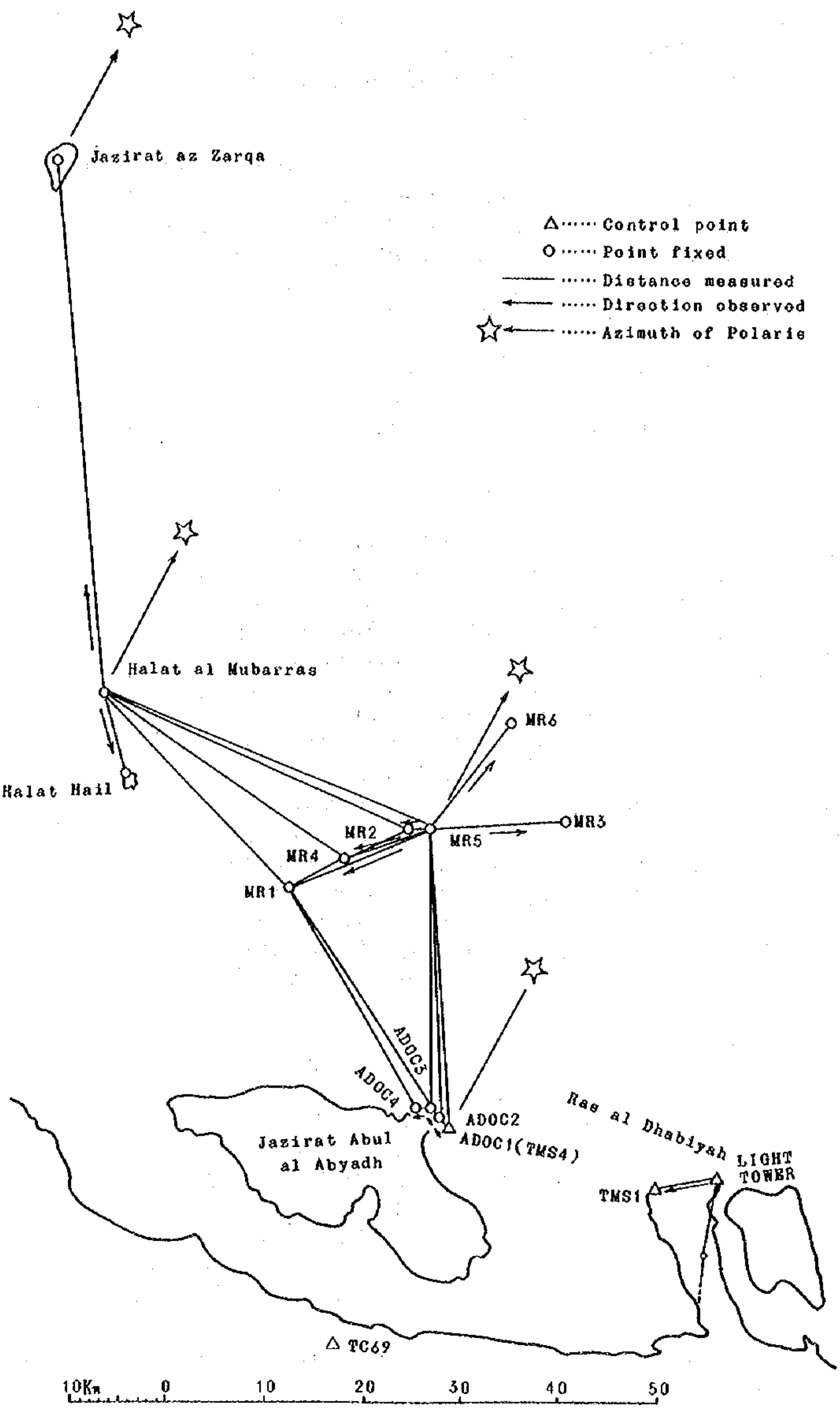


Fig. 1 Geodetic Network

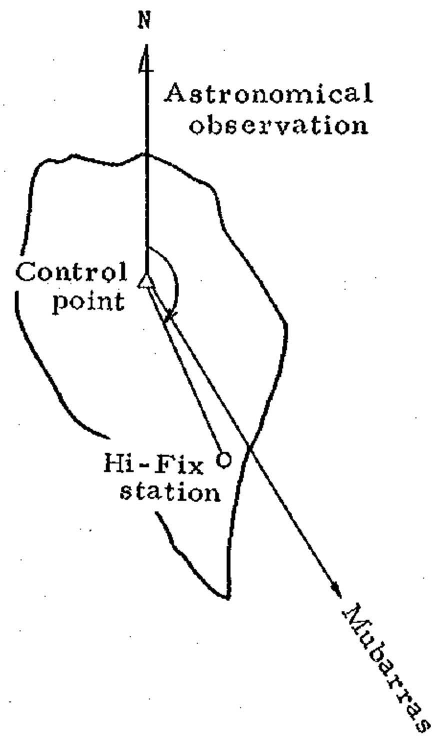


Fig. 2 Survey of Hi-Fix station point at Zarqa.

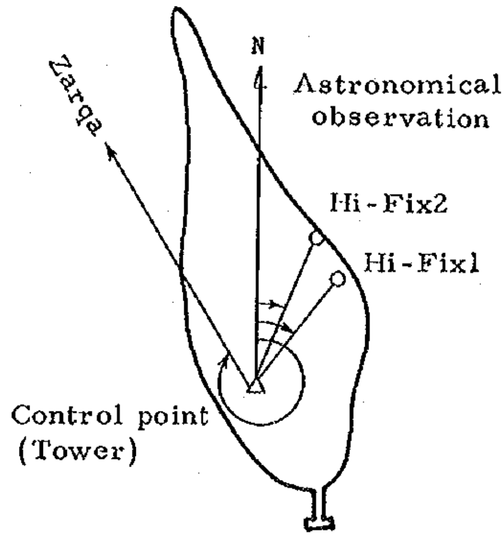


Fig. 3 Survey of Hi-Fix station point at Mubarras.

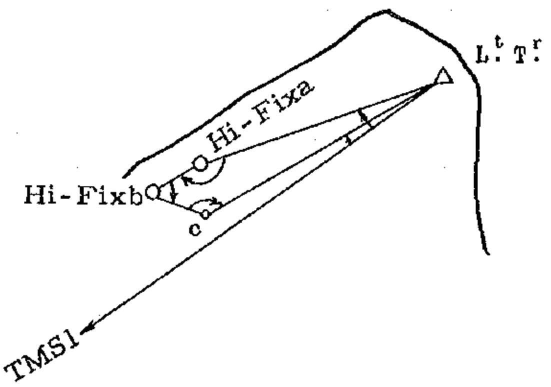


Fig. 4 Survey of Hi-Fix station point at Dhabiyah

The geographical coordinates of the reference point at Zarqa which was made as the control point and of the light tower (reference point) at Dhabiyah are as follows:

	Lat.	Long.
Zarqa	24°52'50''.333N	53°04'07''.907E
Light tower	24 19 34 .147N	54 08 54 .428N

Datum : 33°19'10''.87N 44°43'25''.54E (Nahrwan).

Spheroid : Clarke 1880.

(2) Instruments Used, Method of Measurement and Computation

(a) Distance Measurements

Distance measurements were carried out with Tellurometer MRA 101. The measurements were made by interchanging the interrogator and responder each time. At each measurement rough readings were made twice and fine readings 10 times. In order to make meteorological corrections to measured values, an aneroid barometer and a dry-wet thermometer were used to measure atmospheric pressure and temperatures by dry and wet balls of the thermometer. The correction values were obtained by the following equations with using an electronic computer:

$$(n-1)\cdot 10^{6} = \frac{77.62}{T}(P-e) + \frac{60.70}{T}\left(1+\frac{57.48}{T}\right)e$$

$$e = e' - 0.5\,(t-t')\frac{1.333}{755}P$$

$$\log_{10} e' = -7.90298\left(\frac{373.16}{T}-1\right) + 5.02808\log_{10}\left(\frac{373.16}{T}\right)$$
$$- 1.3816\times 10^{-7}\left(10^{11.344\left(1-\frac{T}{373.16}\right)}-1\right)$$
$$+ \log_{10} 1013.246$$

where

- n : refractive index of electromagnetic wave in atmosphere,
- t : mean temperature measured by dry thermometer (°C),
- t' : mean temperature measured by wet thermometer (°C),
- P : mean atmospheric pressure,
- e' : saturated steam pressure (mb),
- T : 273.16 + t.

(b) Angular Measurements

For angular measurements, Wild T-3 theodolite was used. Each horizontal angle was measured three series by the directional observation method. Vertical angles were measured for correction of inclination at the traverse.

Astronomical observations of the azimuth of the Polaris were carried out 12 series. For the measurement of the time of observation, a wrist watch (Seiko KS) was used. Corrections to the time were made on the basis of the time signal from Moscow. As markings on land, revolving illumination apparatus and rotating lights were used.

For each value obtained from the astronomical azimuthal observations, the corrections for level were made in accordance with the following equation.

$$\triangle A = \frac{d''}{4} \tan h \ (L - R)$$

where

- $\triangle A$: level correction value,
- d'': value of a unit graduation of an air bubble tube.
- h : altitude of the star.
- L, R : readings of the both sides of the air bubble.

(c) Computation Equations

Computations for adjustment were made by the electronic computer (TOSBAC 3400). The following equations were employed:

Computation of tentative coordinates:

$$\phi_2 = \phi_1 + \frac{D \cdot \cos(A - \frac{2}{3}P)}{R_y \cdot \sin 1''} - Q$$

$$\lambda_2 = \lambda_1 + \frac{D \cdot \sin(A - \frac{1}{3}P)}{N_x \cdot \sin 1''} \cdot \sec(\phi_2 + \frac{1}{3}Q)$$

$$A_{21} = 180° + A_{12} + (\lambda_2 - \lambda_1) \sin(\phi_2 + \frac{2}{3}Q) - P$$

where

- ϕ_2 : Latitude of unknown point,
- ϕ_1 : Latitude of known point,
- λ_2 : Longitude of unknown point,
- λ_1 : Longitude of known point,

D : Geodetic distance between two points,
A_{12}: Azimuth from known point to unknown point,
R : Radius of curvature of meridian,
N : Radius of curvature of parallel,
A_{21} : Azimuth from unknown point to known point,

$$P = \frac{D^2 \cdot \sin A \cdot \cos A}{2R_x \cdot N_x \cdot \sin 1''}$$

$$Q = \frac{D^2 \cdot \sin^2 A \cdot \tan \phi_x}{2R_x \cdot N_x \sin 1''}$$

where the suffix x means $\phi_x = \phi_1 + \frac{D \cdot \cos A}{R \cdot \sin 1''}$ and the suffix y means $\phi_y = \frac{1}{2}(\phi_1 + \phi_x)$

Computation of geodetic distance:

$$D' = D - \frac{\triangle H^2}{2D} - \frac{H_0 \cdot D}{R_N} + \frac{D^3}{24R_N^2} - \frac{H_0 \cdot D^3}{8R_N^3} + \frac{H_0^2 \cdot D}{R_N^2} + \frac{\triangle H^2 \cdot H_0}{2 \cdot R_N D} - \frac{\triangle H^4}{8D}$$

where

D' : Geodetic distance,
D : Slant distance,
$\triangle H = H_2 - H_1$
$H_0 = \frac{1}{2}(H_1 + H_2)$
H_1, H_2: Elevation of observation instruments,

$$R_N = \frac{N \cdot R}{N \cdot \cos^2 A + R \sin^2 A}$$

R_N : Mean radius of curvature of surveyed line on the surface of the ellipsoid.
R : Radius of curvature of medidian,
N : Radius of curvature of parallel.

Adjustment computation of azimuth obtained by astronomical observations:

$$H \cdot A \cdot (t) = U \cdot T - R \cdot A - \lambda$$

$$\tan A = \frac{\sin t}{\cos \phi \cdot \tan \delta - \sin \phi \cdot \cos t}$$

$$A_z = 360° - \text{observed angle} - C \cdot C - L + A$$

$$C \cdot C = \tan A \cdot m_i$$

$$m_i = \frac{2 \sin 2\ 1/2}{\sin 1''}$$

where γ is the difference in observation time, and m_i is obtained from a table.

Adjustment computation equations for coordinates:

$$V(d)\cdot\frac{1}{D\cdot\sin 1''}=\frac{N}{D}\cos\phi_n\cdot\sin A\cdot\delta\lambda_1''$$

$$-\left(\frac{R}{D}\cos A+\frac{N\cdot\sin\phi_m\cdot\sin A\cdot\triangle\lambda}{2D}\right)\delta\phi_1''$$

$$+\frac{N}{D}\cos\phi_m\cdot\sin A\cdot\delta\lambda_2''$$

$$+\left(\frac{R}{D}\cos A-\frac{N\cdot\sin\phi_m\cdot\sin A\cdot\triangle\lambda}{2D}\right)$$

$$+\frac{D_c-D_0}{D\cdot\sin 1''}$$

$$V(\alpha)=\cos\phi_m\left(\frac{N}{D}\cos A-\frac{\tan\phi_m}{2}\right)\cdot\delta\lambda_1''$$

$$+\left(\frac{R}{D}\sin A-\frac{N\sin\phi_m\cos A\cdot}{2D}\right)\cdot\delta\phi_1''$$

$$+\cos\phi_m\left(\frac{N}{D}\cos A-\frac{\tan\phi_m}{2}\right)\cdot\delta\lambda_2''$$

$$-\left(\frac{R}{D}\sin A+\frac{N\cdot\sin\phi_m\cdot\cos A\cdot\triangle\lambda}{2D}\right)\cdot\delta\lambda_2''$$

$$+A_c''-A_0''$$

$$V(\theta)=\left\{(a_{13})_1-(a_{12})_1\right\}\delta\lambda_1''+\left\{(b_{13})_1-(b_{12})_1\right\}\delta\phi_1''-(a_{12})_2\cdot\delta\lambda_2''-(b_{12})_2$$

$$\times\delta\phi_2''+(a_{13})_3\cdot\delta\lambda_3''+(b_{13})_3\cdot\delta\phi_3''+\theta_c''-\theta_0''$$

where

- V : Residual of observed value,
- $\delta\lambda$, $\delta\phi$: Fine correction value in longitude or latitude,
- R, N : Radius of curvature at meridian and parallel,
- D : Geodetic distance between each pair of points,
- $\phi_m=\frac{1}{2}(\phi_1+\phi_2)$: Mean latitude of the two points,
- $\triangle\lambda : \lambda_2-\lambda$: Difference in longitudes between the two points,
- $A=\frac{1}{2}(A_1+A_2)$: Mean azimuth between the two points,

$\alpha = A_{12}$	:	Bearing from P_1 to P_2.
θ	:	Angle between the two points measured in clockwise direction.
D_0, A_0 θ_0	:	Observed values of distance, bearing and angle, respectively.
D_c, A_c, θ_c	:	Computed values of distance, bearing and angle, respectively.
$(a_{13})_1$	:	Coefficient of $\delta\lambda''$ in the observation equation for the bearing from P_1 to P_3,
$(b_{12})_2$	:	Coefficient of $\delta\phi_2''$ from P_1 to P_2.

2-3-4. Sounding Plan

Originally it was planned to carry out parallel sounding by two groups of survey boats, each group consisting of three boats. It was found, however, that sounding operations should be conducted by four boats separately because of unavailability of suitable boats in this locality and the possible language barrier between the survey team and the boat's crew which would hamper smooth maneuvering of the boats.

2-3-5. Selection of Sites for Tidal Observation

It was planned to establish a Fuess tide gauge at the pier of Mubarras island, and a portable tide gauge at Pipe 31 in the offing.

2-3-6. Tidal Current Observation Plan

It was planned to carry out continuous observation of 15 days at two stations (two layers at one station and one layer at the other), and one-day-and-night observations at 11 stations (two layers at 6 stations and one layer at 5 stations).

2-3-7. Buoyage

The positions for lighted buoys should be adequately selected in the vicinity of the positions already proposed by a consultant of maritime shipping. Those positions should be fixed by both Hi-Fix and Main Decca Chain readings.

3. PLANNING FOR THE SURVEY

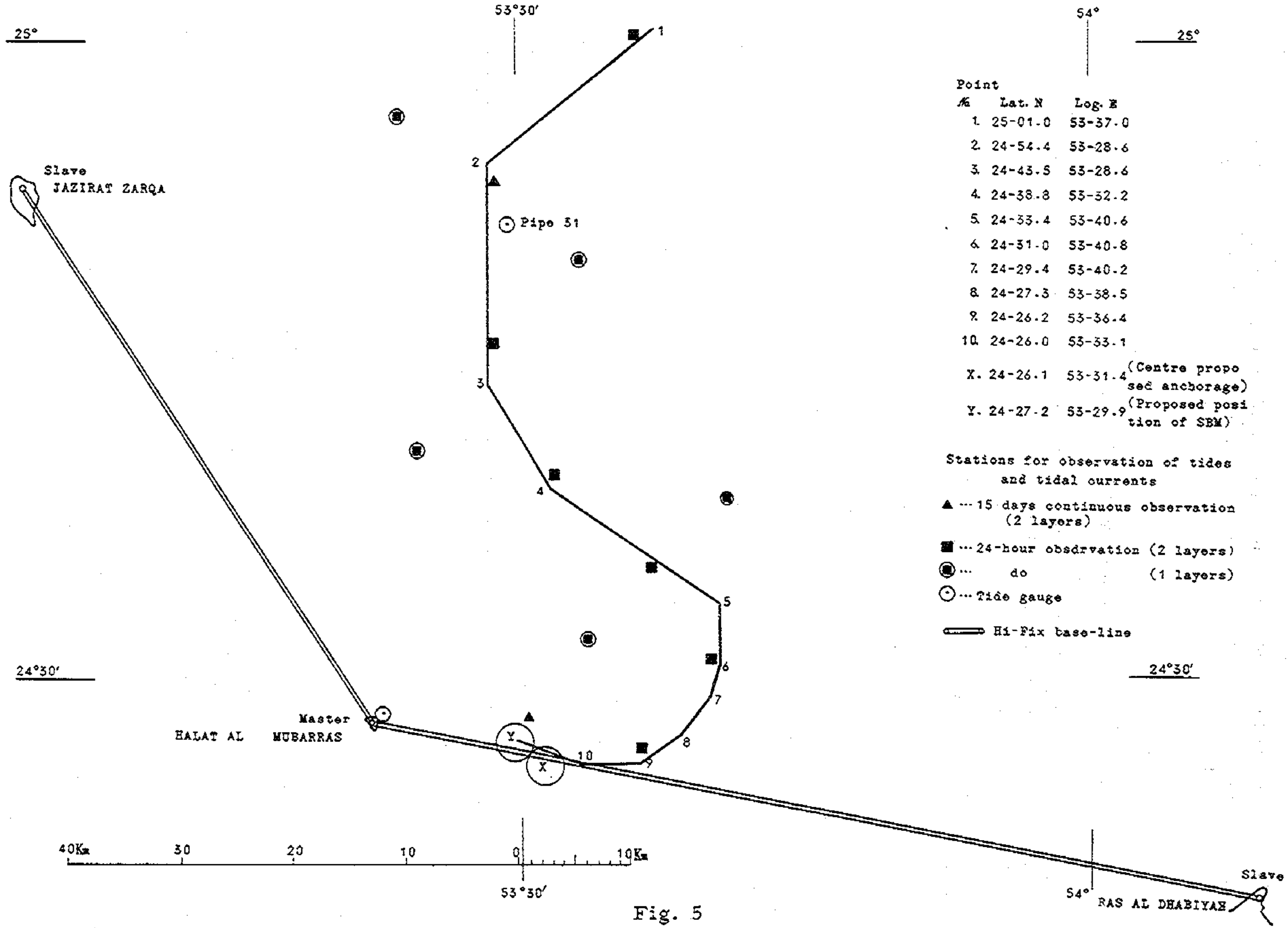
3-1. Objective

The hydrographic survey will be conducted for the purpose of affording deep draught vessels with navigational safety when they are entering or leaving the oil terminal at Mubarras on the coast of Abu Dhabi, United Arab Emirates. The survey operations will include precise hydrographic survey of ship's route, observations of tides and tidal currents and investigation of characteristic of the sea-bottom.

3-2. Survey Areas

The areas to be surveyed will be as follows:

A. An area with a width of 1.5 kilometres on either side of the centerline shown on Fig. 5.



Point №	Lat. N	Log. E	
1.	25-01.0	53-37.0	
2.	24-54.4	53-28.6	
3.	24-43.5	53-28.6	
4.	24-38.8	53-32.2	
5.	24-33.4	53-40.6	
6.	24-31.0	53-40.8	
7.	24-29.4	53-40.2	
8.	24-27.3	53-38.5	
9.	24-26.2	53-36.4	
10.	24-26.0	53-33.1	
X.	24-26.1	53-31.4	(Centre propo sed anchorage)
Y.	24-27.2	53-29.9	(Proposed posi tion of SBM)

Fig. 5

B. A circular area with a radius of 1.5 kilometres centred at the planned position of an oil loading mooring buoy (single buoy mooring).

C. A circular area with a radius of 1.5 kilometres which will be used as an anchorage.

3-3. Method of Survey

(1) Earth's Spheroid and Horizontal Control Datum;

Earth's spheroid : Clarke 1880.
Horizontal control datum : Nahrwan.

(2) Projection and Scale of the Smooth Sheet of Survey:

Projection : Universal Transverse Mercator projection.
Scale : 1/50,000 (2 sheets), as shown in Fig. 6.

Sheet Layout of Smooth Sheets of Survey and Divisions for Zo

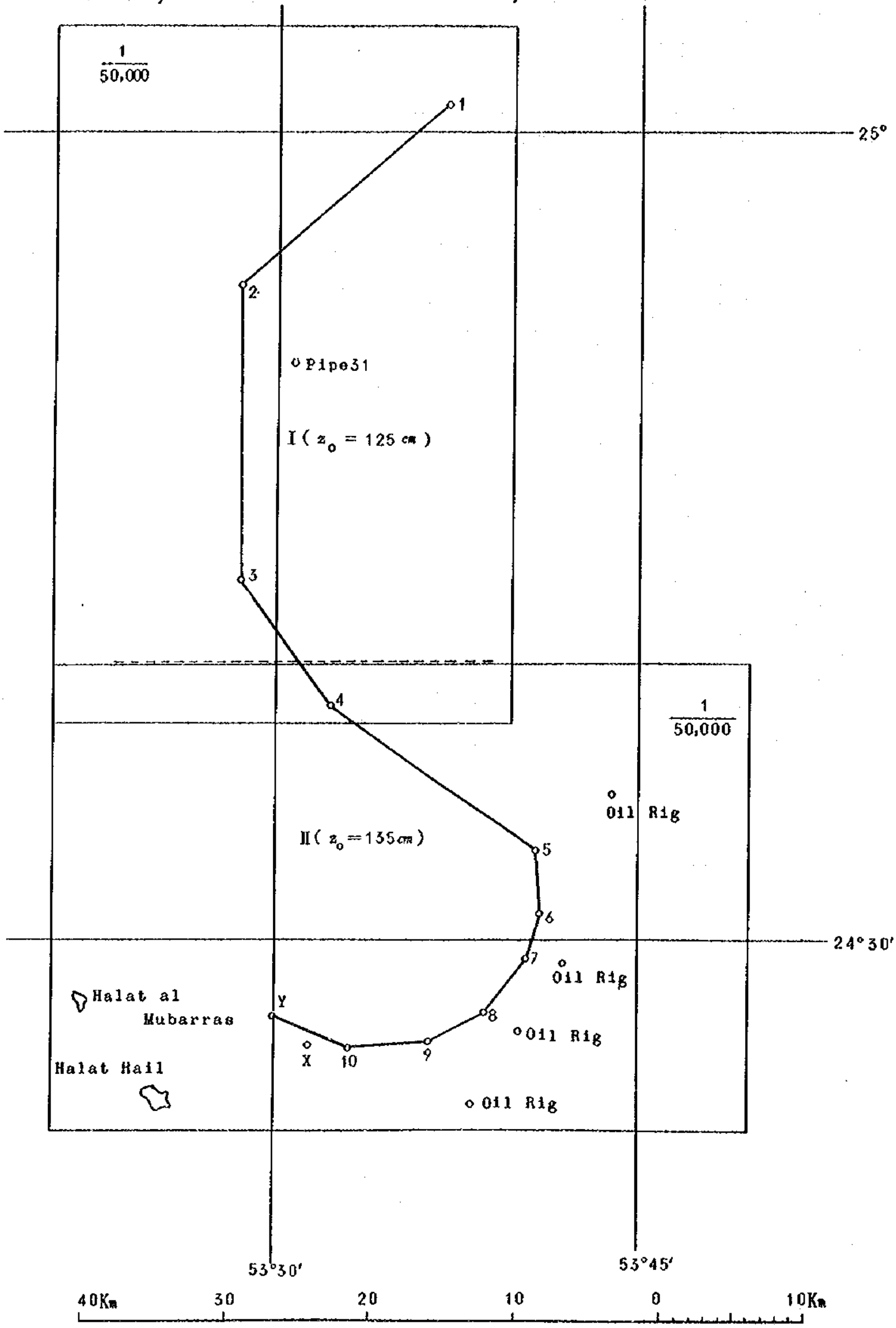


Fig. 6

(3) Datum Level:

The mean sea level will be computed by the following equation from the comparison with the data of the mean sea levels of 30-day observation at both tide guages and the mean sea level at the tide gauge at Das island during the same period:

$$A_0' = A_1' + (A_0 - A_1)$$

where

A_0 : Mean Sea Level at Das island tide gauge.

A_0' : Mean Sea Level at the tide gauge at Mubarras island or Pipe 31.

A_1, A_1' : Short-term Mean Sea Levels at both tide gauges above during the same period.

In case where the tidal record at Das island is unavailable, the Mean Sea Level will be obtained by adding the following seasonal changes obtained from the British Admiralty Tide Tables to the 30-day Mean Sea Level at each tide gauge.

Seasonal Changes in M. S. L. (Value on the 1st day of the month)			
June	July	August	Remark: The positive sign indicates that the M. S. L. of this particular period is above M. S. L.
+3 cm	+9 cm	+12 cm	

Based on the British Admiralty Tide Tables, Z_0 is divided into two values, 125 cm and 135 cm, for area I and area II, respectively, as shown in Fig. 6.

(4) Method of Sounding and Corrections

(a) As for the area A, sparse sounding will be conducted first, and on the basis of the results obtained, close sounding will be conducted in an area with a width of 1 kilometre. In areas B and C, close sounding will be carried out.

(b) The interval of sounding lines for the sparse sounding will be 200 metres with two sounding boats. For the close sounding, the sounding line spacing will be 15 metres (class B sounding) with four sounding boats which will operate separately. The allowable deviation shall be less than 3 metres.

(c) Four-beam echo-sounders will be used for sounding, the facing angles of the transducers for slant beams being 20°.

(d) In principle, correction for velocity of sound in sea water will be made according to the results of bar checks conducted on the day of sounding operation.

(e) Tidal corrections will be made by using the observed data obtained from the tide gauge to be established a Pipe 31 for area I and the tide gauge at Mubarras island for area II. (Fig. 6)

(f) Correction for draught of transducers will be made from actually measured values of the draught on the day of sounding operation.

(g) Accuracy in sounding shall be less than ±0.3 metre. Sounding figures shall be shown to the next lowest decimetre down to 31 metres, and to the next lowest metre in deeper waters.

(5) Position Fixing

(a) Position fixing will be made by hyperbolic position line method using Decca Hi-Fix (Type A).

(b) The transmitter will be of medium-power type. A track plotter will be used at the receiving station (survey ship).

(c) Correction for position errors depending on the difference between the assumed and actual propagation speeds of electronic waves will be made on the basis of the results of base-line measurements as well as the measurements of known positions.

(d) Ship's position fixing by both Decca Navigator and Hi-Fix will be made near Point 1 in Fig. 5 to obtain referencial information for deep draught vessels' navigation in future.

(e) Lane setting and checking for Hi-Fix will be made at lane identification points at oil rigs situated in the vicinity of the proposed shipping route, at pipe 31 and at marker buoys to be laid in appropriate positions.

(f) Monitoring of condition of the electronic positioning system such as changes in the speed of propagation of electronic wave will be made at the Master station and at the same time at a monitor station to be established on the man-made islet near Point 6.

(g) The plotting of positions fixed will be made, in case of sparse sounding, on a 1/50,000 sounding sheet of myler base on which Hi-Fix lattices are shown. In case of close sounding, the survey areas will be divided into several divisions, and for each division a section paper will be prepared on which lane numbers of Pattern I and Pattern II are shown, and the positions fixed will be plotted on these section papers (track charts).

(6) Tidal Observation

(a) A Fuess tide gauge will be established on Mubarras island, and a P.F.T. will be installed on Pipe 31 in the offing.

(b) Corrections for reduction ratio will be made by comparison observation of a tide pole.

(c) A B.M. will be established on Mubarras island, and its relation to the datum level will be observed.

(7) Tidal Current Observation

(a) One self-recording current meters will be used for tidal current observations.

(b) The propellers to be used will be those calibrated within twelve months.

(c) Observation stations are as indicated on Fig. 5, two of them being for 15-day continuous observation of two layers except the one in the offing where one layer only will be observed and 11 stations for 24-hour observations (6 stations for two layers and 5 for one layer).

(8) Investigation of Bottom Characteristics

Bottom sampling will be made for 13 stations and discrimination of the characteristic of the bottom with hand-lead for 37 stations.

(9) Buoyage

The positions where buoys are to be laid will be selected considering the survey results, in the vicinity of those positions already proposed by a consultant of maritime shipping. The selected positions will be fixed with both Decca Hi-Fix and Navigational Decca chain readings.

3-4. Survey Schedule and Operations

The schedule of the survey operations is as shown in Table 1. The kind, quantity and others of the operations are as follows:

Table 1 SCHEDULE OF HYDROGRAPHIC SURVEY OF SHIPS' ROUTE ON THE COAST OF ABU DHABI (APPROACHES TO MUBARRAS I.)

o Preparation for survey	May 29	June 8
o Establishing Hi-Fix stations	June 9	June 15
o Base-Line measure-memts establishing tide gauges	June 16	17
o Sparse sounding (spare days and days for replenishment inclusive)	June 18	June 30
o Close sounding, seaching for dangers, bottom sampling (〃)	July 1	Aug. 19
o Observation of tides	June 18	Aug. 19
o Tidal current observations	June 18	July 12
o Removal of stations and packing	Aug. 20	Aug. 29
o Determination of close sounding areas (An officer from Hydrographic Department)	June 29	July 2
o Examination of survey results (An officer from H. D.)	Aug. 11	Aug. 24
o General supervision (An officer from H. D.)(Head of party)	Aug. 19	Aug. 24

Operation	Quantity, Amount	Remarks
Sounding	Sparse : 291 km^2	Line spacing: 200 metres(2 survey boats)
	Close : 111 km^2	Line spacing: 15 metres (4 survey boats)
Observation of tides	2 stations.	For location of the stations, Fig. 5 refers.
Tidal current observation	2 stations for 15-day continuous observation, and 11 stations for 24-hour observation.	
Investigation of characteristics of the bottom	Sampling of the bottom surface : 13 stations, Discrimination : 37 stations.	

3-5. Products and Data of Survey

The products and data of survey to be prepared are as follows:

(1) Products

Item	Quantity
Smooth sheet of survey	1 set (2 sheets: 1/50, 000 × 2) (with graduation of parallels and meridians at inner neat lines).
Survey report	2 copies.
Measured data on reference level of tide gauges	2 copies.
List of geographical positions	2 copies.
Reference sheets of geographical positions	2 copies.
Results of harmonic analysis of tides	1 copy.
Results of harmonic analysis of tidal current	1 copy (24-hour and 15-day).

(2) Data

Item

Calculation book on control points

Angle (distance) measurement book

Sounding book

Tide book

Sounding sheet

Track chart (section paper)

Boat sheet (aluminum-kent paper)

Echogram

Plotter record

Pattern monitoring record

Hi-Fix correction data

Tidal curves

Data for determining datum level

Record of self-recording current meter

Record of read values of current observation

Bottom sampling chart

Other referencial papers to be prepared in the course of data processing.

3-6. Submission of Survey Results and Data

The survey results and data should be submitted by the end of November 1972.

4. HYDROGRAPHIC SURVEY

4-1. List of Survey Team Members

Chief :	Dr. Daitaro Shoji	Hydrographic Department, Maritime Safety Agency
Deputy Chief :	Dr. Kazuhiko Sato	Hydrographic Department, Maritime Safety Agency
Member :	Mr. Kazuhisa Matsuoka	Overseas Technical Cooperation Agency
	Mr. Sozo Takahashi	Hydrographic Department, Maritime Safety Agency

Mr. Katsuyoshi Shibata	Hydrographic Department, Maritime Safety Agency
Mr. Fumiaki Kuwakino	Hydrographic Department, Maritime Safety Agency
Mr. Nobuo Sato	Pacific Aerosurvey Co.
Mr. Tadao Yoshida	Pacific Aerosurvey Co.
Mr. Kiyoto Hayakawa	Pacific Aerosurvey Co.
Mr. Toshio Kitahara	Pacific Aerosurvey Co.
Mr. Kuniaki Fukuma	Pacific Aerosurvey Co.
Mr. Makoto Kanda	Pacific Aerosurvey Co.
Mr. Heijiro Tokita	Pacific Aerosurvey Co.
Mr. Kosaku Ushioda	Pacific Aerosurvey Co.
Mr. Kunihiko Yokoo	Pacific Aerosurvey Co.
Mr. Masami Tagawa	Pacific Aerosurvey Co.
Mr. Masayuki Suzuki	Pacific Aerosurvey Co.
Mr. Toshio Machida	Pacific Aerosurvey Co.
Mr. Satoshi Aiba	Pacific Aerosurvey Co.
Mr. Masaichi Kondo	Pacific Aerosurvey Co.
Mr. Ikuo Hisaoka	Pacific Aerosurvey Co.
Mr. Yuichiro Yamada	Pacific Aerosurvey Co.

4-2. Progress of Survey Operations

4-2-1. From the Commencement of Field Work to the Establishment of Hi-Fix Land Stations (30 May - 18 June)

The first group (5 members) of the survey team arrived at Abu Dhabi on 30 May, and immediately started the preparatory work such as procuring materials, arrangements for supply of water and foods, contacting with local agencies concerned, etc. The second group of six members reached Abu Dhabi on 2 June and joined the first group, and engaged in the work of opening the packages of instruments sent from Japan and adjustments of the instruments and trial construction of prefabricated houses to be used as the Hi-Fix station, and they opened the base of the Hydrographic Survey Team at Abu Dhabi. From 6 June, they started construction of the station at Dhabiyah. From 8 to 10 June, the survey ships gathered at Abu Dhabi Port. The third group consisting of five members arrived at Abu Dhabi on 7 June, and joined the first two groups. They engaged in the work of mounting survey instruments aboard survey ships and their adjustments.

Mr. Shibata and Mr. Kuwakino arrived at Abu Dhabi on 14 June, and joined the party to make deliberation about the programme of field operations, including conditions of the survey ships and their working schedule, and supply of water.

In the meantime, two ships, the *Creek Gal* and the *Lilian 16*, were engaging in the construction work of Hi-Fix stations at Zarqa and Mubarras from 14 to 18 June. Operators were stationed at each station. During this period, rough seas continued for two days and the ships were forced to take shelter behind the island of Zarqa. Due to this, unloading of instruments from the ships was delayed.

4-2-2. From the Opening of Hi-Fix Land Stations to the Completion of Sparse Sounding and Determination of Close Sounding Areas (19 June to 11 July)

From 19 to 21 June, mounting of multi-beam echo-sounders, Hi-Fix receivers and other instruments aboard the survey ships were carried out, and experimental transmission of Hi-Fix and subsequent adjustments were performed. From 22 to 25 June, base-line observation of Pattern I and Pattern II as well as counting of total lane number and of lane numbers of oil rigs MR 1, MR 2 and MR 4 were carried out. These oil rigs were used as lane identification points later. In addition, lane identification buoys were laid in two places. A tide gauge was established at Mubarras island at the same time. On 25 June, a tidal current meter was laid at station 15-2. During this period, the work was suspended for one day due to rough weather.

On 26 June, sparse sounding was started by the *Lilian 16*, . However, due to her unstableness in steering, the idea of using this ship as a survey ship was abandoned, and the ship was then used solely for supply of fuel and provisions to the land station at Zarqa and for tidal current observations. From 27 June to 11 July, unfavorable weather prevailed and the sea was rough for 5 days. In particular, from 6 to 8 July, the sea became extremely rough due to a stormy shamal, and the *Jackson Creek*, which was to be used for sparse sounding, could not be brought to the survey site from Abu Dhabi. The ship came to Mubarras from Abu Dhabi on 9 July, and survey instruments were immediately installed aboard the ship. On the next day, she was engaged in setting of current meters and then carried out sparse sounding only partially. Such being the case, the sparse sounding was carried out almost only by the *Creek Gal* . Although efforts had been exerted by extending the working hours, it was finally decided that, in the northern part of the survey area, the spacing of sounding lines were made wider than those originally planned.

Owing to the rough seas, tidal current observations were carried out but behind the schedule. Despite this, the observations were completed at six stations, g, H, i, J, K and 15-2, and current meters were set at Stations 15-1 and A.

Total milage of sounding lines covered during this period was 440 miles.

Mr. Takahashi arrived at Abu Dhabi on 4 July, and until he left there for home he examined the results of sparse sounding from various points of view, and as the result of consultation with survey team members and people concerned in maritime shipping, the areas for close sounding as shown in Fig. 8 were finally determined.

4-2-3. First Half of the Survey (12 - 31 July)

On 12 and 13 July, a current meter was set at Station D by the *Jackson Creek*. The observation of tidal currents at Station A and 15-1 were completed. In order to make clear the time difference and tidal height ratio between the station and Mubarras, a tide pole was established at Pipe 31 and the observation of the tide pole was carried out.

From 14 July, close sounding operations were started from the southern portion of the survey area by the *Creek Gal* and the *Jackson Creek*. During this period, both ships had breakdowns of AC circuits for two days. However, this period had comparatively favorable weather and the progress of the survey operation was smooth due to the good weather and the intensified operation system in which actual working hours became 12 hours. Nevertheless, the original schedule could not be caught up with.

In the meantime, on 20 July, sparse sounding were completed by the two ships in the vicinity of the proposed anchorage determination of which had been left pending at the time of determining the close sounding areas, and also in the area north of the Point 3. On 21 July, bottom sampling at 20 stations on the shallow waters in the southern area were made by the *Jackson Creek*. Tidal current observations at the Station 15-2 (upper layer) and the Station F were completed by the *Lilian 16*, and a current meter was set at the Station b. From 28 to 29 July, a tide gauge was established on Pipe 31. At Mubarras island, levelling between the tide gauge and the temporary B. M. was carried out.

The total milage of sounding line covered during this period was 1,006 miles, including the sparse sounding for one day.

4-2-4. Second Half of the Survey (1 to 25 August)

During this period, the weather was generally fine and the number of days when operations were suspended due to rough seas was only two. However, the *Greek Gal* still hand a trouble in AC, and from this time various breakdowns became remarkable in her engine and generator. On the other hand, fresh water became short in the city of Abu Dhabi due to a break of water pipeline from Al Ain so that water supply at the Port of Abu Dhabi became difficult and the survey ships went to Dubai for this purpose. Thus, the totaled number of days wasted due to these troubles amounted to five days per each ship on the average.

In order to remedy the delay in schedule, a survey ship, the *Pirate* , was newly engaged in the survey operations from the beginning of this period. Moreover, all the ships thereafter engaged in the sounding operations from sunrise to sunset daily. Despite these efforts, it was expected that the completion of the close sounding would be considerably behind the schedule. Such being the case, for the area north of Point 5 where, judging from the results of the sparse sounding, any existence of shoal could not escape notice even if the spacing of sounding lines were windened, the close sounding were carried out at 30- or 40-meter spacing.

Thus, the close sounding of the whole area was completed on 25 August. The *Pirate* left the survey site on 24 August. The tidal current observations at the four stations, 15-2 (lower layer), A, c and e, were completed by the *Lilian 16*, and the *Jackson Creek*, . On 13 August, observation of the tide pole was carried out at Pipe 31.

The total milage of sounding lines covered during this period was 2,200 miles.

4-2-5. From Supplementary Survey to Completion of Operations at Sea (26 August to 4 September)

The last spurt was made during this period for supplementary syrvey, seeking for shoals and other final stage of survey operations.

However, the *Greek Gal* at last caused troubles in her engine and generator, whose omen had already been seen, and went to Dubai for repair. But the troubles had not fully been repaired and they recurred soon after her returning to the survey site. Accordingly, the use of this ship in September was given up. Under these circumstances, the *Jackson Creek*, , receiving supplies of water and provisions from the *Greek Gal* and the *Lilian 16*, carried out the supplementary sounding, bottom sampling (31 stations) and simultaneous measurements of Hi-Fix and Navigational Decca lane numbers at the proposed positions of buoys.

From 1 to 4 September, the *Greek Gal* was unable to participate in the operations as stated above, so that the *Jackson Creek* had to carry out supplementary sounding, sounding of check lines and measurement of elevation of oil rigs, under the 24-hour watch system.

In order to make clear the relationship between the positions of Zarqa and Dhabiyah, the Slave station at Zarqa was changed to the Master and counting of total lane numbers between Zarqa and Dhabiyah stations was made.

Thanks to all the possible efforts as above-mentioned, the whole operations at sea were completed on 4 September.

At Mubarras island, levelling between the B.M. at the central part of the island and the tide gauge was carried out on 28 August.

The operations were suspended for one day due to rough weather during this period.

4-3. Outline of the Daily Progress of the Operations

30 May	N. Sato and other 4 members arrived at Abu Dhabi. Made arrangements for operations at ADOC office.
31 May	Consultation with Pacific Consultant (PCKK) as to procurement of materials in Abu Dhabi and logistics.
1 June	Consultation with PCKK as to provisions for workmen.
2 June	Fukuma and other 5 members arrived at Abu Dhabi. Examined the details of working schedule with PCKK.
3 June	Unpacking of cargo sent by air (echo-sounders, tide gauges and others). Adjustment of the instruments. Procurement of batteries and other materials.
4 June	Trial construction of prefabricated house and fitting for land stations of Hi-Fix.
5 June	The Abu Dhabi survey base opened. Equipment of the base and procurement of materials. Hi-Fix instruments were transported to the base from the Abu Dhabi Decca Station. Matsuoka arrived at Abu Dhabi.
6 June	Establishment of Hi-Fix land station at Dhabiyah. Consultation with ADOC.
7 June	Equipment and materials from PCKK transported to the base. Preparation of materials for the station houses. Consultation with the Ministry of Petroleum and Industries.

8 June	Tagawa and other 4 members arrived at Abu Dhabi. Survey ships, *Greek Gal* (*G*) and *Lilian 8 (L8)* entered the Port of Abu Dhabi. Equipment of the Base. Procurement of materials. Consultation with the Ministry of Defence.
9 June	Arrangements of operation with the master of *Greek Gal*. Inspection of electric power supply and other instruments on board the ship. Survey ships, *Confidence 1 (C1)* and *Confidence 2 (C2)* entered the Port of Abu Dhabi.
10 June	Arranged the observation room and others of *G*. Survey ships, *Lilian 16*, (*L16*) and *Lilian 11* (*L11*) entered the Port of Abu Dhabi.
11 June	Procurement of materials and adjustment of instruments. Arranged survey equipment on board the survey ships. Consultation with the Ministry of the Interior.
12 June	Customs clearance of survey instruments. Installation of the instruments on board the survey ships.
13 June	Installation of survey instruments on board the survey ships and adjustments.
14 June	Shibata and Kuwakino arrived at Abu Dhabi. Adjustment of the Dhabiyah station (Hisaoka remained). *G* and *L16* left Abu Dhabi for Mubarras.
15 June	Consultation on the progress of operations and future schedule (at Abu Dhabi). *G* and *L*16 left Mubarras for Zarqa. They anchored and took shelter behind Zarqa due to rough weather.
16 June	*L8*, *L11*, *C1* and C2 were inspected for survey and navigation instruments, and they made test runs at Abu Dhabi. Due to rough seas disembarkment of equipment and materials to Zarqa could not be carried out. Took shelter behind the island.
17 June	Hi-Fix equipment and prefabricated houses were landed on Zarqa. Station house built (Kondo remained at the station). Returned to Mubarras. Deliberation on the schedule of the use of ships and water supply at Abu Dhabi.
18 June	*G* and *L*16 transported equipment of Hi-Fix Master station to Mubarras, where the station house built and equipment installed. The ships left Mubarras for Abu Dhabi. Consultation on the substituting ships for *C1* and C2.
19 June	Echo-sounder was installed on board *G*. Hi-Fix land stations made test transmissions.
20 June	Echo-sounders and Hi-Fix equipment were installed on board every survey ship.

21 June	Hi-Fix land stations made test transmissions for adjustment. *G* and *L*16 left Abu Dhabi for Mubarras.
22 June	The transmitter and receiver at the Master station changed. Platform for tide gauge established. *L*16 went to Zarqa for supply.
23 June	*L*16 could not make baseline observation of Pattern I due to rough seas in the vicinity of Zarqa. After supply she returned to Mubarras. *G* made baseline observation of Pattern II and Pattern I (min) and measured total lane numbers via Oil Rig (MR 4) (relayed at a buoy off Dhabiyah). *L8* and *L11* left Abu Dhabi for Dhabiyah. Tide gauge established at Mubarras. Matsuoka left Abu Dhabi for home.
24 June	*L8* and *L11* made baseline observation of Pattern II (max). Then relayed to *G* and measured total lane numbers of Pattern II and made baseline observation of Pattern I (min). *L*16 made baseline observation of Pattern II and Pattern I (min), and measured total lane numbers of Pattern I and baseline observation of Pattern I (max).
25 June	*G* established current meter at Station 15-2. Measured patterns at Oil Rigs (MR 1, 2 & 4). Established lane identification buoys in two places. *L*16 made baseline observation of Pattern I and Pattern II (min). *L8* again measured total lane numbers of Pattern II.
26 June	*G* measured the pattern at Pipe 31. Established current meters at Stations 15-1, g, H and i. *L*16 carried out sparse sounding.
27 June	*G* commenced sparse sounding. *L11* and L16 left Mubarras for Abu Dhabi.
28 June	*G* carried out sparse sounding. *L8* picked up the current meters from Stations g, H and i and reestablished them at Stations J and K.
29 June	*G* carried out sparse sounding. Picked up the current meters from Stations J and k. *L*16 left Abu Dhabi for Zarqa. *L8* left Mubarras for Abu Dhabi.
30 June	*L*16 supplied materials and provisions to Zarqa. *G* processed sparse sounding data.
1 July	*G* waited due to rough seas.
2 July	*G* waited due to rough seas.

3 July	*G* carried out sparse sounding. *L*16 supplied materials and provisions to Zarqa, then went to Das.
4 July	Takahashi arrived at Abu Dhabi. *G* carried out sparse sounding. *L*16 went to ADMA (Das island) for handing over tide gauge.
5 July ~ 6 July	*G* carried out sparse sounding. Due to very rough seas survey boats waited at Mubarras.
8 July	Data processing of sparse sounding and preparation of boat sheet
9 July	*G* carried out sparse sounding. *Jackson Creek (J)* left Abu Dhabi for Mubarras. Hi-Fix receiver and echo-sounder installed aboard *J* at Mubarras.
10 July	*G* carried out sparse sounding. After completion, went to Abu Dhabi. *J* picked up the current meter from Station 15-2 and re-established it at station A, and carried out sparse sounding.
11 July	*G* replenishment at Abu Dhabi. Data processing. Close sounding areas determined on the basis of the results of sparse sounding. *J* equipped with transducers of echo-sounder at Mubarras.
12 July	*G* equipped with transducers of echo-sounder. *J* picked up the current meter from Station A and established it at Station 15-1 (lower layer). Established tide pole at Pipe 31.
13 July	*G* had AC troubles and waited for repair. *J* picked up the current meter from Station 15-1 and re-established it at Station D. Observation of tide pole at Pipe 31. Takahashi left Abu Dhabi for home.
14 July	*G* started close sounding. *J* started close sounding. *L*16 picked up the current meter from Station 15-2 (upper layer) and reestablished it at the lower layer of the same station, and established current meter at Station F. Kuwakino left Abu Dhabi for home.
15 July	*G* and *J* carried out close sounding. *L*16 picked up the current meter from Station F and re-established it at Station b. Carried out levelling between Mubarras tide gauge and temporary B. M.
16 July	*G* and *J* carried out close sounding. *Tag Tahil (T)* left Abu Dhabi for Mubarras.

17 July	*G* and *J* carried out close sounding. *T* supplied materials and provisions to Zarqa.
18 July	*G* and *J* carried out close sounding.
19 July	*G* and *J* carried out close sounding. In the afternoon they returned to Mubarras due to rough seas.
20 July	*G* carried out sparse sounding in the vicinity of Point X. *J* carried out sparse sounding in the area north of Point 3.
21 July	*G* carried out close sounding. *J* carried out bottom sampling at 20 stations in the southern area, and then went to Abu Dhabi. *T* supplied parts of generator to Zarqa.
22 July	*G* carried out close sounding. *J* replenishment. Consultation at ADOC about the close sounding areas in the vicinity of Point Y.
23 July	*G* carried out close sounding. *J* replenishment.
24 July	*G* replenishment. Processed close sounding data. *J* had AC troubles. Processed close sounding data.
25 July	*G* processed close sounding data. Water could not be supplied. *J* processed close sounding data. AC under repairs.
26 July	*G* processed close sounding data. Had AC troubles and under repairs. *J* processed close sounding data. AC repaired.
27 July	*G* AC repaired. *J* carried out close sounding. *T* supplied provisions and materials to Zarqa.
28 July	*G* and *J* carried out close sounding. *L16* set tide gauge at Pipe 31.
29 July	*G* and *J* carried out close sounding. *L16* completed setting tide gauge at Pipe 31.
30 July	*G* and *J* carried out close sounding.
31 July	*G* and *J* carried out close sounding. In the afternoon they returned to Mubarras due to rough seas. *Pirate* *(P)* left Abu Dhabi for Mubarras.
1 August	*G* and *J* waited due to rough seas. *P* equipped with Hi-Fix receiver and echo-sounder.
2 August	*G*, *J* and *P* carried out close sounding.
3 August	*G*, *J* and *P* carried out close sounding. *L16* made supply to Zarqa. Then picked up the current meter from Station b.

4 August	*G*, *J* and *P* carried out close sounding. *L*16 reestablished current meter at Station 15-2 (lower layer).
5 August	*G*, *J* and *P* carried out close sounding.
6 August	*G*, *J* and *P* had replenishment. Processed close sounding data.
7 August	*G*, *J* and *P* prepared boat sheets for determination of positions of buoys to mark the shipping route. Water could not be supplied.
8 August	*G* had AC troubles. *J* could not be replenished. *P* completed replenishment.
9 August	*G* had engine troubles and under repairs. *J* could not be replenished. *P* carried out close sounding. Waited due to rough seas.
10 August	*G* engine repaired. Engaged in close sounding. *J* accurate measurement of patterns of each Oil Rig. *P* waited at Mubarras due to rough seas. *L*16 supplied materials and provisions to Zarqa.
11 August	*G*, *J* and *P* carried out close sounding. *L*16 inspected the tide gauge at Pipe 31, and established current meter at Station A (upper layer).
12 August	*G*, *J* and *P* carried out close sounding. J, after finishing close sounding, picked up the current meter from Station A (upper layer). *L*16 had engine troubles and under repairs.
13 August	*G* and *P* carried out close sounding. *J* established current meter at Station C, and then carried out close sounding. *L*16 made observation of tide pole at Pipe 31 tide station.
14 August	*G*, *J* and *P* carried out close sounding. *L*16 picked up the current meter from Station C and re-established it at Station e.
15 August	*G* and *J* carried out close sounding. *L*16 picked up the current meter from Station e, but re-established it at the same station due to failure in recording.
16 August	*G* carried out close sounding. *J* and *L*16 had replenishment. Sato, Deputy Chief of the Survey Team, and Matsuoka arrived at Abu Dhabi.
17 August	*G*, *P*, *J* and *L*16 gathered at Abu Dhabi. Replenishment. Data processing. Report on progress. Consultation on future schedule.

18 August	*G* and *P* carried out close sounding. Final schedule decided. Data checked.
19 August	*G* and *P* carried out close sounding. Data checked. *L16* picked up the current meter from Station e. Consultation with ADOC.
20 August	*G* had engine troubles and under repairs. Data checked. *J* and *P* carried out close sounding. *L16* picked up the current meter from Station 15-2.
21 August	*G* had engine troubles and under repairs. Data checked. *J* and *P* carried out close sounding. Current meter established again at Station e. *L16* supplied materials and provisions to Zarqa.
22 August	*G*, *J* and *P* carried out close sounding.
23 August	*G*, *J* and *P* carried out close sounding. (*P* contract period expired.) *L16* supplied materials and provisions to Zarqa.
24 August	*G* and *J* carried out close sounding. *L16* picked up the current meter from Station e.
25 August	*G* and *J* carried out close sounding. Completed close sounding of the whole areas. *L16* inspected tide gauge.
26 August	*G* and *J* carried out supplementary sounding and sounding on check lines.
27 August	*J* carried out supplementary sounding, sounding on check lines and sampling of the bottom at 17 stations. *G* had troubles in engine and generator and under repairs. Shoji, Chief of the Survey Team, arrived at Abu Dhabi.
28 August	*G* under repairs. *J* waited due to rough seas. Equipped with Decca receiver MK12 and 8017. Levelling was carried out between the B.M. at the center of Mubarras island and the tide station. Chief of the Survey Team and other two members visited the Ministry of Petroleum and Industries and Ministry of Foreign Affairs at Abu Dhabi to report on the survey.
29 August	*J* carried out bottom sampling at 8 stations in the vicinity of planned anchorage, and made simultaneous measurements of Hi-Fix and Navigational Decca at the positions proposed for establishing buoys marking the shipping route. *G* had troubles and under repairs. Chief of the Survey Team and other two members visited the Ministry of the Interior at Abu Dhabi to report on the survey.

30 August *J* made simultaneous measurements of Hi-Fix and Navigational Decca at the positions proposed for establishing buoys (Approach and Entrance) marking the shipping route, as well as at Oil Rig (Pegasus), and carried out supplementary sounding and bottom sampling at 4 stations.
G repairs of troubles completed.
Chief of the Survey Team and other two members visited the Ministry of Defence to report on the survey.

31 August *J* carried out supplementary sounding, sounding on check lines and bottom sampling at 2 stations.
G carried out supplementary sounding and sounding on check lines.

1 September *J* carried out supplementary sounding and sounding on check lines under 24-hour watch system.
G again had engine troubles, and the use of the ship was abandoned.
Shoji, K. Sato and Matsuoka left Abu Dhabi for Kuwait.

2 September *J* completed supplementary sounding by noon. Carried out measurement of elevations of Oil Rigs MR 1 through MR 6. Survey equipment unloaded from *G*.
Shibata left Abu Dhabi for home.
Chief of the Survey Team and other two members visited the Embassy of Japan in Kuwait to report on the survey.

3 September *J* carried out the measurement of total lane numbers between Dhabiyah (S2') and Zarqa (M) and Zarqa (M) and Mubarras (S1) by switching the Slave at Zarqa over to the Master.
Chief of the Survey Team and other two members left Kuwait for home.

4 September *J* completed the whole operations at sea. Inspected Mubarras tide gauge and went to Abu Dhabi.

5 September Survey equipment unloaded from survey ships.

6 September Inspection of survey equipment and packing.
Kitahara and other 6 members left Abu Dhabi for home.

7 September ~ 8 September Packing of survey equipment, data and materials.

9 September N. Sato and other 6 members left Abu Dhabi for home.
Hayakawa and Machida remained for final arrangements.

4-4. Position Fixing

For position fixing, a hyperbolic positioning system using Hi-Fix (Type A) was employed both for sparse sounding and close sounding. The composition of each of the land stations and ship stations is described in paragraph 4 - 10.

For lane identification of Hi-Fix, oil rigs as well as a few temporary buoys in survey area that was remote from oil rigs, were used. The lane numbers of those temporary buoys were derived from those at the oil rigs.

The Hi-Fix chart was computed and drafted on the UTM projection (system 39) at the scale of 1/50,000 on the basis of the factors of : pattern frequency: 1,900.25 kHz; assumed propagation velocity: 299,650 km/s; dimensions of the earth : Clarke 1880.

The performance of Hi-Fix system was good on the whole. No thunders occurred throughout the survey period and accordingly lane missing never occurred except at the time of breakdown of the equipment. Since the propagation paths of radio waves were almost over the sea and there was no rainfall, the stability of patterns was good even at night. The totaled hours of breakdown of the equipment were about 15 hours.

For monitoring patterns, it was originally planned to set a monitoring station at a man-made islet. However, this idea was abandoned because movements of iron materials during the survey period were not expected so much due to delay in construction works of tanks and other oil loading facilities at Mubarras island and, in addition, it was felt difficult to station any personnel at the islet due to the limited number of members as it seemed unable to leave the maneuvering of survey ships to the ships' crew while sounding. Instead, the monitoring was carried out at the Master and Slave stations, and whenever good opportunities were available, observation of minimum values on the baseline extensions on the Master side were made. The observation of minimum values were carried out several times during the survey period, and it was found that the maximum deviation was ± 0.02 lane for both Pattern I and Pattern II, which was good for the accuracy of the survey.

4-5. Sparse Sounding

4-5-1. Sounding Area and Interval of Sounding Lines.(See Fig. 7)

(1) Southern Area

As for the southern area south of Point 4, sounding was carried out at the interval of 200 metres between the sounding lines within the 3-kilometre-wide area which extends on either side of the centerline of the proposed shipping route.

(2) Northern Area

As for the northern area, the original plan was changed and the sounding was carried out at the line spacing of about 2,000 metres from the following reasons:

SOUNDING INTERVAL (SPARSE SOUNDING)

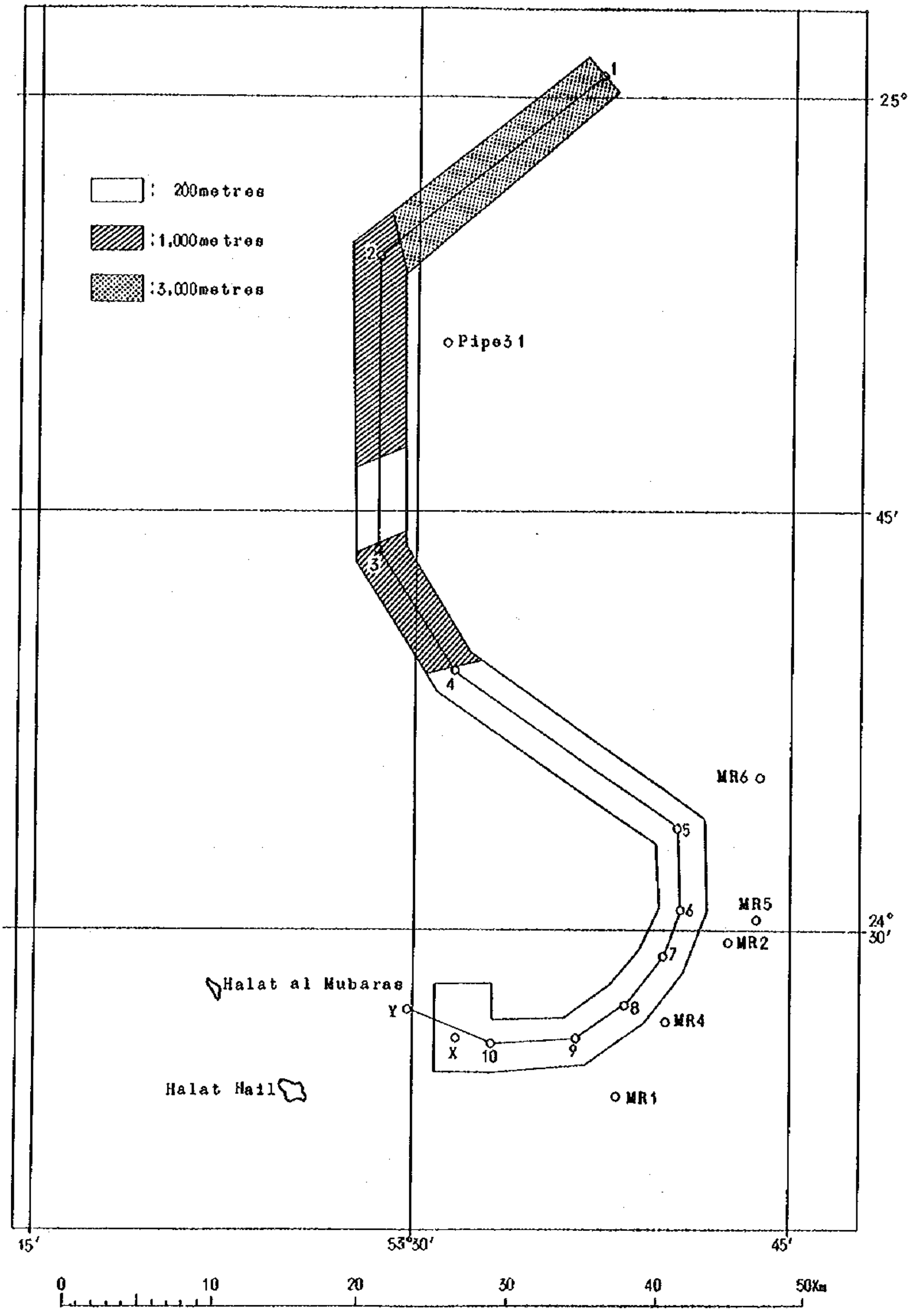


Fig. 7

(a) Judging from the existing B.A. chart, water depths are generally greater than those in the southern area.

(b) The bottom configuration is not so intricated as in the southern area.

(c) By setting the direction of sounding lines so as to cross the deeper channel of the bottom, the areas for close sounding can be delimited.

Such being the case, sparse sounding at 200-metre interval was carried out again in the area where the depths might be less than 19 metres in the north of Point 3. (See Fig. 7)

(3) Anchorage and Its Vicinity

Taking into account the frequency in velocity and blowing direction of wind in this locality, it was considered desirable that the anchorage should be located northeastward of the proposed position for SBM. Accordingly, sparse sounding for selecting location of anchorage was made at 200-metre spacing of sounding lines as for the area in Fig. 7.

4-5-2. Sounding Lines

For the southern area, sounding was carried out along the predetermined lanes of Pattern I. In the northern area, sounding was carried out along the predetermined lanes of Pattern I between Points 1 and 2 and those of Pattern II between Points 2 and 3.

4-5-3. Survey Ships and Echo-Sounders Used

Most part of sounding was carried out by the *Greek Gal* . The areas north of Point 3 and in the vicinity of the entrance to the shipping route (Point 1) were sounded by the *Jackson Creek* . At the first stage, the *Lilian* 16 was used for sounding but for only one day as she was found inadequate for sounding operations, and since then she was never used for sounding.

The echo-sounders used were Four-Beam Echo-Sounder type 4, but their Vertical 1 transducers only were used.

The period of each ship in operation was as follows:

Greek Gal	:	27 June to 10 July and 20 July.
Jackson Creek	:	10 July and 20 July.
Lilian 16	:	26 June.

4-6. Determination of Areas for Close Sounding

Based on the results of sparse sounding, the areas for close sounding were determined as follows:

4-6-1. Southern Area

It was found impossible to obtain any 1,000-metre wide shipping route in which depths of 55 feet can be assured in the southern area. In addition, the close sounding area not only included shoal patches but also it was crossed by two shoals. Despite these difficulties, the area as shown in Fig. 7 was finally determined so that a 1,000-metre wide comparatively deep channel, free from the requirement of the depth of 55 feet, might avoid shoal waters as far as possible.

4-6-2. Northern Area

As for the northern area, the results of sparse sounding showed fairly well the depths of cross section of deeper channel. Accordingly, the 1,000 metre wide area was selected by joining the deeper portions of the bottom. The entrance was taken slightly southward to clear the shoal on its north side. That part north of Points 2 and 3 was taken slightly to the eastward while the part on the southern side of those points slightly to the westward. The area thus defined is shown in Fig. 8.

There was a shoal water extending northwestward on the east side of the channel near Point 3, which implied possible existence of depths less than 19 metres. Therefore, it was decided that this part should be resounded at 200-metre line spacing and if any portion less than 18 metres deep might be found the area of close sounding should be changed to clear it. The sparse sounding in this area was conducted on 20 July, and it was confirmed that there existed no depth less than 18 metres. Therefore, no change was made to the primarily defined area for close sounding.

4-6-3. Area Around the Planned Position of SBM and Planned Anchorage

The examination of the results of sparse sounding in the planned anchorage area necessitated the change of original plan so as to carry out close sounding in the following areas (Fig. 8 refers):

(1) Around Point Y of the original plan (in a circular area with a radius of 1.5 kilometres).

(2) In a circular area with a radius of 2.0 kilometres centred at the position of a temporary buoy laid at the site where SBM No. 1 is to be established (near Point X of the original plan).

CLOSE SOUNDING AREA

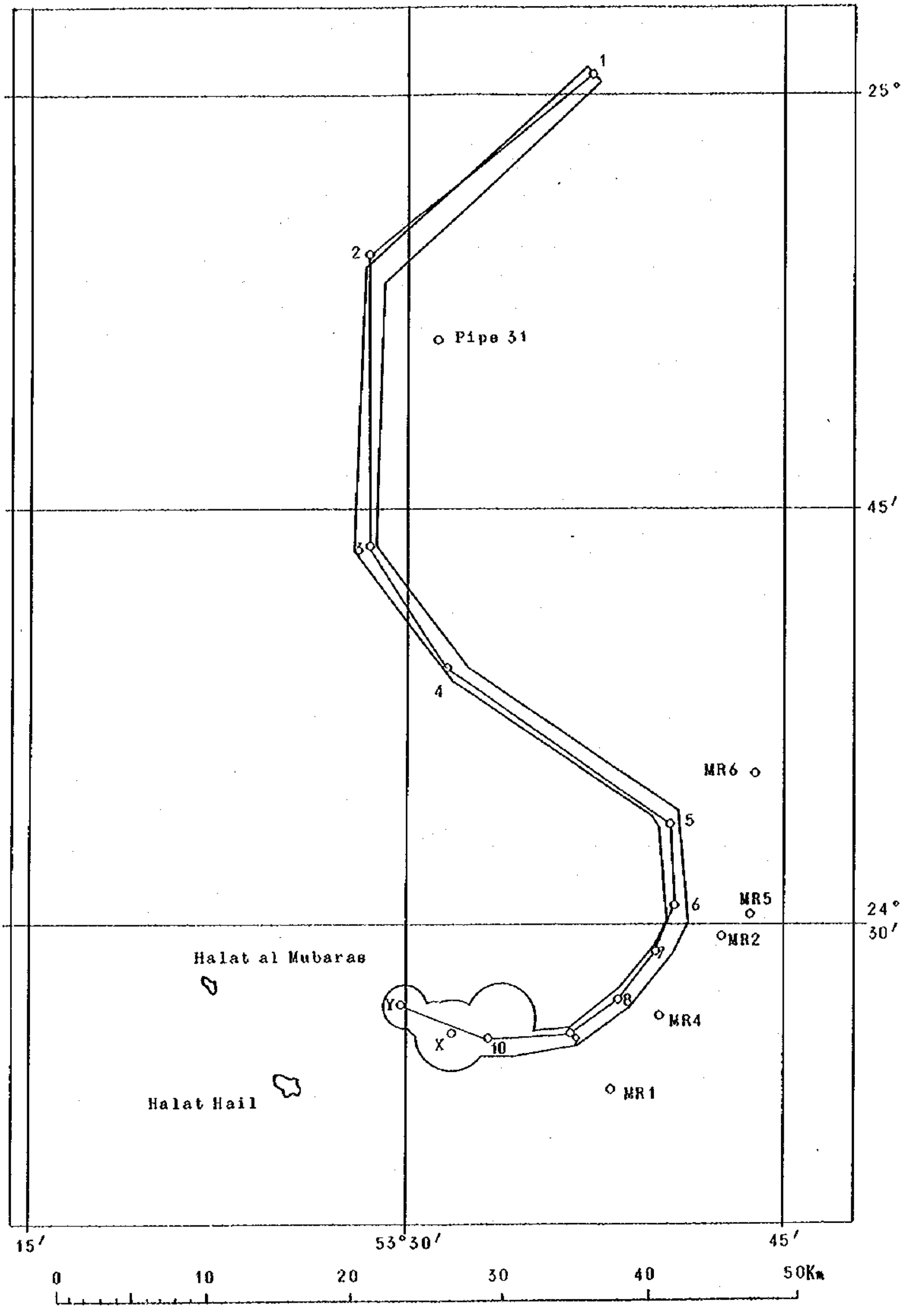


Fig. 8

SECTION AND SOUNDING INTERVAL PLAN

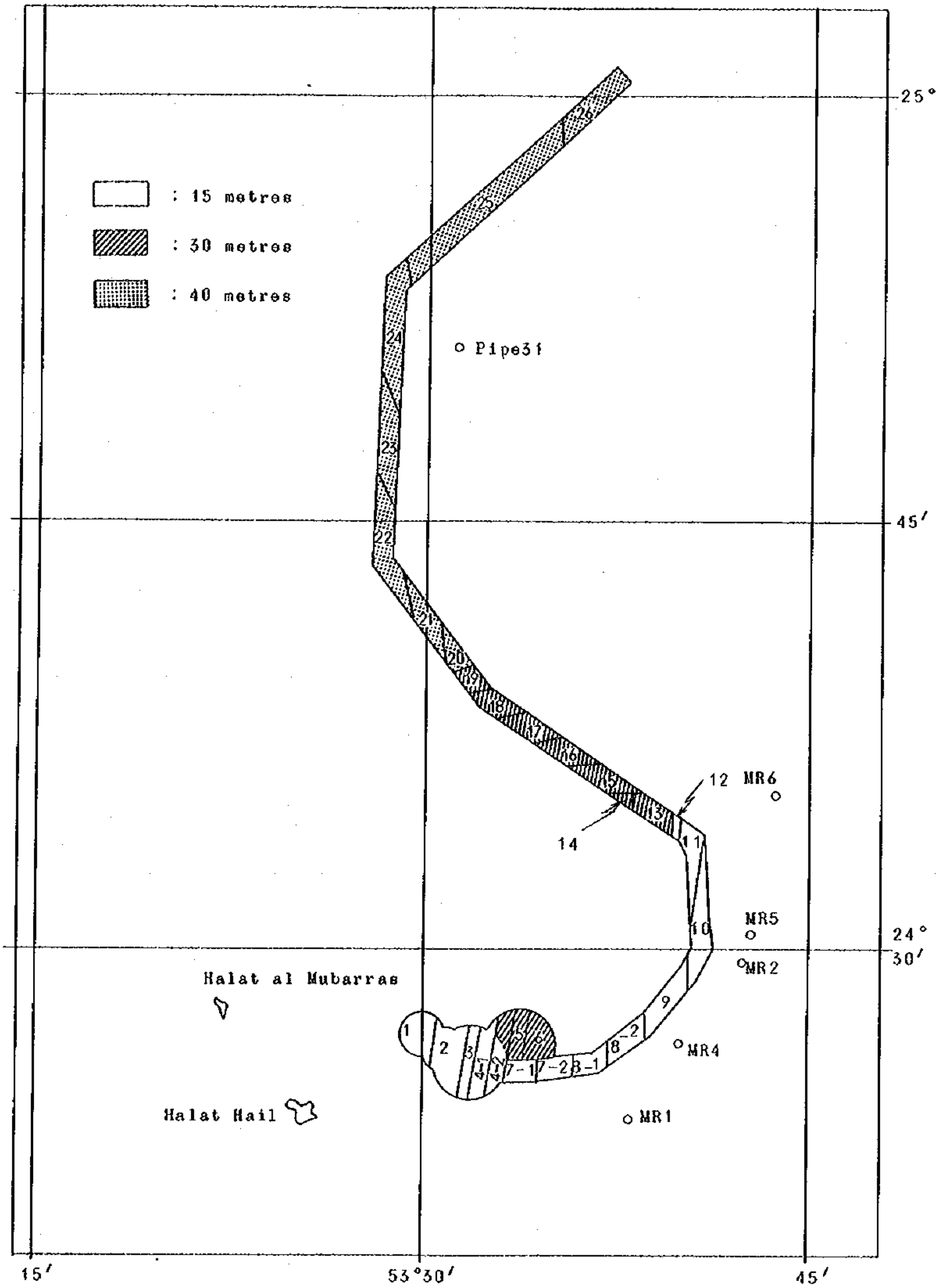


Fig. 9

(3) In a circular area with a radius of 2.0 kilometres centred at the following point which would be the centre of the proposed anchorage:

Lat. 24° 26' .85 N   Long. 53° 33' .90 E

4-7. Close Sounding

4-7-1. Sounding Area and Sounding Line

The close sounding areas as defined in the preceding paragraph were divided into 28 sections as shown in Fig. 9, and for each section a section paper showing the lane numbers of Pattern I and Pattern II was prepared as a track chart.

Close sounding was carried out along the lanes of Pattern II of the section papers, except for those Nos. 15 through 19, 25 and 26 where sounding was carried out along the lanes of Pattern I.

4-7-2. Sounding Line Spacing

According to the original plan, the sounding was to be carried out along the lines at interval of 15 metres in all cases. However, from the under-mentioned reasons the spacing was expanded to 30 metres in areas from Points 4 to 5 and in the vicinity of the proposed anchorage, and 40 metres in the area north of Point 4.

The reasons for the change were :

(1) In the southern area, judging from the results of close sounding carried out in the vicinity of the shoal patches of coral bottom, it was considered possible to confirm any existence of isolated shoal even if the spacing were windened double.

(2) From the results of close sounding between Point 5 and the proposed position of SBM, it was found that there were no channel in which the depth of 55 ft might be secured as originally expected, so that it would be inevitable to make the full-loaded draught of tankers to be two metres less than the planned draught, and consequently it was considered that enough allowance under keel would be anticipated on the channel north of Point 5.

(3) According to the result of sparse sounding, depths in the area from Point 4 to Point 5 were more than 18 metres and the bottom was flat where no extreme undulation could be recognized.

(4) For the area north of Point 4, the depths were more than 20 metres except for a small portion, and no abrupt change in the buttom was recognized.

(5) Those tankers to lie at anchor in the proposed anchorage would be unloaded ones having shallow draught, and the sea bottom in this area was flat except for the northern portion.

(6) While carrying out close sounding, searching for the shallowest portions can be carried out when the sounding is considered not catching them.

4-7-3. Survey Ships and Echo-Sounders Used

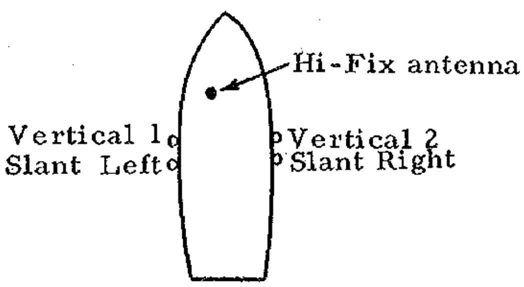
Survey Ship	Echo-Sounder	Period of Operation
Creek Gal	Echo-Sounder type 4	From 14 July to 31 August
Jackson Creek	Echo-Sounder type 4	From 14 July to 2 September
Pirate	Echo-Sounder type 4	From 2 to 23 August

4-7-4. Equipment of Transducers

(1) The positions of transducers installed aboard the survey ships are as shown in Fig. 10.

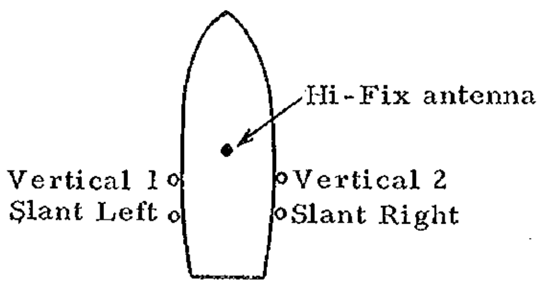
Creek Gal

125 t, length 26.7 m, width 6.7m



Jackson Creek

125 t, length 27.5 m, width 6.7 m



Pirate

40 t, length 18.0 m, width 4.8 m

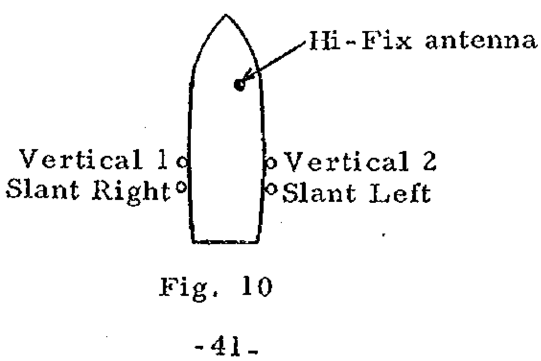


Fig. 10

(2) Draughts of Transducers

Creek Gal	:	2.0 m
Jackson Creek	:	1.5 m, and 1.8 m (as from 28 July)
Pirate	:	1.5 m

However, those draughts varied daily and the actual draughts were read every morning.

4-7-5. Lines of Positions Fixed

Lines of positions fixed were drawn on the echogram at every integer lane in the area south of Point 4 and every two integer lanes in the northern area in accordance with the pattern information of Hi-Fix receiver.

4-7-6. Bar Checks

Bar checks were carried out every day in principle as for the transducers of Vertical 1 and Vertical 2. Echos from the bar while being lowered and heaved were recorded at depths of every 2 metres.

4-7-7. Re-Sounding and Supplementary Sounding

Re-sounding was carried out in such areas where no record was taken on the echogram of close sounding, or where the record was illegible due to noises caused by radio telephone.

Supplementary souding was made in such areas where sounding lines were extremely meandering, where a shoal was considered to exist between the sounding lines judging from the records of slant echoes, where isolated shoal had been found by sparse sounding, and where abnormal record appeared on the echogram.

4-8. Tidal Observation

4-8-1. General

As for the tides in the middle part of the Arabian Gulf (Persian Gulf) where the survey was conducted, a study was made on the basis of tidal harmonic constants and non-harmonic constants obtained from the British Admiralty Tide Tables. As the result, it was decided to divide the survey area into two divisions, i.e. northern and southern, to which Z_o = 125 cm and Z_o = 135 cm were determined, respectively, and to establish a tide gauge at Pipe 31 and Mubarras island for these two divisions to obtain tidal correction values.

4-8-2. Tidal Observation

For the southern division of the survey area, a Fuess long-term automatic recording tide gauge (float type) was established at the pier of Mubarras island. For the northern division, a portable Fuess long-duration automatic recording tide gauge was set at Pipe 31.

The observation period was from 25 June to 24 September at the Mubarras station, during which for only two days the observation was suspended due to explosion operation of rocks nearby. At Pipe 31, the observation period was originally planned as the same duration as at the Mubarras station. However, because of Pipe 31 being an oil rig owned by a foreign private company and also of rough weather, establishment of the tide gauge was delayed and the observation started from 12 August, which was barely in time for the survey operations.

(1) Mubarras Island Tide Station

The observed value of standard level at the time of establishment was determined as $6^{m}.20$. Thereafter, taking every opportunity such as the time of changing recording paper, that of cutting recording paper, etc., observation of the standard level, time checking, observation of tide pole, etc. were carried out to assure accurate observation of tides. As the result, the tidal observation was recognized as normal.

(2) Pipe 31 Tide Station

Comparative observations with a tide pole were frequently carried out, and simultaneous tide pole observations were carried out together with the Mubarras station. It was found from these observations that the reduction ratio was normal and accurate observation had been made.

4-9. Tidal Current Observation

15-day continuous observations were made at two stations (15-1 and 15-2) and 24-hour observations at 11 stations (A, b, c, D, e, F, g, H, i, J and K). Positions of the stations are shown in Fig. 11 and Table 2. Observations of two layers were carried out at Stations 15-2, A, D, F, J and K, at 5 metres below the sea surface and 5 metres above the bottom. At the other stations, observations were made at a layer 5 metres below the sea surface.

TIDAL OBSERVATION STATION

Station	Latitude	Longitude
15—1	24° 56′ 31″ N	53° 28′ 35″ E
15—2	24 27 17	53 30 19
A	25 01 07	53 36 58
b	24 56 31	53 24 01
c	24 50 04	53 31 25
D	24 45 28	53 28 29
e	24 40 19	53 24 46
F	24 38 56	53 32 03
G	24 38 51	53 40 44
H	24 35 06	53 37 58
i	24 31 13	53 33 40
J	24 31 01	53 40 42
K	24 26 12	53 36 28

Table 2

LOCATION OF TIDE AND TIDAL CURRENT OBSERVATION

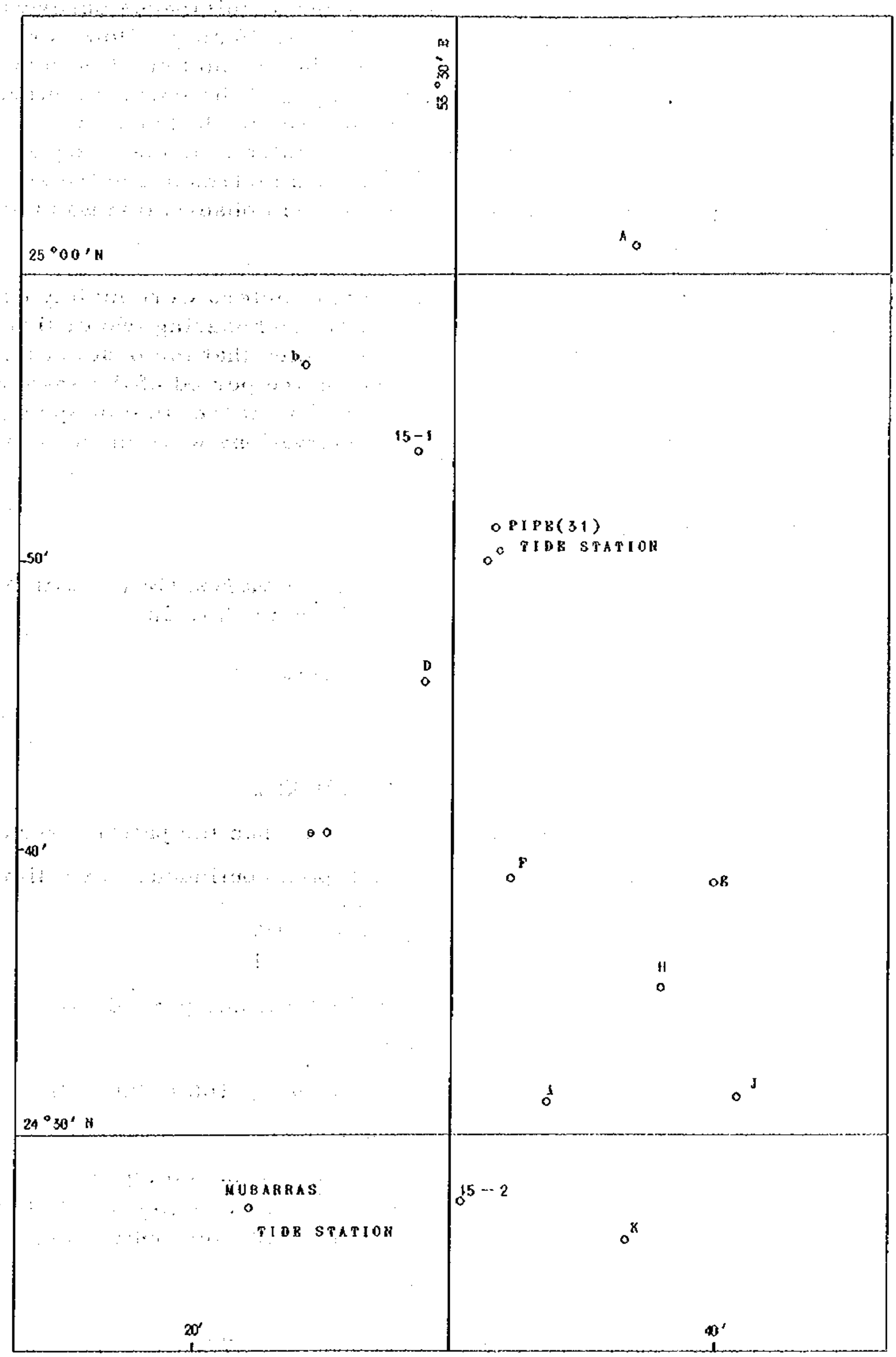


Fig. 11

At both of the 15-day continuous observation stations, a long-term self-recording current meter was used and simultaneous observations were carried out for 15 days from 27 June to 10 July. However, the observation of the layer 5 metres above the sea bottom at Station 15-2 was not simultaneously made due to missing of the current meter. Accordingly, another 15-day observation was made from 5 to 19 August. Also at Station 15-1, it was scheduled to make an observation during the time of spring tide at the layer 5 metres above the sea bottom, but due to a spell of bad weather this observation was not carried out.

For 24-hour observation, Ono current meters were mainly used, and the observations were carried out at neighbouring two or three stations at a time. Although it was scheduled that the observations were to be made at all the stations during the period of the 15-day observation, a spell of rough weather falling at the time of spring tide did not allow this, and the final observations were made from 21 to 22 August.

4-10. Bottom Sampling

Bottom sampling was carried out by the *Jackson Creek* with Niino sampler. The sampling stations are shown in Fig. 12.

4-11. Specifications of Survey Instruments

4-11-1. Hi-Fix

(1) Pattern frequency : 1,900.25 kHz

(2) Trigger frequency : 60 Hz less than the pattern frequency.

(3) Type of wave : Interrupted continuous wave; time sharing
Master : F9
Slave : A1

(4) Period of time sharing : 60 ± 1 times per minute

(5) Antenna power : 120 W

(6) Maximum operating range at sea : 100 to 200 miles

(7) Receiver bandwidth : 100 Hz

(8) Power supply : All units are fed with 24 V D.C. supply. The receiver type 9217/III requires a 12-volt centre-tap.

(9) Composition of ship station
Receiver (9217/III)
Blower and Synchro Supply Unit (9369)
Distribution Unit (9218)
Track Plotter (9232)

BOTTOM SAMPLING POSITION

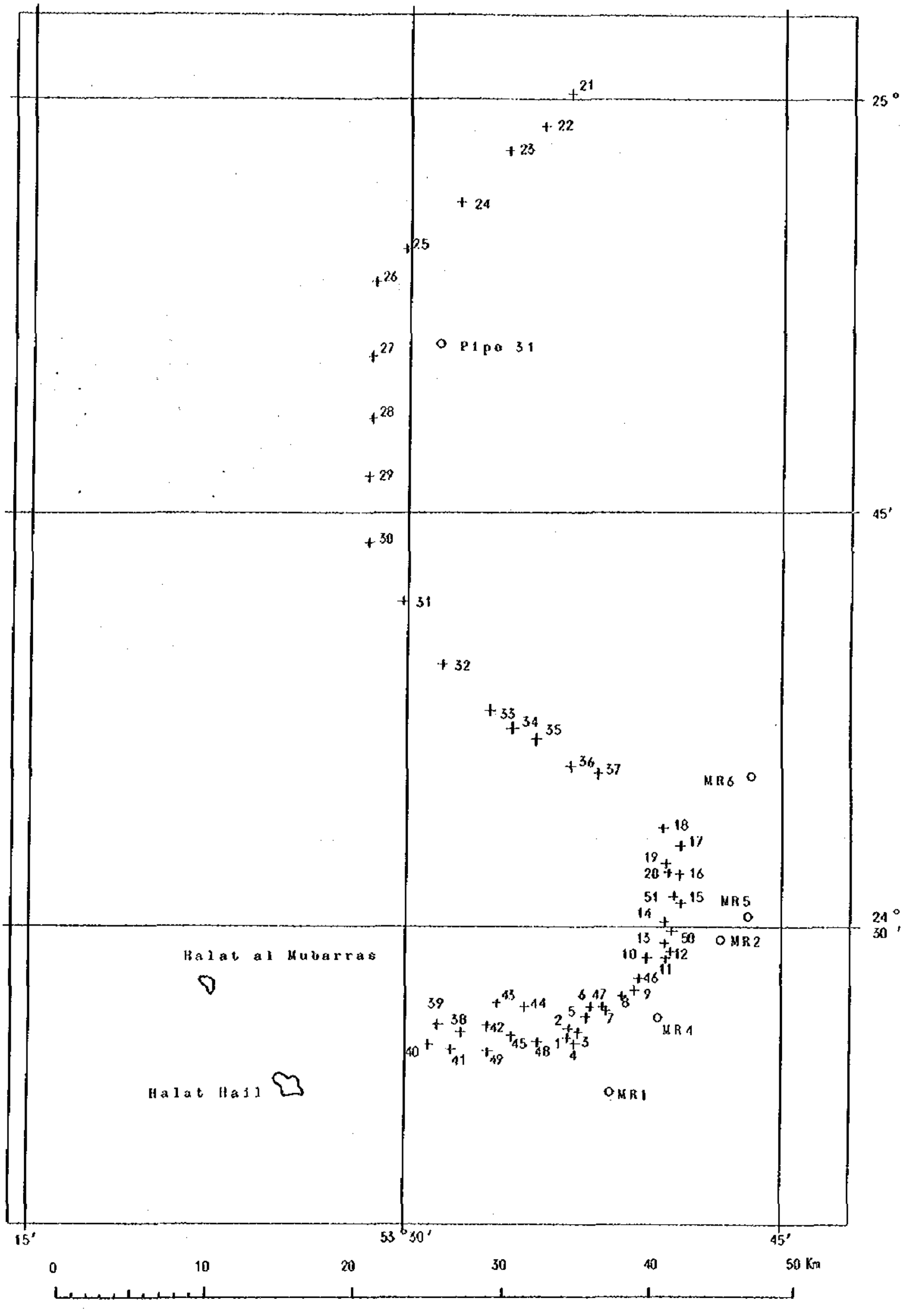


Fig. 12

L/R Indicator (9367)
Receiver Antenna (9367)
Battery Charger
Cables

(10) Composition of Master station
Master Drive Unit (9216)
Blower and Synchro Supply Unit (9369)
Medium Power Transmitter (9362)
Distribution Unit (9218)
Receiver for Monitoring (9217/III)
Two-Channel Recorder (1679/H)
Transmitter Antenna (GB 36) and Earth Matt
Battery (24 V)
Motor-Generator (Honda E 4000 and E 1000)
Battery Charger
Cables
Tools, spare parts and testing instruments

(11) Composition of Slave station
Receiver (9217/III)
Blower and Synchro Supply Unit (9369)
Medium Power Transmitter (9362)
Distribution Unit (9218)
Transmitter Antenna (GB 36) and Earth Matt
Battery (24 V)
Motor-Generator (Honda E 4000 and E 1000)
Battery Charger
Cables
Tools, spare parts and testing instruments

4-11-2. SSB Transmitter-Receiver (PYE 130 M) (PYE 125 T)

(1) Frequency : 3,631 kHz

(2) Antenna power : 100 W

(3) Power supply : 24 V

4-11-3. Echo-Sounder Type 4

(1) Maximum sounding range : 100 m

(2) Range :

	Shallow	Deep
Range 1	0 - 20 m	0 - 40 m
Range 2	10 - 30 m	20 - 60 m
Range 3	20 - 40 m	40 - 80 m
Range 4	30 - 50 m	60 - 100 m

(3) Unit graduation : Shallow : 0.2 m ; Deep : 0.4 m

(4) Accuracy : $\pm(0.1 + D \times \frac{1}{1000})$m, where D : depth of water.

(5) Frequency of synchronous oscillator : 300 Hz

(6) Paper feeding speed : 40 mm/min

(7) Paper width and length : 150 mm × 20 m

(8) Recording type : Linear recording, electric discharging type.

(9) Frequency of ultrasonic wave : Vertical : 100 kHz ± 5 kHz
Slant : 200 kHz ± 5 kHz

(10) Transmission system : Condenser discharging system controled by photo-transister.

(11) Receiving system : Super-heterodyne system

(12) Transducer : Magnetrostrictive transducer of Barium Titanate.

(13) Power supply : D.C. 24 V

4-11-4. Tide Gauge

(1) Long-Duration Fuess Self-Recording Tide Gauge (LFT-IV)

(a) Type : Float type

(b) Recording range : 7 m

(c) Scale : 1/20

(d) Paper feeding speed : 20 mm/h

(e) Recording paper : Width 375 mm, length 17 m

(f) Clock : Electric clock, 6 V

(g) Diameter of float : 300 mm ϕ, 180 mm in height

(h) Steel tape for measuring Datum Level : 10 m (stainless steel)

(i) Dimension : 470 × 570 × 380 mm

(j) Maximum period for continuous recording : 1 month

(2) Portable Tide Gauge (PFT)

(a) Type : Float type

(b) Recording range : 0 - 4 m

(c) Scale : 1/20

(d) Paper feeding speed : 20 mm/h

(e) Recording paper : Width 200 m, length 17 m

(f) Clock : Electric clock, 6 V

(g) Diameter of float : 100 mm ϕ

(h) Dimension : 320 × 330 × 350 mm

(i) Size of conducting pipe : Outer diameter 140 mm ϕ; inner diameter 125 mm ϕ

(j) Maximum period for continuous recording : 1 month

4-11-5. Current Meter

(1) One Self-Recording Current Meter (OC)

(a) Propeller : Weak current 0 - 2 knots
Medium current 0 - 4 knots
Strong current 0 - 6 knots

(b) Maximum depth : 50 m

(c) Weight : In the air, 24 kg; in the water, 16 kg

(d) Maximum period for continuous recording : 7 days

(e) Recording paper : 60 mm × 6 m or 60 mm × 12 m

(2) Long-Duration Self-Recording Current Meter (NC-II)

(a) Propeller : Weak current 0 - 2 knots
Medium current 0 - 4 knots
Strong current 0 - 6 knots

(b) Maximum depth : 200 m

(c) Weight : In the air, 33 kg; in the water, 22 kg

(d) Maximum period for continuous recording : 20 days

(e) Recording paper : Effective range of oscillation (speed) 240 mm
Effective range of oscillation (direction) 36 mm
Length : 12 m

(f) Paper feeding speed : 5 mm/20 min

5. DATA PROCESSING

5-1. General

The data obtained from the hydrographic survey were processed after the completion of the field operations, for 70 days from 26 September to 4 December 1972.

5-2. Position Fixing

In order to maintain the phasing relationship normally between Master and Slave signals of Hi-Fix under the actual propagation velocity of radio-waves, baseline observations were conducted immediately after completion of the adjustment of instruments. The observations were made simultaneously on the both extensions of the base lines between the Master and Slave stations. After repetition of observations and readjustments, the actually measured values of the total lanes on each of the baselines from Master to Slave 1 and Master to Slave 2 and their computed values based on the assumed propagation velocity of 229, 650 km/s were obtained as given in the following table:

	Baseline Length	Total Lane		Actual Propagation Velocity
		Computed Value	Measured Value	
Pattern I	53, 580. 84^{m}	679. 57	679.52	299. 673$^{km/s}$
Pattern II	79, 234. 49	1004. 94	1003. 88	299. 967

When comparing those actual and computed values of total lanes, it was found that a considerable difference amounting 1. 06 lanes had been caused as to Pattern II, while those for Pattern I almost coincided, the difference being only 0. 05 lane. Due to this, the measurements were repeated three times at the survey site in order to find whether there was any error in counting integer lane. The repeated measurements revealed no error had been made.

As to the difference in total lanes of Pattern II between computed value and measured one, it was considered that, since at the time of the survey for location of stations carried out during the reconnaissance, Master-Slave 1 and Master-Slave 2 could not be directly connected, the big difference might have been caused by the discrepancy in separate geodetic networks where the triangulation station at Zarqa and the light tower at Dhabiyah (control point) were located, respectively, which the positions of the stations were based upon.

Under such circumstances, the following measurements were carried out in addition to the total lane measurements of Pattern I and Pattern II, in order to obtain actual propagation velocity and at the same time to locate the position of Slave 2 with reference to the Master:

(1) Measurement of lane numbers at Oil Rigs (MR 1, 2, 4 and 5) on the normal Hi-Fix pattern.

(2) Measurement of lane numbers of Oil Rigs (MR 1, 2, 3, 4 and 5) on the modified Hi-Fix pattern where the Slave 1 was changed to the Master and the Master changed to Slave 1.

(3) Measurement of total lanes from Zarqa to Dhabiyah (Slave 1 to Slave 2 on the normal pattern) on the modified pattern in (2) above.

The measurements of (1) and (2) above were made in the following manner in order to avoid possible disturbance on radiowaves as the oil rigs were of considerably large size (on three or four supports) made of iron:

The survey ship turned around the rig, clearing it at 50 to 100 metres distance, and readings of Hi-Fix lanes were carried out when the ship came on the extension of a line joining two supports (excluding diagonal), and the positions thus fixed were plotted on the enlarged Hi-Fix chart. Then, by means of the construction method the Hi-Fix lane numbers of the rigs were obtained.

The results of the measurements are as follows:

	Total lane	MR 1	MR 2	MR 3	MR 4	MR 5
Pattern I	679.52	30.91	77.28	——	49.17	85.81
Pattern II	1,003.88	347.11	416.41	——	373.67	436.60
Modified Pattern I	679.52	648.66	602.31	562.92	593.52	547.98
Modified Pattern II	1,556.02	932.09	955.02	1,056.87	966.53	910.47

From the measured values at the oil rigs in (1), the propagation velocities as to each of Pattern I and Pattern II were obtained. The results are as follows:

	MR 1	MR 2	MR 4	MR 5
Pattern I	300,101 km/s	300,018 km/s	300,041 km/s	300,154 km/s
Pattern II	299,674	299,727	299,681	299,738

According to the results, the propagation velocity of Pattern I showed a fairly large value of 300,079 km/s on the average. It was considered that there might have been some problems in relocating the Master station at the position previously fixed at the reconnaissance, because the marking of the position had been missing at the time of establishing station and the position had to be determined from a reference point in the vicinity.

Thus, the positions of the Master and Slave 2 stations were found somewhat questionnable, but it was impossible to make a detailed resurvey of the station sites.

Such being the case, the following computations for adjustment were made to obtain the positions of Slave 1 (Zarqa) and Slave 2 (Dhabiyah) from Hi-Fix total lane numbers and the measured value of lane numbers at each oil rig, considering that the radiowave propagation paths within the survey area totally over the sea:

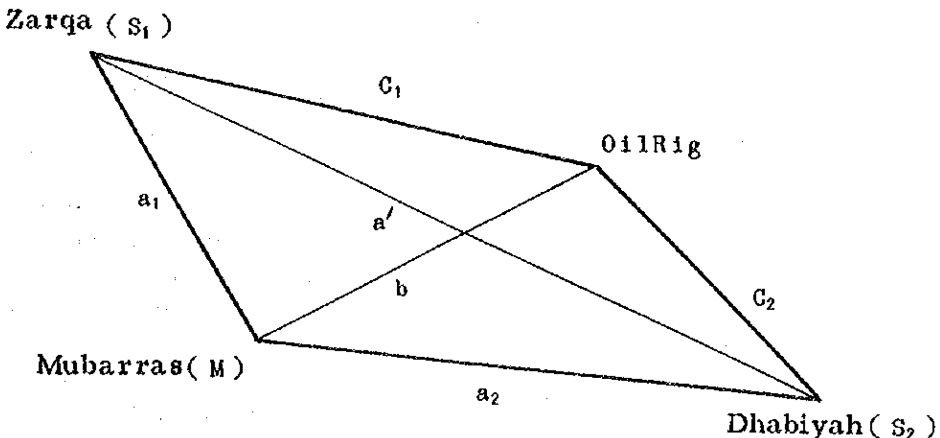


Fig. 13

Namely, in the layout of stations in Fig. 13, the distance of each side can be given as follows:

C_1 : Known

$$a_1 = \frac{v}{2f} \cdot Tl_1 ,$$

$$a_2 = \frac{v}{2f} \cdot Tl_2 ,$$

$$a' = \frac{v}{2f} \cdot Tl'$$

$$C_2 = -\frac{v}{f} \cdot P'_2 + \frac{v}{2f} \cdot Tl' + C_1$$

Also, "b" can be obtained in regard to Pattern I as follows:

$$b = \frac{v}{f} \cdot P_1 - \frac{v}{2f} \cdot Tl_1 + C_1$$

and in regard to Pattern II:

$$b = \frac{v}{f} \cdot P_2 - \frac{v}{2f} \cdot Tl_2 - \frac{v}{f} \cdot P_2' + \frac{v}{2f} \cdot Tl' + C_1$$

Taking the mean of the two values, we obtain

$$b = \frac{1}{2} \left\{ \frac{v}{f}(P_1 + P_2 - P_2') - \frac{v}{2f} (Tl_1 + Tl_2 - Tl') \right\} + C_1$$

where

Tl_1 : Total lane of S_1 - M

Tl_2 : Total lane of S_2 - M

Tl' : Total lane of S_1 - S_2

P_1 : Lane number of Pattern I at Oil Rig

P_2 : Lane number of Pattern II at Oil Rig

P_2' : Lane number of modified Pattern II at Oil Rig

From these relationships, the distance of each side can be obtained if propagation velocity "v" is assumed. These distance are considered to be spherical distances along the sea surface. Hence, the position of M and S_2 were obtained by computations for taking means of three sides of the triangulation network of S_1, MR1, MR2, MR3, MR4 and MR5, using "v" as a parameter varying every 10 km/s from 299,550 km/s to 299,700 km/s. The difference between the two distances, the one obtained from the differences in longitude and latitude of the position thus obtained and of the given point, and the other obtained by the measured values, was taken. Then, such a propagation velocity that may make the scattering of the above-mentioned difference to be minimum was obtained, together with the positions of M and S_2 corresponding to that propagation velocity. The results are as follows:

v : 299,620 km/s

	Lat.	Long.
M :	24° 27' 23".431 N	53° 22' 25".562 E
S_2 :	24° 19' 28".403 N	54° 08' 25".965 E

Error of mean square of scattering: M:±1.2m; S_2:±3.2m

The difference in the latitude and longitude between the positions thus obtained and the previously obtained positions of Master and Slave 2 are as follows (previous value minus computed value):

M : - 0".53 in latitude and -0".23 in longitude
S_2 : - 0".28 in latitude and +2".98 in longitude

Based on the results of the computations, the distance from each oil rig to Master and Slave stations was computed from the differences of longitude and latitude, and the Hi-Fix lane numbers were computed by using the actual propagation velocity of 299,620 km/s. The error of mean square of the difference between the value thus computed and the actually measured value became ±0.048 lane.

In order to make corrections to the errors in positions due to the difference between the assumed propagation velocity and the actual one as well as to the errors caused by the change in positions of Master and Slave 2 stations, another Hi-Fix chart was reprepared and used at the time of data processing, by using the positions of stations and actual propagation velocity newly computed as a for

5-3. Sounding

5-3-1. Reading of Sounding Value

For each survey ship, actual draught of transmission and reading scale were determined from the record of bar checks. By using the reading scale, the instrumental error and the error due to the difference between the assumed propagation velocity and the actual one were corrected. The effective transmission lines for ranges switched over were determined on the echogram. The corrections for draughts of transducers and the tidal corrections were also carried out on the echogram.

Soundings were read at half the unit of graduation, i.e. 10 cm, of the reading scale. Reading was made at each position fixed as well as in such a manner so that there might be no shallower portions between the fixed positions. The reading scales used were ranging from +3.5 ~ + 4.0% throughout the survey period.

5-3-2. Tidal Corrections

For tidal corrections, the tidal records at the Pipe 31 tide station and the Mubarras tide station were used for the northern and the southern areas, respectively.

As to the corrections for the sparse sounding in the northern area, the tide gauge had not yet been established at Pipe 31 at that time so that corrections were made from the observation record at the Mubarras tide station with time difference (0) and tidal height ratio (0.92).

5-3-3. Preparation of Boat Sheet

The soundings in the close sounding areas were plotted on a myler base overlayed on the track chart of the section paper (myler base). After the plotting, depth contours in metres were delineated, and soundings were examined and selection of soundings to be adopted on the smooth sheet of survey was made. For those soundings selected, corresponding Hi-Fix lane numbers were read out from the track chart, and the position were pricked on the aluminum-kent paper on which Hi-Fix lattices had been printed. The soundings were entered on the pricked points.

The density of soundings shown was determined to be about 5 mm apart each other. The first priority in plotting soundings was given to shallow waters, and the soundings were selected and co-ordinated accordingly.

For the sparse sounding area, a myler base was overlayed on the sounding sheet of the Hi-Fix chart (myler base) where planned shipping route was drawn. And the values of soundings at fixed positions and shoal soundings in-between were entered on the myler base, which became the boat sheet.

5-4. Smooth Sheet of Survey : Specifications

For the smooth sheet of survey, a myler base (#500) was used, and soundings were transcribed it from the aluminum-kent boat sheet. Those soundings obtained by the sparse sounding outside the areas of close sounding were selected from the myler base boat sheet so that they might be entered on the smooth sheet of survey at the interval of about 10 to 15 mm.

The specifications of the smooth sheet are as follows:

(1) Size

96 cm X 63 cm for both Sheet 1 (Northern Area) and Sheet 2 (Southern Area).

(2) Projection

Universal Transverse Mercator.

(3) Contents

(a) Title
(b) Depths.
(c) Depth Contours in Metres.
(d) Grids
(e) Positions of Oil Rigs and Master station.
(f) Scale in Metres.

(4) Items to be Included in the Title

(a) Name of Sheet : APPROACHES TO HALT AL MUBARRAS AND ANCHORAGE, ABU DHABI, UNITED ARAB EMIRATES.

(b) Number of Sheet : Sheet 1 and Sheet 2.

(c) Scale : 1/50,000.

(d) Surveyed by : Japanese Survey Team for Conducting Hydrographic Survey in Abu Dhabi.

(e) Period of Survey : June to September 1972.

(f) Reference Spheroid: Clarke 1880.

(g) Projection : Universal Transverse Mercator.

(h) Central Meridian : 51° E.

(i) Sounding Datum : Sheet 1; 4.44 m below B.M. (Pipe 31).
Sheet 2; 4.43 m below B.M. (Middle of Halat al Mubarras).

(j) Sounding Unit : Metre (under 31 in metre and decimetre).

(5) Spacing of Sounding Figures

About 5 mm for close sounding areas.
About 10 ~ 15 mm for sparse sounding areas.

(6) Depth Contours

Contours shown of 10 metres and 20 metres in accordance with the chart symbols.

(7) Master Station and Oil Rigs

Positions shown in red.

(8) Grids

Shown at the interval of 5' of both longitude and latitude.

(9) Distance Scale

A scale in metres shown.

6. FINDINGS

6-1. Sounding

(1) Northern Area (Smooth Sheet 1 refers)

The general trend in the northern area almost coincides with that shown on the existing B.A. Chart No. 3707 (1/330,000).

Outline of the result of sounding will be explained from north to south as following:

In the area in the vicinity of Point 1, about 11 miles north-northeastward of Pipe 31, the 20-metre depth contour runs in east-west in the northern side of the survey area, where a shoal of 19.8 metres exists. About 2.5 miles southwest of Point 1, a shoal extends from north to south and the least depth over it is 19.9 metres. About 4 miles north of Pipe 31, a pipeline crosses the close sounding area, extending west-northwestward to Jazirat Das from Zakum oil field. The elevation of the pipeline from the sea bottom is about 1 metre, and the depths over the pipeline are 20.8 to 22.0 metres.

Around Point 2 about 3.5 miles northwest of Pipe 31, depths of 24 odd metres which are the deepest of the survey area are seen, and this deepest portion extends northeastward. The area from Point 3, about 8 miles south-southwest of Pipe 31, to the northward for about 3.5 miles, is shallower than 20 metres, and the least depth is 18.3 metres.

The portions of the close sounding area other than those above-mentioned have the depths of 21 to 24 metres and the bottom is generally flat.

(2) Southern Area (Smooth Sheet 2 refers)

In general, the hydrographic information of the southern area almost coincides with that of the existing B.A. Chart No. 3707. At this survey, however, a number of isolated shoal patches have been found, which cannot sufficiently be represented on a smaller scale chart.

In the section from Point 4, about 14 miles northeast of Mubarras island, to the southeastward for about 5 miles, the 20-metre depth contours are intricated, presenting a rather complicated topography. In the close sounding area in this section, a shoal with a depth of 18.0 metres exists about 1.9 miles southeast of Point 4.

From a point about 5 miles southeast of Point 4 to Point 5, about 4 miles southwest of MR 6, the depths are 17 to 21 metres and the sea bottom is comparatively flat.

The close sounding area from Point 5 to Point 7, about 2.5 miles north of MR 4, passes through the deep portion of the depths of more than 16 metres. In this area, however, there are 10 shoal patches having depths of 15.0 metres, 15.5 metres, 14.5 metres, 14.8 metres, 13.0 metres, 12.2 metres, 13.6 metres, 12.9 metres, 11.4 metres and 14.8 metres scattering from north to south. Among them, those of 14.5 metres, 12.2 metres and 13.6 metres are considered as the critical shoals to which special caution should be exercised when proceeding in the vicinity.

On the east and west sides of this close sounding area, the 16-metre isobath runs in north-south direction, and on the east side the depths abruptly become shallower and shoals of less than 10-metre depth exist in several places, the least depth being 7.8 metres. A shoal of 9.4 metres deep exists in the portion where the 16-metre isobath on the east side maximally expands to the westward.

The section from Point 7, about 2.3 miles westward of MR 2, to the southwestward for about 2.5 miles has a comparatively flat bottom. About 2.7 miles southwest of Point 7, a 0.5-mile-wide shoal with depths of less than 16 metres over it crosses the close sounding area, and at its western extremity exists a shoal of 14.6 metres deep, while a shoal of 14.8 metres and of 14.9 metres exist on the western and eastern sides, respectively of the close sounding area.

At the position close northward of Point 9, about 3.2 miles west of MR 4, where a depth of 3 fathoms 1 foot (5.8 metres) is charted on the B.A. Chart No. 3707, a shoal with a depth of 5.6 metres exists, and the 10-metre depth contour centred at this shoal extends in close vicinity to the close sounding area. In the close sounding area to the southward of this position, shoal patches with depths less than 15 metres scatter, among which a shoal of 14.1 metres exists in the north side, shoals of 14.3 metres, 14.9 metres and 14.9 metres in the middle part and those of 14.5 metres and 13.5 metres in the south side of the close sounding area, presenting the principal bottleneck of the proposed shipping route.

As for the area from the planned anchorage about 5.6 miles west of MR 4 to the originally planned position of Y, about 6.6 miles east of Mubarras, the 10-metre depth contour extends from north to south on the north side of the proposed anchorage, terminating at a shoal of 8.5 metres deep. In the north side of a circular area within 2 kilometres of the centre of the proposed anchorage, a 16-metre depth contour runs across from west to east, and the portion north of the isobath is shallow and not adequate as an anchorage. On the other hand, the shallow area less than 16 metres extending from Mubarras island further extends towards southeastward. Its shallowest portion has the depth of 10.6 metres.

Comparatively flat sea bottoms are seen in the areas other than those abovementioned. However, shoal patches of 15 odd metres over them scatter in the southwestward of the proposed anchorage as well as in the vicinity of proposed SBM position about 7.6 miles westward of MR 4.

The representative shoals in the northern and southern survey areas are enumerated in Table 3.

Table 3 SHALLOW WATERS

NO	Lat. N		Long. E		Depth	Quality of the Bottom
1	24°	59!10	53°	35!23	19.9	Sh.Co
2	24	45.21	53	28.36	18.3	
3	24	37.56	53	34.26	18.0	Sh.Co
4	24	32.94	53	40.79	15.0	Sh.S.Co
5	24	31.94	53	40.93	9.4	Co.Sh
6	24	31.87	53	40.58	14.5	Co
7	24	30.83	53	40.95	13.0	
8	24	30.31	53	40.40	12.2	Co
9	24	29.94	53	40.69	13.6	S.Sh
10	24	29.34	53	40.69	12.9	Co.Sh
11	24	28.89	53	40.44	11.4	Co.Sh.S
12	24	27.10	53	37.89	14.8	Co
13	24	27.08	53	37.42	14.6	S
14	24	26.91	53	38.63	14.9	
15	24	26.39	53	36.58	14.1	
16	24	26.19	53	36.91	14.3	Sh.Co
17	24	26.11	53	36.97	14.9	S.Sh.Co
18	24	25.87	53	36.80	13.5	Co

6-2. Tides

Harmonic analyses were made to the tidal observation records at the Mubarras island (30 days in August 1972) and at Pipe 31 (15 days in August 1972), and component tides were computed. The results are shown in Table 4.

Table 4

TIDAL CONSTANTS
ARABIAN GULF

MUBARRAS
LAT : 24° 27' 22" N
LONG : 53° 24' 34" E
ZONE : -4.00h
DAYS OF OBS : 30 DAYS
AUG. 1972

TIDE	H(cm)	K(°)
M_2	29.1	5.1
S_2	13.5	64.4
K_2	3.7	64.4
N_2	5.5	344.5
K_1	43.1	152.6
O_1	24.0	108.7
P_1	14.4	152.6
Q_1	2.7	111.6
M_4	0.6	204.9
MS_4	2.5	287.5
L_2	0.7	34.5
V_2	1.1	344.5
M_2	2.5	86.1

ZUQUM(PIPE-31)
LAT : 24° 51' 07" N
LONG : 53° 31' 26" E
ZONE : -4.00h
DAY OF OBS : 15 DAYS
AUG. 1972

TIDE	H(cm)	K(°)
M_2	0.28	12.0
S_2	0.17	57.0
K_2	0.05	57.0
N_2	0.04	6.0
K_1	0.29	148.0
O_1	0.23	96.0
P_1	0.10	148.0
Q_1	0.04	75.0
M_4	0.02	77.0
MS_4	0.01	172.0

TIDAL CURRENT CONSTANTS
ST OF OBS : 15-1 LAT. 24° 53' 49" N LONG. 53° 28' 45" E
DAYS OF OBS : 15 DAYS 1972 JUN. LAYER 5.OM
ZONE : -4.00h

	N-COMP.		E-COMP.		ELEMENTS OF ELLIPSE				MAINDIR.310°	
	H Kn	K°	H Kn	K°		D°	V Kn	L°	V Kn	K°
M_2	0.203	98	0.366	238	L	296	0.401	66	0.395	70
					S	26	0.118	156		
S_2	0.092	212	0.171	325	L	285	0.176	152	0.169	165
					S	15	0.083	242		
K_2	0.025	212	0.047	325	L	285	0.048	152	0.050	165
					S	15	0.023	242		
N_2	0.069	355	0.087	149	L	308	0.109	138	0.114	339
					S	38	0.024	48		
K_1	0.385	259	0.155	310	L	16	0.399	348	0.201	231
					S	106	0.117	258		
O_1	0.212	181	0.163	233	L	34	0.244	217	0.118	122
					S	124	0.111	127		
P_1	0.128	259	0.051	310	L	16	0.132	348	0.070	231
					S	106	0.039	258		
Q_1	0.060	91	0.092	79	L	57	0.110	82	0.039	246
					S	147	0.010	352		
M_4	0.009	59	0.016	228	L	299	0.018	51	0.023	52
					S	29	0.001	321		
MS_4	0.020	323	0.011	277	L	25	0.021	87	0.014	7
					S	115	0.008	357		
CONST	− 0.012		0.143			95	0.144		− 0.113	

Types of tides are generally expressed by the ratio of diurnal tide and semi-diurnal tide, i.e. by the following three types: (1) Semidaily type : $\frac{K_1+O_1}{M_2+S_2} < 0.25$, (2) Mixed type : $0.25 < \frac{K_1+O_1}{M_2+S_2} < 1.50$, and (3) Daily type : $1.50 \leqq \frac{K_1+O_1}{M_2+S_2}$.

The values of the ratio in this locality are 1.3 at Mubarras island and 1.2 at Pipe 31, which fall in the category of (2) Mixed type. This type of tide has high waters and low waters twice about a day, but considerable differences are seen between the heights of successive two high waters or two low waters, and often it becomes the daily type (diurnal inequality). The diurnal inequality attains its maximum when the moon is farthest parted from the equator (tropic tide) and becomes minimum when the moon is around the equator (equatorial tide). The tidal difference varies according to the moon's age, distance between the moon and the earth, declination of the moon, etc.

Tidal curves of the four seasons were obtained by using six principal component tides (M_2, S_2, K_2, O_1, P_1 and K_1) at the Mubarras tide station, as shown in Fig. 14. The tidal curve of each season shows the tide about the time of the vernal equinox (about 21 March), the summer solstice (about 22 June), the autumnal equinox (about 24 September) and the winter solstice (about 23 December), respectively. The height of tide is shown in centimetres above the Datum Level, and the time is based on 60°E.

The tide at Pipe 31 has the time difference of about + 20 minutes and the tidal height ratio of 0.9 against the tide at Mubarras island. However, the time difference cannot accurately be obtained when the diurnal inequality is large.

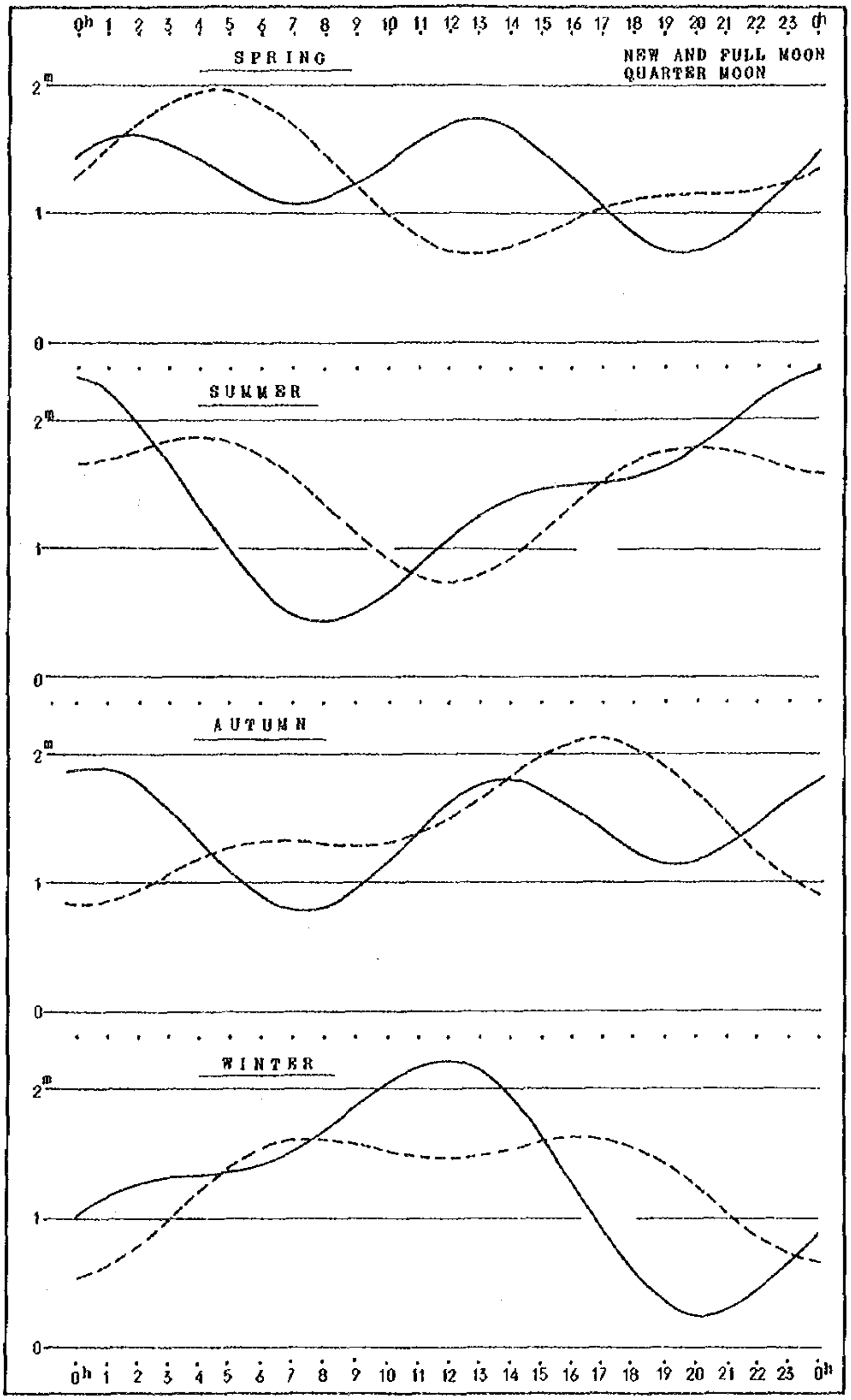
The non-harmonic constants at Mubarras island are as follows:

(A)	Mean High Water Interval	00^h10^m	(11^h10^m)
(B)	Mean Low Water Interval		(19^h40^m)
(C)	Mean High Water Springs	152^{cm}	(211^{cm})
(D)	Mean Low Water Springs	92^{cm}	(45^{cm})

The values in ( ) refer to tropical tides, and when the declination is south, they are to be added to the time of the moon's lower transit over the meridian.

The Bench Mark (B.M.) was established at Mubarras island and its height above the datum level of the tide station was measured. As the result, the datum level (D.L.) was $4^m.23$ below the top of the B.M.

THE TIDAL CERVES OF FOUR SEASONS AT MUBARRAS



——— spring

– – – – neap

Fig. 14

At Pipe 31, the heights of the datum level of the tide station and of the tide pole were measured. As the result, the D.L. was $4^{m}.44$ below the basic point of the tide pole.

The diagram showing the relationship between the various levels at both stations is illustrated in Fig. 15.

6-3. Tidal Currents

From the records of current meters, average speed and direction of currents every 20 minutes were read out, and they were divided into the north and east component tidal currents for computational convenience. Namely, if θ and V are direction and velocity, respectively, the north component velocity V_N and the east component velocity V_E can be obtained by

$$V_N = V \cdot \cos\theta, \text{ and } V_E = V \cdot \sin\theta.$$

When V_N and V_E are plotted on the coordinates where time is taken on the abscissa, periodical tidal velocity curves are obtained.

(1) In case of 15-day continuous observation, velocities at every hour were obtained from the velocity curve, and various component tidal currents having peculiar periods were obtained as to following elements, the results being shown in Table 5:

(a) Amplitude and phase lag(*) of the north and east components.

(b) Direction and length of the major axis (maximum) and minor axis (minimum) of an ellipsoid produced by combination of the values of the north and east components, and the phase lag.

(c) Velocity and phase lag of each component corrected uniformly to the principal direction ($\frac{\Sigma D \cdot V}{\Sigma V}$) determined by the direction of major axis D and velocity V of each component.

(2) In case of 24-hour observation, values of V_0, R_1, R_2, R_4, ζ_1, ζ_2 and ζ_4 were obtained on the assumption that the velocity at every hour can be expressed as follows:

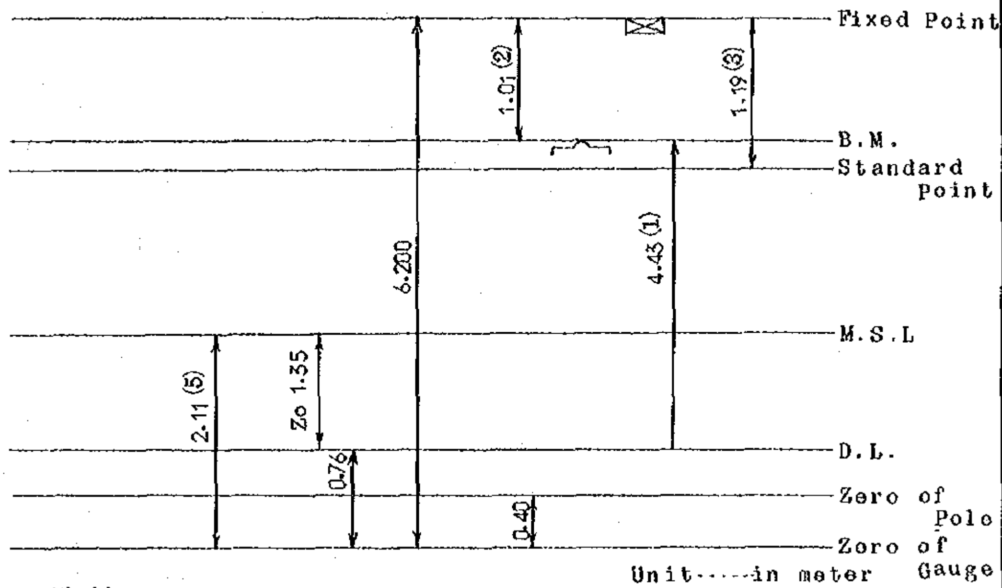
$$V_t \cdot V_0 + R_1 \cdot \cos(15°t - \zeta_1) + R_2 \cdot \cos(30°t - \zeta_2) + R_4(60°t - \zeta_4).$$

V_0 is called the constant current which is a non-periodical current mainly generated by wind. Besides, there are included drift currents due to topographic features and the influence of oceanic currents in the area adjacent to the outer ocean, as well as long-term tidal currents in case of 24-hour observation.

(*) The interval, expressed in angles, between the time of upper transit of a heavenly body over the meridian of the observation site and the time when the current attains its maximum velocity.

RELATIONSHIP BETWEEN VARIOUS LEVELS

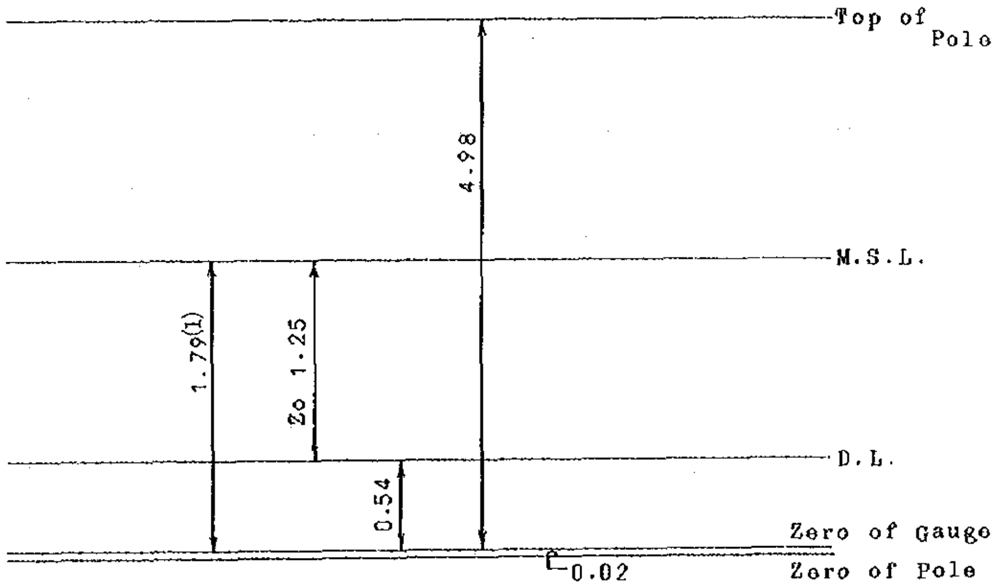
MUBARRAS



(1). (2). (3) Levelling Data.

(5) Mean Value of one month observations

PIPE(31)



(1) Mean Level of 15 Days Observation

Fig. 15

Table 5

ST. OF OBS : 15-2 LAT. 24° 27' 17" N LONG. 53° 30' 19" E
DAYS OF OBS : 15 DAYS 1972 JUN. LAYER : 5.0M
ZONE : -4.00h

	N — COMP		E — COMP		ELEMENTS OF ELLIPSE				MAIN DIR. 312°	
	H	K	H	K		D (°)	V (Kn)	L (°)	V (Kn)	L (°)
M_2	0.180 cm	116°	0.424 cm	278°	L	292	0.458	100	0.435	103
					S	22	0.052	190		
S_2	0.029	192	0.148	322	L	277	0.149	143	0.128	149
					S	7	0.022	233		
K_2	0.008	192	0.041	322	L	277	0.041	143	0.039	149
					S	7	0.006	233		
N_2	0.057	123	0.082	250	L	299	0.091	84	0.094	90
					S	29	0.041	174		
K_1	0.170	258	0.074	317	L	14	0.175	346	0.104	229
					S	104	0.062	256		
O_1	0.076	222	0.071	319	L	331	0.078	212	0.082	180
					S	61	0.068	122		
P_1	0.056	258	0.025	317	L	14	0.058	346	0.038	229
					S	104	0.021	256		
Q_1	0.041	251	0.021	259	L	27	0.047	326	0.017	242
					S	117	0.002	236		
M_4	0.027	267	0.023	304	L	39	0.033	25	0.016	201
					S	129	0.011	115		
MS_4	0.001	85	0.024	354	L	270	0.024	174	0.023	172
					S	0	0.001	84		
CONST	— 0.116		0.048		157° 0.126				— 0.109	

ST. OF OBS : 15-2 LAT. 24° 27' 17" N LONG. 53° 30' 19" E
DAYS OF OBS : 15 DAYS 1972 AUG. LAYER : 5.0M UPPER BOTTOM
ZONE : -4.00h

	N — COMP		E — COMP		ELEMENTS OF ELLIPSE				MAIN DIR. 296°	
	H (Kn)	K (°)	H (Kn)	K (°)		D (°)	V (Kn)	L (°)	V (Kn)	K (°)
M_2	0.170	96	0.247	262	L	304	0.298	87	0.299	86
					S	34	0.034	357		
S_2	0.136	163	0.160	313	L	309	0.202	145	0.202	141
					S	39	0.055	55		
K_2	0.037	163	0.044	313	L	309	0.055	145	0.059	141
					S	39	0.015	55		
N_2	0.075	40	0.081	208	L	313	0.109	33	0.110	31
					S	43	0.012	123		
K_1	0.060	194	0.046	188	L	37	0.076	204	0.020	359
					S	127	0.004	114		
O_1	0.046	198	0.026	23	L	330	0.053	218	0.049	201
					S	60	0.002	128		
P_1	0.020	194	0.015	188	L	37	0.025	204	0.010	359
					S	127	0.001	114		
Q_1	0.007	69	0.006	20	L	38	0.009	49	0.009	166
					S	128	0.004	319		
M_4	0.021	279	0.011	340	L	18	0.022	34	0.015	215
					S	108	0.009	304		
MS_4	0.019	314	0.003	325	L	10	0.019	88	0.010	307
					S	100	0.001	358		
CONST	0.033		0.033		45° 0.046				— 0.010	

R_1 and ζ_1 are diurnal current group (one cycle a day), R_2 and ζ_2 are semi-diurnal current group (two cycle a day) and R_4 and ζ_4 are quarter-diurnal current group (four cycles a day). R and ζ indicate amplitude and phase lag, respectively. The velocities of their north and east components were obtained, and by composing them, elements of the ellipsoid of each current group were obtained. The results are shown in Table 6. The elements of ellipsoid thus obtained are those on the day of observation, and they vary according to the moon's age and declination. Therefore, in order to obtain the conditions of flow from the results of 24-hour observation, it is necessary to make appropriate corrections.

As seen in the results of harmonic analysis, the diurnal current is dominant as compared with the semi-diurnal current at Station 15-1, and the diurnal inequality is large. At Station 15-2, the semi-diurnal currents are dominant in general, and more comparatively regular changes are seen than at Station 15-1.

The tidal currents in this locality can roughly be divided into two types, the one is represented by the type at Station 15-1 and is seen in the northern areas including the stations north of Station D, and the other is represented by the type at Station 15-2 and is seen in the southern areas south of Station F. Namely, the value of $\frac{K_1+O_1}{M_2+S_2}$ is larger at the northern stations, and tidal hours are about 1.0 to 1.5 hours earlier than at the southern stations. At the time of moon's upper transit, south- or southwest-going currents are seen, and they gradually turns westerly as time passes by, and the westerly or northwesterly currents attain the maximum velocity about 2.2 hours in the northern area or about 3.5 hours in the southern area after the moon's upper transit over the meridian. Then, the currents turn to northerly to easterly flow, and the southeasterly currents attain the maximum velocity about 10 hours before the moon's lower transit. In this way, the currents turn in clockwise direction almost all the time, but for short time an counter-clockwise turn is seen, presenting a very complicated status of flow.

As to the velocity, it is slightly faster in the northern area as compared with the southern area. However, even in the northern area, the currents are weak and their maximum velocity is about 1.1 knots. The maximum velocities expected at each stations were obtained by using the harmonic constants, the results being shown in Fig. 16.

Table 6 24-HOUR TIDAL CURRENT HARMONIC CONSTANTS

NO.	DAY OF OBS. / TRANSIT	MOON AGE / DECL	DAY -ER		DIURNAL			1/2 DIURNAL			1/4 DIURNAL			CONST. CURRENT	
					D	V	L		V	L	D	V	L	D	V
A	1972 8.11 ~ 12	$1^d.3$	m 5	L	18°	0.33 Kn	204°	288°	0.45 Kn	78°	34°	0.03 Kn	282°	172°	0.03 Kn
	1972 8.11 14 05	N $6^\circ.2$		S	108	0.09	294	18	0.24	168	124	0.02	192		
	1972 7.11 ~ 12	$29^d.3$		L	42	0.38	224	281	0.50	66	17	0.03	258	37	0.13
	1972 7. 11 13 00	N $22^\circ.8$		S	132	0.07	314	11	0.07	156	107	0.01	348		
b	1972 7.26 ~ 27	$15^d.8$	5	L	356	0.41	63	280	0.49	99	31	0.07	264	49	0.13
	1972 7. 27 00 58	S $14^\circ.3$		S	86	0.27	153	10	0.12	189	121	0.02	354		
c	1972 8.13 ~ 14	$3^d.3$	5	L	25	0.22	173	299	0.57	69	51	0.07	288	335	0.08
	1972 8. 13 15 31	S $5^\circ.0$		S	115	0.02	263	29	0.27	159	141	0.02	18		
D	1972 7.14 ~ 15	$2^d.8$	5	L	5	0.49	228	313	0.57	96	10	0.08	234	329	0.10
	1972 7. 14 15 30	N $10^\circ.0$		S	95	0.11	318	43	0.22	186	100	0.01	144		
	〃	〃		L	43	0.30	171	313	0.61	78	43	0.04	174	4	0.16
	〃	〃		S	133	0.02	261	43	0.20	168	133	0.00	84		
e	1972 8.21 ~ 22	$11^d.3$	5	L	11	0.31	74	294	0.44	129	52	0.04	324	156	0.16
	1972 8. 21 21 58	S $23^\circ.5$		S	101	0.08	164	24	0.09	219	142	0.02	54		
F	1972 7.14 ~ 15	$3^d.8$	5	L	12	0.21	209	297	0.76	96	332	0.05	294	267	0.23
	1972 7. 15 16 13	N $4^\circ.5$		S	102	0.12	299	27	0.12	186	62	0.01	24		
	〃	〃		L	23	0.18	179	320	0.74	90	32	0.05	234	358	0.06
	〃	〃		S	113	0.02	269	50	0.12	180	122	0.03	144		
g	1972 6.26 ~ 27	$15^d.3$	5	L	50	0.33	78	294	0.34	99	278	0.02	6	288	0.11
	1972 6. 27 00 31	S $24^\circ.7$		S	140	0.13	168	24	0.06	189	8	0.02	276		
H	1972 6.26 ~ 27	$15^d.3$	5	L	24	0.31	50	302	0.40	111	350	0.04	228	129	0.13
	1972 6.27 00 31	S $24^\circ.7$		S	114	0.06	140	32	0.12	201	80	0.01	138		
	〃	〃		L	64	0.16	17	316	0.41	105	359	0.03	210	65	0.04
	〃	〃		S	154	0.04	287	46	0.12	195	89	0.01	120		
i	1972 6.26 ~ 27	$15^d.3$	5	L	17	0.28	62	309	0.44	111	40	0.04	354	221	0.13
	1972 6.27 00 32	S $24^\circ.7$		S	107	0.06	152	39	0.11	201	130	0.00	264		
J	1972 6.28 ~ 29	$17^d.3$	5	L	25	0.29	45	311	0.43	102	2	0.07	276	286	0.13
	1972 6.29 02 14	S $17^\circ.7$		S	115	0.09	135	41	0.12	192	92	0.01	186		
	〃	〃		L	12	0.30	29	314	0.46	99	353	0.08	264	343	0.14
	〃	〃		S	102	0.07	119	44	0.14	189	83	0.01	174		
K	1972 6.28 ~ 29	$17^d.3$	5	L	25	0.31	71	320	0.34	102	57	0.06	246	288	0.05
	1972 6.29 02 14	S $17^\circ.7$		S	115	0.04	161	50	0.11	192	147	0.03			
	〃	〃		L	44	0.27	29	302	0.36	99	68	0.04	354	85	0.17
	〃	〃		S	134	0.01	299	32	0.11	189	158	0.03	264		

PREDICTED MAXIMUM VELOCITY

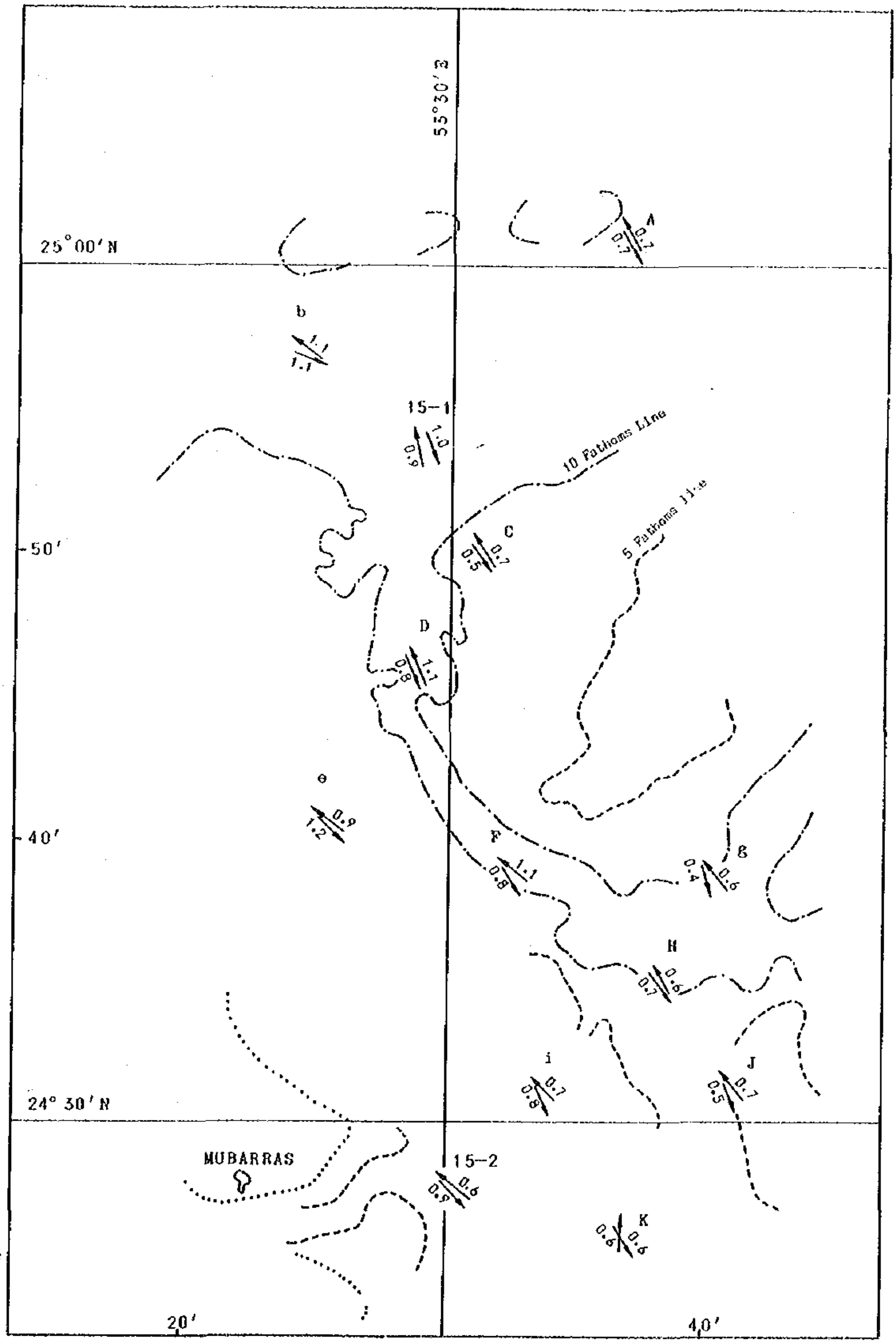


Fig. 16

In order to represent the current condition of this area, hodographs of tidal currents of the four seasons were obtained at Station 15-1 as for the northern area and at Station 15-2 as for the southern area. The constants used are the velocities of north and east components. Computations were made to each component and the results were combined. Fig. 17 and Fig. 18 show the hodographs thus obtained. Fig. 19 shows the actually meausred hodograph at the time of syzygy in summer. At Station 15-1, the flattening ratio of the ellipsoid of each component is small, and both velocity and direction of flow vary largely as the diurnal current is dominant, thus showing a quite different status as compared with that of Station 15-2.

Tidal observation was carried out at Mubarras island, and the study on the relationship between tides and current status in this locality has revealed the following:

About the time in the middle between high water and low water, the west- or northwest-going current attains its maximum velocity, and about the time in the middle between low water and high water the southeast-going current attains its maximum velocity. However, when diurnal inequality is large, the flowing condition is complicated. (Tidal curves in Fig. 14 and hodograph in Fig. 17 refer)

At Stations A, D, F, J, H and K, comparative observation of two layers, one 5 metres below the sea surface and the other 5 metres above the bottom were carried out. At the lower layer of each station, the tidal hours were about 0.5 hour earlier and the velocity was about 10% less than the upper layer (except for Station J where 10% more than the upper layer). At each station, the changes in direction and velocity of currents observed were similar between the upper and lower layers.

According to the observation data recorded during the period when strong northerly or northwesterly wind called *Shamal* was blowing, any northwesterly current was not seen and only southwest- or southeast-going currents were flowing for three days. This seems to be due to the wind, and it is considered that the influence of wind over the current is considerably large, although the data were only from the layer 5 metres below the surface of water.

As above-mentioned, diurnal tide is dominant both in tides and tidal currents in this locality, and due to this the diurnal inequality is large, to which the general conception of spring tide or neap tide according to the moon's age is not applicable. Namely, the influence due to the change in the moon's declination is large, and in addition, types of tides considerably vary according to areas, so that it is difficult to obtain predictions of tides and tidal currents at any point from the observations at a few particular reference stations.

HODOGRAPH OF TIDAL CURRENT

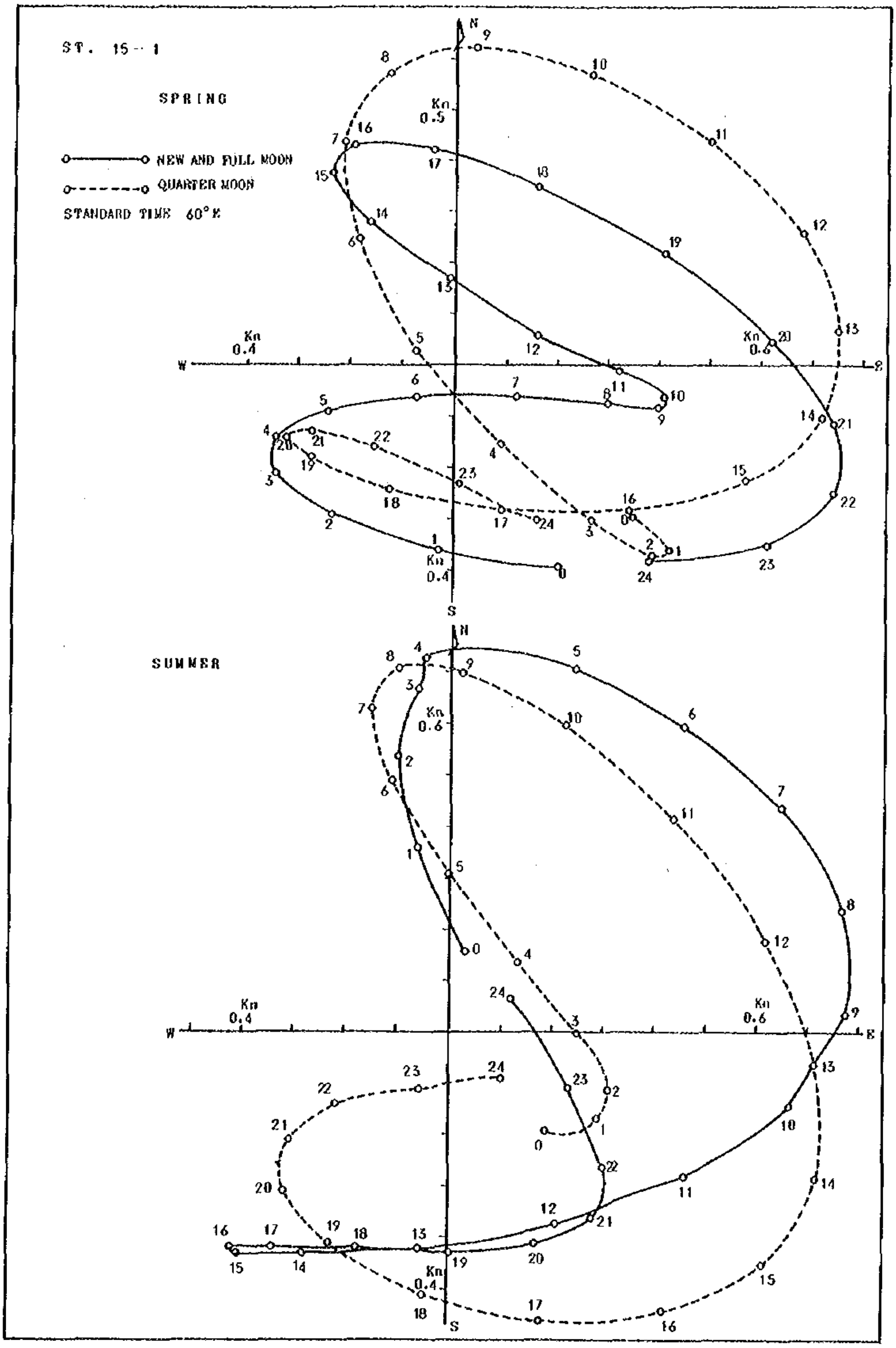


Fig. 17

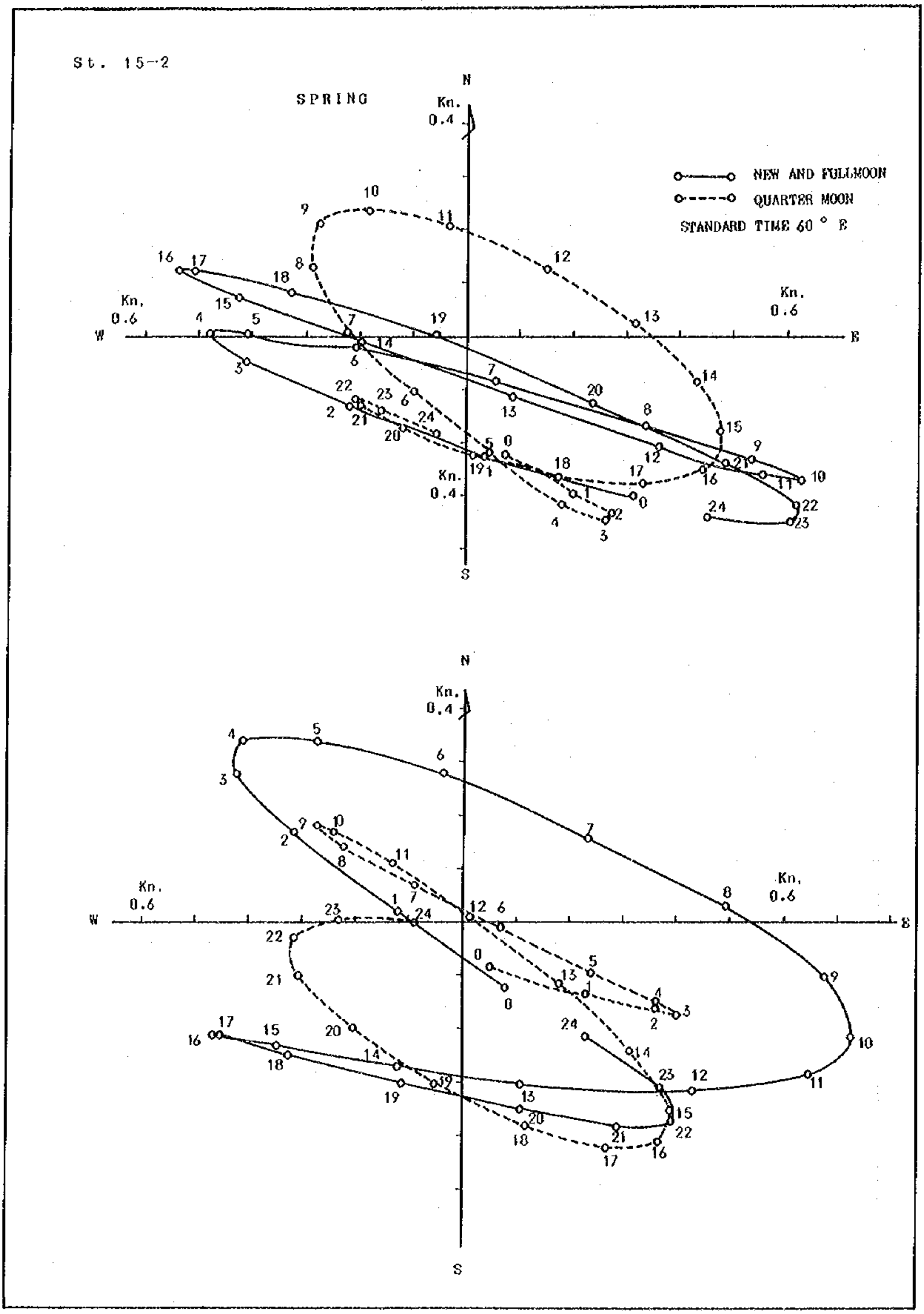

St. 15-2
SPRING
NEW AND FULLMOON
QUARTER MOON
STANDARD TIME 60 ° E
N
S
W
E
Kn.
0.4
0.6

Fig. 18

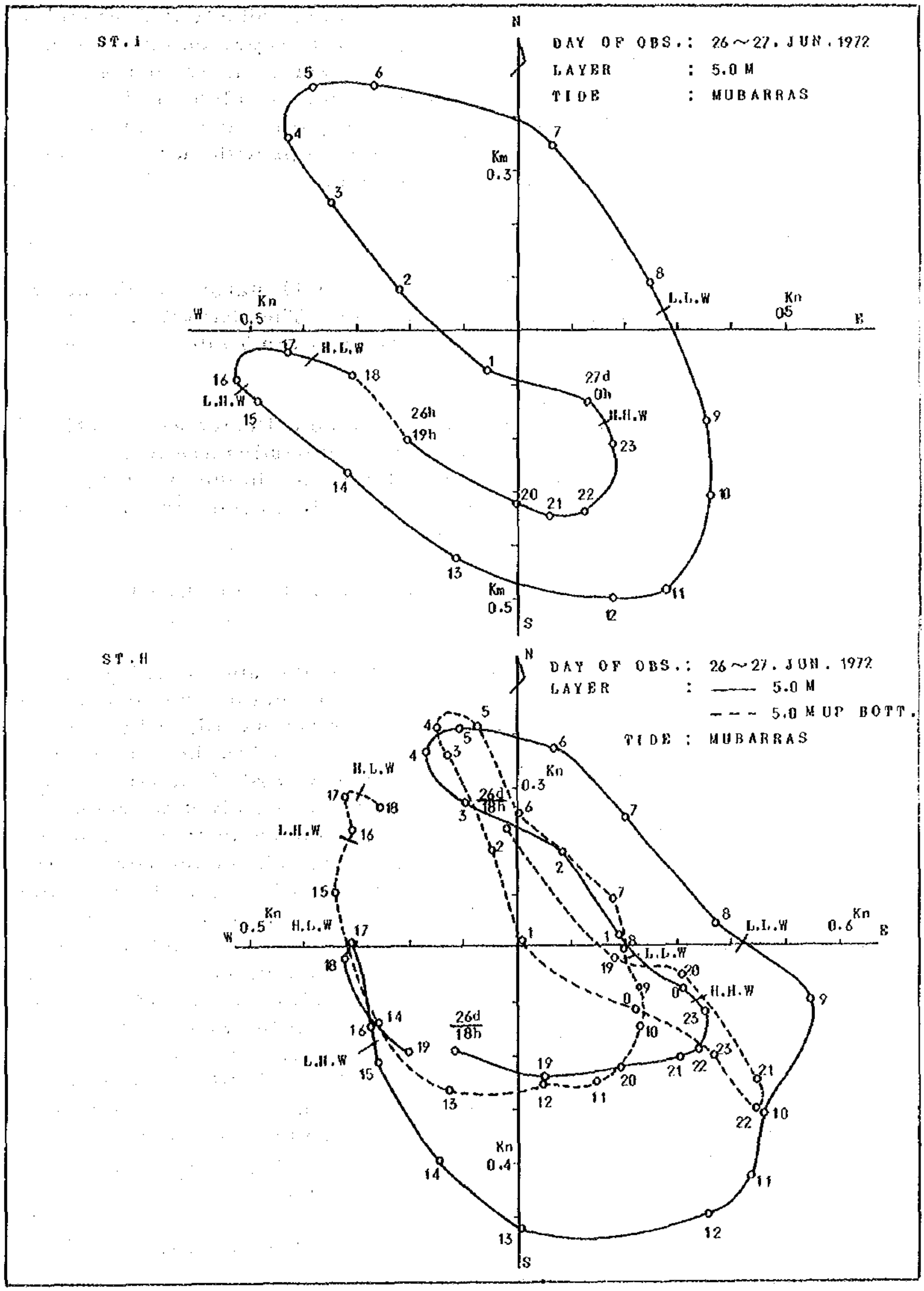

ST.I
DAY OF OBS.: 26~27. JUN. 1972
LAYER : 5.0 M
TIDE : MUBARRAS
N
S
W
E
Kn 0.5
Kn 0.5
Kn 0.3
Kn 0.5
L.L.W
H.L.W
L.H.W
H.H.W
26h 19h
27d 0h
ST.II
DAY OF OBS.: 26~27. JUN. 1972
LAYER : —— 5.0 M
- - - 5.0 M UP BOTT.
TIDE : MUBARRAS
Kn 0.3
Kn 0.5
Kn 0.6
Kn 0.4
26d 18h
H.L.W
L.H.W
L.L.W
H.H.W

Fig. 19

As for tidal currents, in particular, the direction of major axis of ellipsoid of diurnal current and that of semi-diurnal current tend to cross at right angles mutually, and accordingly it is considered that the status of currents cannot fully be represented by means of a generally employed method where predictions are made by uniforming the major axes. As the tides are also complicated, it is considered necessary to make a long-term and highly accurate tidal observations in order to provide ships with sufficient information for their efficient maneuvering.

6-4. Bottom Characteristics

The bottom sampling was carried out at 11 stations in the northern area and 41 stations in the southern area. The characteristics of the bottom and sampling positions are shown in Table 7 and Fig. 20, respectively.

Throughout the whole area, the samples collected are mostly of shell and sandy sediments. Coral characteristics are found in the complicated bottom areas. On the flat bottom in the southern area where changes in depths are not appreciable, muddy or mixture sediments of sand and mud are found.

A review of the distribution of bottom characteristics from north to south reveals the following:

From Point 1, about 11 miles north-northeastward of Pipe 31, to the southwestward for about 4 miles, sediments of sand and shell as well as coral are seen. The further goes southward, the greater becomes the ratio of shell mixed with sand, and in the portion from Point 2 to Point 4, about 14 miles northeastward of Mubarras island, sediments of fine sand mixed with shells are widely distributed, except for the area less than 20 metres deep north of Point 3 where corals are seen. At Point 4 and southward, shells and corals are seen, but in the portion from there as far as Point 5, about 4 miles southwestward of MR 6, the sediments are of mud or mud and sand mixtures. In the area south of Point 5, mixture of sand and mud as well as coral are seen on the shoal patches between Point 5 and Point 6, about 4 miles northward of MR 4, as well as at the complicated bottom on the east side of Point 9, about 3 miles westward of MR 4. In approaches to Point 7, about 2.5 miles northward of MR 4, and in the area from Point 9 to the planned position of SBM, mud or mixture of mud and sand are seen except the area northeastern part of the proposed anchorage. On the shoal with depths of 11 to 16 metres over it extending from Point 5 as far as the proposed anchorage, calcareous algae on coral are partially seen.

The calcareous algae are not seen on the bottom deeper than 16 metres.

Table 7-1 Bottom Characteristics

№	Date	Lat. N	Long. E	Depth	Nature of Bottom
1	21th July	24° 25′ 55″	53° 36′ 25″	15.1 m	S.Sh.Co
2	〃	24 26 11	53 36 30	16.8	S.Sh.Co
3	〃	24 26 02	53 36 53	14.3	Sh.Co
4	〃	24 25 43	53 36 42	13.6	Co
5	〃	24 26 32	53 37 13	16.3	Co
6	〃	24 27 00	53 37 22	14.8	S
7	〃	24 26 54	53 38 02	16.1	S.Sh
8	〃	24 27 24	53 38 34	16.0	S.Sh
9	〃	24 27 35	53 39 00	16.2	fS
10	〃	24 28 48	53 39 41	16.3	M
11	〃	24 28 49	53 40 26	11.4	Co.Sh.S
12	〃	24 29 12	53 40 41	13.8	Co.Sh
13	〃	24 29 28	53 40 25	16.2	Sh.S
14	〃	24 30 06	53 40 21	13.6	Co
15	〃	24 30 45	53 40 53	15.8	Sh.S
16	〃	24 31 45	53 40 53	11.4	Co.Sh
17	〃	24 32 49	53 40 46	15.1	Sh.S.Co
18	〃	24 33 28	53 40 08	16.7	M.Sh
19	〃	24 32 11	53 40 18	17.0	M
20	〃	24 31 46	53 40 31	14.7	Co
21	27th Aug	25 00 05	53 36 20	22.0	S.Sh.Co
22	〃	24 59 04	53 35 18	19.9	Sh.Co
23	27th Aug	24° 57′ 51″	53° 33′ 48″	22.0m	Sh.Co
24	〃	24 56 11	53 31 50	22.0	S.Sh
25	〃	24 54 22	53 29 52	23.5	Sh.S
26	〃	24 53 09	53 28 38	24.2	Sh
27	〃	24 50 42	53 28 32	23.4	fS.Sh
28	〃	24 48 13	53 28 31	22.4	fS.Sh

Table 7-2

No.	Date	Lat. N	Long. E	Depth	Natture of Bottom
29	〃	24 46 03	53 28 20	19.2	Sh.S.Co
30	〃	24 43 48	53 28 25	21.4	fS.Sh
31	〃	24 41 47	53 29 51	23.2	fS.Sh
32	〃	24 39 26	53 31 22	22.6	Sh.fS
33	〃	24 37 50	53 33 23	19.1	S.Sh
34	〃	24 37 22	53 34 14	18.0	Sh.Co
35	〃	24 36 48	53 35 12	18.5	Sh.fS
36	〃	24 36 01	53 36 31	20.0	Sh.Co
37	〃	24 35 35	53 37 36	20.6	M.S
38	29th Aug	24 26 09	53 32 10	16.1	M.S
39	〃	24 26 23	53 31 15	17.1	M.S
40	〃	24 25 35	53 30 56	16.7	M.S
41	〃	24 25 27	53 31 50	16.8	M.S
42	〃	24 26 27	53 33 12	15.9	M.S.Sh
43	〃	24 27 14	53 33 41	15.7	M
44	〃	24 27 03	53 34 45	13.6	S.Sh.Co
45	〃	24 26 02	53 34 14	18.3	M.S
46	30th Aug	24 28 09	53 39 21	17.5	M
47	1 St Sep	24 27 00	53 37 51	14.8	Co
48	30th Aug	24 25 38	53 35 16	18.0	M
49	〃	24 25 24	53 33 20	17.9	S.M
50	31th Aug	24 29 50	53 40 43	13.6	S.Sh
51	〃	24 30 46	53 40 35	17.0	M.S.Sh

BOTTOM CHARACTERISTICS DISTRIBUTION CHART

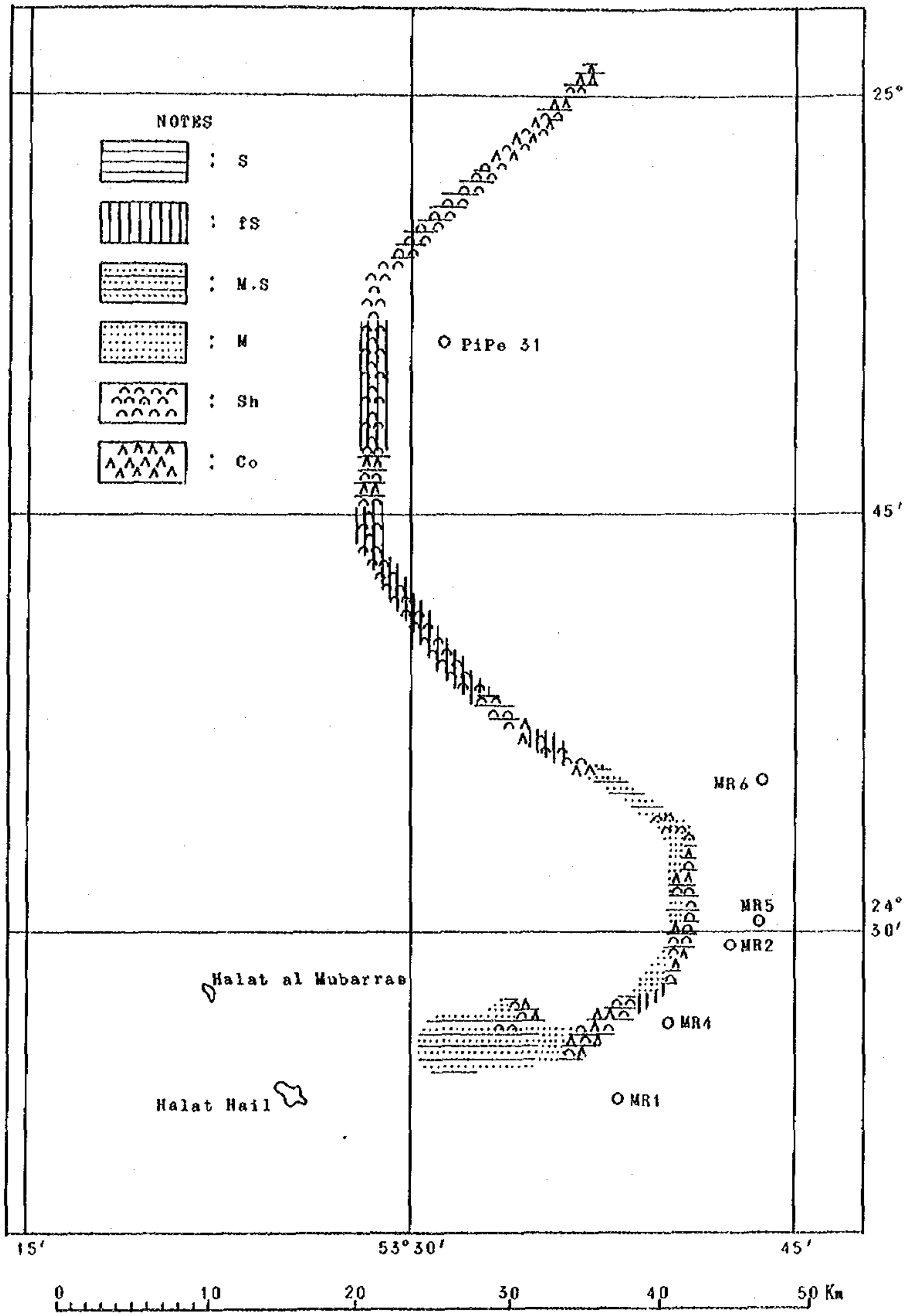


Fig. 20

6-5. Fixing of Planned Positions of Lighted Buoys

The positions where lighted buoys should be laid were determined on the basis of the results of sparse sounding and the results of close sounding in the southern area. From Point 1 to Point 5, the positions were selected on the port-hand side (starboard-hand side when entering Mubarras) of the shipping route to indicate the bending points of the route. From Point 5 to the proposed anchorage, it was decided to establish port- or starboard-hand lighted buoys to mark the positions of critical shoals for navigation.

Despite the original schedule, laying operations of the lighted buoys were not carried out during the period of the survey due to unavoidable circumstances. Therefore, position fixing by Hi-Fix became impossible at the time of establishing light buoys. Accordingly, during the survey the survey boat was led to those positions by Hi-Fix readings where she also carried out measurements of Navigational Decca readings, with which lighted buoys were laid in the right positions at a later date. The lighted buoys are 15 in number, i.e. "Mubarras Approach", "Mubarras Entry", No. 1, No. 3, No. 5, and Nos. 6 through 15.

The positions of those buoys from "Mubarras Approach" to No. 5 and No. 15 were determined on the Hi-Fix chart, while the other positions of buoys to indicate positions of critical shoals were obtained from the echogram by means of the readings of Pattern I and Pattern II of Hi-Fix. The survey boat was led to the buoy positions by those Hi-Fix readings, and carried out measurement of Navigational Decca readings. The Decca receiver used was MK 12 Type 8017. The results of the measurements are shown in Table 8.

It is remarked that the Decca chain reading at "Mubarras Approach" will be usefully referred in future by those navigators bounded to Mubarras carrying Decca receiver when they are approaching the n the northern extremity of the close sounding area.

7. LIST OF DOCUMENTS OF SURVEY RESULTS

(1) Smooth Sheet of Survey ..... 2 sheets (1 sheet each for the northern and southern areas)

(2) Survey Report .... 1 volume

(3) Tables of Results of Levelling of the Tide Stations .... 2 volumes each for the two stations

(4) List of Geographical Positions .... 2 volumes

(5) Reference Sheets of Geographical Positions .... 2 sheets

Table 8 PLANED POSITION OF BUOYS BY HI-FIX AND DECCA READINGS

Buoy	HI-FIX		Decca		
Name	P I	P II	Red	Green	Purple
Mubarras Approach	401.36	333.60	A 0.76	D 32.20	G 76.55
Mubarras Entry	398.85	228.47	A 4.54	C 31.57	G 57.23
No. 1	274.60	184.27	A 11.60	B 42.99	G 79.45
3	117.10	218.77	A 14.25	B 43.18	H 78.16
5	114.10	357.60	A 14.80	C 30.42	J 61.39
6	94.75	370.84	A 16.15	B 47.72	J 67.62
7	93.00	364.02	A 16.40	B 47.33	J 66.42
8	85.85	380.90	A 16.78	B 47.51	J 71.30
9	80.15	370.86	A 17.44	B 46.71	J 70.04
10	78.00	379.19	A 17.53	B 46.85	J 72.19
11	53.00	328.45	A 20.64	B 43.25	J 65.31
12	69.10	375.06	A 18.46	B 46.05	J 72.68
13	42.10	302.24	A 22.16	B 41.58	J 61.53
14	41.50	309.62	A 22.17	B 41.76	J 63.15
15	29.30	227.98	B 0.38	B 38.40	I 78.10

(6) Results of Harmonic Analysis of Tides .... 2 volumes (1 volume each for the northern and southern division)

(7) Results of Harmonic Analysis of Tidal Currents .... 1 volume (24-hour and 15-day observations)