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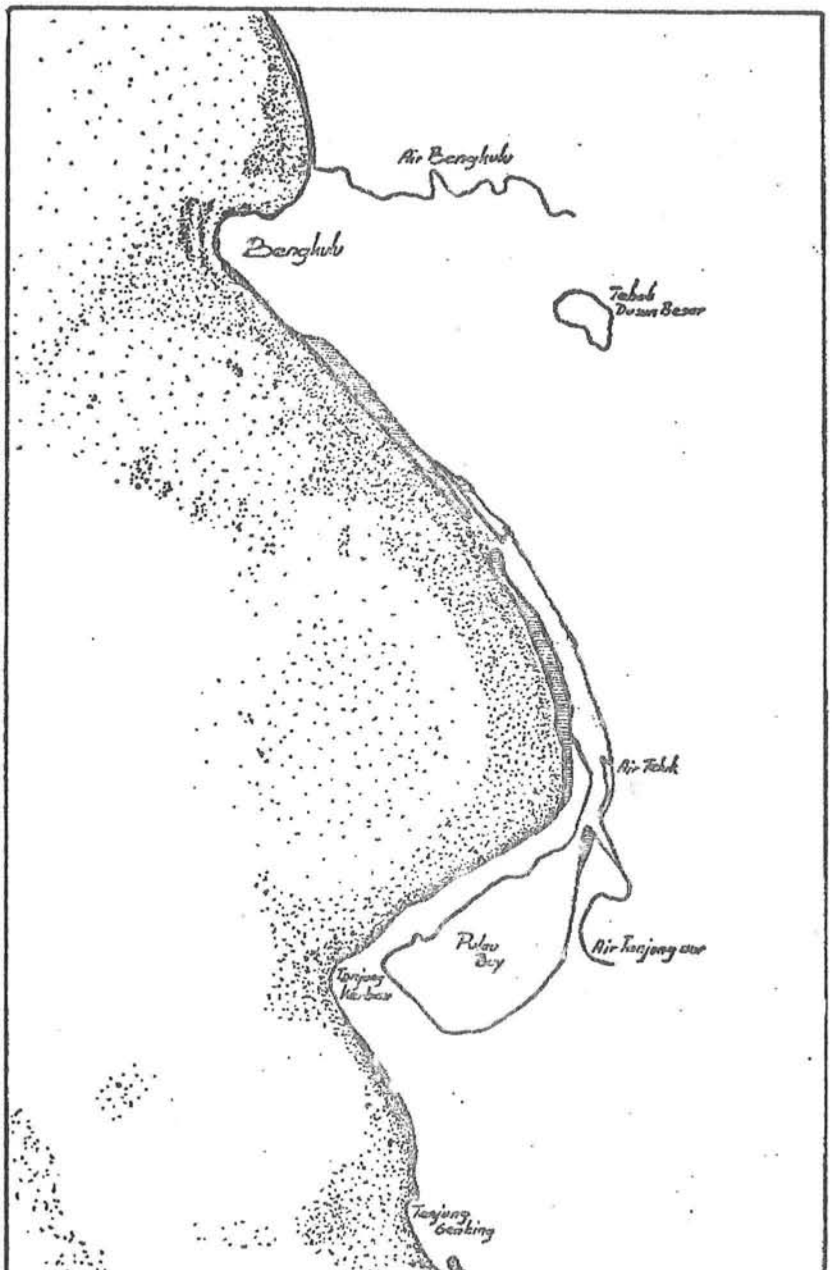


BENGKULU HARBOUR PROJECT

preliminary investigation

Dik Ludikhuize & Henk Jan Verhagen May '77

Contents

1. General introduction

The Indonesian gouvernment is stimulating development of areas outside Java to increase the food production of the country and to decrease the population density on Java. Also the Bengkulu district on the west coast of Sumatra has to be developped. Important for development is a good infrastructure, and in an archipelago like Indonesia sea-transport is cheap and easy. But harbours are necessary.

Nowadays Bengkulu has a small harbour with an averidge depth of 1 m, and of course this harbour is too shallow for normal shiphandling. Hence most of the merchantships are loaded and unloaded on the roadstead.

Fig 1.1

Further Bengkulu has two road connections with Palembang. These roads cross the Barisan mountainchain. They have a poor condition. Improving these roads is difficult and expensive.

There is no railway traffic in the Bengkulu district. The nearest railway station is Lubuklinggau, just on the other side of the Bukit Barisan. To build a railroad through the Bukit Barisan is even more difficult than building a road, and plans to give Bengkulu a railway-connection are not realistic in the present circumstances.

Improving harbour facilities is necessary, because loading and unloading ships on the poor protected roadstead is not always possible, specially not in the January-March monsoon period.

Several possibilities to improve the present situation are possible:

- I To improve the roadstead to assure protection agains waves.
- II To improve the existing harbour in Bengkulu.
- III To build a new harbour at an other location, for exemple in the Pulau Bay.

Pulau Bay is a bay, about 20 km south of Bengkulu, protected by a sand spit from the sea, and with a depth of 10 m. The natural entrance of this bay is the mouth of the Air Teluk, which has silted up and is not navigable.

To make a good decision about what to do it is necessary to know several things.

1. What are the needs of Bengkulu with respect to harbour facilities, now and in future ?
2. What is the wave climate along the coast of Bengkulu ?
3. What is the morphological situation of the Bengkulu coast ?
4. How is the interaction between wave climate and morphological situation on one side, and the new harbour facilities on the other side ?

In this preliminary investigation we tried to investigate the first three of these four points.

The general problem in our investigations was a shortage of accurate measurements. For a detailed description of wave climate or sand transport several years of continuous observations are necessary. Because they don't exist and development of this area can't wait until enough measurements are available it is necessary to estimate the essential data outof observations of other places and interpolations of short-time measurements. Of course the results are less accurate and they have to be regarded with a lot of distrust. When these data have to be the basis of construction calculations it is necessary to introduce safety coefficents.


George Town
Malacca
Kuala Lumpur
Singapore
Meurenda
Atjeh
Lhoksukon
ATJEH
Belawan
Medan
Tebing-tinggi
Tapakkuan
Bakungan
Truman
Samosir
Tandjung balai
Bagan-siapiapi
P. Rupat
Toba meer
Singkil
Sibolga
P. Musala
NIAS
Natal
Rokan
Airbangis
P.P. Batu
Bukit tinggi
Pariaman
Padang
Solok
Taluk
Rengat
Kepulauan Riau
Kepulauan Lingga
Muaratebo
Painan
SIBERUT
Muara labuh
Batang Hari
Djambi
Indrapura
Sipora
Kepulauan Mentawai
Bangko
Mukomuko
P.P. Pagai Selatan
Musi
Palembang
Ketaun
Lais
Lubuklinggau
Benghulu
P. Mega
Manna
Bintuhan
LAMPUNGS
P. Enggano
Krui
Radjabassa
Labuhanwaiharu
Belimbingo
Tampang
Teluk betung
Selat Sunda
JAVA
Indian Ocean
N
road
railroad
river
marsh
Sumatra
scale 1:6.000.000
0
100
200
300
400 km
Fig. 1.2

2. Some geological and geophysical considerations

On the west side of Sumatra a border between two geological plates is found. Geophysical research shows in this area an intense activity of earth-movements. Here the Indian Ocean Plate meets the Sunda Plate. Earthquakes show the edge where the Indian Ocean Plate is forced beneath the Sunda Plate. This system is also recognisable by gravimetry. Gravimetrical research by Vening Meinesz showed negative anomalia on the west side of Sumatra.

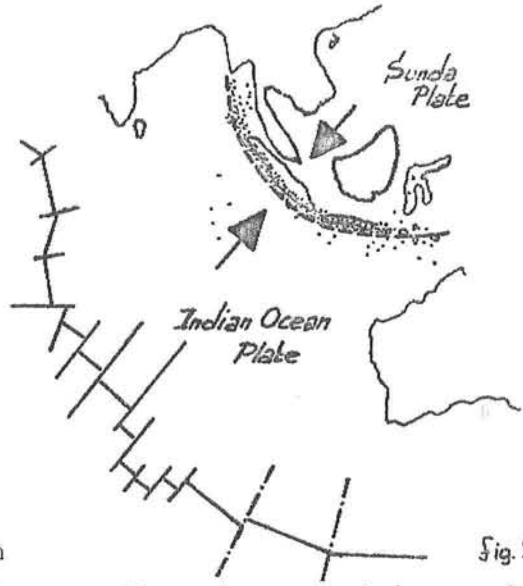


fig. 2.1

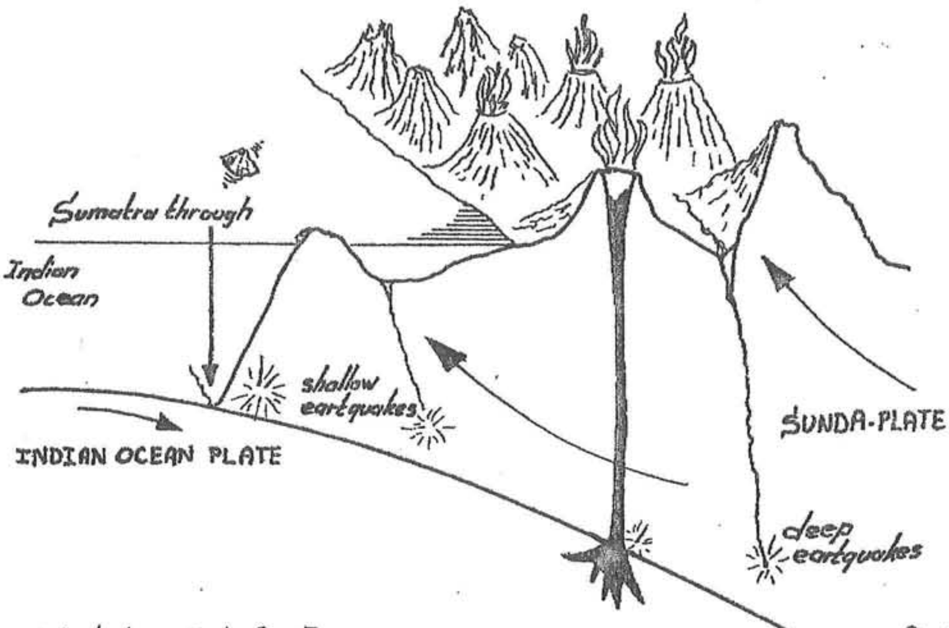
Together with the locations of earthquakes (deep earthquakes on the eastern side of the fault and shallow quakes on the western side) and the location of the volcanos, they give a good impression of the tectonical system in West Sumatra.

fig. 2.2

fig. 2.3

fig. 2.4

By this tectonical system the west-coast of Sumatra is moved upwards very slowly (slowly from a technical point of view, from a geological point of view it is quit fast). A negative beach propagation, i.e. the coastline moves seaward, is the result of this movement. On the coast a lot of coral reefs can be found several meters above m.s.l.
Because the coast is rather steep this negative beach propagation has nog caused a large extension of the land



Adapted from Baker [1972]

Fig. 2.5

On the geological map of Sumatra this area is found as a small quarternary strip along the coast. Near Bengkulu this strip starts south of Pulau Bay.

Observations of Erb (1905) show that the coast is still rising, with a (from a geological point of view) remarkable speed. Verstappen (1973) confirms this and suggests that Bengkulu and Tanjung Kerbau are lying on horsts which are somewhat higher than their surroundings.

Sumatra
geological
scale 1:7.500.000

Fig 2.6

3. Waves on the Bengkulu coast

Introduction

Knowledge of the wave climate along the coast is a basic need for coastal engineering. For a description of this wave-climate a lot of long term measurements in deep water are necessary. Unfortunately no long term measurements were made in the Bengkulu area. The Dwidelta corp. and the Yogyacarta University measured in a few short periods wave heights and sometimes wave periods. These were no continuous measurements, but measurements once per hour, and with each measurement only one to ten waves were measured. Hence statistical operations with these data are impossible.
It is possible to predict waves with hindcasting procedures from detailed weather charts. Because the Indian Ocean south of the equator is not frequented by ships also meteorological data are scarce. More detailed information is available along the south coast of Java. So it is usefull to try to use these data for the Bengkulu area. These two areas are influenced by aproximately the same winds and storms.

Tides and currents

Because Bengkulu lies at the coast of an ocean no large tidal influences have to be expected. Indeed the tidal difference is only 60 cm (Admiralty tide table, 1976). No important longshore currents were measured (0.02 - 0.07 m/s, Dwidelta 1975). Also the prevailing drifts are not important to influence the waves. A slow drift occurs between the islands west of Sumatra and the Sumatran coast. These drifts will have some influence on morphology.
This subject will be studied in the next chapter.

Wind systems near Bengkulu

In Indonesia winds are semi-annual, because of the monsoon-system. In January Australia is heated and therefore air flows towards this area. In July the central parts of China (Gobi) are heated and thus the air is flowing in the opposite direction. These winds are influenced by the rotation of the earth according to the law of Buijs-Ballot.
The results of this system are a SE wind in July and a NW wind in January along the western coast of Sumatra. Between these two periods the winds are changing (transition). This is in March/May and September/November.

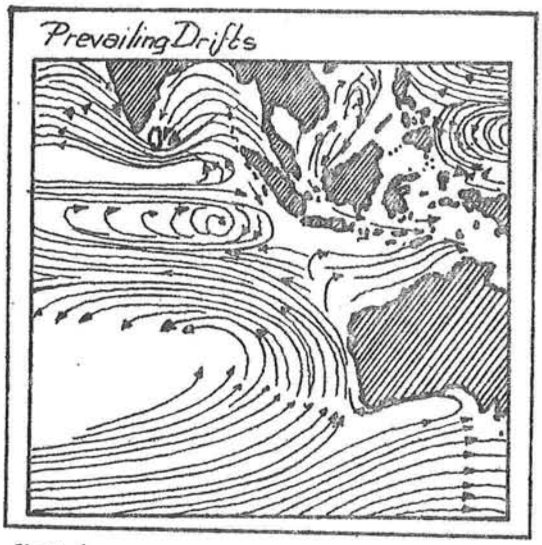


fig. 3.1

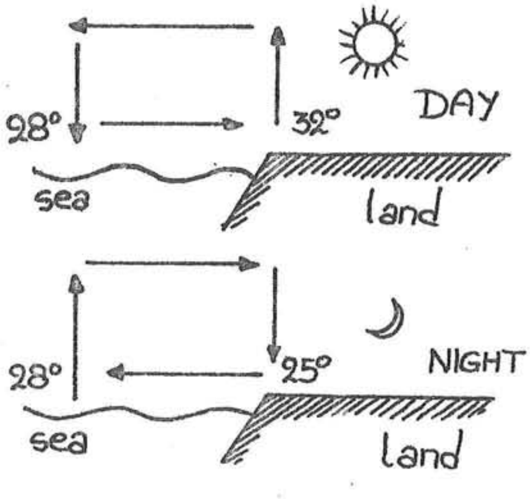


fig. 3.3. The daily monsoon system

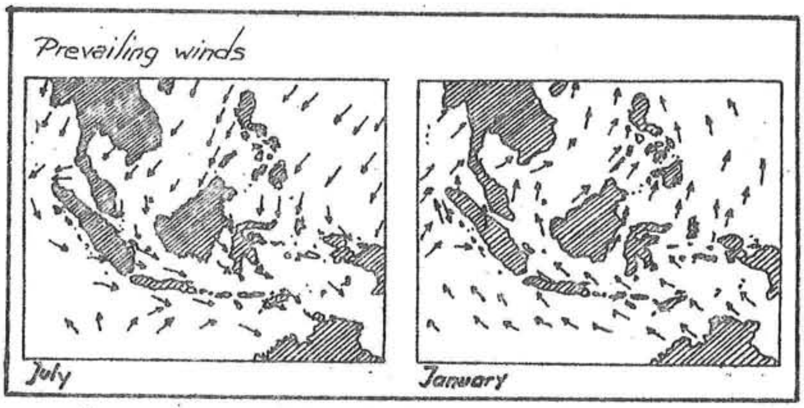


fig. 3.2.a

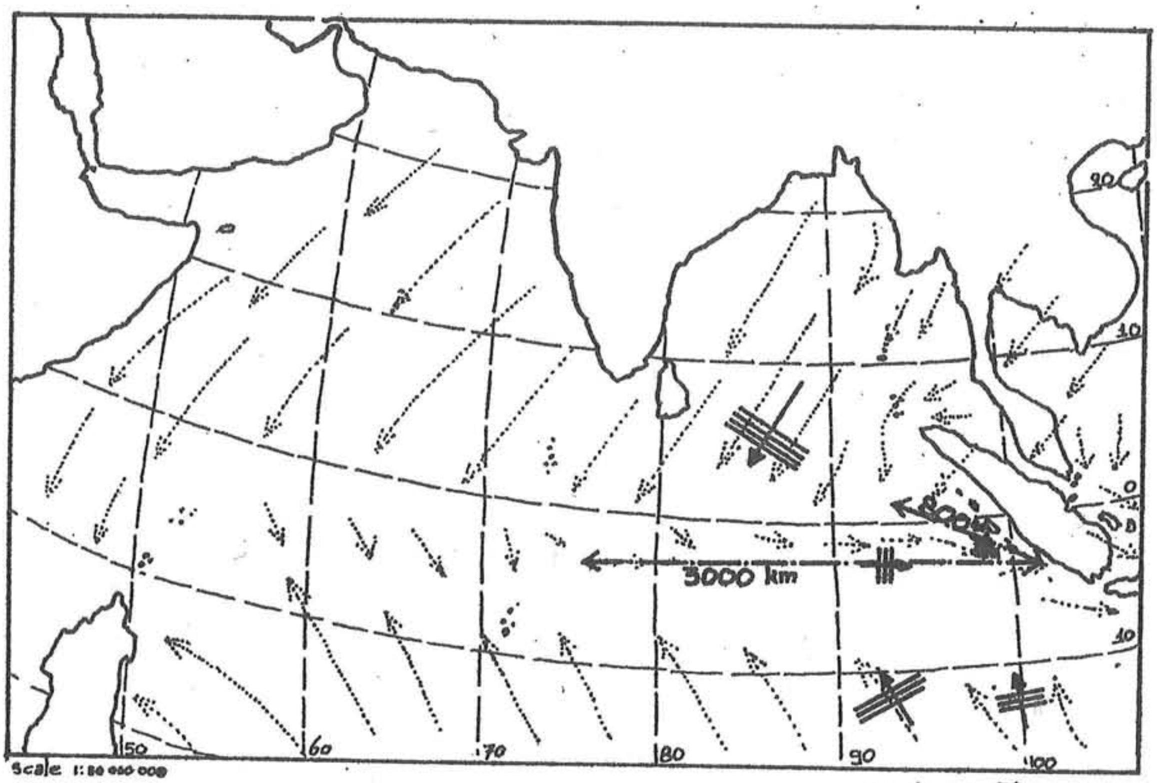
An other wind system is called "daily monsoon". During the day the land is warmer than the sea. At night the sea is warmer. Therefore by day the air flows from the sea to the land, and at night the air flows from land to sea. Local measurements show both the normal as the daily monsoon.

Wave types

As follows from the former paragraph two windsystems are present in this area. So we may expect also two types of wind waves: waves generated by the normal monsoon, and waves generated by the daily monsoon.

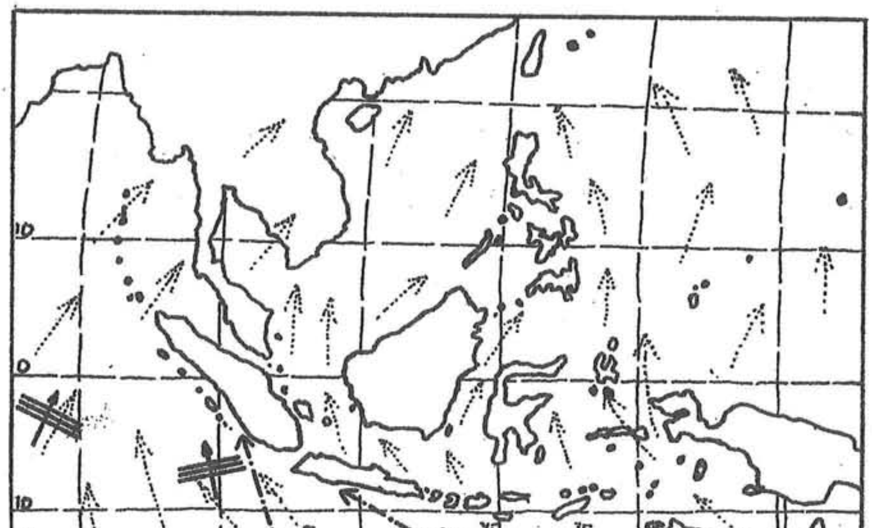
Of course also swell is possible. This swell has to be generated in the storm areas at latitude 50 °S. It is to be expected that these swell waves are low (0.5 - 1.5 m) and very long (15 sec and more). The monsoon waves will have a medium height (1.5 - 5.0 m) and period (7 - 15 sec). The daily waves will be short (3 - 7 sec). The swell waves will come from a SW direction, specially in the period between May and September (winter on the southern hemisphere). The monsoon-waves will come from SE in June-August and from NW in December-February.

The daily waves will come from W and SW, and specially in the afternoon.



Scale 1:80 000 000

Situation in January



Scale 1:60 000 000

Situation in July

·········> Prevailing winds

─╫╫╫─> Probable wave direction

<·—·—·> Fetches

In the next sections all wave types are discribed, which contribute to the wave-climate in the Bengkulu area. Before analysing and combining this information it is necessary to know for which purpose it will be used. The description of the wave climate is necessary for the calculation of:

- a breakwater. For this calculation significant wave heights of storms which are seldom exceeded (1 per 10-100 years) have to be known.
- wave heights in the harbour and on the roadstead. For this calculation wave heights have to be known which are exceeded a few times per year. During this time ships cannot be loaded or unloaded. The directions of the waves and their periods are important for this calculation. The direction is important because the entrance of the harbour and the protection of the roadstead have to be situated in such a way that the influence of waves is small. The period is important because with certain wave periods ship movements will increase heavily, due to resonance. Waves with these periods should not often enter harbour and roadstead.
- the sand transport. For this calculation the wave heights (H_{rms} = $H_{root\ mean\ square}$ = $\sqrt{(\Sigma H^2)/n}$), the directions and the periods have to be known near the breakerzone.

The different wave types have to be combined just before the breakwater, in the harbour, on the roadstead and in the breakerzone.
The waves generated by the daily winds have little influence, because their heights are very small (ca. 0.40 m). These waves may possibly be omitted from further calculation, unless their stir-factor becomes important (sand transport). Also when considerable refraction or diffraction appears, these waves could become important, because they are less refracted, resp. diffracted than the longer waves.
Also when the periods are near to the period of resonance of ships it is not allowed to omit these waves.
For the calculation of all items the distribution of the significant wave height (or H_{rms}) has to be known. This distribution has to be calculated from the distribution of two or three of the mentionned wave types. It is not allowed to add these distributions. First the distributions have to be multiplied with a weighing-factor, which is dependent from the importance of the wave type. The estimate of these weighing-factors will be made in the final report.

Swell waves

Calculation of swell waves is nearly impossible when no detailed weather information is available about the whole ocean. But it can be assumed that swell at the southcoast of Java is about the same as it is near Bengkulu (apart from nearshore effects, e.g. refraction). As can be seen on the map of the Indian Ocean, the differences in direction and distance are nearly negligible.

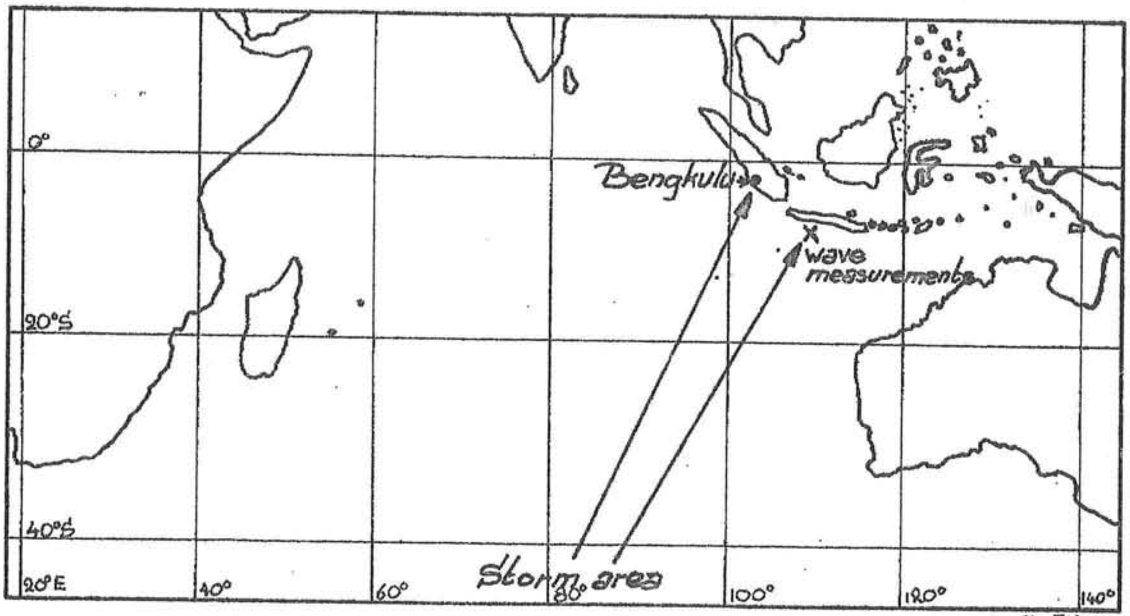


fig. 34

At the southcoast of Java two types of wave measurements are available. A continuous measurement with a Wave-Rider (three months) and data of February, April, August and December. The latter data are obtained from ships by visual observation.

It is not clear how these measurements were made. It is not mentioned in the original report. The first idea is that these are observations of merchantmen, collected by the weather-bureaus. But merchantmen observations are collected in areas, and not in specific point. The given observations are from 8°15'S/110°30'E and from 7°49'S/109°10'E.

These observations give very detailed information, e.g. waves of 15 sec and longer with a height of 60 cm were measured. Therefore it is to suppose that these observations were made from survey-vessels. In tables frequencies of wave heights, wave periods and wave directions are given.

Frequencies of wave heights are crosstabulated with directions and with periods.

direction	Significant Wave Height Groups (m)							total
	0.00 0.60	0.60 1.20	1.20 1.80	1.80 2.40	2.40 3.00	3.00 5.00	5.00 plus	
N	4.2	0.5	0.1	--	--	--	--	4.8
NE	5.7	0.9	0.2	--	--	--	--	6.8
E	13.2	3.7	2.3	1.4	1.0	0.8	0.3	22.7
SE	9.8	2.7	1.6	1.0	0.7	0.5	0.2	16.5
S	5.4	1.3	0.6	0.4	0.2	0.2	0.1	8.2
SW	7.7	1.7	0.8	0.4	0.3	0.2	0.1	11.2
W	12.9	2.7	1.4	0.7	0.5	0.3	0.1	18.6
NW	8.4	2.0	0.6	0.2	---	---	---	11.2
total	67.3	15.5	7.6	4.1	2.7	2.0	0.8	100.0

annual

table 3.1

Significant Wave Period	Significant Wave Height Groups (m)						
	0.00 0.60	0.60 1.20	1.20 1.80	1.80 2.40	2.40 3.00	3.00 5.00	5.00 plus
0 - 4 sec	57.3	34.9	20.3	10.5	5.3	2.3	0.0
5 - 6 sec	26.0	35.5	31.9	22.0	14.4	8.0	4.0
7 - 8 sec	10.7	17.2	27.1	34.3	31.6	23.9	16.9
9 - 10 sec	4.0	7.5	11.5	18.7	27.7	35.2	36.3
11 - 12 sec	1.2	2.9	5.2	8.1	11.7	16.5	24.0
13 - 14 sec	0.5	1.4	2.8	4.2	5.6	7.0	8.4
15 - 16 sec	0.2	0.4	0.8	1.4	2.1	3.9	5.4
17 + sec	0.1	0.2	0.4	0.8	1.6	3.2	5.0
total	100	100	100	100	100	100	100

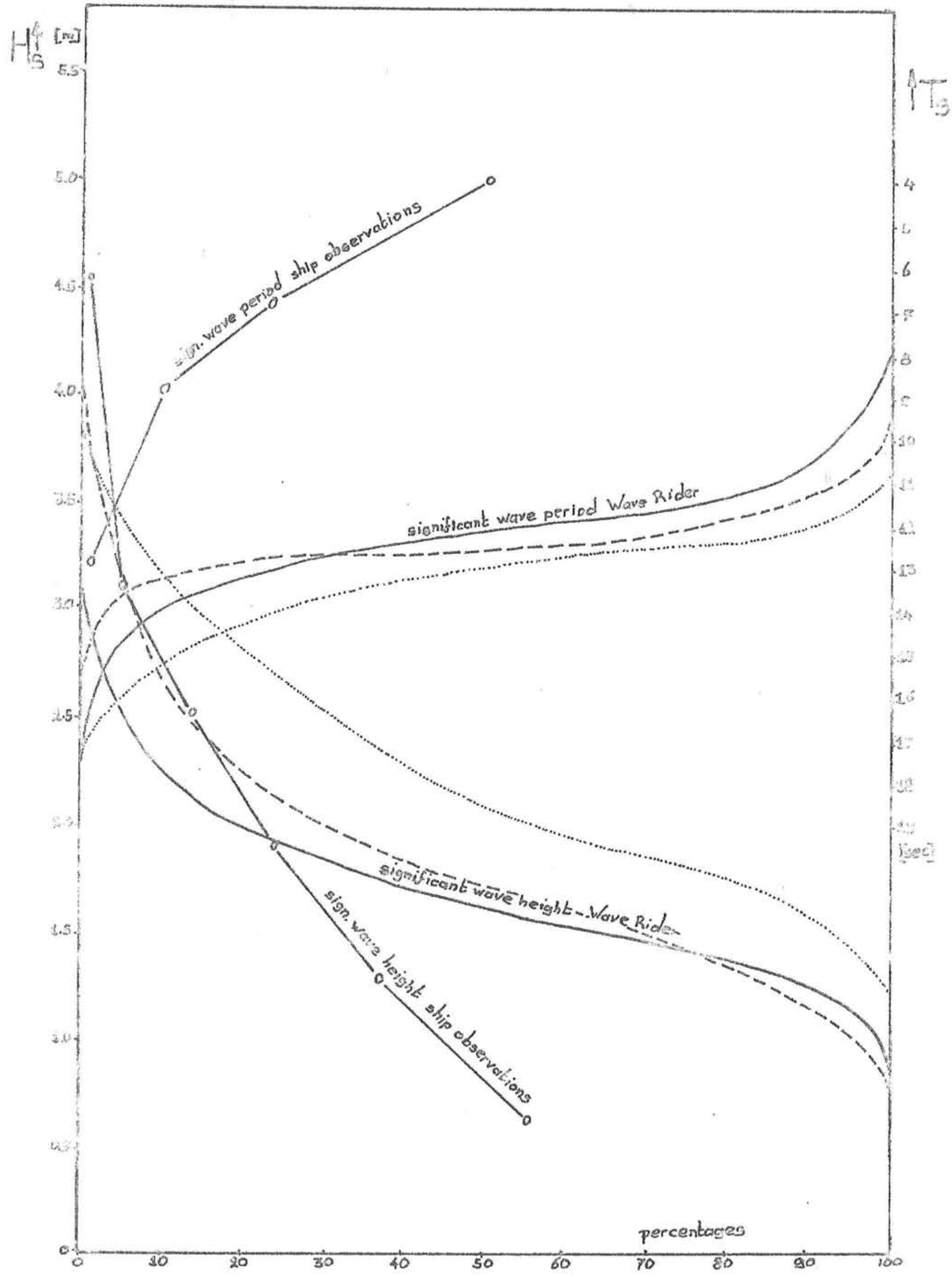
annual

table 3.2

To determine the swell a crosstabulation of periods with directions is necessary. Unfortunately this table is missing, and it is not possible to calculate this table, because the original data are missing too.

So it is necessary to analyse the available data very accurately. Also at the southcoast of Java three types of waves do exist (waves generated by local winds, by monsoon winds and by storm depressions). Only the swell from the storm depressions at 50° S is searched for. After some arithmetic it is possible to write table 3.2. in an other form. (table 3.3)

Table 3.2 gives the distribution of T_s within the distinguishable wave-height groups. Table 3.3 gives the distribution of H_s within the distinguishable wave period groups. From table 3.3 follows that the distribution of short waves differ from the distribution of long waves. This can be seen better in a graphical impression of table 3.3.(fig. 3.6)



Wave distribution south of Java

August — July ..... September ----

Fig. 3.5

Significant Wave Period	Significant Wave Height Group (m)							Total
	0.00 0.60	0.60 1.20	1.20 1.80	1.80 2.40	2.40 3.00	3.00 5.00	5.00 plus	
0 - 4 sec	82.9	11.8	3.5	1.1	0.4	0.1	--	100
5 - 6 sec	61.3	21.6	10.4	4.1	1.8	0.8	--	100
7 - 8 sec	47.4	18.0	13.8	10.1	6.5	3.8	0.4	100
9 - 10 sec	33.5	16.0	12.7	11.7	11.7	11.5	2.8	100
11 - 12 sec	26.3	13.4	12.1	11.2	11.2	12.5	13.4	100
13 - 14 sec	24.1	15.2	14.3	11.6	10.7	9.8	14.3	100
15 - 16 sec	33.3	10.3	10.3	10.3	10.3	15.4	10.3	100
17+ sec	31.8	13.6	9.1	9.1	13.6	22.7	--	100

annual

table 3.3

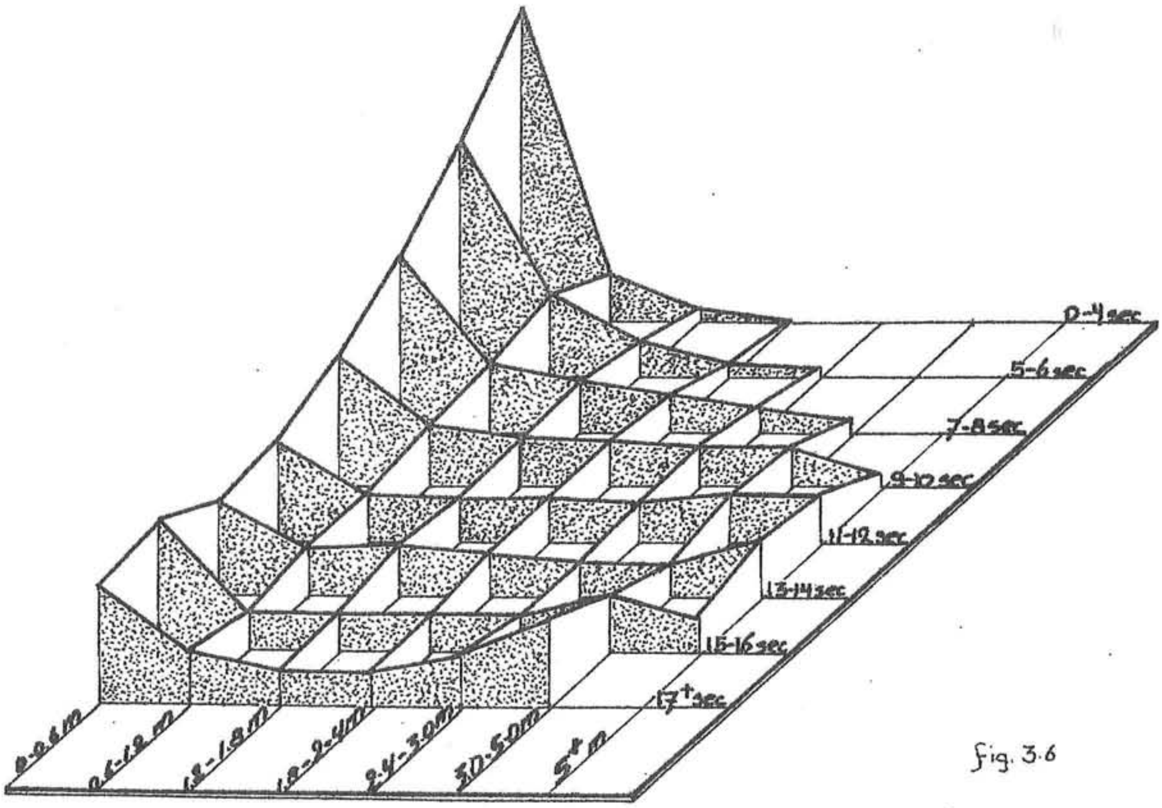


fig. 3.6

Most of the short waves are also low waves. Short, low waves are mostly wind waves, generated in the measurement area. In the distribution of long waves it is remarkable that also low, long waves exist. It is impossible that these waves are generated by monsoon or daily winds. These low waves have to be swell waves. The direction of these waves is not known, but swell waves can only come from SW.

It is not to expect that the high, long waves are swell waves too, because waves with heights between 1.2 and 2.4 m occur seldomly. It is to be expectedthat the distribution of long waves is the sum of the distribution of swell waves (with a decreasing probability of occurance when the wave height increases) and a distribution of monsoon waves (with an increasing probability of occurance when the wave height increases until 5 m).

From these tables the conclusion is that south of Java Swell waves with heights up to 1.80 m may occur, with periods of 13 - 17 sec. From these data it is not possible to estimate the probability of occurance of these waves.

When the results of these observations are compared with the data from the Wave Rider - measurements a different pattern of wave distribution becomes clear (fig. 3.5).

The difference between the two measurements is that on the ships much more small waves were measured, and in general the periods are too short. Possibly these differences are due to a systematic error in the wave measurements on the survey vessel. An other difference is that the Wave-Rider measurements are continuous measurements, observations from ships are only samples. Observation of long, low waves from a rather small vessel is extremely difficult. The large number of small waves cannot be explained very well. Perhaps not enough large waves were measured because is was not possible to measure in bad weather.

The Wave Rider measurements are very thrustworthy, even the measurements of long, low waves.

As already mentioned Wave Rider data are only available for three months, July, August and September 1971. These three months have about the same climate. In August wave height was less than it was in July and September. This can be explained as a period of relative good weather in the sea between Java and Australia in August 1971. July is known as the worst month in this region.

Wave periods in August are as long as they are in July, but longer than they are in September. In September spring starts in the southern hemisphere, and the weather gets better. So less swell is coming from SW. Also transition starts and the influence of the monsoon winds decreases.

The impression from these data is that the period of swell is 13 - 17 sec and the wave height is moderate (up to 1.5 m). This is the same conclusion as was made from the ship observations. The only diffe-

rence is that long waves occur far more often than indicated by the ship measurements.
In Bengkulu the same swell may be expected. Hence swell waves of 1 - 1.5 m and 13 - 17 sec from SW do occur, specially in July and August. In the other months swell with a shorter period and a lower wave height does occur, due to seasonal influences in the South Pole area.
For further calculation it is necessary to estimate the probability of occurance of these swell waves. It is not possible to calculate this probability In the final report will be tried to estimate this probability.

Monsoon waves

Monsoon waves are wind waves generated by a continuous wind. The speed of this wind is not extremely high, but it is a constant wind, blowing over a very long fetch.
From a detailed map of the Indonesian monsoon system (fig. 3.2b) follows that in June - August a rather constant wind comes from SE. But in the December - February monsoon winds come from several directions between N and NW.
Because in the June - August period the wind situation is quite similar to the situation at the south coast of Java, the assumption can be made that wave distribution is the same for both areas in this period.

In this period the monsoon waves propagate nearly parallel to the coast line. For the December - February period the situation is more complicated because comparision with the area south of Java is not allowed. The character of the monsoon winds near Bengkulu in December - February differ totally from those south of Java.
Only few wave measurements in open sea are available near Bengkulu. Some wave data can be found in the Oceanogrphic atlas of the world (U.S. Navy, 1976), but the number of observations is small (only 10 - 20 observations each month).
The impression is that most of the waves come from N, W and NW; wave heights vary from 1 to 3 m. It will be extremely difficult to estimate a reliable probability of occurance.

Wave data from the Bengkulu region (US NAVY, 1976)

	January						February						March					
dir.	0	1	2	3	4	tot	0	1	2	3	4	tot	0	1	2	3	4	tot
N	05					05								17				17
NE						00							13					13
E							07					07						
SE	03					03												
S	13					13		07				07	07	25				32
SW	17	07				24			21			21		02				02
W	09	18		04		31		13	21			43			07			07
NW	05	01		01		07		23				23		03				03
CALM		16				16	07					07	13	07				20
tot	47	42		05		100	14	43	43			100	40	54	07			100

	April						May						June					
dir.	0	1	2	3	4	tot	0	1	2	3	4	tot	0	1	2	3	4	tot
N							INSUFFICIENT DATA						13					13
NE	07																	
E																		
SE	29	21				50								13	12			25
S		07				07								22	06			28
SW																		
W	05					05												
NW	09					09							04					04
Calm	14	07				21								12	18			30
tot	64	36				100							18	47	35			100

	July						August						September					
dir	0	1	2	3	4	tot	0	1	2	3	4	tot	0	1	2	3	4	tot
N	INSUFFICIENT DATA																	
NE																		
E																		
SE							08	10				18		43	12	06		61
S							08	06				14		29	06			35
SW							02					02		04				04
.W							19					19						
NW							10	15				25						
Calm								23				23						
tot							46	54				100		76	18	06		100

	October						November						December					
dir	0	1	2	3	4	tot	0	1	2	3	4	tot	0	1	2	3	4	tot
N								09				09	06					06
NE													02					02
E													06					06
SE		06				06		12	12			24	02					02
S	17	06				23		12	12			24		13				13
SW		01				01		01				01		02				02
W		10	31			41		22				22			06	06		12
NW			31			31		15				15		23	02	02		27
Calm								06				06		31				31
tot	17	22	61			100		76	24			100	15	69	08	08		100

Table 3.4

Theoretically these observations include both monsoon waves and swell waves. But these observations are all visual observations from ships, and long waves are mostly not recognised from ships. A technique has to be searched to devide these observations into monsoon waves and swell waves, each with their probability of occurance.
This is necessary because swell waves and monsoon waves have different directions. Hence they induce also different longshore currents, as will be indicated in the last section of this chapter.

Daily waves

Because of the daily monsoon system, in the afternoon a wind is blowing towards the coast. The fetch is not exactly known, but is expected to be about 20 km. The influence of micro climate phenomena is never considerable. The wind velocity is about 3 - 5 m/s in April (Dwidelta 1975). This wind will generate waves of 3 seconds and 0.4 m according to Brettschneider (U.S. Army 1973). Because the daily monsoon is constant all over the year, it can be supposed that every afternoon these waves may be expected.

The influence of the islands in front of the Sumatran coast

A part of the wave energy of the waves from the Indian Ocean is dissipated on the islands in front of the coast. In the Bengkulu area waves, not influenced by refraction, can reach the coast from a SW direction. Waves from southern and western direction lose a small part of their energy on the islands.
We shall neglect the diffraction of the waves from the just mentioned directions around the islands in front of the Bengkulu coast. The wave have still to travel about 200 - 300 km from the islands to the coast, therefore we assume that the wave energy is already redistributed. The only consequence might be that long waves enter the Bengkulu area from a direction which is slightly different from the directions which should be expected without diffraction around these islands. The ocean waves which come from north-western directions have less influence in the Bengkulu area. There are two possibilities for these waves to reach the coast:

- The waves may travel through the gap between P. Pagai and P. Enggano. Because the angle between the wave - orthogonals and the coast line is very small, the influence of refraction on the shoals around these islands is negligible (see fig. 3.20)

The waves can travel between the islands and the coast with wave orthogonals parallel to the coast. Most of these waves dissipate their energy on the coast after bent to the coast by refraction. Therefore few waves from this direction reach the Bengkulu coast.

Refraction analysis

As was already mentioned wave generating winds are blowing either from NW or SE, ie. parallel to the coastline.
At sea wave orthogonals will also have about the same direction as the coastline. The period of the NW-monsoon is the worst season for the Bengkulu area. Information from literature and visitors agree that in this period loading and unloading of ships on the roadstead is extremely difficult. Waves coming from southern directions do not have any influence at all, because of the geographical position of the Bengkulu harbour. The roadstead of Bengkulu (just north of the harbour) is protected from these southern waves by some reefs west of Bengkulu (Pata Sambilan). Because of these reefs waves from west and south-west cannot reach Bengkulu harbour either. The Bengkula

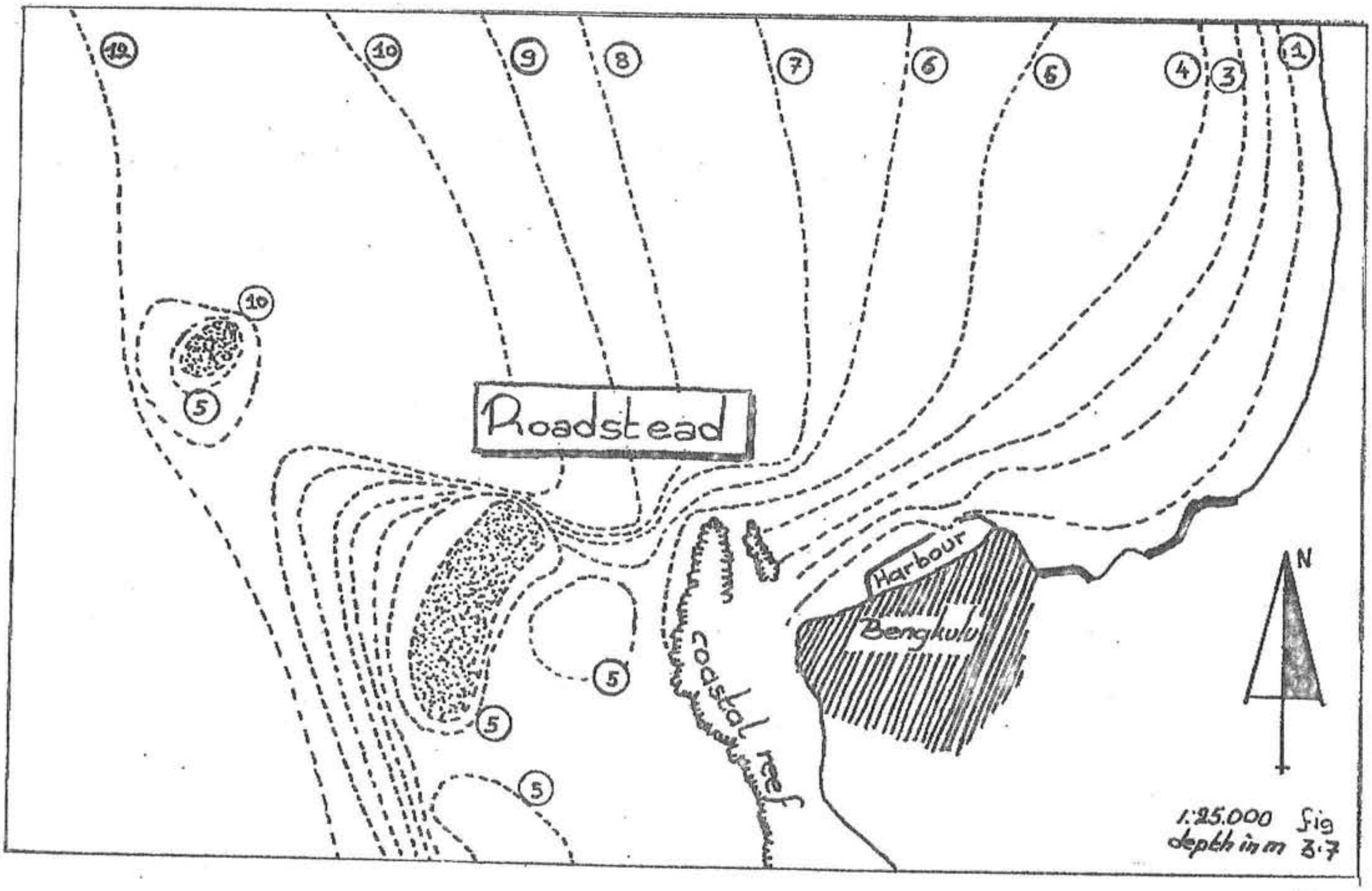


fig 3.7

roadstead has no protection against these waves. Both harbour and roadstead are not protected against waves from northern directions. The coastline north of Bengkulu until Pasar Seblat has a direction of 305° (see fig. 3.8). So waves may come from this or a more westward direction. Bathymetrics show that waves from 295° to 305° hardly will be refracted to the Bengkulu area. These waves will reach the coast either north of Laïs or south of Pasar Ngalami. Waves with directions between 285° and 295° have a maximum fetch of 200 km. From the south the limitation is 150°. Waves from a more eastward direction will have no influence in the Bengkulu area. The influence of the Enggano isle (at 150 km, 170°-190°) is expected to be small.

The monsoon cannot generate very long waves; the wind speed is not high enough. But swell waves with a period of 15 sec do occur regularly. This swell has to be generated in regions near the South Pole. So swell waves will come to the Bengkulu coast from directions between 200° and 250°. These waves will hardly refract because they reach the coast nearly perpendicular to the depth-contours.

Refraction analysis was carried out for waves with period of 7, 10 and 15 seconds. Small scale diagrams show that the influence of the depth contours until the 10 m line is small for a 7 sec wave. From fig. 3.9 follows that 7 sec waves cross the 10 m line with directions between 190° and 280°. More detailed information is given in fig. 3.10 and 3.11. Because of the shoal west of Bengkulu only waves with directions between 240° and 280° are important. On these diagrams also waves from 290° and 300° are indicated. As mentioned before, these waves have no long fetch, and are therefore less important.

Only waves between 270° and 300° may enter the harbour. Waves from a more southern direction pass the harbour entrance and reach the coast more eastward. This area, just east of the harbour is always influenced by waves, without regard to the direction they originally came from.

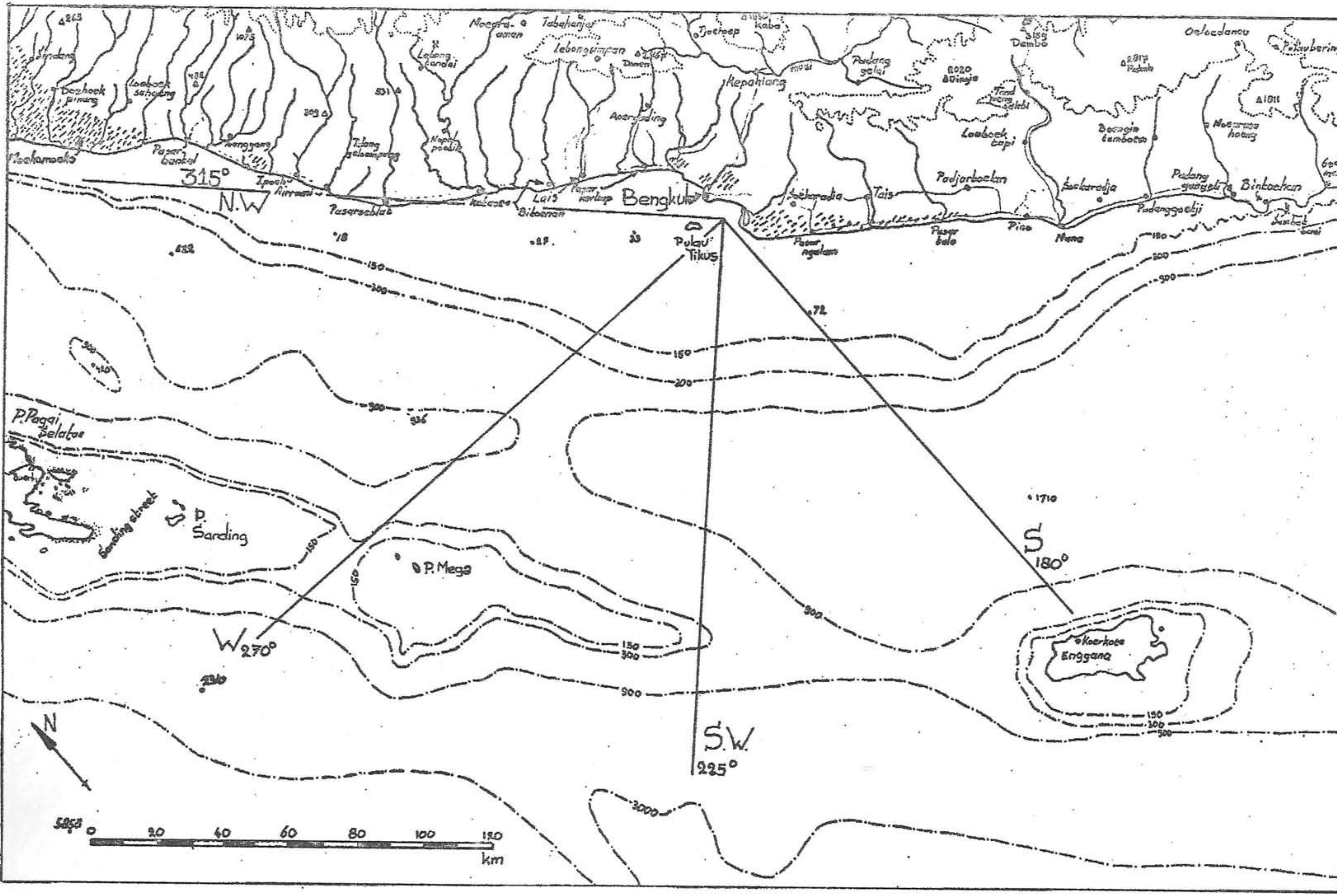
Refraction of longer waves is of course more important. From the dtailed diagrams 3.13 and 3.14 can be concluded that only waves from the NW monsoon may enter the harbour. The refraction coefficents are small, thus wave height is reduced very much.

From these diagrams refraction coefficients can be calculated for Bengkulu harbour and Pulau Bay (near Tanjung Kerbau).

site	direction of incoming wave	refraction coefficients		
		7 sec	10 sec	15 sec
Bengkulu Harbour	285°	0.63	0.50	0.32
	270°	0.56	0.50	--
Pulau Bay	285°	0.70	0.60	0.52
	270°	0.58	0.54	0.50

table 3.5

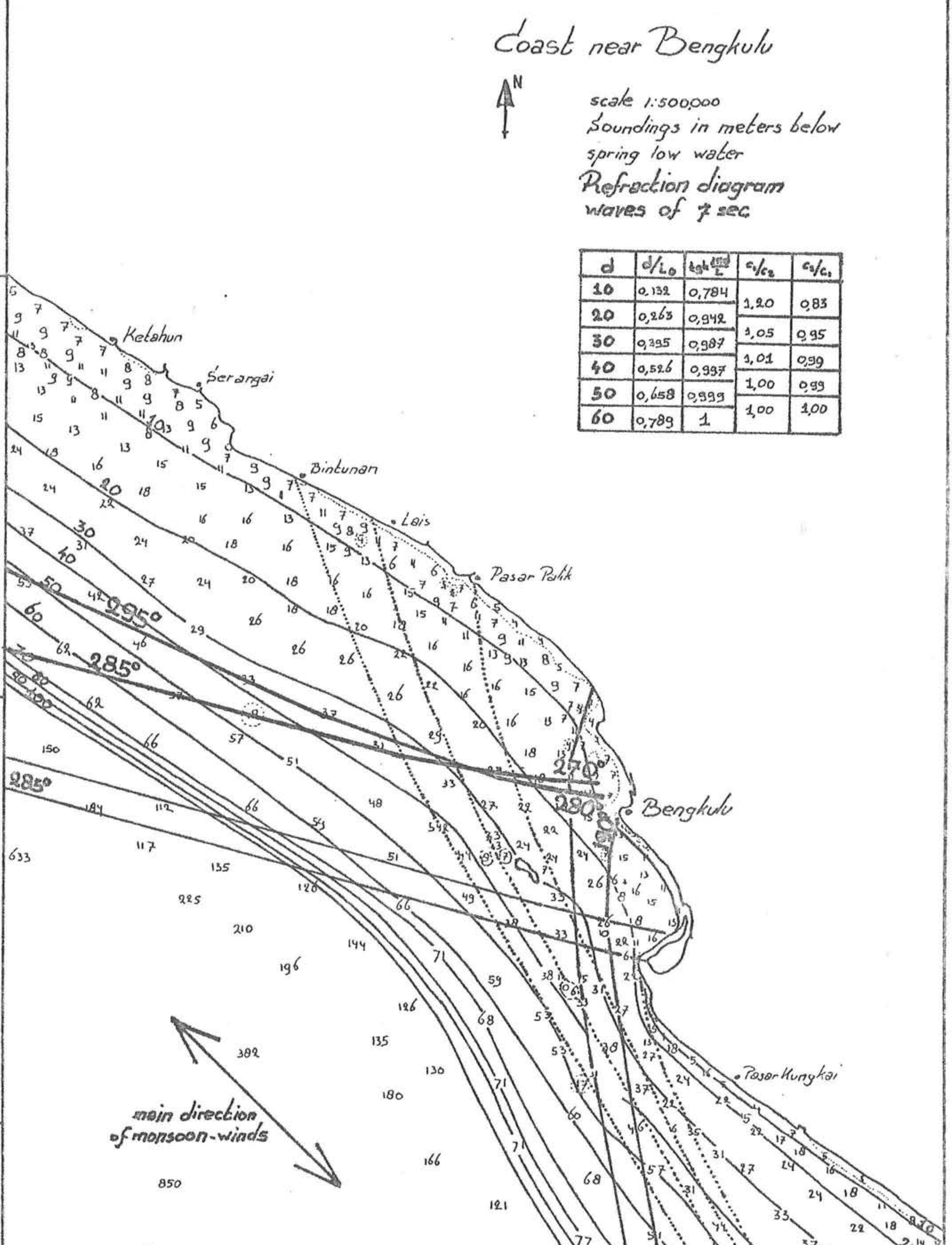
For waves coming from 180° - 270° K_r is less than 0.50. Exact calculation is difficult. It is to suppose K_r is 0.40.



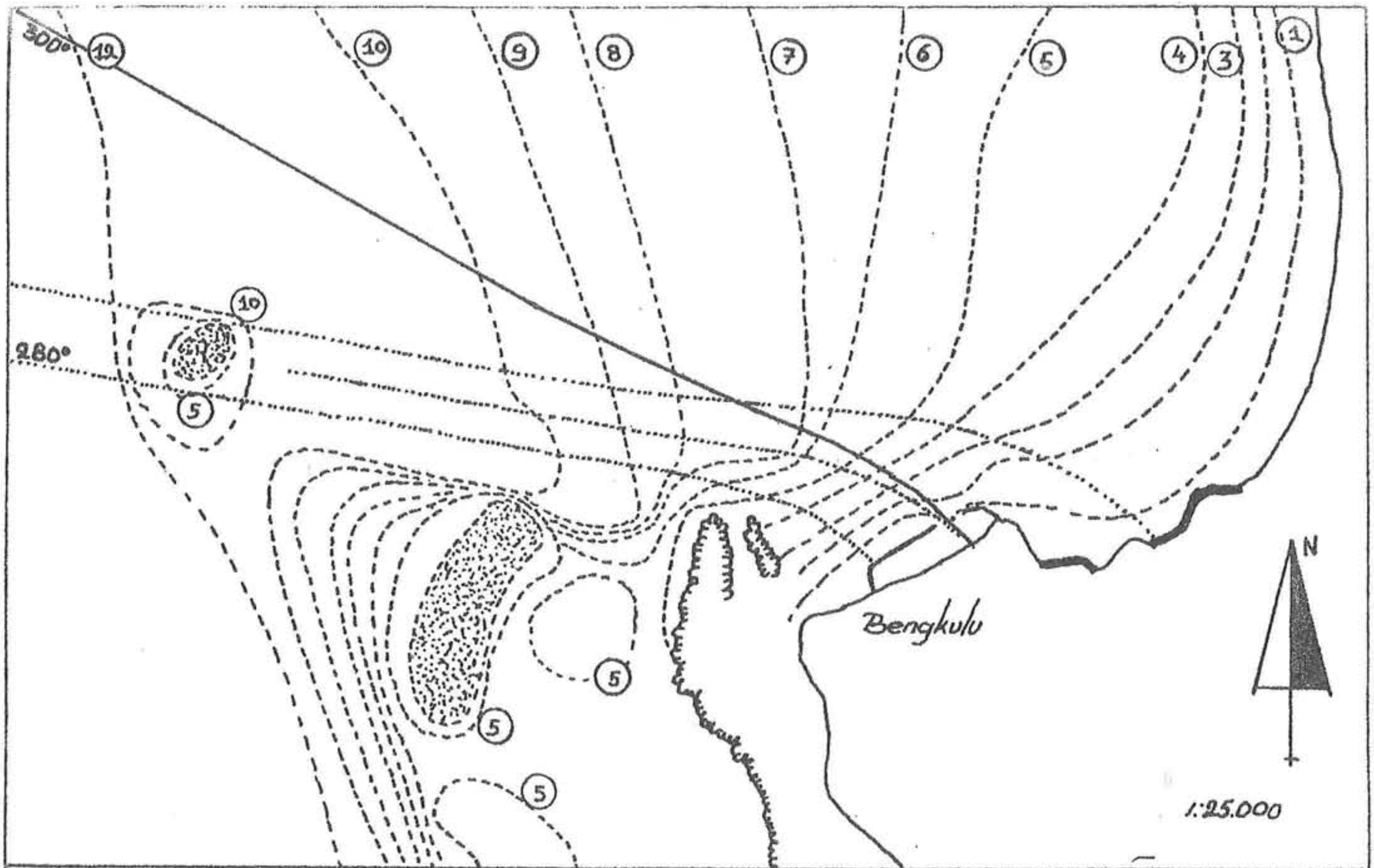
Bengkulu
Pulau Tikus
N.W 315°
W 270°
S.W. 225°
S 180°
P. Pagai Selatan
P. Sarding
P. Mega
Koerkoe
Enggano
Kepahiang
Tais
Padjarboelan
Seloeradja
Padang gegeti
Bintoehan
Pasar bantal
Pasarseblat
Lais
Pasar bale
Pino
Mana
Padanggoetji
Moekomoeko
Lebongsimpan
Tabahanjar
Tjoerop
Kaba
Oeloedanau
Dambo
N
0
20
40
60
80
100
120
km
150
200
300
900
3000
1710

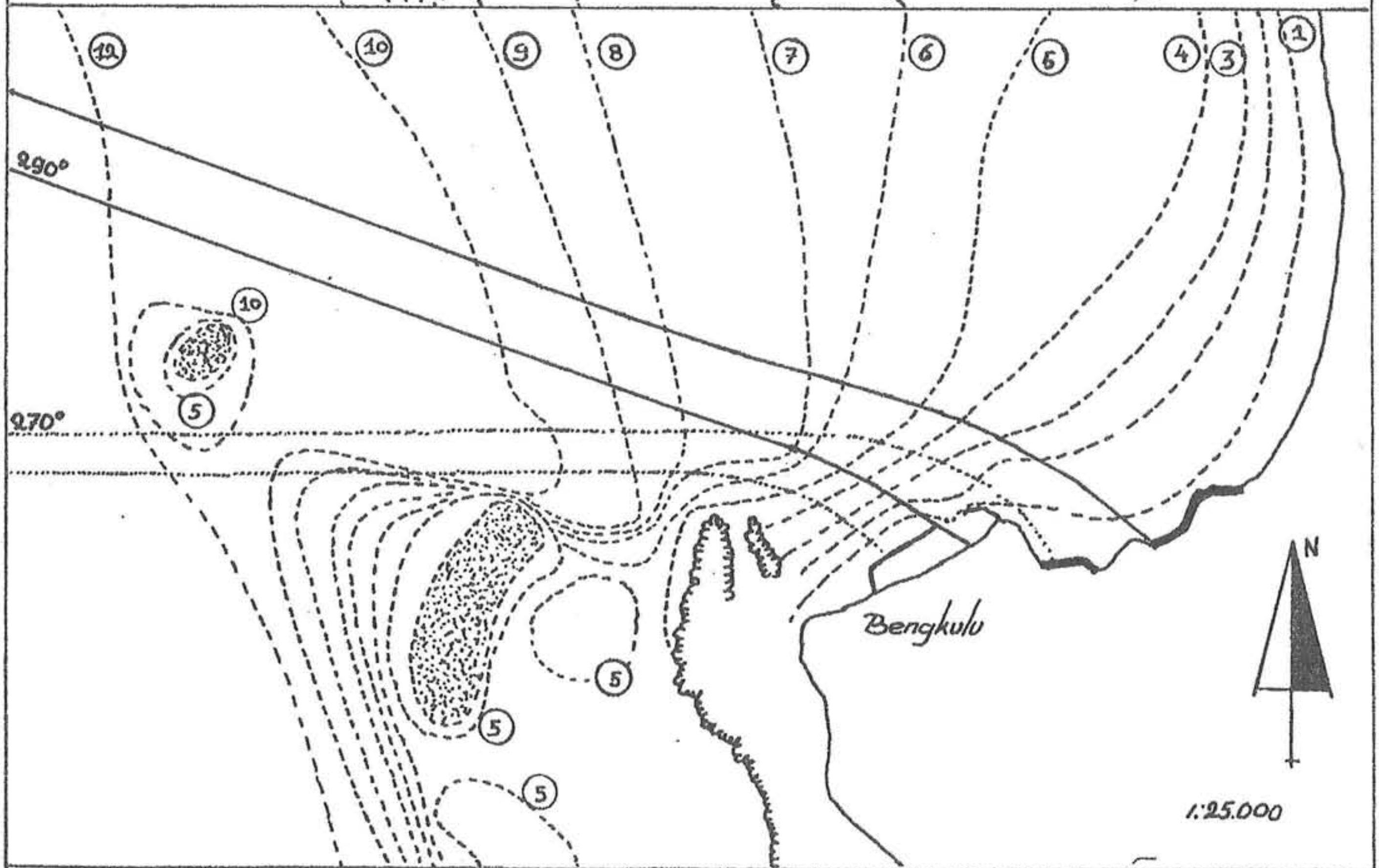
Fig. 3.8

Fig 3.9



d	d/L₀	tgh 2πd/L	c₁/c₂	c₂/c₁
10	0,132	0,784	1,20	0,83
20	0,263	0,942	1,05	0,95
30	0,395	0,987	1,01	0,99
40	0,526	0,997	1,00	0,99
50	0,658	0,999	1,00	1,00
60	0,789	1		





d	d/L_0	$tgh\frac{2\pi d}{L}$	c_1/c_2	c_2/c_1
1	0,013	0,282		
2	0,026	0,393	1,39	0,72
3	0,039	0,475	1,21	0,83
4	0,053	0,545	1,15	0,87
5	0,066	0,599	1,10	0,91
6	0,079	0,646	1,08	0,93
7	0,092	0,687	1,06	0,94
8	0,105	0,723	1,05	0,95
9	0,118	0,754	1,04	0,96
10	0,132	0,784	1,04	0,96

Refraction diagrams
Bengkulu harbour

Wave period 7 sec $L_0 = 76$ m

fig 3·10

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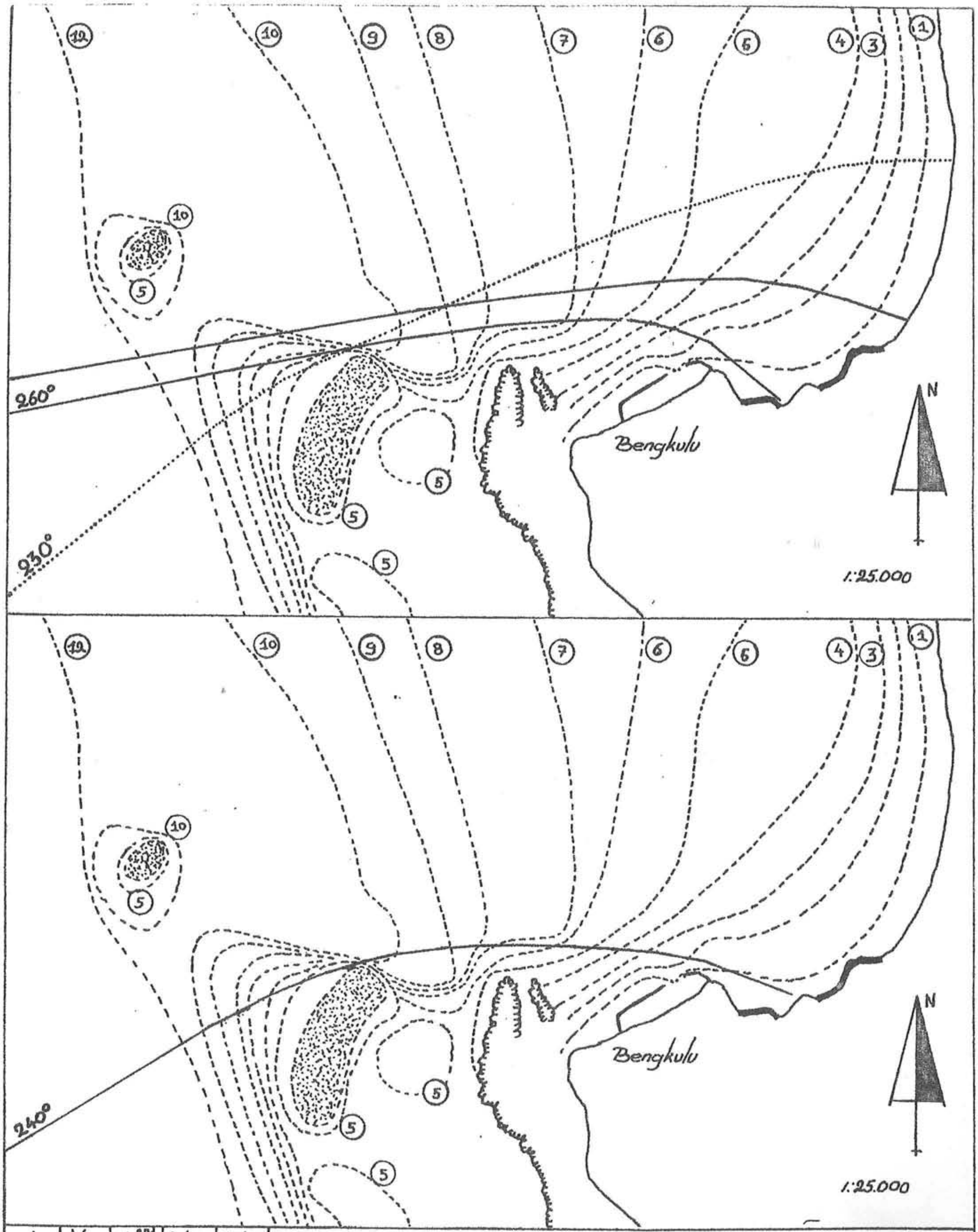

d	d/L_o	$tgh\frac{2\pi d}{L}$	c_1/c_2	c_2/c_1
1	0,013	0,282	1,39	0,72
2	0,026	0,393	1,21	0,83
3	0,039	0,475	1,15	0,87
4	0,053	0,545	1,10	0,91
5	0,066	0,599	1,08	0,93
6	0,079	0,646	1,06	0,94
7	0,092	0,687	1,05	0,95
8	0,105	0,723	1,04	0,96
9	0,118	0,754	1,04	0,96
10	0,132	0,784		

Refraction diagrams
Bengkulu harbour

Wave period 7 sec $L_o = 76$ m

Fig 3.11

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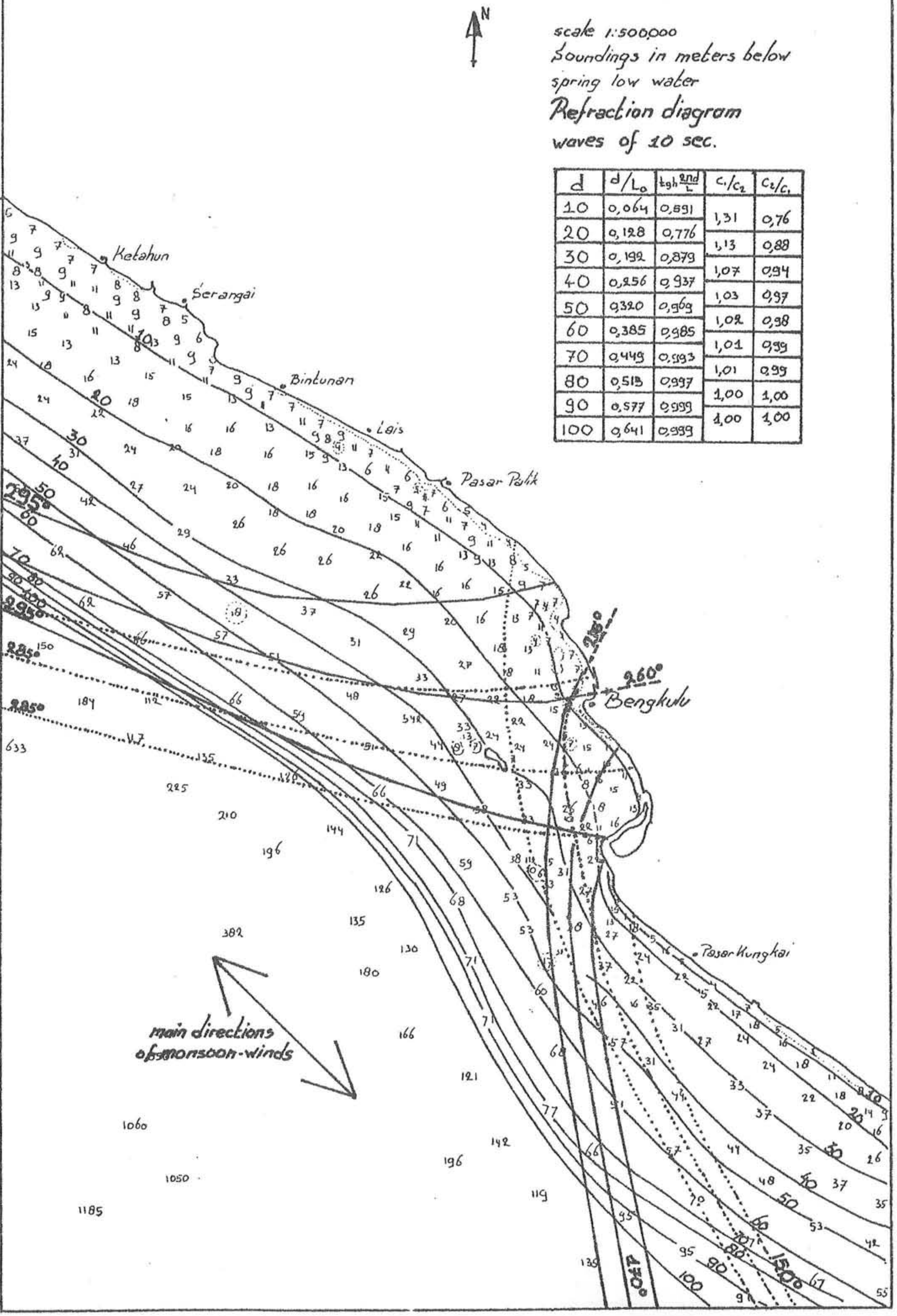
Fig 3.12

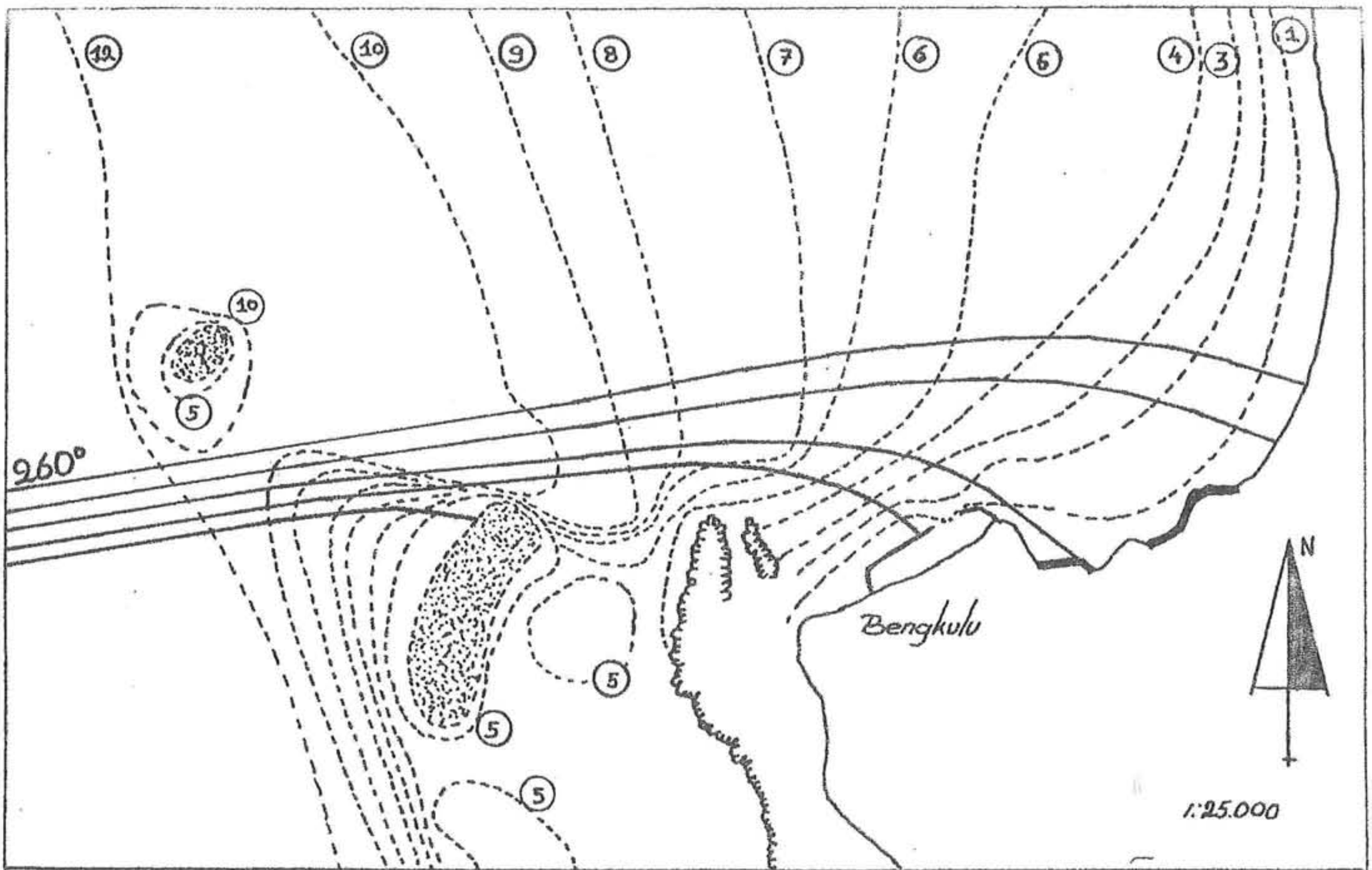
Coast near Bengkulu

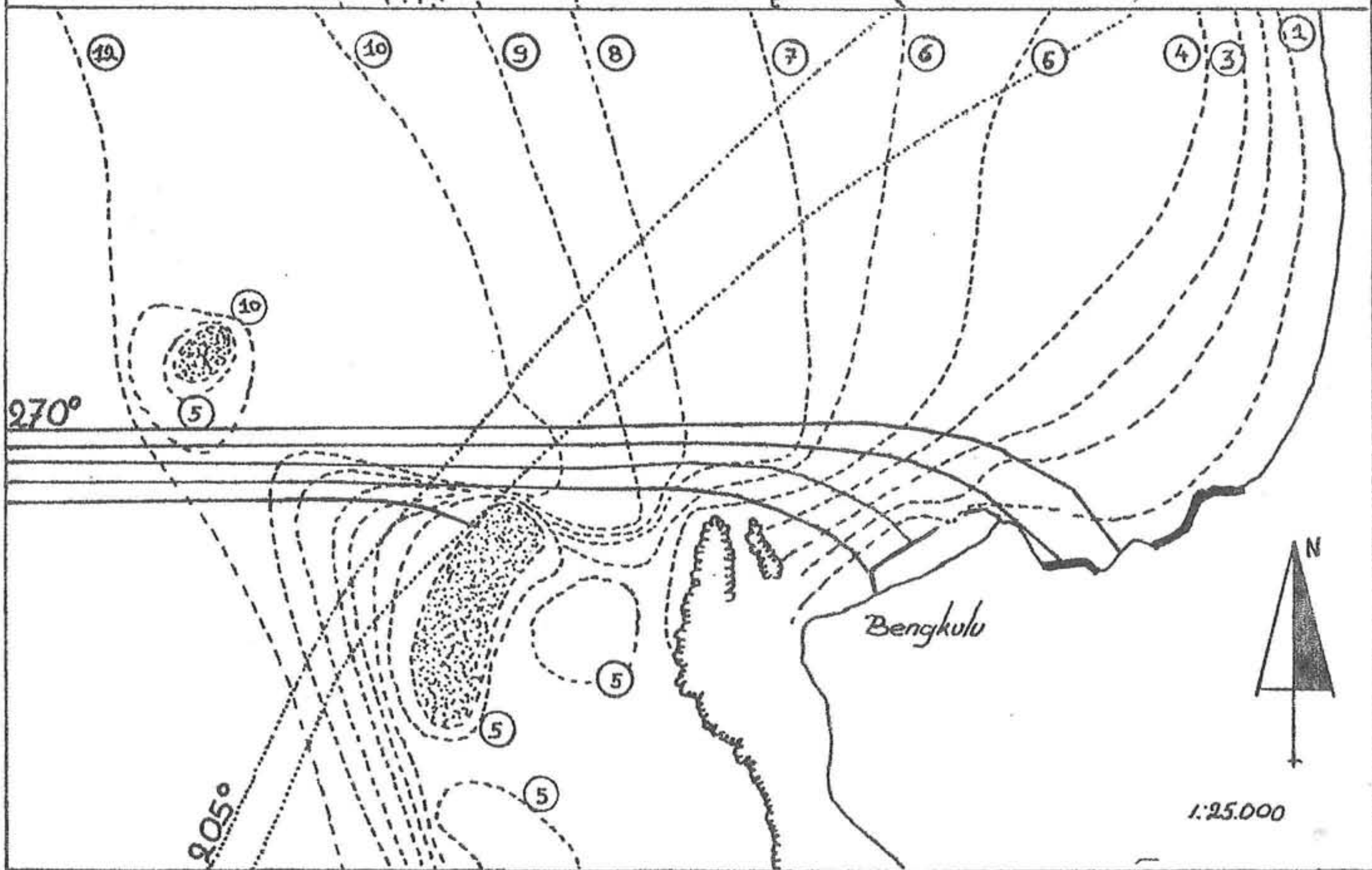
scale 1:500000
Soundings in meters below spring low water

Refraction diagram
waves of 10 sec.

d	d/L_0	$tgh\frac{2\pi d}{L}$	c_1/c_2	c_2/c_1
10	0,064	0,891	1,31	0,76
20	0,128	0,776	1,13	0,88
30	0,192	0,879	1,07	0,94
40	0,256	0,937	1,03	0,97
50	0,320	0,969	1,02	0,98
60	0,385	0,985	1,01	0,99
70	0,449	0,993	1,01	0,99
80	0,513	0,997	1,00	1,00
90	0,577	0,999	1,00	1,00
100	0,641	0,999		







d	d/L_0	$tgh\frac{2\pi d}{L}$	c_1/c_2	c_2/c_1
1	0,0064	0,199	1,42	0,70
2	0,0128	0,282	1,20	0,83
3	0,019	0,339	1,16	0,86
4	0,026	0,393	1,10	0,91.
5	0,032	0,433	1,08	0,92
6	0,038	0,469	1,08	0,93
7	0,045	0,507	1,06	0,94
8	0,051	0,536	1,06	0,94
9	0,058	0,567	1,04	0,96
10	0,064	0,591		

Refraction diagrams
Bengkulu harbour

Wave period 10 sec $L_o = 156m$

fig. 3.13

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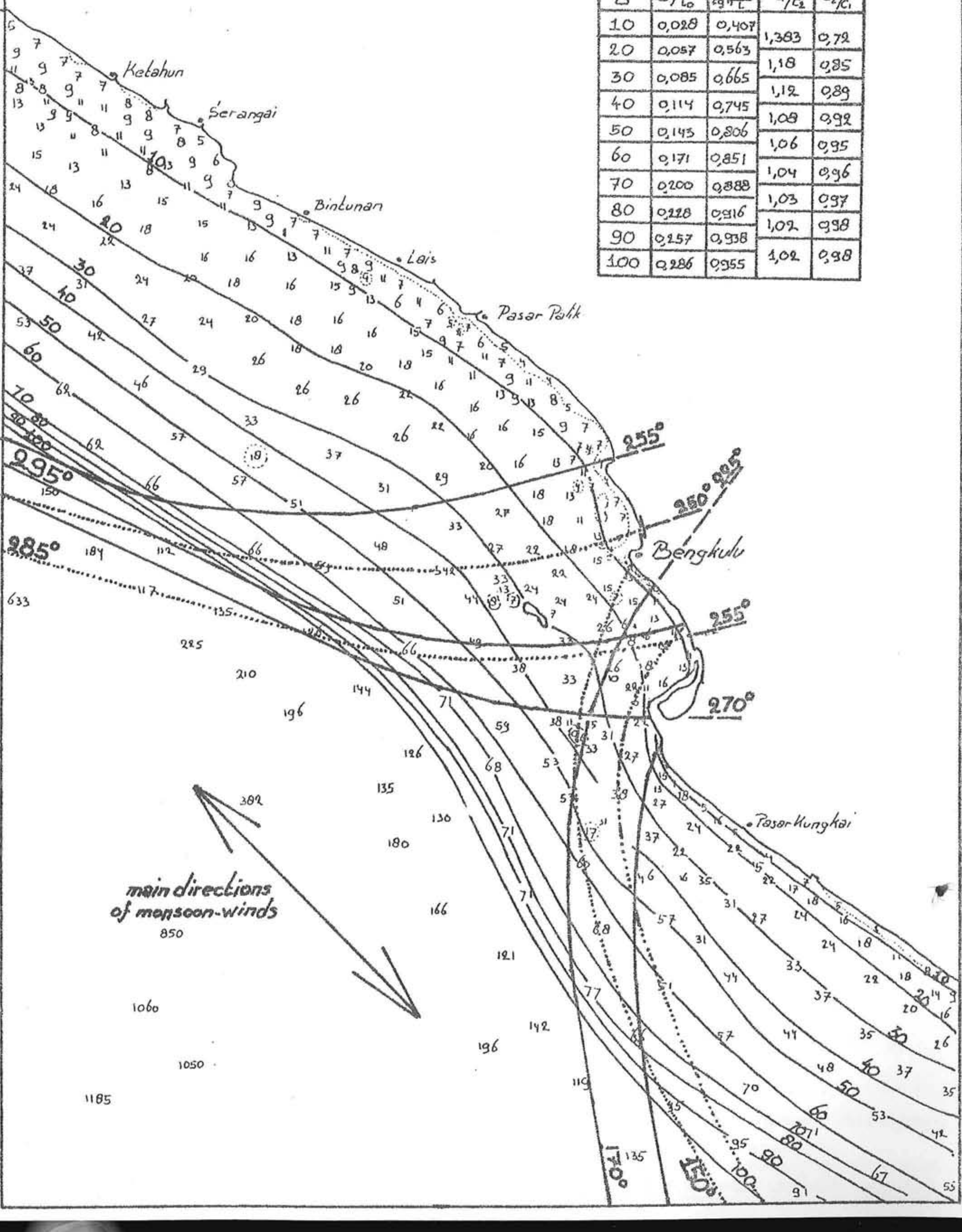
Fig 3.14

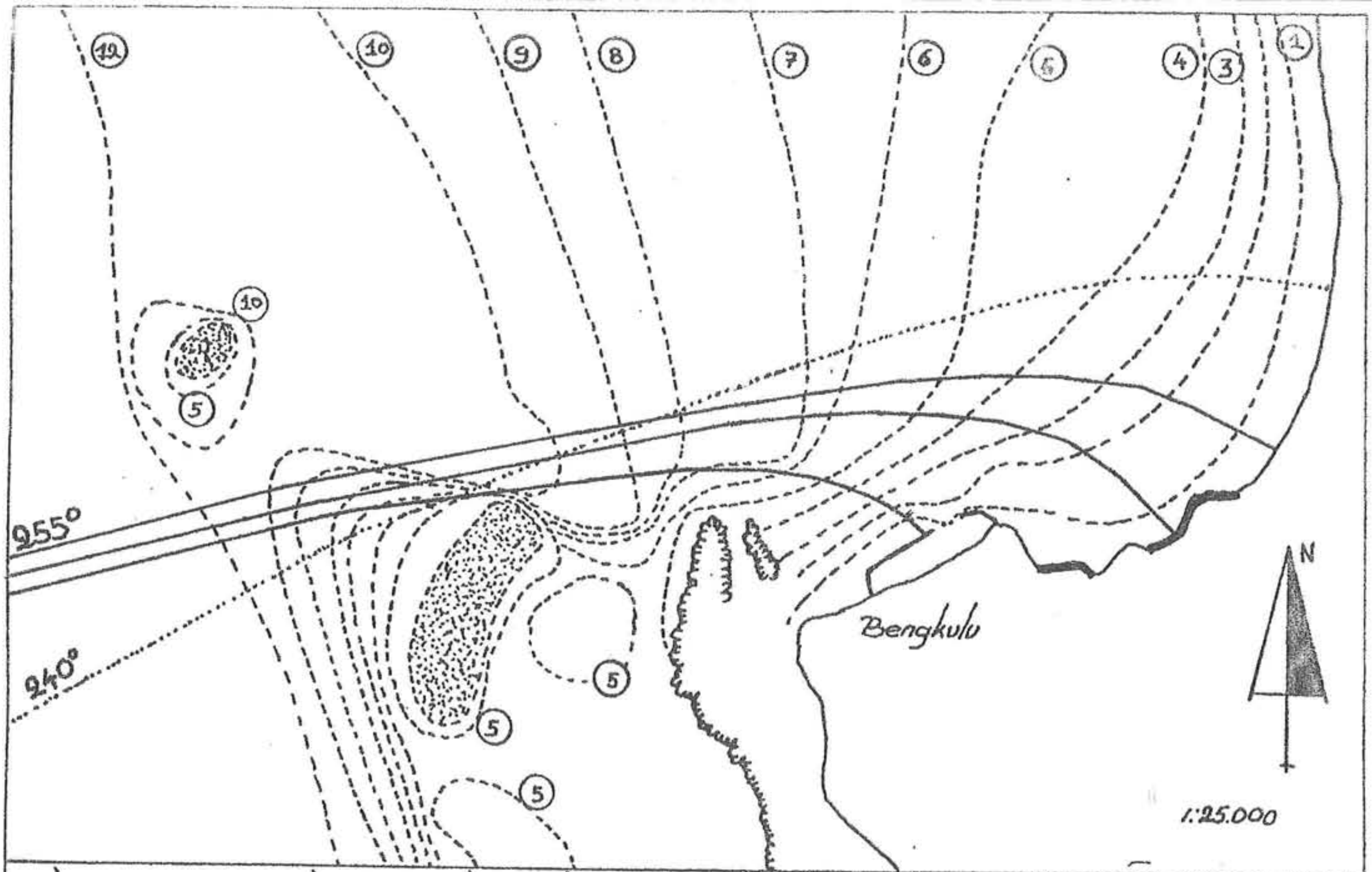
Coast near Bengkulu

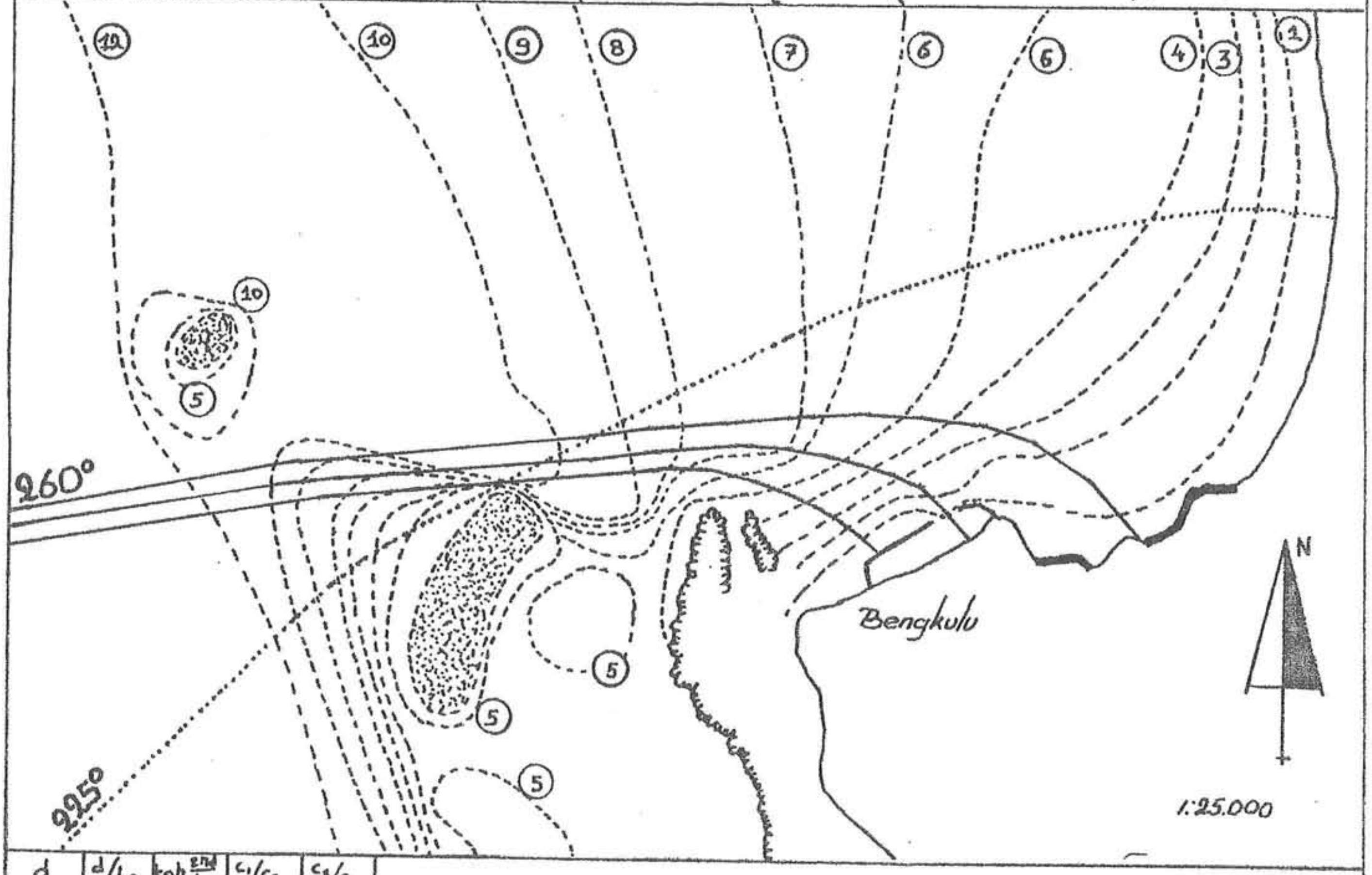
scale 1:500.000
Soundings in meters below spring low water

Refraction diagram
waves of 15 sec.

d	d/L₀	tgh 2πd/L	c1/c2	c2/c1
10	0,028	0,407		
20	0,057	0,563	1,383	0,72
30	0,085	0,665	1,18	0,85
40	0,114	0,745	1,12	0,89
50	0,143	0,806	1,08	0,92
60	0,171	0,851	1,06	0,95
70	0,200	0,888	1,04	0,96
80	0,228	0,916	1,03	0,97
90	0,257	0,938	1,02	0,98
100	0,286	0,955	1,02	0,98







d	d/L₀	tgh 2πd/L	c₁/c₂	c₂/c₁
1	0,0028	0,132		
			1,42	0,702
2	0,0057	0,188		
			1,59	0,629
3	0,0085	0,229		
			1,14	0,881
4	0,0114	0,260		
			1,12	0,890
5	0,014	0,292		
			1,10	0,909
6	0,017	0,321		
			1,08	0,925
7	0,020	0,347		
			1,07	0,935
8	0,023	0,371		
			1,06	0,944
9	0,026	0,393		
10	0,029	0,414	1,05	0,949

Refraction diagrams
Bengkulu harbour

Wave period 15 sec $L_o = 350$ m

fig 3·15

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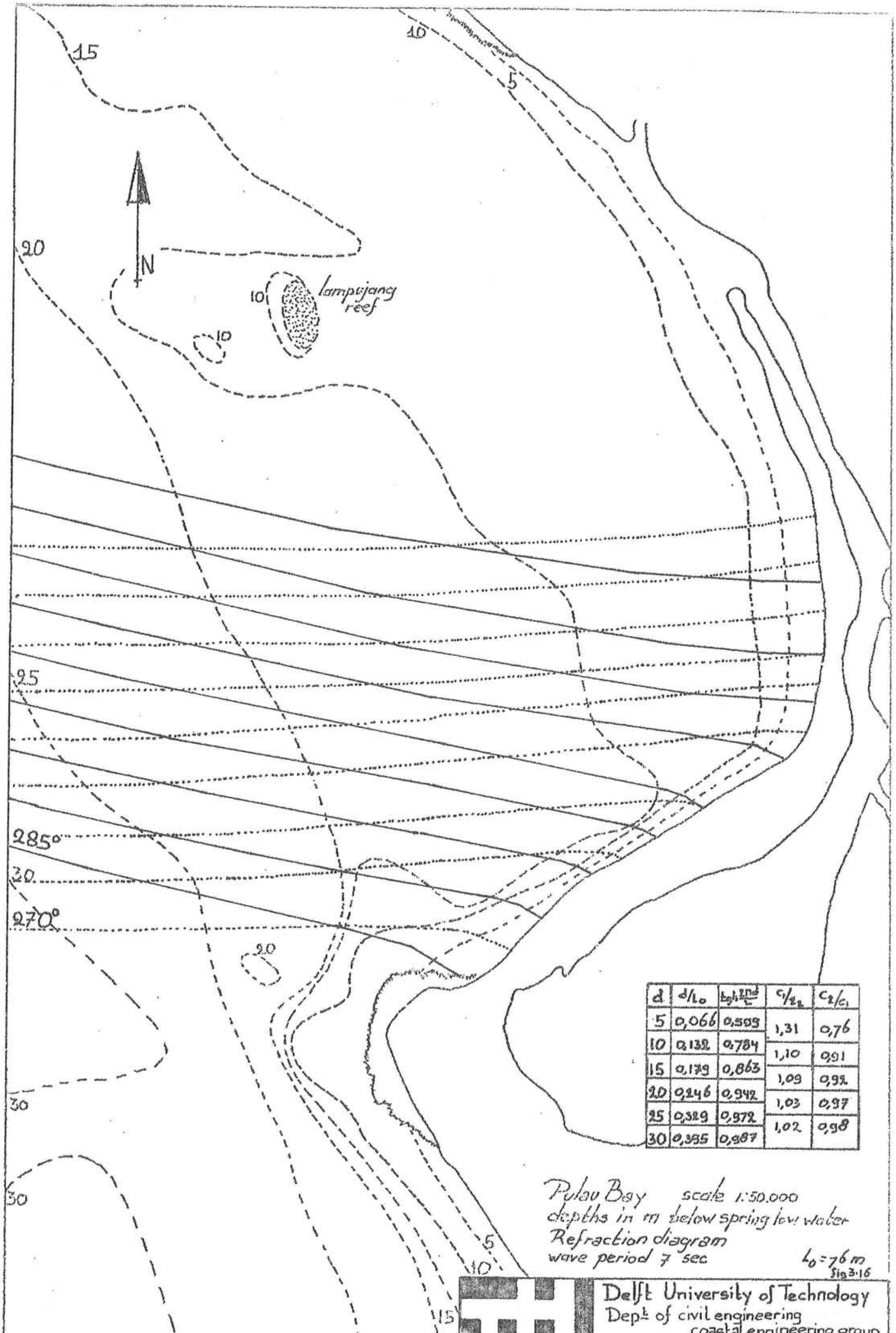

d	d/L_0	$tgh \frac{2\pi d}{L}$	c_1/c_2	c_2/c_1
5	0,066	0,509	1,31	0,76
10	0,132	0,784	1,10	0,91
15	0,179	0,863	1,09	0,92
20	0,246	0,942	1,03	0,97
25	0,329	0,972	1,02	0,98
30	0,395	0,987		

Pulau Bay scale 1:50.000
depths in m below spring low water
Refraction diagram
wave period 7 sec
$L_0 = 76$ m
fig 3.16

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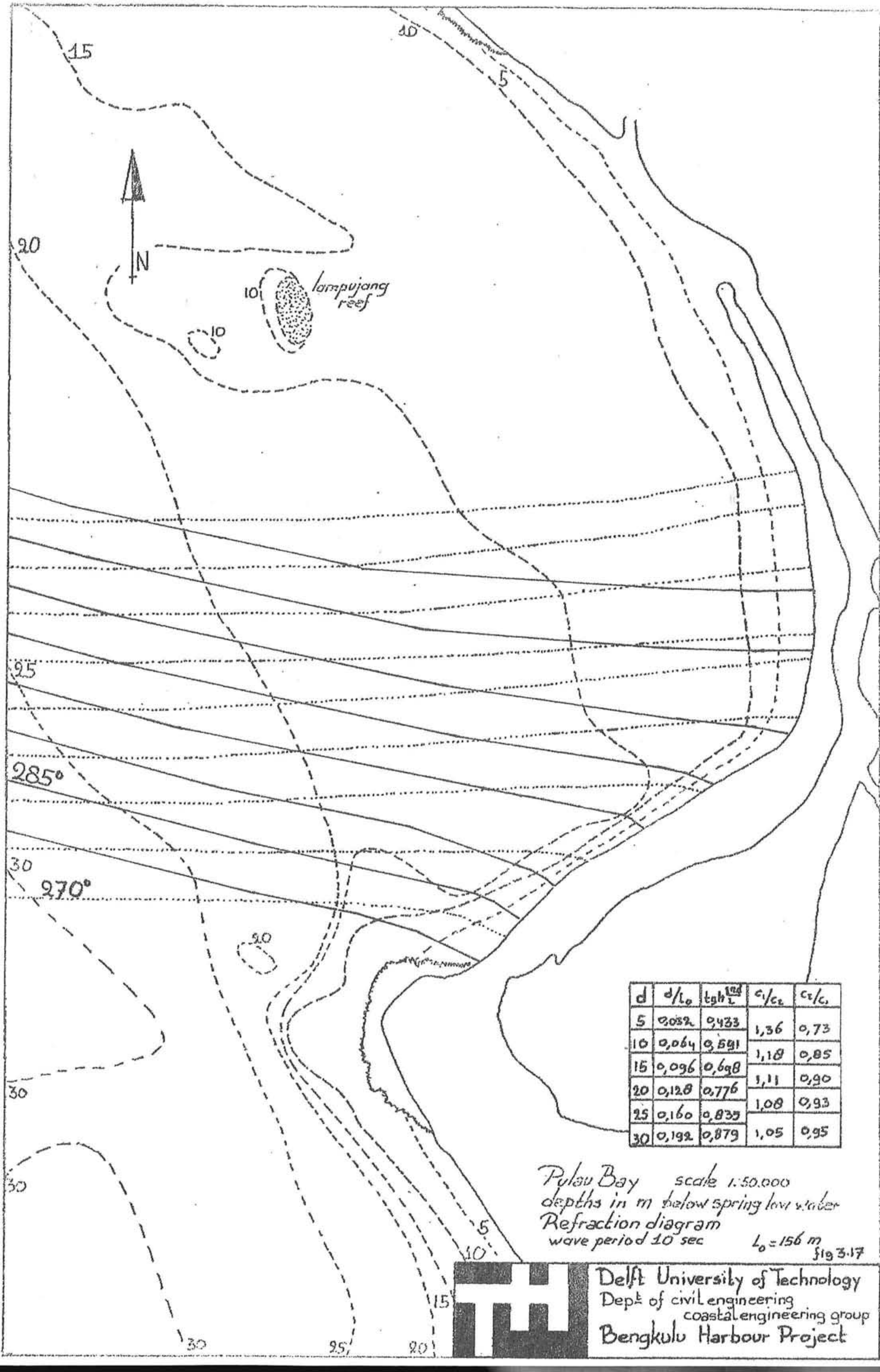

d	d/L_o	$tgh\frac{2\pi d}{L}$	c_1/c_2	c_2/c_1
5	0,032	0,433		
			1,36	0,73
10	0,064	0,591		
			1,18	0,85
15	0,096	0,698		
			1,11	0,90
20	0,128	0,776		
			1,08	0,93
25	0,160	0,835		
			1,05	0,95
30	0,192	0,879		

Pulau Bay scale 1:50.000
depths in m below spring low water
Refraction diagram
wave period 10 sec $L_o = 156$ m
fig 3.17

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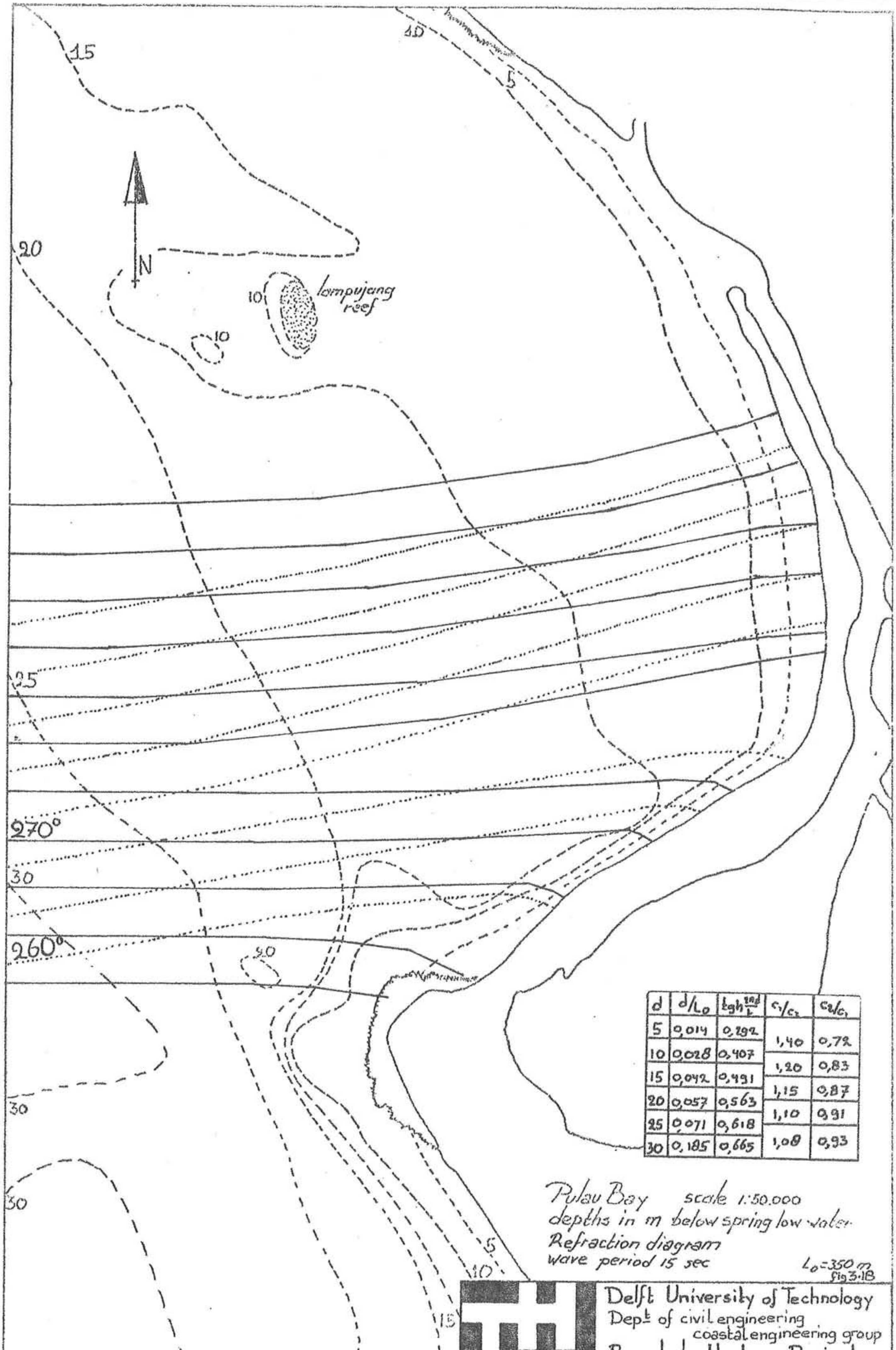

d	d/L_0	$\tanh \frac{2\pi d}{L}$	c_1/c_2	c_2/c_1
5	0,014	0,292	1,40	0,72
10	0,028	0,407	1,20	0,83
15	0,042	0,491	1,15	0,87
20	0,057	0,563	1,10	0,91
25	0,071	0,618	1,08	0,93
30	0,185	0,665		

Pulau Bay scale 1:50.000
depths in m below spring low water
Refraction diagram
wave period 15 sec

$L_0 = 350$ m
fig 3.1B

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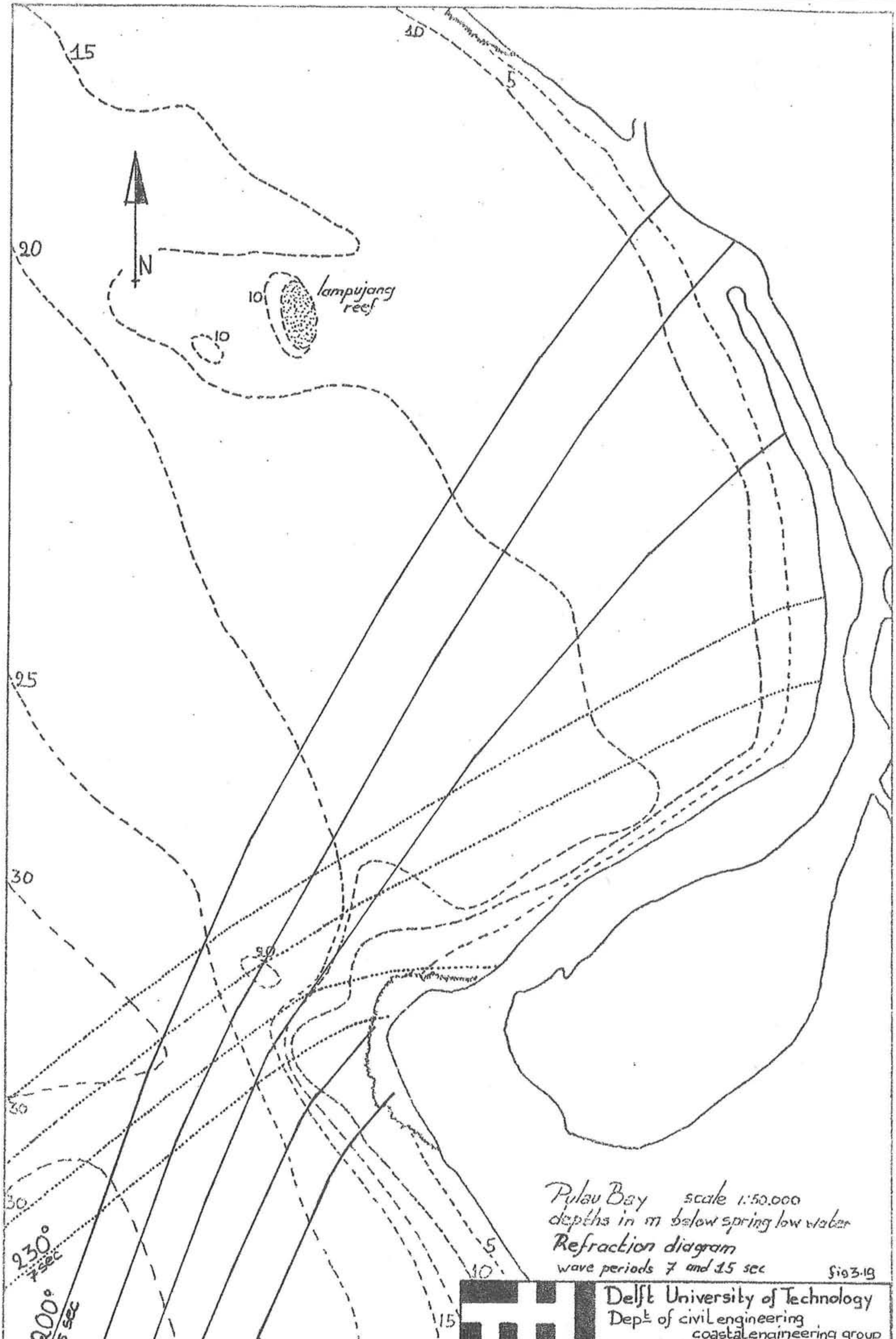

Pulau Bay scale 1:50.000
depths in m below spring low water
Refraction diagram
wave periods 7 and 15 sec
fig 3.19

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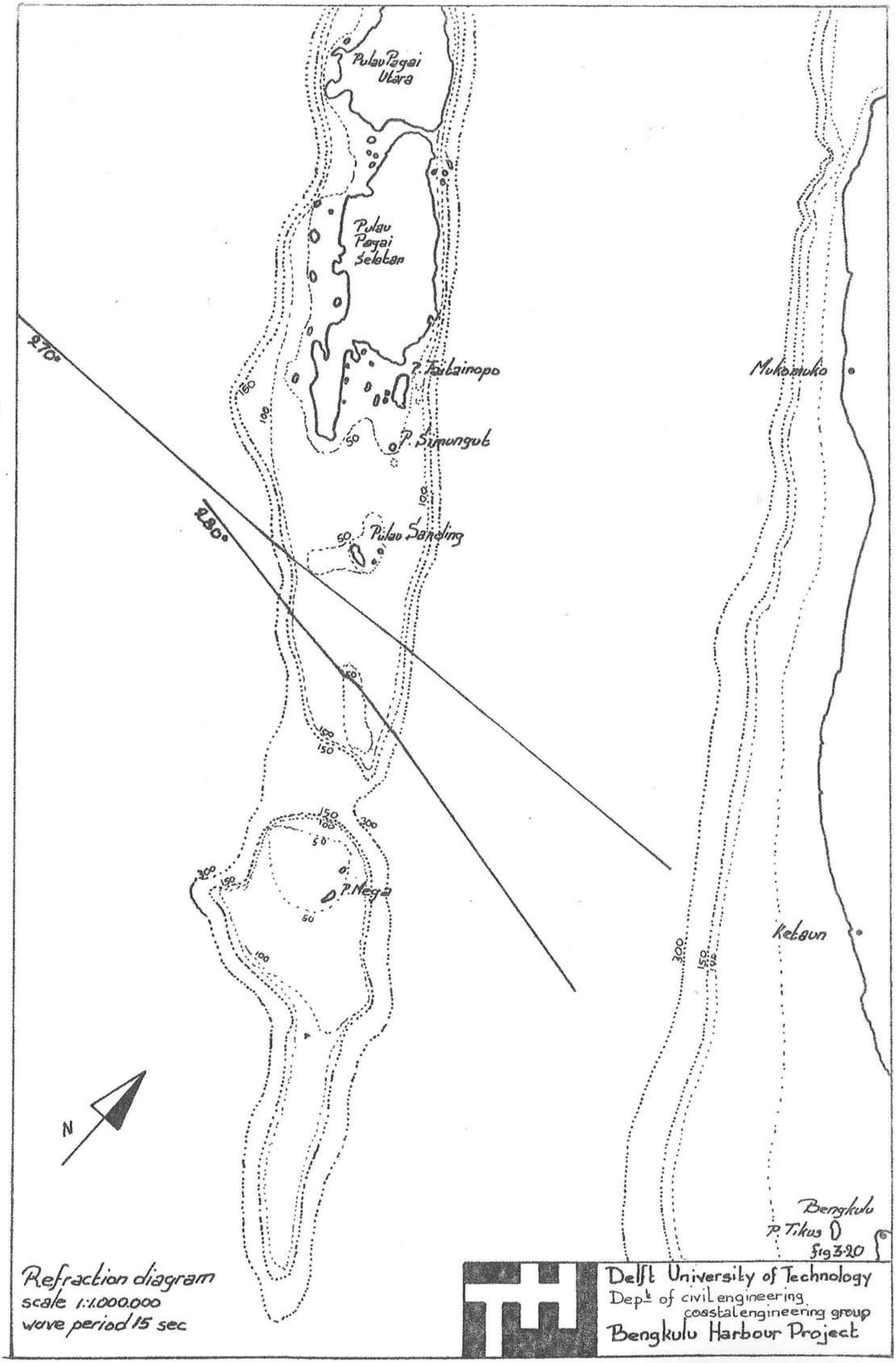
Pulau Pagai Utara
Pulau Pagai Selatan
Pulau Sanding
P. Nega
Mukomuko
Ketaun
Bengkulu
P. Tikus
270°
280°
N
fig 3.20
Refraction diagram
scale 1:1.000.000
wave period 15 sec
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4. Morphology of the Bengkulu coast

Morphology can be studied from the available charts, but also from aerial and satellite photographs. We had the opportunity to study a satellite-picture of this area, made by Landsat I in June 1973. We had four prints, each from a different part of the electromagnetic spectrum. We had two infra-red photos, one from the green part of the spectrum and a photo from the yellow part of the spectrum. The yellow print gives about the same impression as a panchromatic picture. On the green print submerged banks can be seen. On the infra-red ones the difference between land and water becomes clear. From this picture we have made a morphological map of the coast (fig.4.2) and a detailed sketch of the mouth of the Air Teluk (fig. 4.5).

From the wave refraction analysis follows that monsoon waves enter the breakerline at the undisturbed coast, for exemple near Pasar Talo, in June-August out of a southern direction. In the January-March monsoon these waves enter the breakerline out of a northern direction. So there will be a longshore current in a northern direction in the June-August period and a current in the opposite direction in the January-March period.

Because swell always comes from the south the northward current is stronger than the southward current. Therefore resulting transport will have a northern direction. Observations of visitors agree with this. The first description of this coast by Erb (1905) did already mention this current. Prof. Erb visited the south-western coast of Sumatra between Bengkulu and Blimbing. He observed a longshore current in northern direction. He found also a lot of pumice-stome. These stones came from the Krakatau eruption in 1883. It is only possible to find these stones there when a longshore current in northern direction exists. Blocks (ca 3 m^3) are eroded from rocks at the coast, shatteredby waves and transported north in pieces to the next beach where erosion of these stones continues. Also most of the river mouths were offset northward. Terpstra (1936) made a statistical analysis of these river offsets and confirmed the idea of a northward bound longshore current.

On general oceanographic maps (KNMI 1952) an ocean current is indicated in a southern direction, but this is a current outside the breakersone. On the sattelite pictures the influence of both currents can be seen very well, specially along the undisturbed coast from Tanjung Kerbau to Manna. The undersea banks are clearly influenced by currents (fig. 4.1).

In the June-August monsoon period a lot of sand is transported along the coast. At Tanjung Kerbau the coast turns east and therefore the current stops and sand in dumped near a (see fig. 4.2). This accretion area is visible on the satellite pictures, but can also be found on the charts.

fig 41

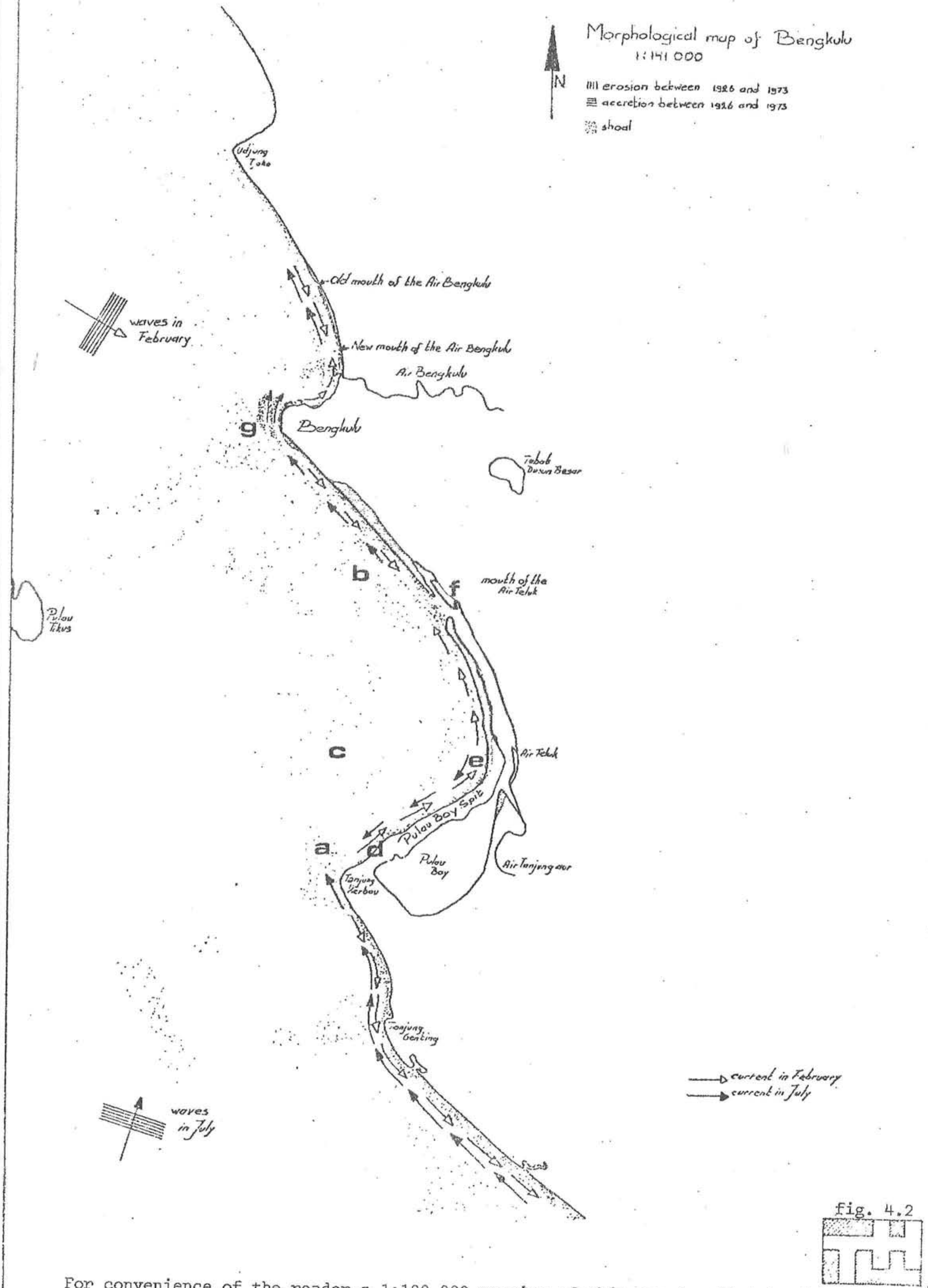
In this period nearly no waves enter the breakerline along the Pulau Bay spit. Hence no wave induced ongshore current will develop. Because of the surf-beat phenomenon (a phenomenon due to radiation stress) the SWL along a coast will rise. This elevation of the SWL is a function of the wave-height. Waves along the spit are lower than waves near f because of diffraction and refraction. Therefore the SWL near f is higher than the SWL near e and d, and so a current will develop from f to e, perhaps to d. It is to expect that this current will have a low velocity.

North of the mouth of the Air Teluk (from f to g) waves enter the breakerzone with an angle. Hence a current will be generated by the radiation stress.

Both of these currents are able to transport sand. The sand is brought in suspension by the incoming waves and thereupon transported with the currents. Bottom and banks are therefore eroded near b, and most of this sand is transported in a northern direction to the Bengkulu cape (g, see fig.4.3). There the situation is quite similar to the situation at Tanjung Kerbau, so sand will be dumped there. Because of the presence of reefs the situation is more complicated. Waves from a southern direction usually break on the reefs near h. The remaining waves will probably break on the coastal reef g (fig. 4.3).

Hence there are two breakerzones. Longshore currents will originate in the channel near i and directly along the coastline.

This current turns somewhat to the east, but because after Bengkulu cape no longer a driving radiation stress exists, sand is dumped at j and also in front of the harbour-entrance.



For convenience of the reader a 1:100 000 version of this map is added to this report

In the January-March monsoon period windwaves come from western and north-western directions, swell is still coming from the south. Wind waves induce a radiation stress and so a longshore current along the Pulau Bay spit from Tanjung Kerbau to the mouth of the Air Teluk. Also a current starts in Bengkulu going tot the same mouth. Probably near b a current will start in western direction. On the satellite picture a shallow channel can be discoverd from the river-mouth of the Air Teluk to k (fig. 4.2).

This current system will erode the accretion near a and transport the sand along the Pulau Bay spit. Near b the current stops and sand will be dumped there. This sand is transported to the Bengkulu harbour in the other season.

Along the Pulau Bay spit a shallow channel exists. This channel can be seen on the satellite picture, but is is also possible to find it on the charts. The Dutch hydrographic chart indicates a rather flat bottom in this area with a depth of 16-18 m. But there are only a few soundings and they are all taken from ships. The Dwidelta chart was made by soundings from a land base. Soundings started at the coast and sounding was continued until a depth of 20 m was reached. Then sounding was stopped. On the chart the impression is given that the whole area has a depth of 20 m. As can be seen from the satellite picture both charts are right and wrong. From the sounding data the conclusion can be made that this channel has a depth of 2 m below the surrounding bottom.

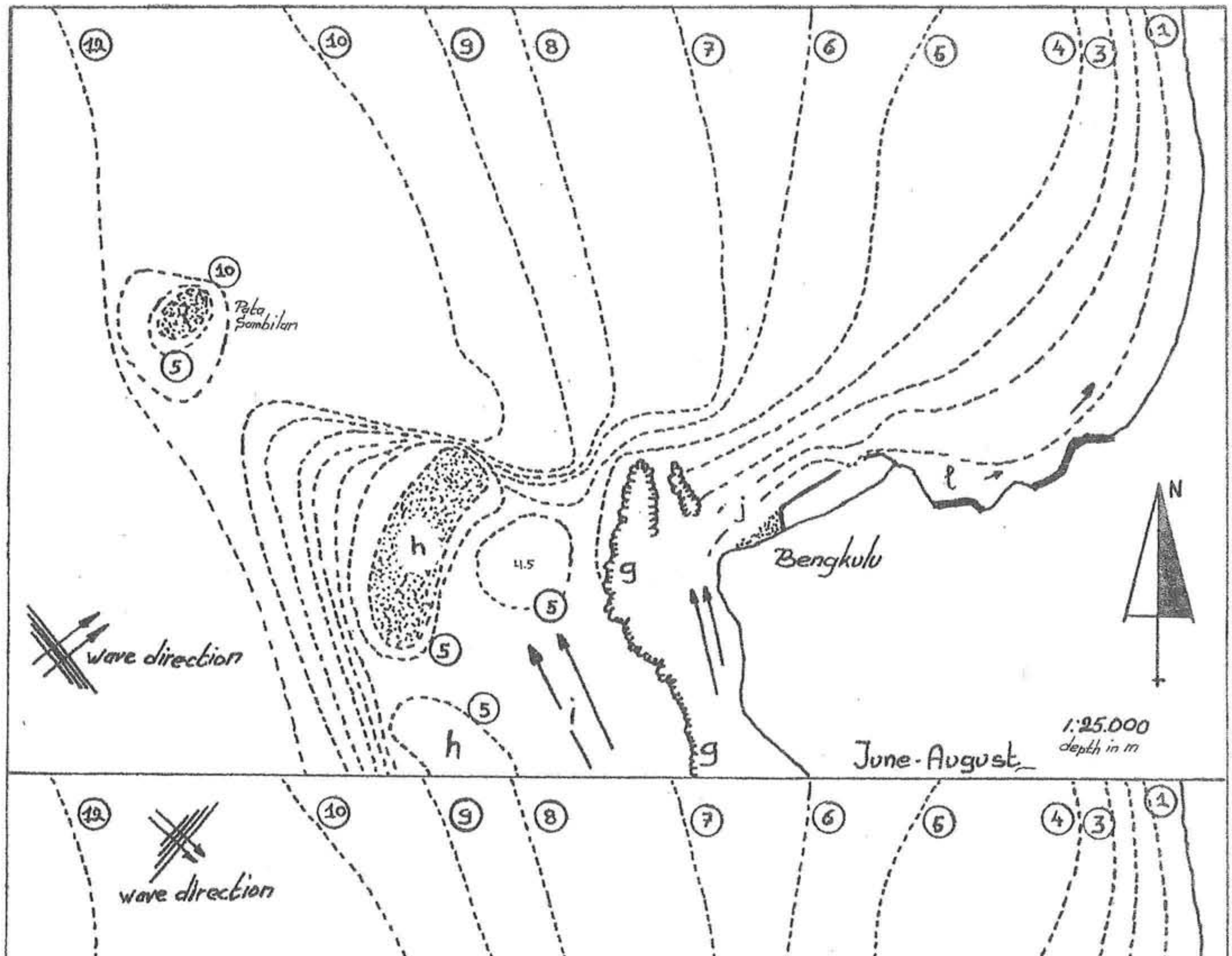
Just east of the Bengkulu harbour there is a wave induced current in eastern direction (near l). This current exists also in the June-August monsoon period because waves from the south are refracted intensely by the reefs west of Bengkulu.

This indicated current will also erode the coast. Deposits from dredging activities in the harbour were removed by this current. This current also formes a spit in front of the mouth of the Air Bengkulu and this mouth will be offset in northern direction (fig. 4.2).

<u>The origin of the sand spit</u>

In the period of the SE-monsoon the longshore current south of Tanjung Kerbau has a northward direction and will deposit its sediment near a. In the other monsoonperiod this sand will be transported along the coast of the spit (from a to e, fig. 4.2).

The oldest available chart of this area is a chart from 1856. On this



Currents near Bengkulu harbour

fig 4.3

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map only a short spit is indicated. As can be seen on fig. 4.4 the spit grew relatively fast. Going back in history, it is to expect that the spit started growing between 1750 and 1800. A question is why the spit started at that moment.

As indicated before in the chapter about geology the coast of Bengkulu is rising. Verstappen (1973) describes Bengkulu and Tanjung Kerbau as horsts. It is to expect that on the location of Tanjung Kerbau an island existed. Behind this island there was a protected area, a bay. This bay was called "island bay" (pulau = island). Because of the rising of the coast and the tombolo-effect, at a certain day the Tanjung Kerbau island was connected with the main land and sand transport had to go around Tanjung Kerbau. At that moment the genesis of the Pulau Bay spit started.

When the spit had grown until e it was to expect that Pulau Bay would be closed from the ocean. But because there is a (small) tidal difference in Pulau Bay, each eight hours water flows into and out off Pulau Bay (about 500 000 m^3). Further the discharge of the Air Tanjungaur and the Air Teluk has to flow to the sea. These currents were responsible for a gap between the spit and the coast. Hence the spit was bent north, and continued growing.

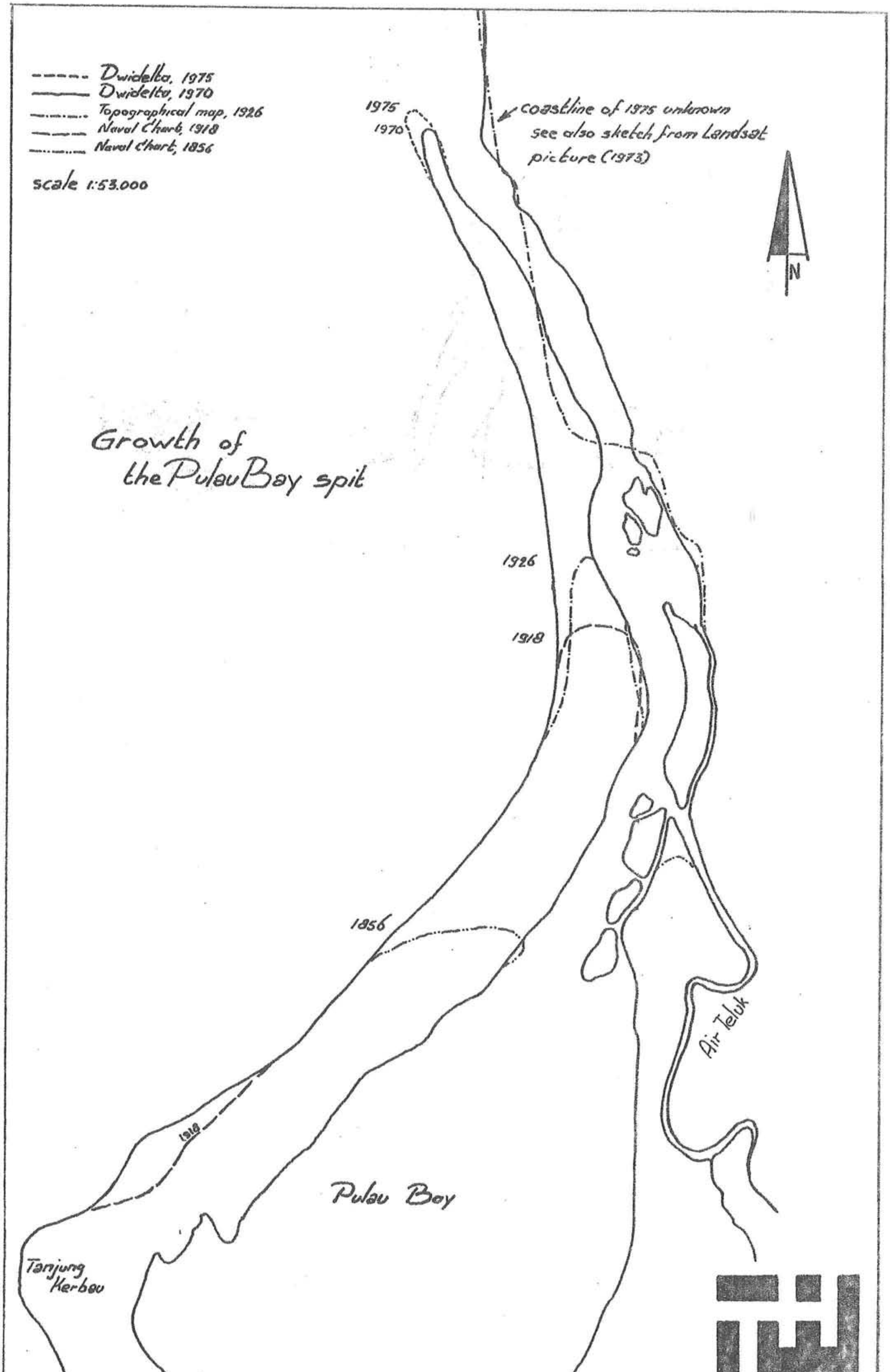
Because in the last 200 years hardly anywhere along the spit erosion occurred and sand is transported along the coast to the edge of the spit, without causing accretion, it is to expect that this coast is in a situation of dynamical equilibrium.

In the Dwidelta report some erosion near d was ascertained but as can be seen on fig 4.4 on this site the coast has grown since 1918. Hence it is to suppose that this erosion is only temporarely.

Sand for growing of the spit the from e to f is supplied by the February longshore current. But this current stops near f. In this area also sand is deposited from the southward current from g. In the July period this sand is carried away by an other current. But transport along the coast near f is low. So a large, but low sediment plateau will be build up here. Hence it is to expect that the mouth of the Air Teluk will stay at about the same site as nowadays, and therefore it is also to expect that the spit will not grow very much.

In 1918 the connection between Pulau Bay and the Indian Ocean was a short channel with nearly no hydraulical resistance. Because the spit grew, this channel got longer, hence the hydraulic resistance increased. This is the reason why the influence of the tide is less nowadays than it was in 1918.

So it is possible that in periods of low river discharge the mouth of the Air Teluk is nearly closed by a bar. This bar can be seen very well



Dwidelta, 1975
Dwidelta, 1970
Topographical map, 1926
Naval Chart, 1918
Naval Chart, 1856
scale 1:53.000
1975
1970
coastline of 1975 unknown
see also sketch from Landsat picture (1973)
N
Growth of the Pulau Bay spit
1926
1918
1856
Air Teluk
1918
Pulau Bay
Tanjung Kerbau

fig 4.4.

on the satellite-picture (The sketch of this mouth is made from the satellite-picture). Behind the bar and the spit a flooded marshy area can be seen. In this area water from the Air Teluk watershed is collected in time of low discharge. This water seeps through the spit to the ocean. In periods of large discharge the bar is carried away by the current. After the high run-off the bar is restored. Erb (1905) describes a similar system for several rivers in this area.

The bar is probably built up from the northern edge of the Pulau Bay spit and from the southern edge of a spit north of the rivermouth.

There is a possibility that the spit will break at an other site between e and f than at the present mouth. Such a break-through occurred also at other rivers in this region. Recently the Air Benkulu has made such a new mouth south of the original mouth.

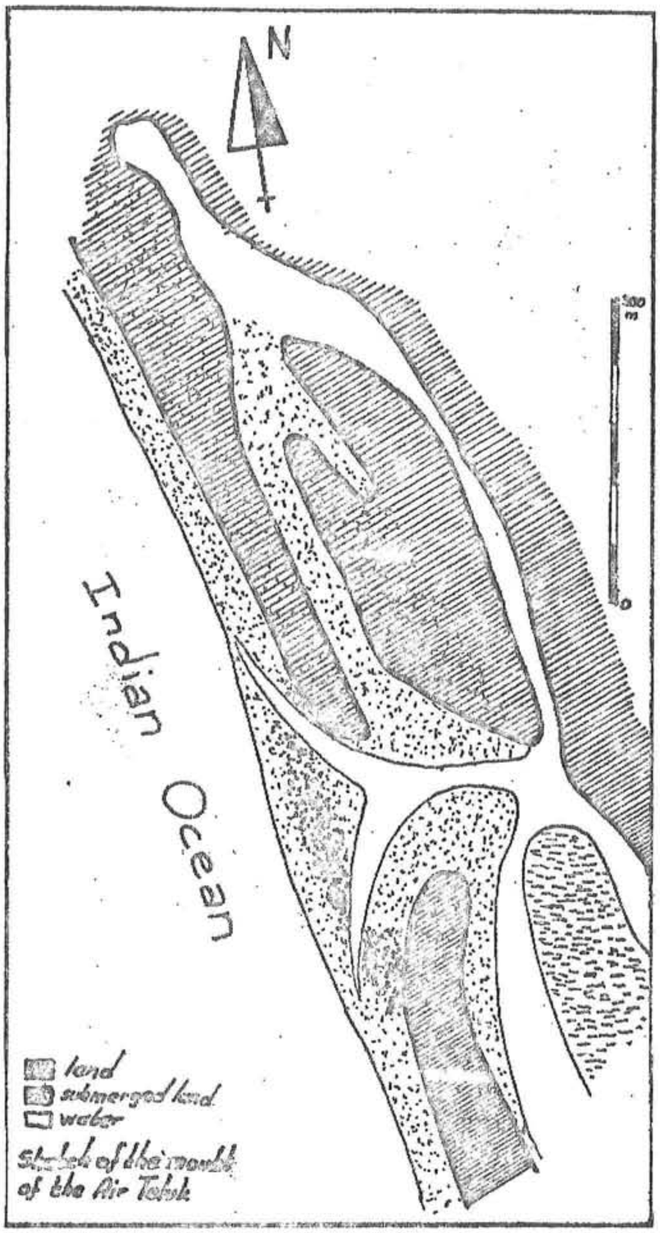


Fig 4.5

Not explained is the channel along the Pulau Bay Spit. One should expect that this channel is caused by a current; probably an eddy of a current outside the breakerzone. This current should have a northern direction. As indicated before the ocean-current outside the breakerzone has an opposite direction, and a southward current can't make an eddy like this.

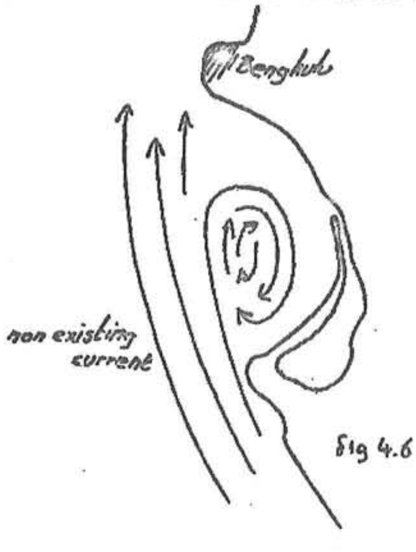


Fig 4.6

5. Economical considerations

Introduction

In principle two possibilities exist for transportation of goods from and to Bengkulu.

1. By land (road and rail) to Palembang
2. By sea

Transport flows exist from Bengkulu to Jacarta, Palembang (both 36 %), Lubuklinggau (11%), Padang (8%), Surabaja (6%) and Semarang (3%). For transports to Lubuklinggau sea transport is not interesting, but transports to the other towns may go over sea.
A decision has to be made which of these two possibilities has to be developed. For the development of sea transport improvement of the harbour facilities is necessary. For development of land transport it is necessary to improve the road from Bengkulu to Lubuklinggau, which is the nearest railway-station.
Due to financial problems it is not possible to do both. Because of the poor condition of the Bengkulu harbour the tendency is an increasing share of land transport.
From an economic point of view that solution has to be developed which is the cheapest in long terms. It is very difficult to calculate the cost-benefit rate of these two possibilities. As will be indicated harbour development is economically only attractive when the costs of improving harbour facilities does not exceed one milliard Rupiahs (Rp 1 000 000 000).
Of course also other considerations are important. Development of the Bengkulu district is easier when a good infrastructure with regional harbour facilities exists.
Perhaps harbour facilities may encourage more industrial activities. It is not possible to express all the benefits of harbour development in terms of money.
Hence the decision to invest one or two milliards of Rupiahs is a political decision, which has to be made by the Indonesian authorities. An important question is when this decision has to be made and wether it is possible to postpone some parts of the total decision to a later date.
In the next sections some date are investigated which can serve as a basis for these decisions.

Estimate of transport quantities

In order to estimate the amount of goods which will be transported through the harbour of Bengkulu, the Dwidelta corp. made an economical survey of the whole Bengkulu province (Dwidelta, 1975b). In this province most commodities are transported over land by truck and by train to and from Palembang (harbour on the east side of Sumatra). The harbours in the Bengkulu region play a less important role, properly speaking only the harbour of Bengkulu is important for the transportation over sea. The other harbours, Muko-muko, Ipuh, Bantal, Bintuhan and Manna are very small.

The commodities transported out of the Bengkulu region consist of spices, coffee, rottan, resin, rubber and other agricultural products; the incoming commodities consist of cement, corrugated iron sheet, sugar, salt, fish, rice, merchandise, kerosine, fertilizer and construction materials. Especially rubber and cement are transported over sea, so they are loaded and unloaded in the harbour of Bengkulu.

About 60 % (1973) of the economic activities in the Bengkulu province are in the agricultural, forestry and fishery sector, the importance of this sector is (economically) decreasing; other sectors are rapidly increasing (more than 5 % a year), such as industry, constructions, transport & communications, administration & defence. The growth of population in the Bengkulu province is estimated to be 2.3 % - 2.4 % for the next years until 1990; the total populations in 1973 was 555 400 inhabitants.

With these figures the Dwidelta corp. made an estimate of the production- and consumption figures. From the last figures the inflow (import) and outflow (export) of goods were calculated for the Bengkulu province and also (with some assumptions) for the Bengkulu harbour. When the mentioned figures (until 1974) concearning the amount of goods transported into and aout of the Bengkulu region are compared with the estimated figures (of 1975) a discrepancy is shown. This discrepancy needs further investigations (e.g. an economical sub-project) and this is beyond the scope of this report.

Therefore an other estimate was made of the development of the transportation of goods in future, based upon the mentioned figures of inflow and outflow.

Outflow (in tons)

year	Bengkulu harbour	Ipuh,Bantal Muko-muko	Bintuhan Manna	Platform Scale Lubuk Tanjung	Platform Scale Pagar Alam
	I	II	III	IV	V
1970	9155	--	--	--	--
1971	9750	590	--	--	--
1972	8595	1845	700	--	--
1973	11225	1560	245	8550	--
1974	7830	2425	120	11600	19595

Outflow (totals) (in tons)

year	I	I+II	I - III	I - IV	I - V
1970	9155	--	--	--	--
1971	9750	10340	--	--	--
1972	8595	10435	11135	--	--
1973	11225	12785	13030	21585	--
1974	7830	10255	10375	21980	41575

Inflow (in tons)

year	Bengkulu harbour	Ipuh,Bantal Muko-muko	Bintuhan Manna	Platform Scale Lubuk Tanjung	Platform Scale Pagar Alam
	I	II	III	IV	V
1970	11890	--	--	--	--
1971	8130	95	--	--	--
1972	8650	345	90	--	--
1973	10320	390	--	13150	--
1974	9195	760	90	9575	17605

Inflow (totals) (in tons)

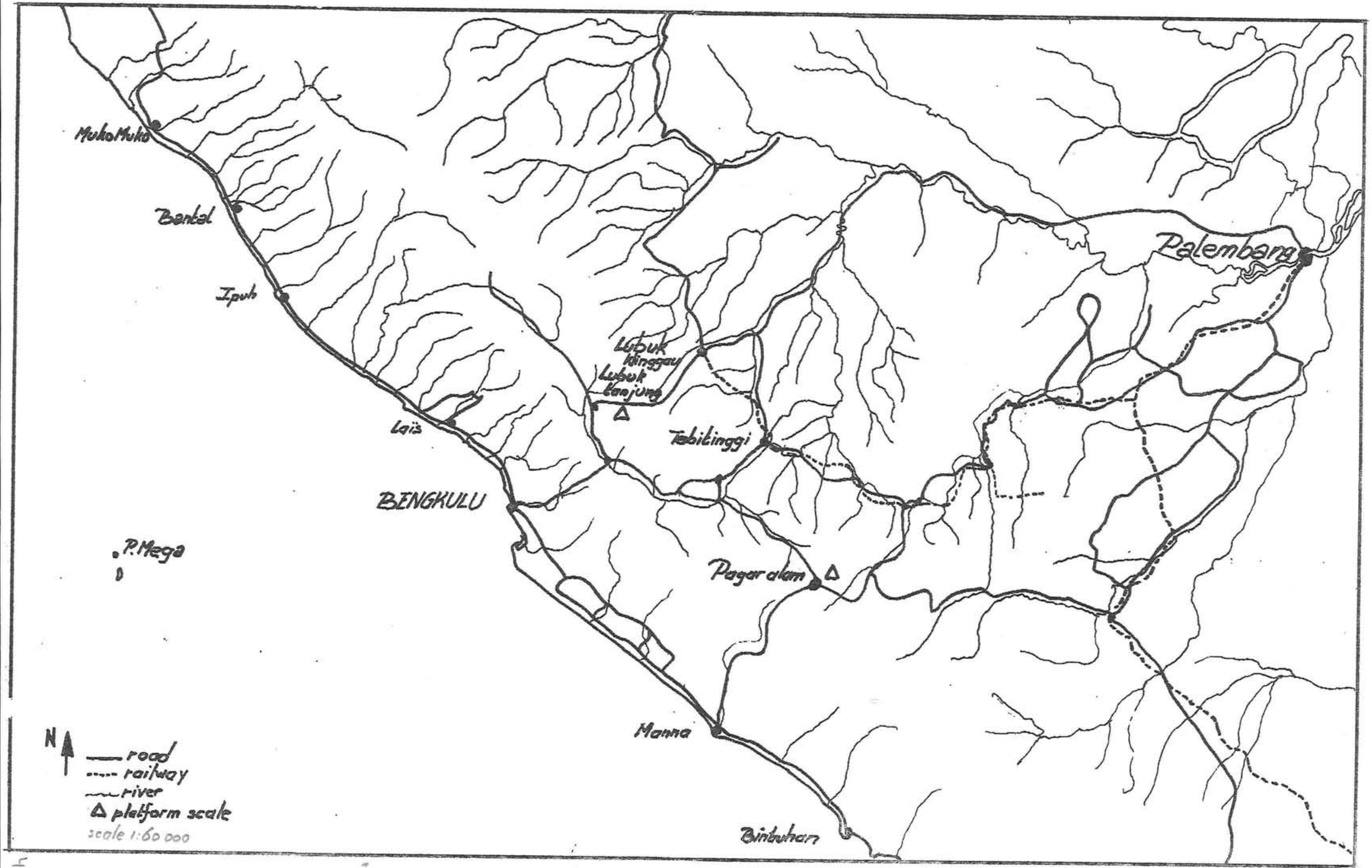
year	I	I + II	I - III	I - IV	I - V
1970	11890	--	--	--	--
1971	8130	8225	--	--	--
1972	8650	8995	9085	--	--
1973	10320	10715	ca 10800	ca 23950	--
1974	9195	9955	10045	20120	37725

I - III sea transport
IV - V Land trnasport

for locations see fig. 5.1

Table 5.1
Transport quantities from and to the Bengkulu region

Nedeco (1973) made a study of the transportation flows in Indonesia. One of the conclusions of this study was that the export (outflow) of traditional commodities (agricultural, forestry, fishery) is not growing very rapidly, only 0 % - 2 % a year. The import (inflow) is growing faster, about 4 % - 6 % a year. The mentioned figures for the Bengkulu province (inflow from and outflow to the other islands) point out to the same trend. Due to the poor condition of the Bengkulu har-


Palembang
Muko Muko
Bantal
Ipuh
Lais
BENGKULU
P. Mega
Lubuk Linggau
Lubuk Tanjung
Tebitinggi
Pagar alam
Manna
Bintuhan
N
road
railway
river
Δ platform scale
scale 1:60 000

bour, its importance in total transportation is decreasing. Transportation over land (to Palembang) is rapidly increasing.
In order to obtain a good view of the development of future transports, an estimate is made of inflow and outflow of goods in the Bengkulu district and harbour. The following assumptions are made:

- I The export (outflow) will increase with 1 % a year until 1985, and then with 2 % a year.
- II a The import (inflow) will increase with 4 % a year until 1985, and then with 5 % a year.
  - b The import will increase with 4 % a year until 1985, and then with 3 % a year.
- III a The importance of the harbour will decrease with 1 % a year until 1980, and then with 0.5 % a year until 1985.
  - b The importance of the harbour will decrease with 1 % a year until 1980, and will stay the same until 1985 when the harbour is supposed to be improved.
- IV a The importance of the harbour will increase with 2 % a year from 1985 until 1990 and with 1 % a year from 1990 until 1995.
  - b The importance of the harbour will increase with 1 % a year after the harbour is improved (1985) for the next 10 years.
- V a The total inflow in 1974 was 37000 tons, the share of the harbour was 24 %.
  - b The total inflow in 1974 was 38000 tons, the share of the harbour was 25 %.
- VI a The total outflow in 1974 was 41000 tons, the share of the harbour was 18.5 %.
  - b The total outflow in 1974 was 42000 tons, the share of the harbour was 19.5 %.

With these given assumptions it is possible to calculate the inflow and outflow of the Bengkulu harbour in future. This calculation gives the minimum and maximum figures as indicated in table 5.2.
The minimum figures were calculated with the assumptions I, IIb, IIIa, IVb, and Va; the maximum figures were calculated with the assumptions I, IIa, IIIb, IVa and Vb.

Expected savings from the new harbour

This economical survey has the intention of being a survey of the amout ofcommodities that will be transported through the harbour (in future) and of the economical savings of the transportation costs, that are caused by the improvement of the harbour. The estimation of this last figure will be very rough, an error of more than 100 % is possible.

Outflow (in tons)

year	total outflow	share of the harbour in %.	share of the har- in tons.
1974	41000-42000	18.5 - 19.5 %	7585- 8190
1975	41410-42420	17.5 - 18.5 %	7245- 7850
1980	43520-44585	12.5 - 13.5 %	5440- 6020
1985	54740-46860	10.0 - 13.5 %	4575- 6325
1990	50500-51735	15.0 - 23.5 %	7575-12160
1995	55755-57120	20.0 - 28.5 %	11150-16280
2000	61560-63065	20.0 - 28.5 %	12310-17975

Inflow (in tons)

year	total outflow	share of the harbour in %.	share of the har- in tons
1974	37000-38000	24.0 - 25.0 %	8880- 9500
1975	38400-39520	23.0 - 24.0 %	8850- 9485
1980	46815-48080	18.0 - 19.0 %	8425- 9135
1985	54270-61365	15.5 - 19.0 %	8410-11660
1990	62915-78320	20.5 - 29.0 %	12895-22715
1995	72935-99960	25.5 - 34.0 %	18600-33985
2000	84550-127575	25.5 - 34.0 %	21560-43375

table 5.2 Future inflow and outflow of the Bengkulu harbour

It only gives an indication of the amount of money (1 milliard or 10 milliard Rupiahs) which can be spent on this project. This financial limitation was calculated only with figures of the direct economic savings (i.e. not including the effects of stimulating economy by a better infrastructure). So the improvement of the infrastructure of the Bengkulu province was not taken into account. The improvement of this infra-structure could have influence upon the growth of industrial, agricultural or other activities.
As already indicated in the introduction of this chapter this may be a reason to invest more money into the harbour than the direct economical (transportation) profits.
The economical savings can be estimated from the figures of inflow and outflow of the Bengkulu harbour with the following assumptions:

- mean costs of transportation (freight costs, including handling and storage) are 10 - 15 Rp/kg (Dwidelta 1975b)
- savings because commodities are transported over sea instead of over land ca 10 % of the total transportation costs
- amount of goods over which no savings are calculated (some kind of a threshold value): inflow 11000 tons, outflow 6000 tons
- the savings are calculated after 1985, when the harbour is supposed to be improved.

	1985	1990	1995	2000
Inflow harbour (tons)	8440-116600	12895-22715	18600-33985	21560-43[illegible]75
Outflow harbour (tons)	4575- 6325	7575-12160	11150-16280	12310-17975
Inflow corrected (tons)	0- 660	1895-11715	9600-22985	10560-32375
Outflow corrected (tons)	0- 325	1575- 6160	5150-10280	6310-11975
Savings per year (million Rp.)	0- 1.5	3.5- 26.8	12.8- 49.9	16.9- 66.5

table 5.3 Expected savings

The total savings over 15 years are about 128 - 585 millions of Rupiahs. Taking into account only the direct economical savings and the costs of construction of the improvement can be paid off in 25 years without interest, the financial limitations of this project are aprx. one milliard Rupiahs (Rp 1 000 000 000). If interest is also taken into account the limitations are with 4 % ca 0.8 milliard Rupiahs and with 8 % ca 0.5 milliard Rupiahs.

In an other report (Dwidelta 1975) a financial survey is given of the costs of construction of a new harbour in Pulau Bay. In that survey the costs of improvement of the infrastructure are also given, specially the costs of new roads and road-improvements. The new roads and road-improvements are necessary for the transportation of stone from the Bukit Sunur quarry to the new harbour. The costs of nearly all of these roads were regarded as costs of improvement of the infra-structure and hence paid by other departments, not being the department of communications, or by the province itself. Therefore the direct direct economical savings are assumed to be spent entirely for the improvement of the harbour.

The conclusions to be drawn from this survey are that the traffic to and from Bengkulu harbour is too small to allow a large improvement, due to economical unattracitiveness.

Special developments

The assumptions made for the estimation of inflow and outflow are based on a "normal" economical growth. Special projects stimulating economical activities are not taken into account.
It came to our knowledge that the Indonesian government will start an agricultural project 50 - 100 km north of Bengkulu. This project may have a large influence on the economical development of the province, and thus on the devopment of the harbour.
This project is a transmigration project.

> *The Indonesian government tries to diminish overpopulation as well as food shortage on the densely populated islands of the country, in particular on Java.*
> *People from these densely populated islands are enabled to settle in transmigration areas. After these areas have been brought under cultivation food production will start.*
> *It is to expect that by means of modern agricultural methods [1] these areas will have a large food surplus, which can be exported to islands with a food shortage.*
> *So transmigration has two effects: less people on the densely populated islands, so less food shortage. And because the transmigrated people start food production in new agricultural areas total food production in Indonesia will increase.*
> *The main problem of transmigration is that people are not interested in leaving their own islands and moving to other islands.*

The area selected in the Bengkulu province is a jungle at this moment. In this area nearly no infra-structure exists. Due to this lack of infra-structure, roads, bridges, irrigation and drainage canals have to be constructed before agricultural activities can start. Also houses and other buildings have to be built.
It is obvious that this project will have an influence on the flow of goods. In the first stage of the project the import of construction materials and machines will be large.
Later the outflow of agricultural products will increase. This outflow will increase more than was expected in the former section. Also the inflow will increase more, due to the necessary commodities for the new agricultural areas (fertilizer, seeds).
It is quite uncertain how this project will develop. When it becomes a succes it will take about 5 - 10 years before this project has any

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[1] *) Modern agricultural methods are not identical with mechanisation !*

influence on the economical activities of the Bengkulu province.
As already mentioned the additional flow of goods as a result of this project was not taken into account in the estimation of the quantity of goods transported trough the Bengkulu harbour.

Short term development

As indicated before the amount of goods transported by sea is decreasing and the importance of the rail and road connections are increasing.
Consequences are that transports from and to Bengkulu will be done by transport companies specialised in rail and road transport with braches in Palembang.
When a decision to build a new harbour would be made this year it would take 5 - 10 years before this new harbour will be operational. In the mean time nearly all transport will go by road and by rail via Palembang. Then it is very difficult for a new harbour to regain its place in the total transport flow. When land transportation has been established every company will have its connections in Palembang and although sea transport will be cheaper, many goods will be sent via Palembang.

Decision dates

When no decision at all is made sea transport will stop in a few years. Hence in a very short time the decision has to be made if sea transport should play a role in the future Bengkulu distribution system.
When this is decided in favour of sea transport the present situation at the Bengkulu roadstead has to be improved as soon as possible in such a way that sea transport keeps its part of total transportation from and to Bengkulu.
Two types of improvements are possible:

- Temporarely improvement of the Bengkulu roadstead and constructing a totally new harbour within 10 years.
- To improve the Bengkulu roadstead in such a way that this improvement is the basis for a new enlarged harbour.

In order to make a good decision about what to do it is necessary to investigate both possibilities.

The decision to improve the roadstead has to be made shortly. When this improvement is done in such a way that enlargement of the existing harbour and constructing a new harbour are both possible, the decision whether enlargement or constructing new can be made in a later stage when more and more detailed information about the development of the Bengkulu area is available.

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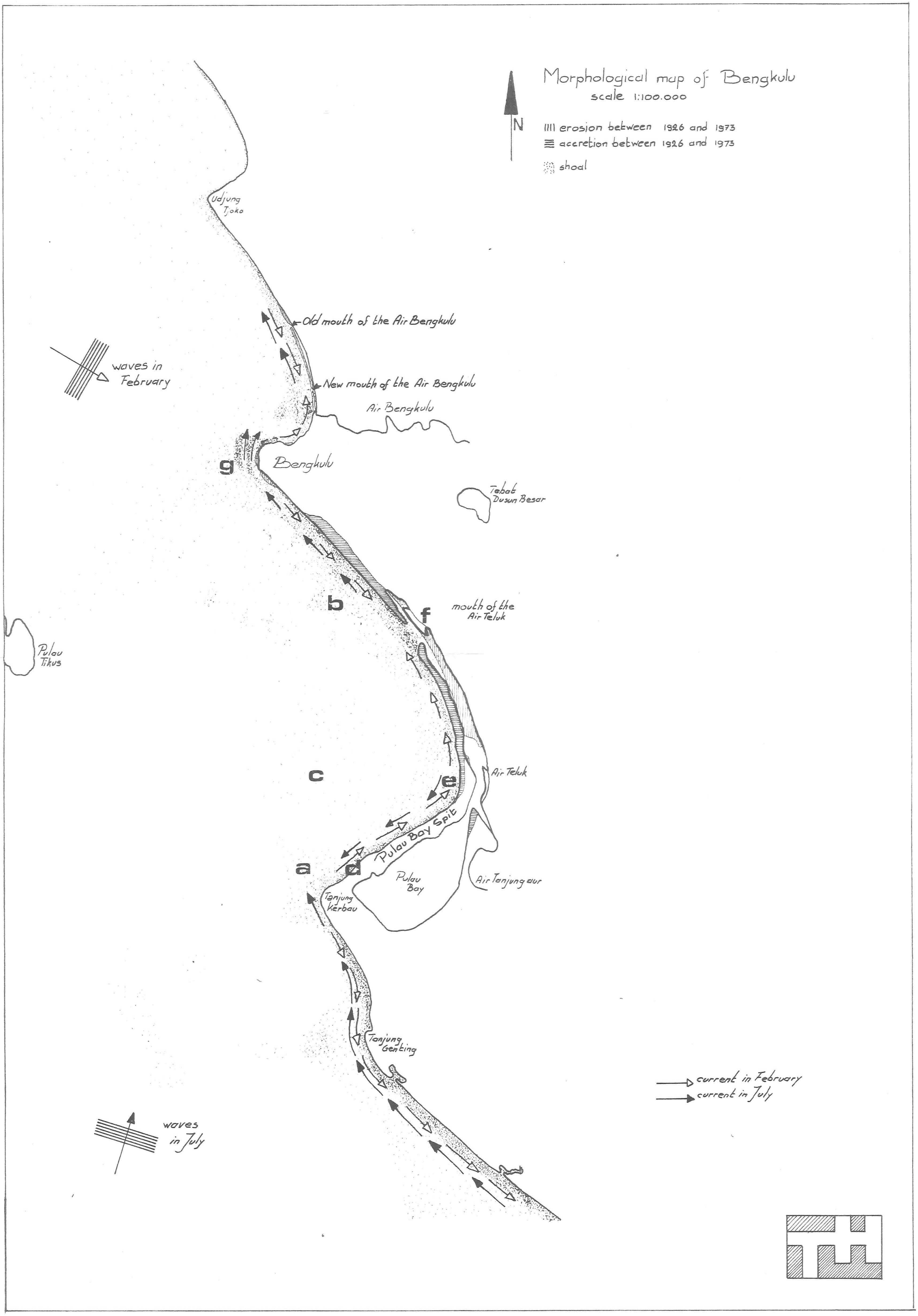

Morphological map of Bengkulu
scale 1:100.000
N
erosion between 1926 and 1973
accretion between 1926 and 1973
shoal
Udjung Tjoko
Old mouth of the Air Bengkulu
waves in February
New mouth of the Air Bengkulu
Air Bengkulu
g
Bengkulu
Tebat Dusun Besar
b
f
mouth of the Air Teluk
Pulau Tikus
c
e
Air Teluk
Pulau Bay Spit
a
d
Pulau Bay
Air Tanjung aur
Tanjung Kerbau
Tanjung Genting
current in February
current in July
waves in July