CHAPTER 3

PRESENT SITUATION OF THE PORT OF ANTSIRANANA

3. PRESENT SITUATION OF THE PORT OF ANTSIRANANA

3.1 General

The port of Antsiranana, 12° 15'S-49° 17'E, 25 km is the SSE from Cape d'Ambre, is located at the end of the wide bay of Diego-Suarez on the northernmost part of the island of Madagascar.

The port has about a 300 m wide mouth and a sufficiently deep water area (Figure 3-1-1.) The port is favorably situated on the European/Asian trade route.

Diego-Suarez bay takes its name from two Europeans, Diego Diaz and Herman Suarez. The former discovered the bay in 1500 and the latter visited in 1506. From 1885 to 1973, there was a large French military base here. A shipyard named SECREN was established to support military and commercial activities and since then SECREN has continued to be a major enterprise in the province of Antsiranana.

The port of Antsiranana supplies daily necessities to the people of the surrounding areas, particularly during the raing season. Agricultural products of the area such as coffee bean, vanilla and salt are exported through this port. Recently, fishery activities have grown rapidly and the quantity of fish handled at the port continues to increase.

The port of Antsiranana is the second largest port behind Toamasina with some 200 thousand tons of cargo throughput. Foreign trade at the port of Antsiranana constitutes two-thirds of cargo throughput.

Figure 3-1-1 Location of the Port of Antsiranana

3.2 Natural Conditions

This section presents an outline of the natural conditions at the port of Antsiranana and its vicinity based on relevant reports, collected information and results of surveys executed in the first field study.

3.2.1 Topography

The bay of DIEGO-SUAREZ has a total surface area of 250 square km and a total coastal length of 150 km. The mouth is situated at the east side of the Bay facing the Indian Ocean, where opposite shores are separated by a distance of only 1,200 meters. This bottleneck shape makes a safe basin for vessels seeking shelter from ocean waves. The port of Antsiranana is located at the opposite side of Cap Diego at the south of the bay, 10 km away from the mouth.

The study team executed topographic and sounding surveys and the results are shown in Figures 3-2-1 and 3-2-2. Geographical characteristics of port and vicinity are summarized as follows:

- The port has a land area of approximately 36,000 square meters in which and warehouses, sheds and tuna cold storage occupy a large portion of the area which reduces the area available for port services such as cargo handling and container service.

- The congested residential quarter and downtown closely run along the boundary of the port.

- The Navy Port Base is located south of the port and there is a vacant space of approximately 300 meters in coastal length that separates the port and the base.

- The north-east zone from the port has a steep slope running to the shoreline. Several dwellings are found at the bottom of this slope.

- The west water area in front of the port has more than 8 meters depth with a wide and flat bottom. Several shipwrecks are scattered.

- The north and north-east water area has a steep bottom with approximately 1:10 slope becoming deeper toward the center of the bay.

- In Anse Melville, located to the east of the port, there is a small artificial island with an area of approximately 14,000 square meters. An old quay is located at the north end of the island where the average depth is 4 meters. The quay is not in use due to a shipwreck just in front of the quay.

- The channel area is starting from the Island and connecting to the offshore. Approach channel nearly has the same depth as the existing approach channel except the shallow zone nearing to the Island.

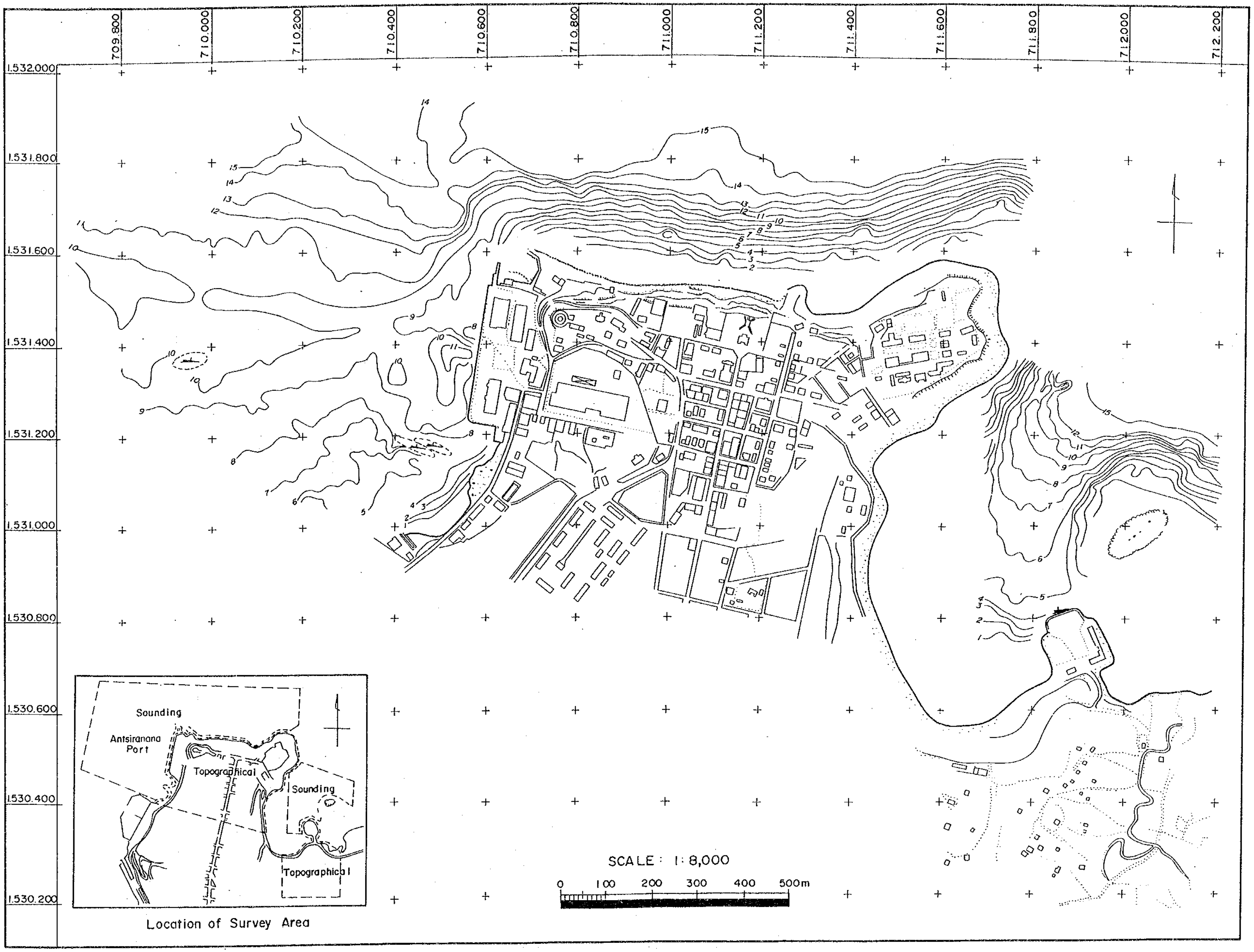


Figure 3-2-1 Topographic Map of the Port of Antsiranana and the Vicinity

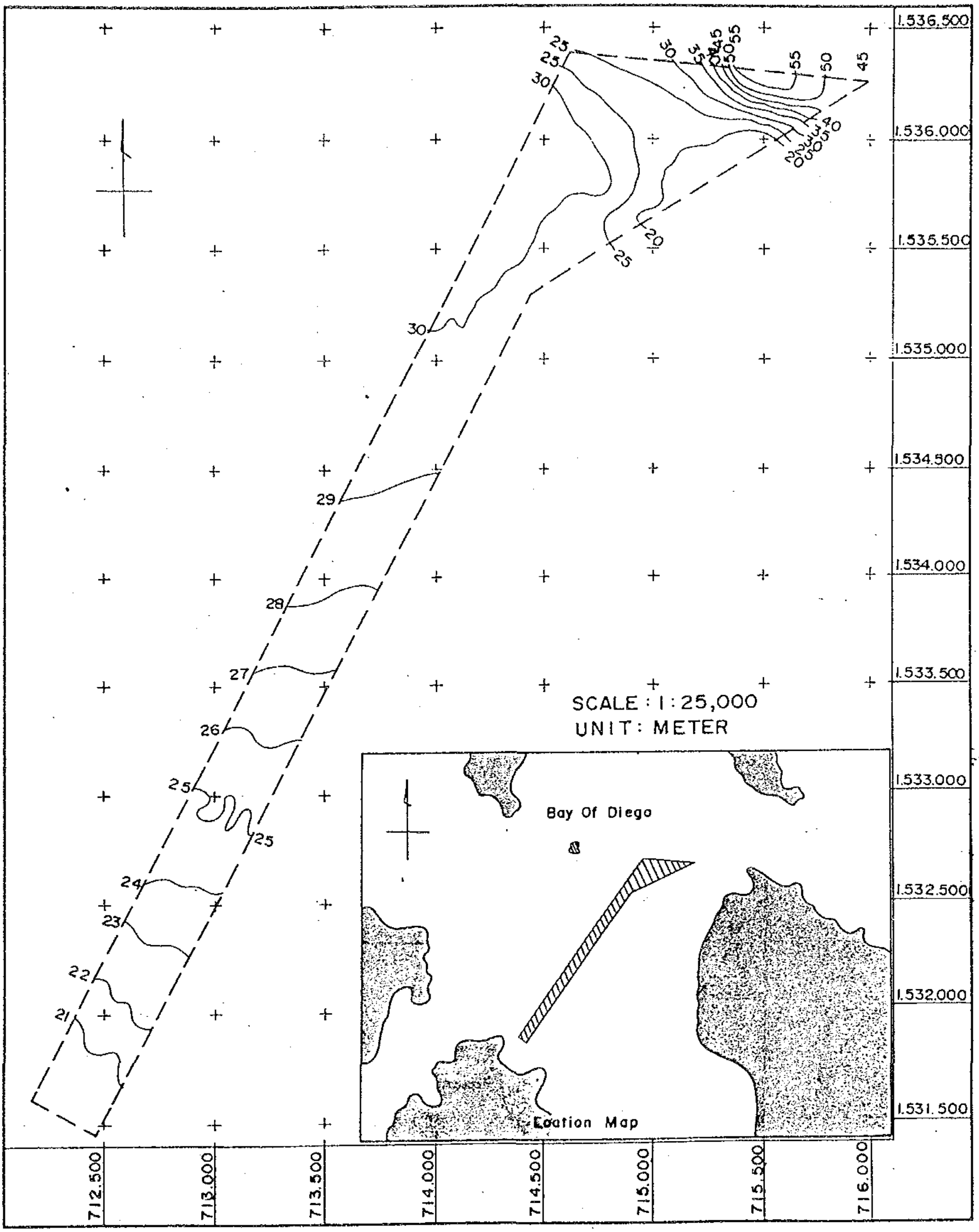


Figure 3-2-2 Sounding Chart of Channel Area of Anse Melville

3.2.2 Meteorology

Meteorological data recorded by the weather station near the Airport of Antsiranana (latitude: 12°21' S, longitude: 49°18' E, altitude: 105 meters) from the years 1961 to 1990 were obtained from the Direction de la Meteorologic et de l'Hydrologie and the monthly averages for the said period as per each meteorological element are as shown in Table 3-2-1.

Table 3-2-1 Meteorological Element (1961 - 1990)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Mean
Tx	30.2	30.2	30.6	31.0	30.4	29.3	28.7	28.7	29.5	30.5	31.5	31.4	30.2
Tn	22.8	22.7	22.9	22.6	21.6	20.2	19.6	19.4	20.0	21.2	22.5	22.9	21.5
TM	26.5	26.5	26.8	26.8	26.0	24.8	24.6	24.1	24.8	25.9	27.0	27.2	25.9
UU	82	84	80	78	72	70	69	66	66	67	70	77	73.4
PP	10.6	10.0	10.7	11.5	13.6	15.5	16.4	16.6	15.9	14.7	13.1	11.6	13.4
RR	337.5	305.8	179.4	52.3	13.4	19.1	19.0	18.7	8.8	17.4	54.6	170.8	*1196.8
NR	16	15	12	6	4	3	4	4	2	3	5	10	8.4
NM	1	0	0	0	0	0	0	0	0	0	0	0	*1

Source: Direction de la Meteorologic et de l'Hydrologie

Note:
Tx : Maximum temperature (degree C)
Tn : Minimum temperature (degree C)
TM : Mean temperature (degree C)
UU : Relative Humidity (%)
PP : Atmospheric pressure (+1000 Hpa)
RR : Precipitation (mm)
NR : Number of days of precipitation >= 1.0 mm
MM : Number of days of mist (1981-1990)
* : Indicates annual total

To summarize the collected information, the meteorological characteristics in Antsiranana are described as following subsections:

(1) Temperature

The mean annual temperature is about 25.9 degrees C, the mean temperature in summer season from December to February is 26.7 degrees C, and that in winter season from June to August is 24.4 degrees C, indicating that temperatures vary little throughout the year. The maximum and minimum monthly mean temperatures are 31.5 and 19.4 degrees C, respectively.

(2) Relative Humidity

The mean annual relative humidity is 73.4% and the difference between the wet and dry season is relatively small.

(3) Atmospheric Pressure

The mean annual atmospheric pressure is 1013.4 Hpa. The mean atmospheric pressure in winter is slightly higher than that in summer, but the monthly variation is very small throughout the year.

(4) Rainfall

The mean annual rainfall is 1,196.8 mm and the monthly variation is remarkably large, registering 337.5 mm in January and only 8.8 mm in September, which highlights the difference in the amount of rainfall between the wet and dry season.

(5) Winds

The data of winds from 1975 to 1984 which were recorded at the weather station near the Airport of Antsiranana (observation height: 10 meters above G.L.) are compiled as shown in Tables 3-2-2 and 3-2-3 and Figure 3-2-3.

Theses Tables and Figure show the following wind characteristics:

- Because of the trade wind blowing from the Indian Ocean, the predominant wind direction throughout the year is in range from east to south-east with a frequency of occurrence of 74%

- However, from January to February, westerly monsoon winds begin to blow and the frequency of occurrence becomes almost the same as that of easterly winds.

- By contrast northerly winds seldom blow, showing a frequency of occurrence of only 2%

- The mean annual wind velocity is 5.8 m/s. That in summer season is lowest,4.0 m/s, and that from August and October is the highest, 8.1 m/s.

Table 3-2-2 Annual Frequencies of Occurrence of Winds by Direction and Intensity (1975 - 1984)

	0.0 to 1.5	1.5 to 3.0	3.0 to 4.5	4.5 to 6.0	6.0 to 7.5	7.5 to 9.0	9.0 to 10.5	10.5 to 12.0	12.0 to 13.5	13.5 to 15.0	15.0 to 16.5	> 16.5 m/s	Total
N	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
NNE	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	1.
NE	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	1.
ENE	0.	0.	0.	1.	0.	0.	0.	0.	0.	0.	0.	0.	2.
E	0.	1.	1.	3.	2.	3.	1.	1.	0.	0.	0.	0.	11.
ESE	0.	2.	2.	5.	4.	8.	3.	3.	1.	1.	0.	0.	29.
SE	1.	4.	4.	10.	5.	6.	2.	2.	0.	0.	0.	0.	34.
SSE	1.	3.	1.	2.	0.	0.	0.	0.	0.	0.	0.	0.	7.
S	0.	1.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	2.
SSW	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	1.
SW	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	1.
WSW	0.	1.	0.	1.	0.	0.	0.	0.	0.	0.	0.	0.	3.
W	0.	1.	0.	1.	0.	0.	0.	0.	0.	0.	0.	0.	3.
WNW	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
NW	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
NNW	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.

Source: Direction de la Meteorologie et de l'Hydrologie
Note: Percentage of calmness: 5.5 %

Table 3-2-3 Wind Speed Records,
Mean and Maximum Instantaneous Wind Speed (1961 - 1990)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Mean
MS	3.9	3.1	3.9	5.0	6.1	6.1	6.9	8.1	8.1	8.1	6.1	5.0	5.8
PD	S	S	SE	SE	SE	SE	SE	SE	SE	SE	SE	SE	---
Wx	61.1	45.0	33.1	>= 70.0	50.0	50.0	63.1	60.0	50.0	53.1	31.9	61.9	---

Source: Direction de la Meteorologie et de l'Hydrologie

Note: MS: Mean Wind Speed (m/s)

PD: Predominant Wind Direction

Wx: Maximum Instantaneous Wind Speed (m/s)

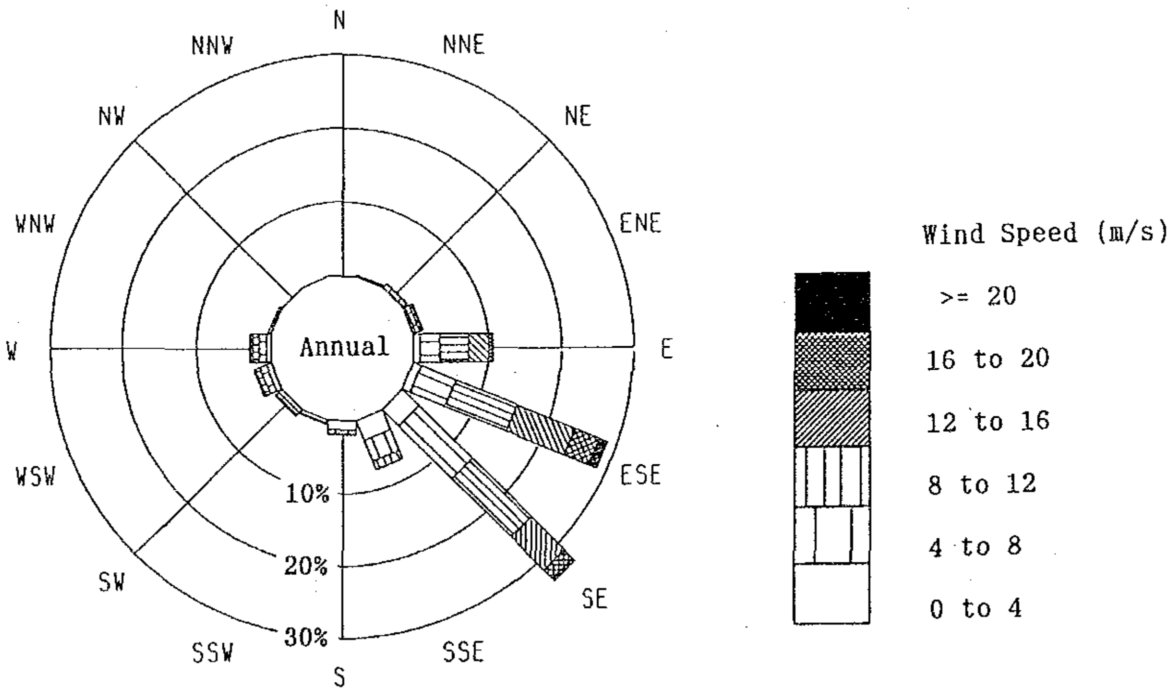


Figure 3-2-3-(1) Wind Rose (Annual)

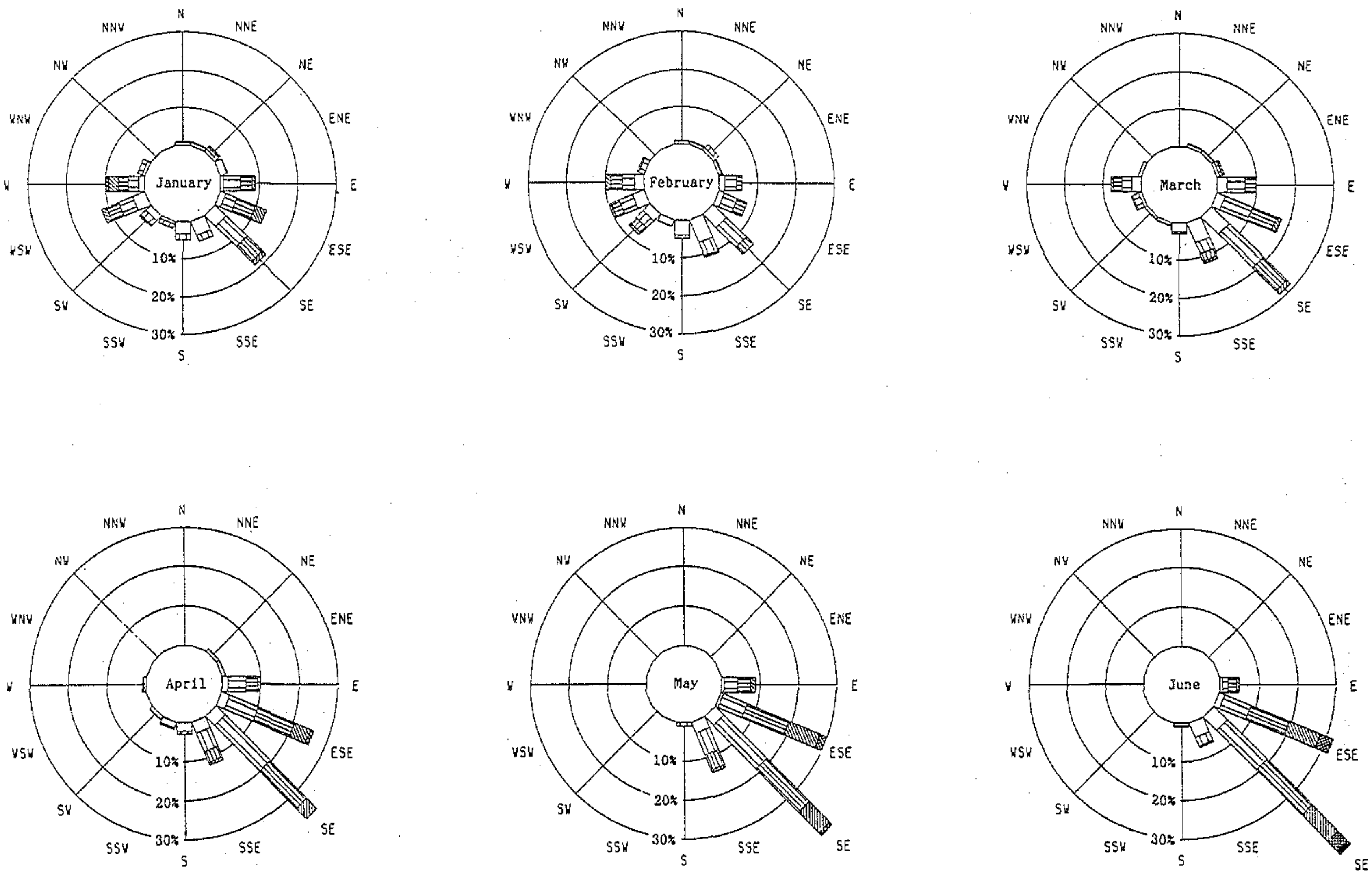


Figure 3-2-3-(2) Wind Rose (January to June)

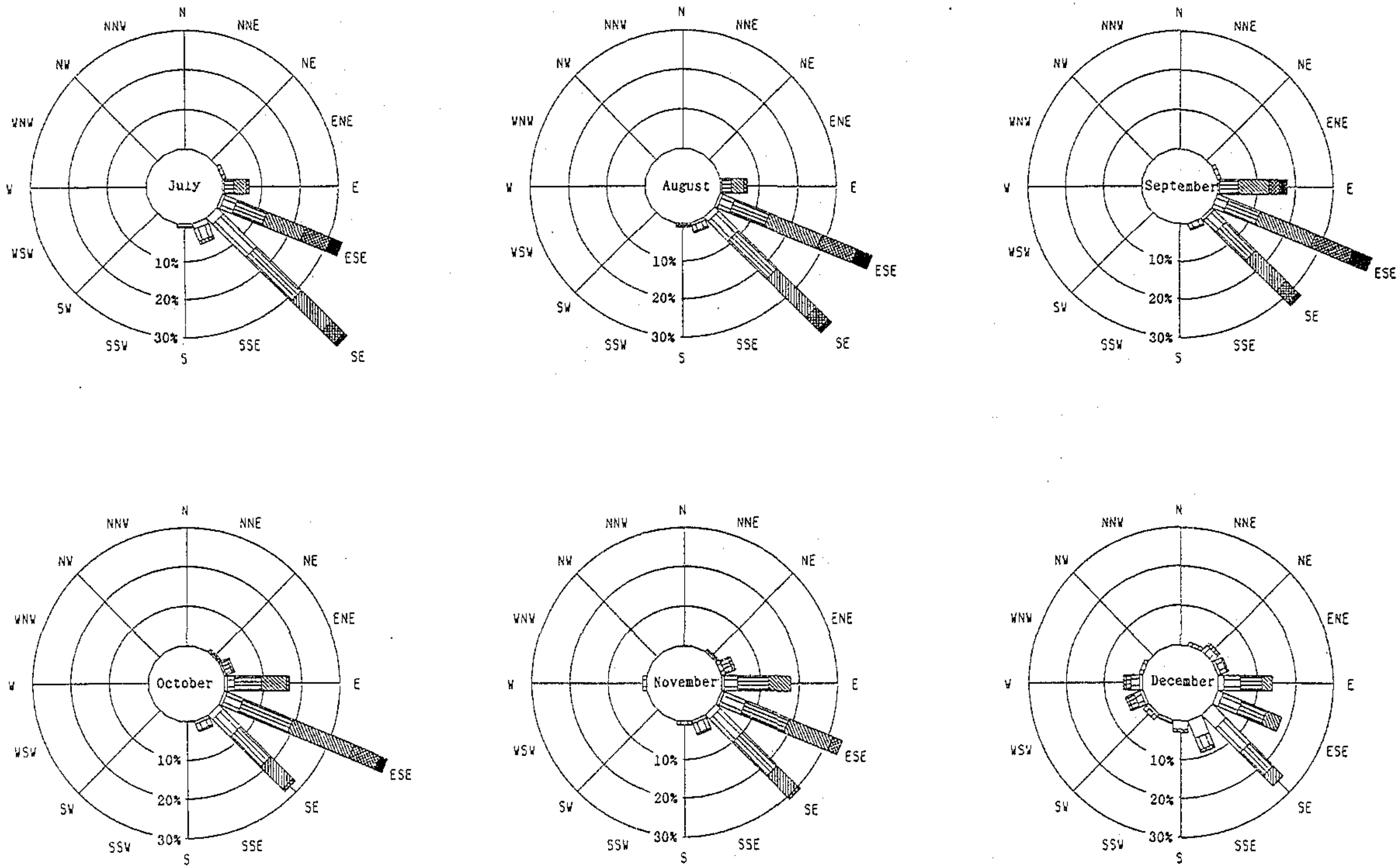


Figure 3-2-3-(3) Wind Rose (July to December)

3.2.3 Sea Conditions

(1) Tide

The study team conducted tidal observation at the north end of the quay at the port of Antsiranana for 34 days from September 22 to October 25 using a marigraph. Measuring was made with a position of zero "0" of the marigraph being set at the level of 3.721 meters below the already known bench mark. The results of observation and analysis have been incorporated into a tide curve shown in Figure 3-2-4, while results of the tide harmonic analysis are presented in Table 3-2-4.

The tidal curve in the Figure shows a typical pattern of semi-diurnal tide.

From the results of the harmonic analysis, the tide amplitude (Zo) consisting of the sum of the four main tide components, M_2 S_2 K_1 and O_1, is calculated to be 1.093 meters. And the tide type index "T" which is expressed in $(K_1+O_1)/(M_2+S_2)$ as 0.197, which highlights the typical characteristics of semi-diurnal tide. Classification of tide index is as follows:

$1.50 <= T$ ------------- Diurnal Tide
$0.25 <= T < 1.50$ ------------- Mixed Tide
$T < 0.25$ ------------- Semi-diurnal Tide

Table 3-2-5 shows the comparison of the tide harmonic constants of the four main components between this study and the Admiralty Tide Table of the British Navy. A high level of agreement is evident.

It is authorized by the Admiralty Tide Table that the lowest possible tide level or the level closest to the lowest tide shall be adopted to the Chart Datum Line, which is obtained by using Zo and the astronomical tide named L.A.T (Lowest Astronomical Tide). The height of L.A.T varies according to the region. Since the height at the port of Antsiranana has been estimated to be 0.340 meters by the Admiralty Tide Table the Chart Datum Line becomes 1.433 (= 1.093 + 0.340) meters below mean sea level.

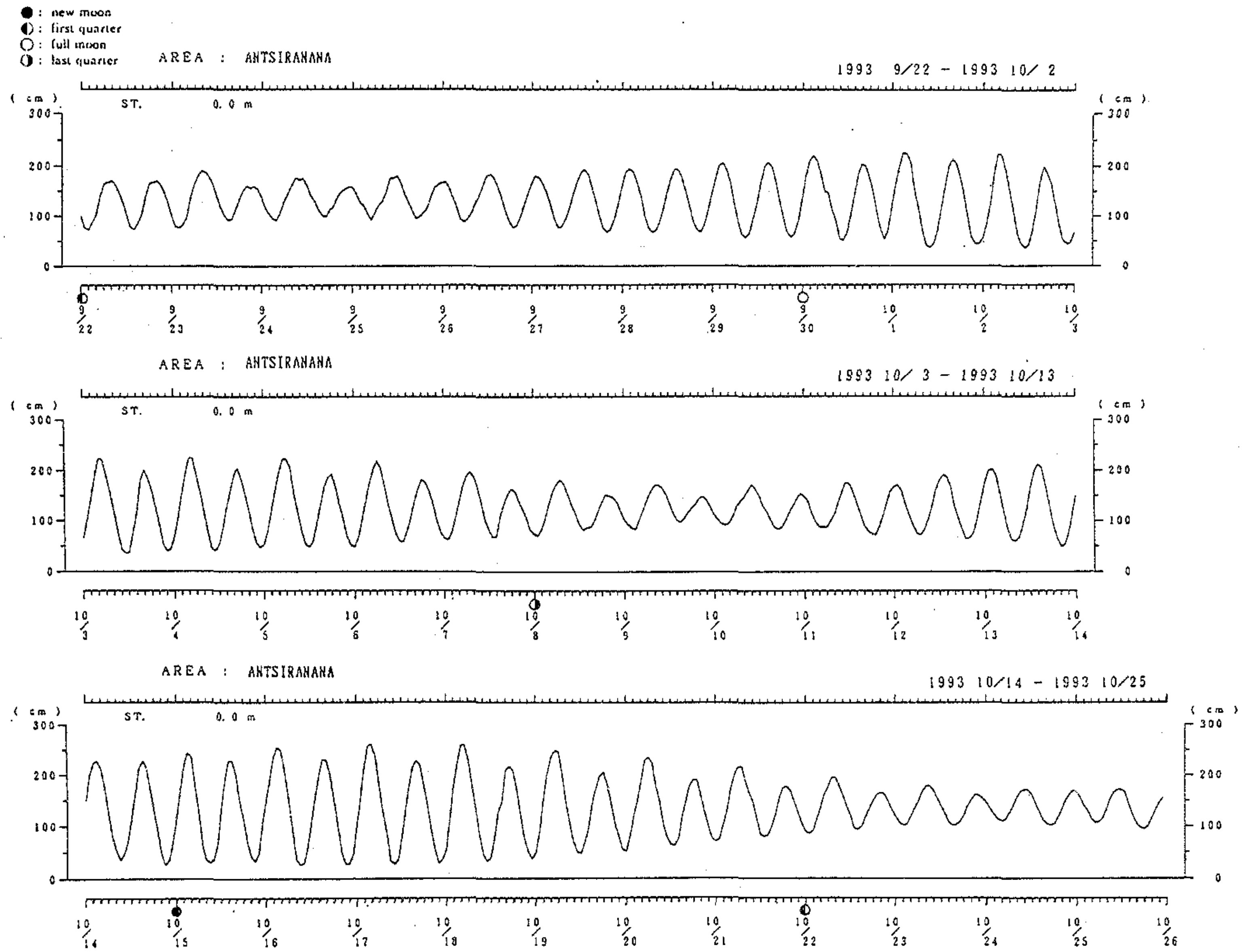


Figure 3-2-4 Tide Curve

Table 3-2-4 Results of Tide Harmonic Analysis

Component Tide	Amplitude (cm)	Lag Angle (degree)
M_2	60.6	90.9
S_2	30.7	135.3
K_2	8.3	136.3
N_2	11.8	54.3
K_1	9.7	35.0
O_1	8.3	46.0
P_1	3.2	35.5
Q_1	1.4	339.9
M_4	1.4	164.3
MS_4	1.5	202.9

Table 3-2-5 Comparison of Tide Harmonic Constants

		M_2	S_2	K_1	O_1	L.A.T	Z_0
Observation	H (m) K (°)	0.606 90.9	0.307 135.3	0.097 35.0	0.083 46.0	0.340	1.093
Admiralty Tide Table	H (°) K (°)	0.620 93.0	0.280 142.0	0.110 49.0	0.080 50.0	0.340	1.093

Note: H: Amplitude, $Z_0 = M_2 + S_2 + K_1 + O_1$

Consequently for the reasons mentioned below, the tide level chart of the port of Antsiranana can be drawn as shown in Figure 3-2-5 by using the amplitude of the four main components obtained in this study.

- The actual tide levels shown in Figure 3-2-4 Tide Curve are almost in accord with the predicted tide levels of the Admiralty Tide Table.

- The four components of the Admiralty Tide Table from which the tide prediction is made show a good agreement with those of this study.

- Therefore, it is proper to determine that the zero "0" positioning 3.721 meters below the already known bench mark is Chart Datum Line (C.D.L)

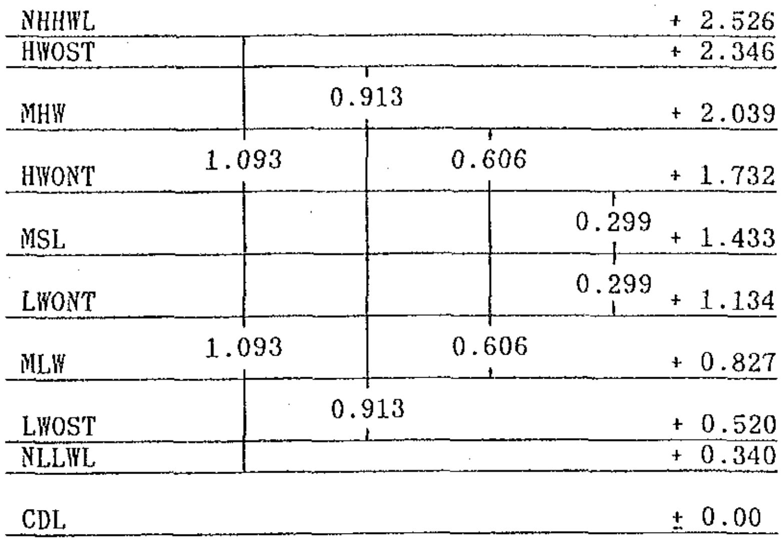


Figure 3-2-5 Tide Level Chart

(2) Tidal Current

The direction and speed of tidal current varies in the vertical direction according to the depth. In this field study, only the drift current near the surface was measured to provide preliminary information. The measurement area was defined within the radius of 1.5 km from the port to account for the area influenced by waste water which will be discussed later in connection with the initial environmental examination.

Measuring of tidal current was executed at spring tide by the following method: a survey boat equipped with global positioning system pursues a drift bottle flowing with drift current. Results are shown in Table 3-2-6 and Figure 3-2-6. It can be seen from the results that the direction of drift current influenced by the south-east trade wind is in range from west-north-west to west-south-west at flood tide and north-north-west at ebb tide. The highest average speed over periods of ten minutes is 1.13 knots and the mean speed during about three hours having the center at the middle of high and low tide is in range from 0.6 to 0.8 knots at flood tide and 0.5 knots at ebb tide.

Table 3-2-6 Observation Record of Drift Bottle

Date Point No.	Time	Duration (Minute)	Coordinate Lon. 49° E	 Lat. 12° S	Distance (m) X	 Y	 L	Speed (knot)	Remarks
17/09/93									
Flood Tide									
1	14:00	0	17.913	15.222	---	---	---	---	
2	:10	10	17.797	15.272	214.832	92.600	234	0.7581	
3	:21	11	17.646	15.287	279.652	27.780	281	0.8359	Max
4	:30	9	17.556	15.302	166.680	27.780	169	0.6026	
5	:40	10	17.450	15.307	196.312	9.260	197	0.6415	
6	:50	10	17.319	15.358	242.612	94.452	260	0.8359	
7	15:00	10	17.202	15.354	216.684	7.408	217	0.6998	
						Ave.		0.6248	
03/10/93									
Ebb Tide									
8	6:50	0	17.211	16.168	---	---	---	---	
9	7:00	10	17.187	16.176	44.448	14.816	47	0.1555	
10	:10	10	17.132	16.150	101.860	48.152	113	0.3693	
11	:20	10	17.123	16.000	16.668	277.800	278	0.8942	
12	:35	15	17.138	15.975	27.780	46.300	54	0.1166	
13	:40	5	17.155	15.950	31.484	46.300	56	0.3693	
14	:50	10	17.125	15.845	55.560	194.460	202	0.6609	
15	8:00	10	17.086	15.768	72.228	142.604	160	0.5248	
16	:10	10	17.050	15.688	66.672	148.160	162	0.5248	
17	:20	10	17.022	15.589	51.856	183.348	191	0.6220	
18	8:33	13	17.063	15.478	75.932	205.572	219	0.5443	
19	8:50	0	17.351	15.850	---	---	---	---	
20	9:00	10	17.330	15.786	38.892	118.528	125	0.4082	
21	:10	10	17.265	15.711	120.380	138.900	184	0.6026	
22	:20	10	17.240	15.633	46.300	144.456	152	0.4860	
23	:30	10	17.163	15.552	142.604	150.012	207	0.6803	Max
						Ave.		0.4971	
03/10/93									
Flood Tide									
24	12:30	0	17.683	15.755	---	---	---	---	
25	:40	10	17.505	15.738	329.656	31.484	331	1.07	
26	13:25	45	16.910	15.644	1,101.940	174.088	1116	0.80	
27	13:35	0	17.194	16.040	---	---	---	---	
28	:40	5	17.138	16.058	103.712	33.336	109	0.70	
29	:50	10	17.003	16.090	250.020	59.264	257	0.84	
30	:59	9	16.871	16.111	244.464	38.892	248	0.89	
31	14:11	12	16.693	16.202	329.656	168.532	370	0.99	
32	:20	9	16.524	16.215	312.988	24.076	314	1.13	Max
33	:30	10	16.394	16.322	240.760	198.164	312	1.01	
						Ave.		0.8250	

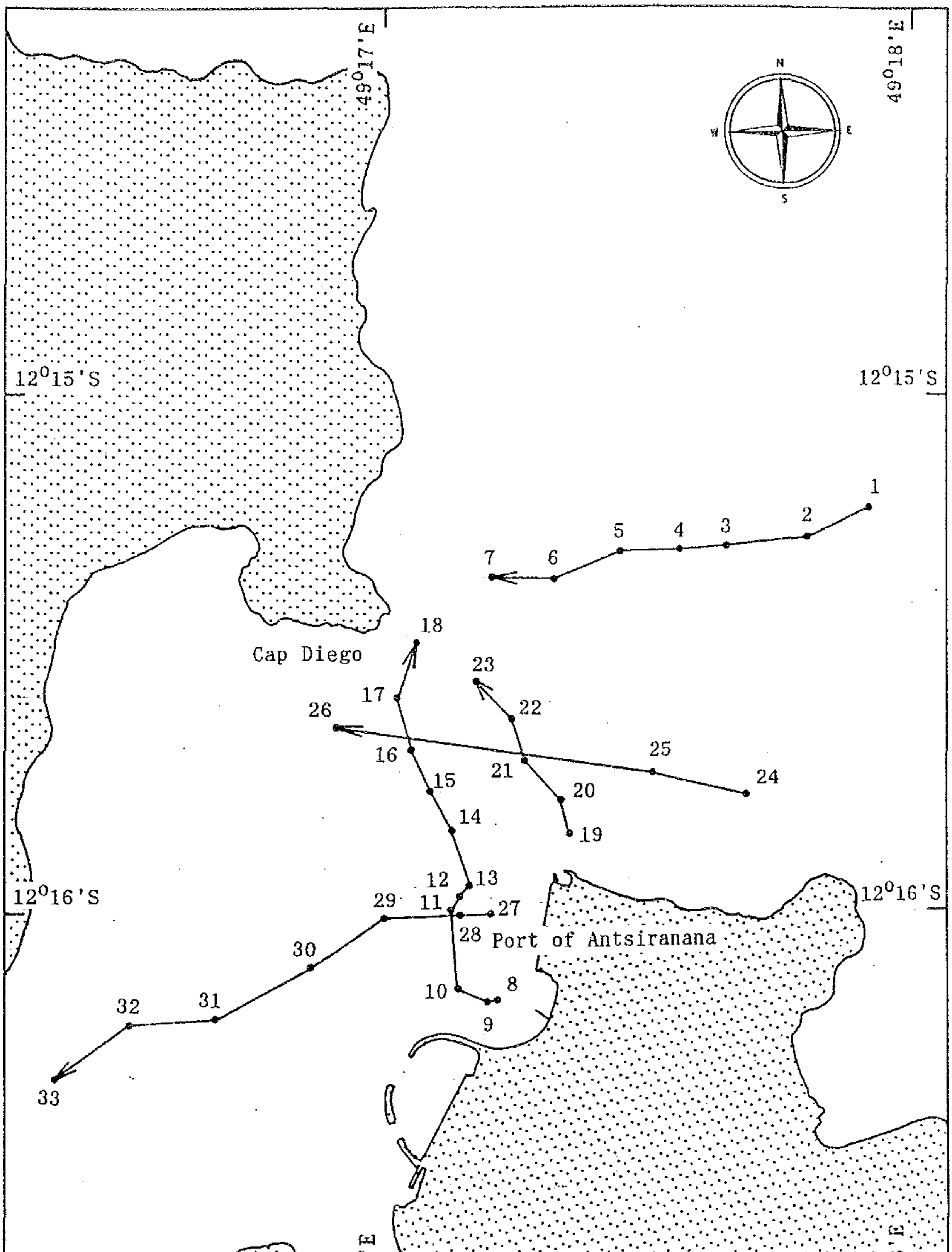


Figure 3-2-6 Track of Drift Bottle (S = 1/20,000)

(3) Wave

The port of Antsiranana located at the south of the bay of Diego-Suarez is protected by the surrounding topographical shape from the direct approach of Indian Ocean waves. Consequently, waves reaching the port have characteristics of primary surface wind waves, and are occasionally accompanied by ocean waves generated by cyclone passing over or near the bay.

Since there is no available date on waves of the bay of Diego-Suarez, the study team attempted the hind cast of waves reaching the port based on the records of surface winds and cyclones. The wave hind cast discussed here is divided into two types according to purposes of use as follows:

- Estimation of a rate of workable days of the port operation (a wave computation on ordinary surface wind conditions was performed).

- Design of revetment of the port (a wave computation on extraordinary wind conditions brought by cyclone was performed).

1) Wave computation on ordinary surface wind condition

Sverdrup-Munk-Bretschneider's method (S.M.B method, method for wave calculation from wind velocity, fetch and duration of wind blowing) was applied. Wind records presented in preceding subsection 3.2.2 were used. The results of computation are shown in Table 3-2-7, Frequencies of Occurrence of Waves by Direction and Height. The frequency of deep water wave of 0.5 meters and above in height is found to be 5.29%. And the maximum height of wave is not more than 1.0 meter. Details of wave computation are given in Appendix A-3.2.1

2) Wave computation on extraordinary wind condition

A cyclone passing over or near the bay of Diego-Suarez brings mostly wind waves generated inside of the bay on account of the aforementioned topographical characteristics. However, in order to estimate the wave dimensions during extraordinary wind conditions, here we will discuss ocean waves which are generated outside of the bay by cyclone and invade from the mouth as well as wind waves generated inside of the bay by cyclone.

According to the preliminary computation results for three large scale cyclones, "ANDRY", "KAMISY" and "BENEDICTE", among the cyclone date recorded from 1979 to 1990, the cyclone "BENEDICTE" of 1981 had a large impact on the port of Antsiranana.

Here this cyclone "BENEDICTE" will be adopted as the model cyclone for the following discussion on wave hindcast.

Ocean waves reaching the mouth from outside of the bay are simulated to be about 5.0 meters in height and 8 seconds in period using a computer model of cyclone which simulates wave conditions brought by wave generation and growth changing with a movement of wind. And the waves shoaling and reaching the port, which are computed by using an energy equilibrium equation, are estimated to be 5% of waves at the mouth in height, that is 25 cm.

Wind waves generated inside of the bay by cyclone are computed by using the same S.M.B method that was applied to the wave computation on ordinary surface wind condition mentioned in foregoing paragraph 1). As a result of computation, the wave dimensions are 1.58 meters in height and 3.9 seconds in period.

The wave during extraordinary wind conditions, which is given by combining both waves computed above, is calculated to be 1.6 meters in height (See following Formula).

$$H_t = \sqrt{H_1^2 + H_2^2}$$

where,

H_t: Height of combined wave

H_1: Height of wave reaching the port which was generated outside of the bay

H_2: Height of wave generated inside of the bay

Since the wave period is largely influenced by wind waves generated inside of the bay, the wave period of wind waves generated inside of the bay, that is 3.9 seconds, is adopted. Details of wave computation are given in Appendix A-3.2.1

Table 3-2-7 Frequencies of Occurrence of Waves by Direction and Height (Annual)

Height(m) / Direction	< 0.1	0.1 to 0.2	0.2 to 0.3	0.3 to 0.4	0.4 to 0.5	0.5 to 0.6	0.6 to 0.7	0.7 to 0.8	0.8 to 0.9	0.9 to 1.0	> 1.0	TOTAL
N	0.03	0.14										0.17
NNE	0.03	0.19	0.08	0.03								0.33
NE	0.04	0.25	0.14	0.18	0.28	0.02						0.92
ENE	0.16	0.34	0.20	0.29	0.24	0.13	0.13	0.02				1.50
E	0.48	1.04	1.83	2.36	2.31	1.86	0.51	0.24	0.13	0.08		10.83
ESE	1.30	4.21	7.09	9.48	4.71	1.32	0.48	0.17	0.07			28.83
SE	12.86	18.16	2.49									33.50
SSE	6.90	0.51										7.42
S	1.77	0.23										2.00
SSW	0.43	0.23										0.67
SW	0.41	0.43	0.29	0.12	0.08							1.33
WSW	0.48	0.62	0.68	0.37	0.35							2.50
W	0.54	0.63	0.84	0.39	0.39	0.10	0.02					2.92
WNW	0.13	0.31	0.06									0.50
NW												
NNW												
CALM	6.58											6.58
TOTAL	32.15	27.30	13.69	13.22	8.36	3.44	1.14	0.43	0.20	0.08		100.00

3.2.4 Soil Conditions

The study team conducted soil investigation by means of soil boring and laboratory tests from September to December, 1993. The soil boring was conducted at 8 points in total. Locations of boring poring points are shown in Figure 3-2-7.

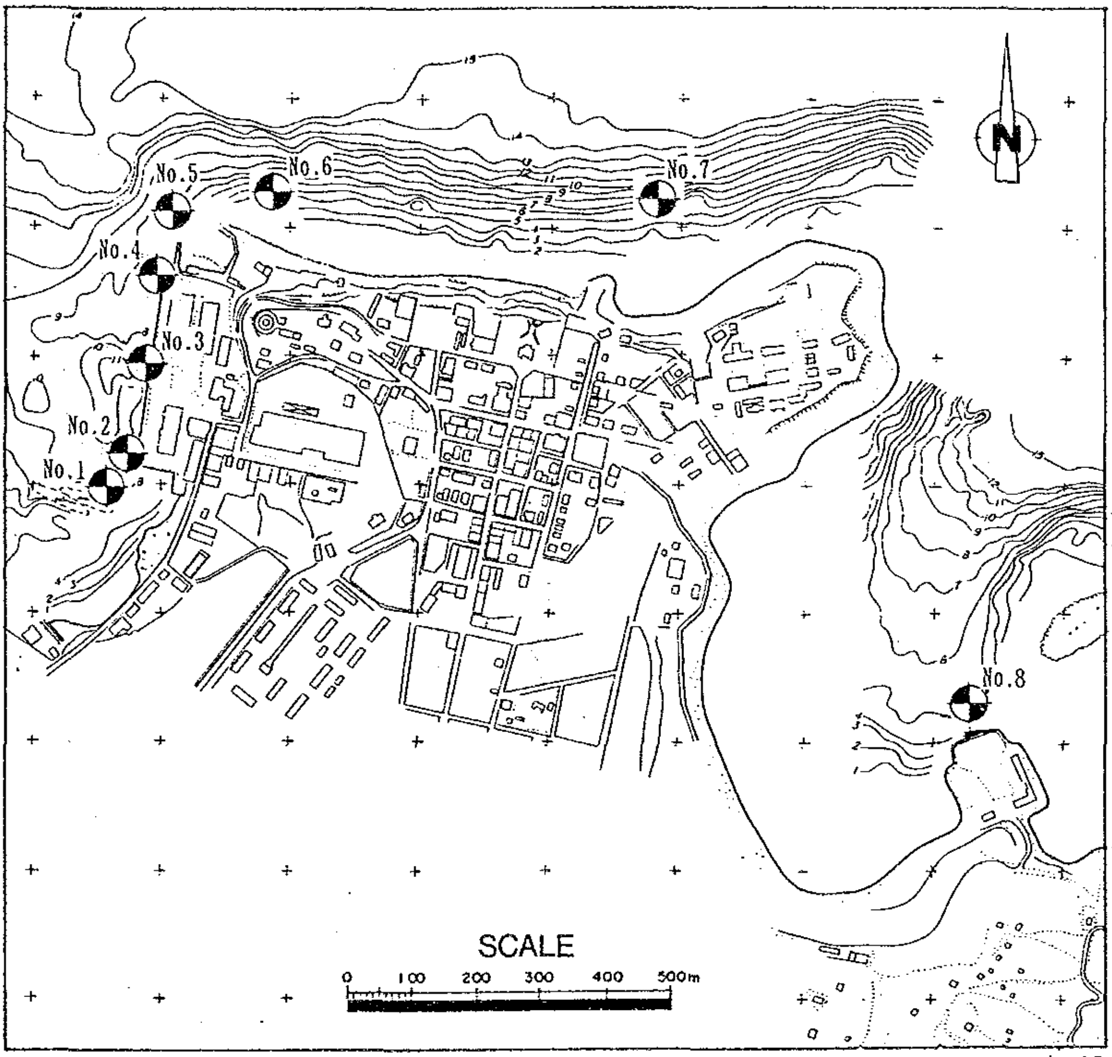


Figure 3-2-7 Locations of Boring Points

(1) Soil Profile and Property

Soil profiles at all boring points are shown in Figure 3-2-8, and the soil natures of each stratum symbolized in the Figure are shown in Table 3-2-8. Greater detailed soil profiles and the results of laboratory test are presented in Appendix A-3.2.2

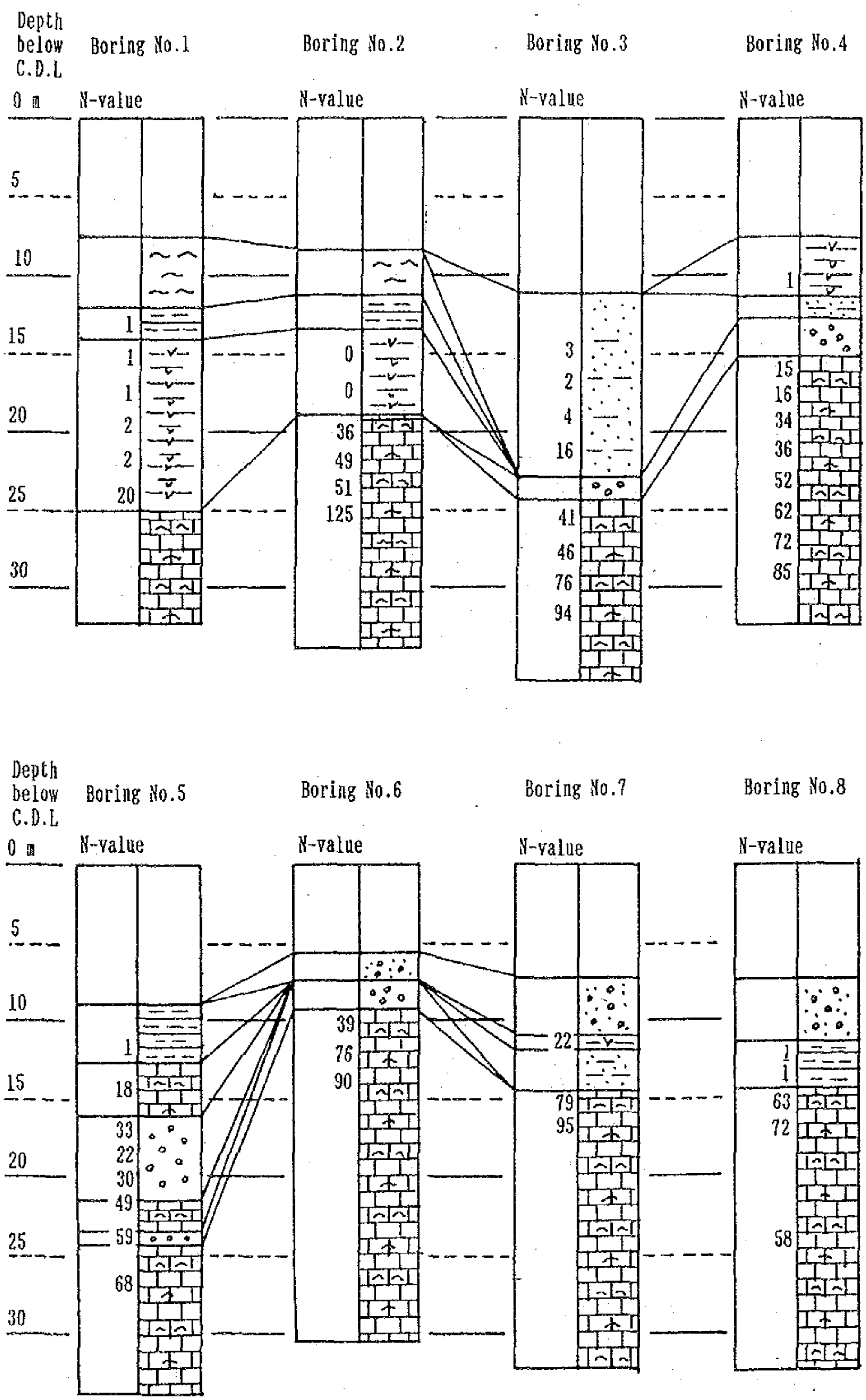


Figure 3-2-8 Soil Profiles

Table 3-2-8 Soil Natures of Each Symbolized Stratum

Symbol	Nature of Soil
	Grey or blackish silt
	Grey soft clay with shell fragments or sandy soft clay
	Grey or yellowish-grey plastic clay with shell fragments or basalt pebbles
	Yellowish-grey or grey limy marl
	Silty sand with shell fragments or scoriated sand with basalt pebbles
	Basalt boulders and pebbles
	Coral sand with shell fragments

Although the number of boring points is limited to the minimum necessary, the soil condition can be summarized as follows:

1) Surface soft soil layer

The surface soft soil layer lies at the southern area of the port consisting mainly of silt and soft clay with N-value of zero "0". This soil layer is of quite poor mechanic characteristics.

2) Plastic clay layer

The plastic clay layer underlies the surface soft soil layer mentioned above and it was also found at the surface of north end of the existing quay. As shown in Table 3-2-9, the natural water content is 30 to 70 % between plastic limit and liquid limit and N-value is very low, 0 to 2, which means that this soil layer has soft plasticity.

Table 3-2-9 Physical Characteristics of Plastic Clay Layer

Natural Water Content	30 % to 70 %
Plastic Limit	30 % to 40 %
Liquid Limit	50 % to 70 %
N-value	0 to 2

3) Limy Marl Layer

This limy marl lies at the lowest layer of the entire surveyed area, and N-value is remarkably high, more than 30, and in some places it registers more than 100. This layer is 10 to 20 meters in thickness as far as drilled in the boring and is foreseen to be more thick. The layer can be considered as a very reliable bearing foundation.

4) Sand layer

Coral sand layer with shell fragments lies at the surface between the north and north-east of the port and is less than 5 meters in thickness. The deeper portion of this layer does not have very good texture with the content of fine silt (grain size less than 0.08 mm) being about 40 %.

Silty sand and clayey sand with shell fragments and chalky marl lie at the surface of central area of the existing quay and is approx. 7 meters in thickness. The shallow portion of this layer has relatively good texture and grain size distribution with the content of sand being 76 % and the coefficient of uniformity, $Uc = D_{60}/D_{10}$, being 30 as shown below, but the deeper portion does not have good texture with the content of sand being 51 %.

D_{60} = 0.460 mm
D_{10} = 0.015 mm
Uc = $D_{60}/D_{10} = 30.7$

(2) Engineering Evaluation

The soil in the front area of the existing quay is generally of poor mechanic characteristics for the surface layer consisting of silt, soft clay and shaly sand mainly. But the soil from the north to north-east area of the port is of relatively good mechanic characteristics including friction stratum with good texture of sand having N-value of 20 to 50 except some parts such as sandy soft clay found at the boring log No.5 to No.7 of Figure 3-2-8. The foundation layer consisting of limy marl, which is found in the entire surveyed area, has a high N-value of more than 30 and can be considered as a very reliable bearing foundation.

Consequently to evaluate the soil conditions from the engineering point of view, the area between the north and the north-east of the port has good friction and bearing strata, so that the steel sheet pile structure, steel pipe pile structure and gravity type structure can be adopted. On the other hand, the area between the north end of the existing quay and boring No.5 has little friction stratum and only bearing stratum, so that the steel pipe pile structure can be adopted but the steel sheet pile structure and gravity type structure require the replacement of surface soft soil layer with sand. However the relatively small number of boring due to the limited study period means that the exact nature of the soil property cannot be stated conclusively and a full boring survey is recommended in the future planning and designing stage.

3.2.5 Environment

In order to get the fundamental data necessary to foresee the environmental impact of the future port plan on the present environmental condition around the existing port area, the study team executed a sampling and quality analysis of sea water and a field survey on the ecosystem in the port area and vicinity.

(1) Quality Analysis of Sea Water

From the field survey and interviews with people concerned, the most influential source of water pollution to the port area is the tuna tin factory because it usually discharges waste water to the front water area of the quay with on treatment. However the volume of sewage from the factory is not remarkably large and the water area around the port has not received serious damage. What follows is a discussion of the reason for the above in conjunction with the results of the quality analysis of sea water.

1) Scope of Survey

The pollution source's of influence is estimated below using a formula established by Dr. Nitta in Japan on the assumption that the discharged volume of sewage is 172,800 cubic meters per day (2.0 m^3/s).

$\log A = 1.2261 \times \log Q + 0.0855$
Q: discharged volume (cubic meter per day)
A: area of expansion (square meter)
Substituting Q = 172,800 (cubic meters per day),
A = 3,215,529 square meters,
Therefore, R (radius) = 1,431 meters.

However, the discharged volume of sewage from the factory was confirmed to be much smaller than the above assumption from the information given by the factory, something like 585 cubic meters per day. That results in a much smaller radius of influence, only 44 meters. However, it is observed visually that the actual area of expansion of sewage is much wider than 44 meters due to the action of tidal and drift current. Also, the area of the Master Plan largely exceeds a radius of 44 meters, extending several hundred meters offshore. Therefore, the radius of influence should be considered to be 1.5 km based on the above-mentioned assumption.

2) Contents of Quality Analysis of Sea Water

For the quality analysis of sea water, samples were taken at 13 points: 11 points within the radius of influence, one point 3 km away from the port and one point near the outlet of sewage just in front of the quay (See Figure 3-2-9). The contents of analysis are as shown in Table 3-2-10.

Table 3-2-10 Contents of Water Quality Analysis

Item No.	Analysis Name	Sampling Points	Number of Times	Equipment Type
1	COD	Point No.1 to 11	upper/lower layer X 2 times	HC407
2	DO	Point No.1 to 13	upper/lower layer X 2 times	UK2000
3	PH	Point No.1 to 13	upper/lower layer X 2 times	UC23
4	SS	Point No.1 to 11	upper/lower layer X 2 times	GFP
5	Salinity	Point No.1 to 10	vertically at each point	EIL Salinometer
6	Transpare ncy	Point No.1 to 11	1 time each	White Disk

Note: 1) Upper layer: 0.5 meters in depth
Lower layer: 1.0 meter above sea bottom
2) Vertically:
every 0.5 meters between 0 and 5 meters in depth,
every 1.0 meters between 5 and 10 meters in depth and
every 2.0 meters below 10 meters in depth.

3) Results of Analysis

The results of the quality analysis of sea water are shown in Table 3-2-11. The environmental evaluation will be discussed later in connection with the initial environmental examination.

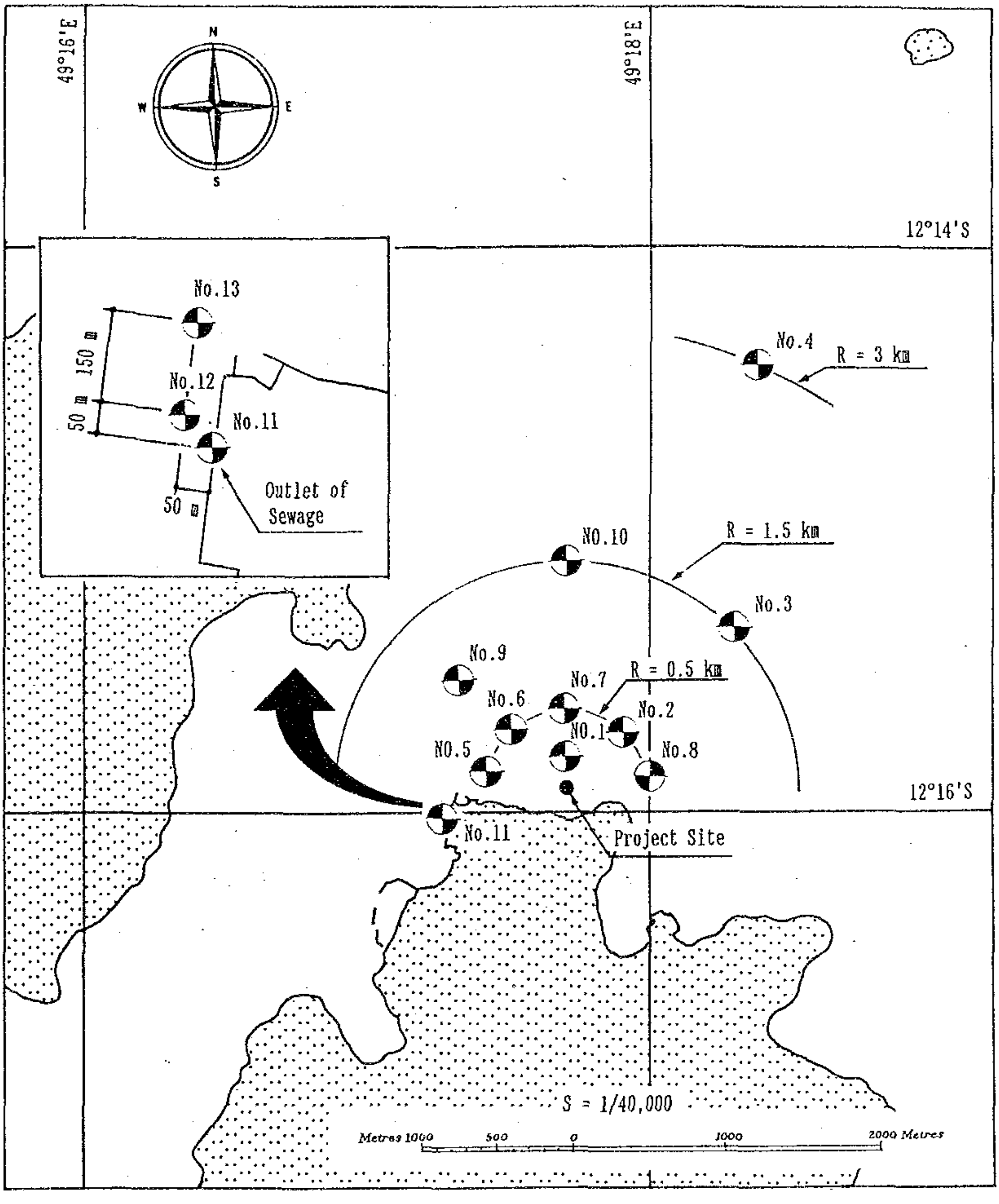


Figure 3-2-9 Locations of Sampling Points

Table 3-2-11 Results of Quality Analysis of Sea Water

Point	Times	Layer	COD (ppm)	DO (ppm)	DO Temp. (°C)	PH	SS (mg/l)	Salinity Sal./Temp. (‰ / °C)	Trans-parance (m)
1	1st	Upper	<1.0	6.83	23.4	7.95	0.85	35.15/23.3 -	
		Lower	<1.0	6.69	23.3	8.02	0.87	35.17/23.3	8.0
	2nd	Upper	<1.0	6.14	24.0	7.84	1.33	35.22/23.9 -	
		Lower	1.2	6.39	23.9	7.87	0.73	35.24/23.9	8.0
2	1st	Upper	<1.0	6.91	23.3	7.98	0.13	35.15/23.3 -	
		Lower	2.2	6.75	23.1	8.03	0.53	35.17/23.2	9.0
	2nd	Upper	1.7	6.34	23.9	7.88	0.27	35.22/23.9 -	
		Lower	1.1	6.47	23.9	7.90	1.00	35.24/23.9	9.5
3	1st	Upper	<1.0	6.92	23.5	7.96	0.07	35.15/23.4 -	
		Lower	<1.0	6.93	23.5	8.03	0.20	35.17/23.4	9.0
	2nd	Upper	<1.0	6.36	24.0	7.89	0.27	35.21/23.9 -	
		Lower	<1.0	6.41	24.0	7.90	0.33	35.23/24.0	9.0
4	1st	Upper	<1.0	6.91	23.4	7.93	0.53	35.16/23.4 -	
		Lower	<1.0	6.87	23.3	8.04	0.47	35.17/23.4	9.5
	2nd	Upper	<1.0	6.38	23.9	7.83	0.53	35.22/23.9 -	
		Lower	<1.0	6.40	23.9	7.86	0.33	35.24/23.9	10.0
5	1st	Upper	<1.0	6.66	23.3	7.95	0.93	35.18/23.3 -	
		Lower	<1.0	6.60	23.2	8.02	0.73	35.19/23.3	9.0
	2nd	Upper	<1.0	6.44	23.9	7.87	0.87	35.23/23.9 -	
		Lower	<1.0	6.42	23.9	7.88	0.73	35.24/23.9	9.0
6	1st	Upper	<1.0	6.94	23.2	7.95	0.53	35.17/23.3 -	
		Lower	<1.0	6.76	23.2	7.99	0.33	35.19/23.2	9.0
	2nd	Upper	<1.0	6.49	23.9	7.91	0.40	35.22/23.9 -	
		Lower	<1.0	6.44	23.9	7.89	0.33	35.23/23.9	9.0
7	1st	Upper	<1.0	6.86	23.2	7.99	0.53	35.15/23.2 -	
		Lower	<1.0	6.83	23.1	8.03	0.13	35.17/23.1	9.5
	2nd	Upper	<1.0	6.37	23.9	7.87	0.47	35.24/23.9 -	
		Lower	<1.0	6.39	23.9	7.87	0.20	35.24/23.9	9.0
8	1st	Upper	1.2	6.74	23.3	8.00	0.07	35.15/23.3 -	
		Lower	<1.0	6.71	23.1	8.03	0.33	35.17/23.2	9.0
	2nd	Upper	1.7	6.47	23.9	7.90	0.93	35.22/23.9 -	
		Lower	<1.0	6.43	23.9	7.90	0.27	35.24/23.9	9.0
9	1st	Upper	1.2	6.90	23.5	8.01	1.20	35.18/23.4 -	
		Lower	<1.0	6.80	23.5	8.04	1.53	35.17/23.4	9.5
	2nd	Upper	<1.0	6.41	23.9	7.86	1.33	35.24/23.9 -	
		Lower	<1.0	6.37	23.9	7.87	1.47	35.24/23.9	9.5
10	1st	Upper	<1.0	6.88	23.6	7.97	0.27	35.15/23.5 -	
		Lower	<1.0	6.81	23.6	8.02	0.00	35.17/23.5	9.5
	2nd	Upper	<1.0	6.33	23.9	7.88	0.20	35.22/23.9 -	
		Lower	<1.0	6.20	24.0	7.89	0.07	35.24/23.9	9.5
11	1st	Upper	14.4	4.03	24.0	6.20	4.67		
		Lower	15.1	3.90	24.2	6.15	3.00	-	1.5
	2nd	Upper	13.7	3.99	24.2	6.22	5.53		
		Lower	14.2	3.94	24.1	6.13	3.07	-	1.5
12	1st	Upper	-	6.47	24.0	7.74	2.90		
		Lower	-	-	-	-	-	-	-
13	1st	Upper	-	6.60	24.1	7.82	1.20	-	-
		Lower	-	-	-	-	-	-	-

(2) Ecosystem

It is well known all over the world that many unique and endemic fauna and flora inhabit Madagascar. The island of Madagascar was created by the breakup of a super continent called Gondwanaland over 120 million years ago, and since then the island has been isolated, allowing many animal and plant species to evolve.

The province of Antsiranana is located in the northern part of Madagascar. Amber Mountain National Park, located to the south-west of Antsiranana, was created in 1958. The Ministry of Water and Forest has been engaged in the preservation of the biological diversity in the region.

The outcome of visual observations is described at the point of view of ecosystem related to geography, flora/fauna and landscape within a radius of 3 km from the port. The observed area is divided into 4 sites as follows (See Figure 3-2-10):

1) Port Site
2) Anse Melville Site
3) Lazaret Site
4) La Pierrot Site

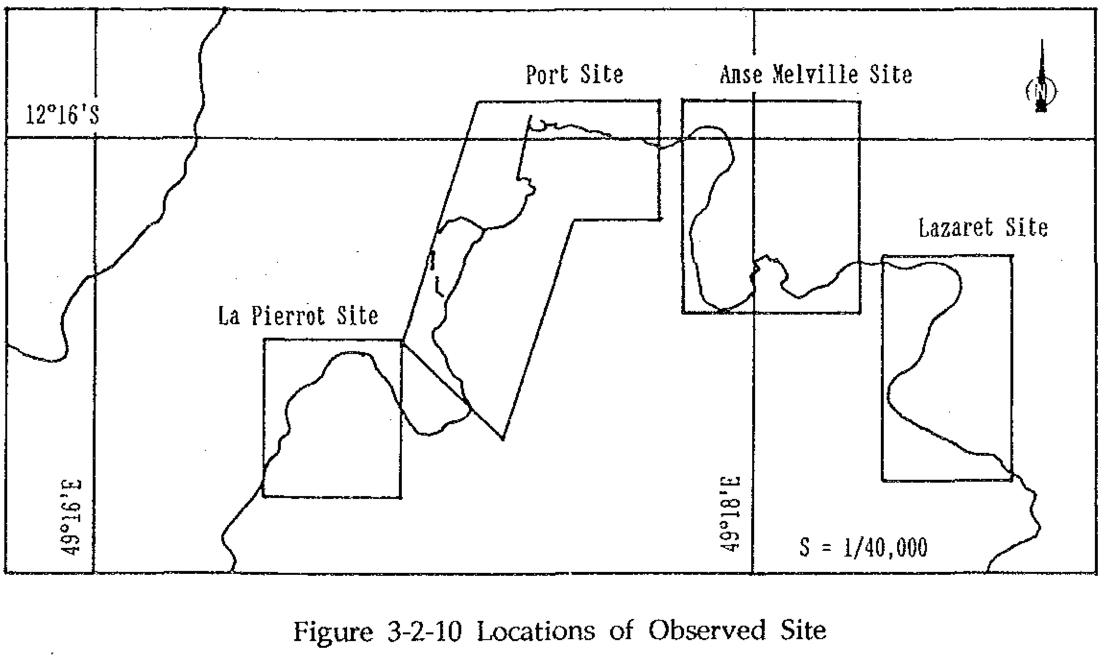


Figure 3-2-10 Locations of Observed Site

1) Port Site

In addition to the port area, there is a factory zone, a military zone and a residential quarter in this site, which forms the urban area of Antsiranana city. This urbanized area has little space for natural inhabitants such as animals and plants, so that there are no flora and fauna existing in this site.

2) Anse Melville Site

Anse Melville is located east of the Port of Antsiranana, where MTM manages the artificial island having a small quay, which is not in use, due to a shipwreck just in front of the quay. The island is connected to the land by a jetty; a wide shoal has appeared at both side of the jetty which seems to have been caused by sand drift phenomenon. There is a hospital, a power plant, congested dwellings, a cow butchery and farmhouses along the shoreline. Waste matters from the dwellings and butchery are thrown into the sea and give off a bad odour, which has spoiled the nature. A few mangroves are still found along the waterfront but face a bleak future.

3) Lazaret Site

Lazaret Site is located to the east of Anse Melville. There spreads a wide and flat hill having a pasture area for cattle, blocks for educational facilities and military billets. The hill slopes gently towards the sea, where bananas and citronnelle are cultivated. The shoreline has been kept natural with no construction, where flora such as mangroves, baobab, etc are dotted.

4) La Pierrot Site

La Pierrot Site is located to the south-west of the port. There spreads a flat hill having a pasture area for cattle, the same as at Lazaret site. Oil storage tanks of SOLIMA, the only petroleum company in Antsiranana, and a radio station are found at this site. The slopes area sharply inclined with a flat area of 50 m in width near the beach, where a fishierman's dwelling stands. The front sea area is littered with shipwrecks. Mangos and bananas are cultivated near the beach, but there are no endemic flora and fauna.

3.2.6 Magnetic Prospecting

It is known from historical data that there exist shipwrecks in the bay of Diego-Suarez. The study team carried out magnetic prospecting in the port area and vicinity.

(1) Outline of Technical Specification

- Prospecting area:	0.7 km^2 for port area
	0.3 km^2 for Anse Melville
- Interval of prospecting line:	20 meters
- Interval of positioning boat:	1 minute
- Speed of survey boat:	1 knot
- Magnetic anomaly sensor:	DTM-2, 3 pieces
- Detectable width/line:	2 meters/line x 3 = 6 meters/line
- Recorder:	U-638

(2) Results of Prospecting

1) Distribution of magnetic detection

In terms of the distribution of magnetic detection with more than 25 $G{\cdot}cm^2$ (See Figure 3-2-11), the water area just in front of the port of Antsiranana shows the highest magnetic detection, followed by the approach channel extending from the quay to the north. But there were few magnetic objects detected in the area of Anse Melville.

2) Number of points having magnetic detection

- For the area of approach channel:	8 points on average per 10,000 square meters (100 m x 100 m)
- For the area of ship basin:	1 to 2 points on average per 10,000 square meters
- For the area of within 30 m from the quay:	densely detected

Table 3-2-12 shows the objective index for the legend in Figure 3-2-11 for references.

Table 3-2-12 Objective Index for Legends in Figure 3-2-11

Classification of Magnetic Detection	Descriptions
100 G·cm^2 and above	Reinforcement Bar (20 mm dia. and 8 m long and above), Steel Pipe (140 mm dai. and 2 m long and above), Wire (30 mm dia. and 3 m long and above)
50 to 99 G·cm^2	Reinforcement Bar (20 mm dia. and 4 m long and above), Steel Pipe (80 mm dia. and 2 m long and above), Wire (20 mm dia. and 2 m long and above)
25 to 49 G·cm^2	Metalic objects less than above

The study team recorded two large magnetic detections that seemed to be shipwrecks (See Figure 3.2.11). The first point of magnetic detection is located 720 meters offshore from the quay (which is beyond the port area) and has 10.0 meters in depth at the object. And the second point is located 100 meters offshore from the quay, which stands out only 50 cm from the sea bottom and has 9.0 meters in depth at the top of the object.

(3) Comments

Because of the limited period of this field survey, the interval of prospecting line was obliged to be set as 20 meters with the detectable width of sensor being 6 meters. Therefore, 14 meters in width per prospecting line have not been covered. In other words, about 70% of the whole area has not been prospected. Therefore, a more detailed survey with diving prospecting in the area of port defined by port planning, if is does not have a sufficient water depth for the design vessel, will be recommended as well as the reprospecting of the above-mentioned second point of magnetic detection. A close examination of past records of wars in the Bay of Diego-Suarez will also be recommended, because the objects having magnetic detection may possibly be dangerous i.e., unexploded bombs.

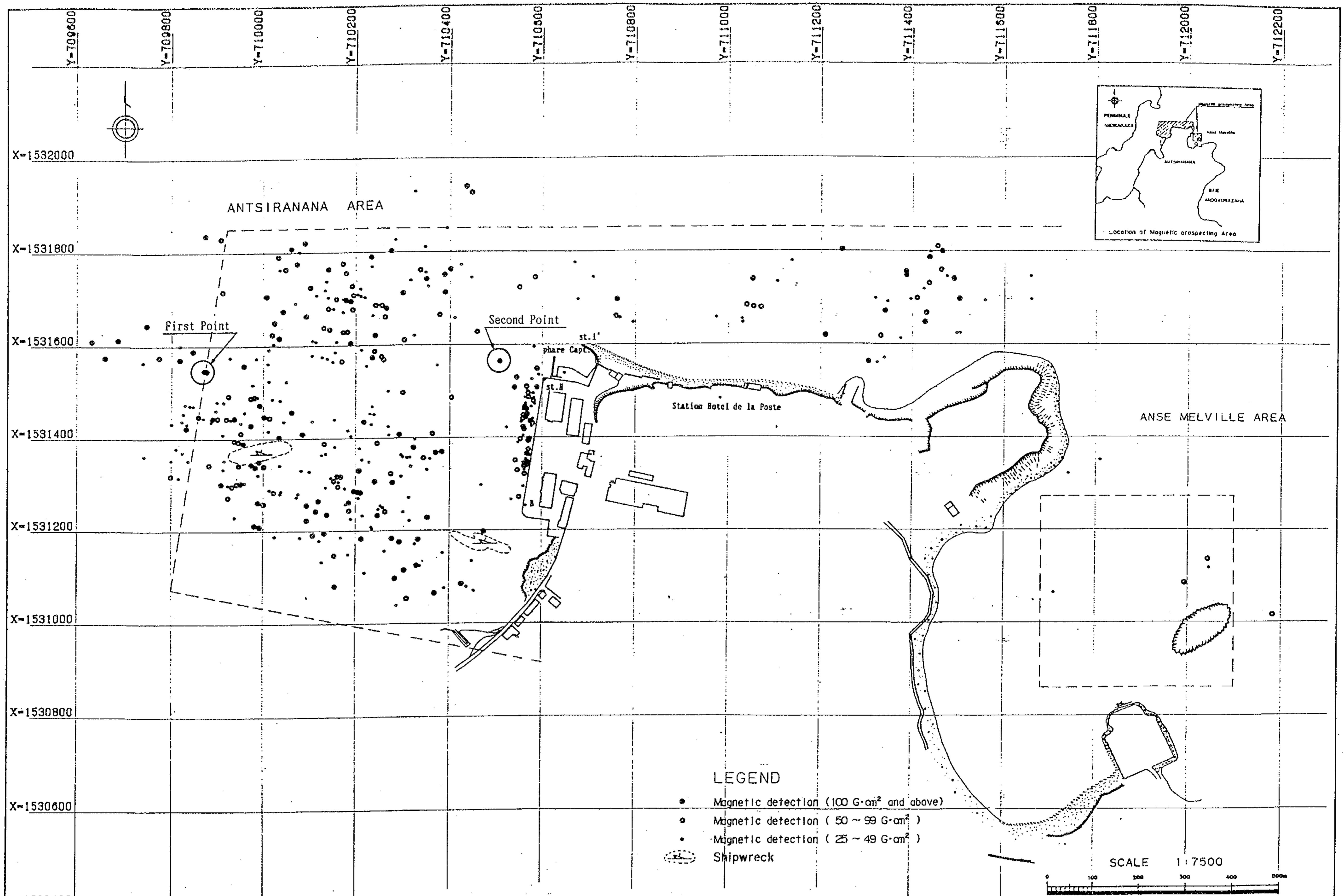


Figure 3-2-11 Plane of Distribution of Magnetic Detection

3.2.7 Land and Water Use

Land area of the port of Antsiranana is only 36,000 m^2 wide much of which is occupied by sheds, warehouses, administration offices, cold storage and so on, and this congestion is a problem. The land area is bounded on the east by a residential quarter and downtown, on the south by a navy port base and a shipbuilding yard. On the other sides, the north and the west are bounded by sea. The other land area 1 km east from the port has a hospital district, a power plant and a cow butchery along the shoreline (See Figure 3-2-12)

Water area of the port is very wide, approx. 200 hectare, while the water depth is more than 8 meters. The approach channel with a length of approx. 10 km runs from the water area toward the mouth of the bay of Diego-Suarez. Fishing activity is found along the north coast of the bay but it does not seem to be flourishing.

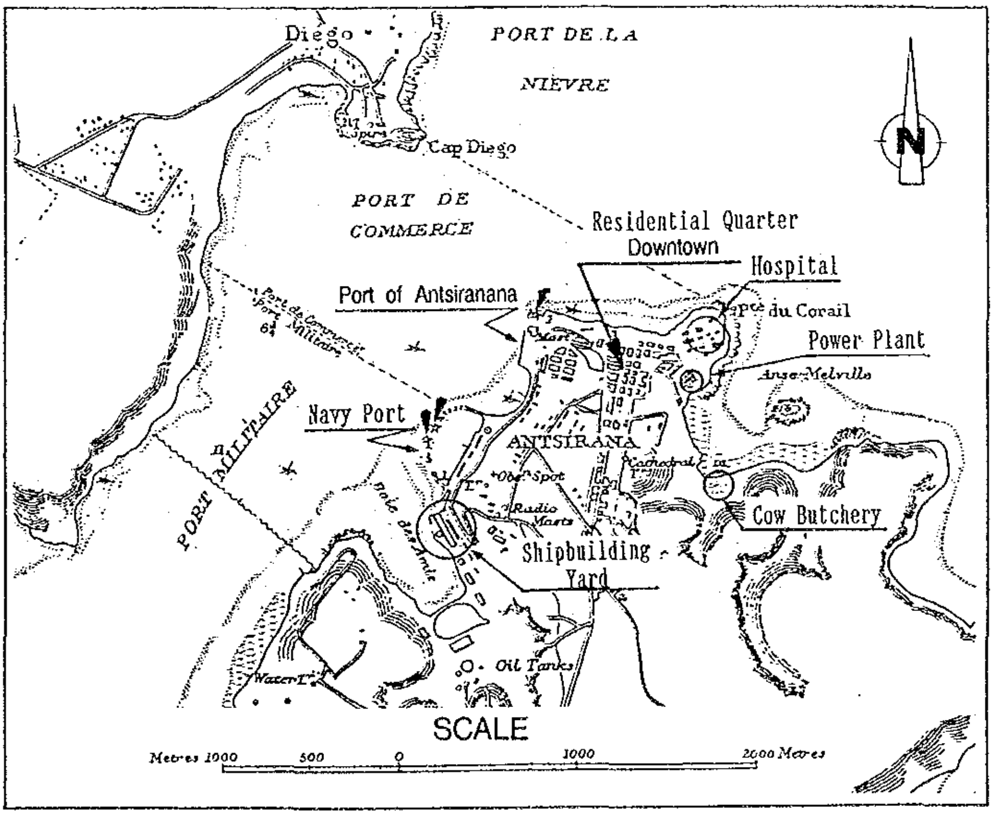


Figure 3-2-12 Land Use of Antsiranana

3.3 Port Facilities

This section presents an outline of the port facilities at the port of Antsiranana based on the relevant reports, information and the results of the field surveys executed in the first field study.

3.3.1 Existing Facilities

The existing facilities at the port of Antsiranana are shown in Figure 3-3-1. The main berth is located in the center of the port, running from north-south. In the south side of the port, the quay is allocated for the coasters and small-boats. The mooring jetty is located at the north end of the quay. A small basin for pilot boat mooring is in front of the port office, protected from intruding waves by the mooring jetty and breakwater. A large portion of the land area is occupied by sheds, magazines and tuna cold storage.

(1) Berthing Facilities

The total berth length of the quay is about 414 meters as shown in Table 3-3-1. The quay is divided into the following portions:

- The ocean-going vessels quay is 301 meters in length and 8.5 meters in depth under zero level of the navigation chart. The depth of the quay seems to be somewhat reduced in the north area at present.

- The coasters quay is 62 meters in length, and a water depth of 4.5 meters under the zero level of the navigation chart.

- The small boat quay forms two square-stations, comprising one 31 meter quay and a 20 meter quay. The water depth of the quays is 2.0 meters under the zero level of the chart.

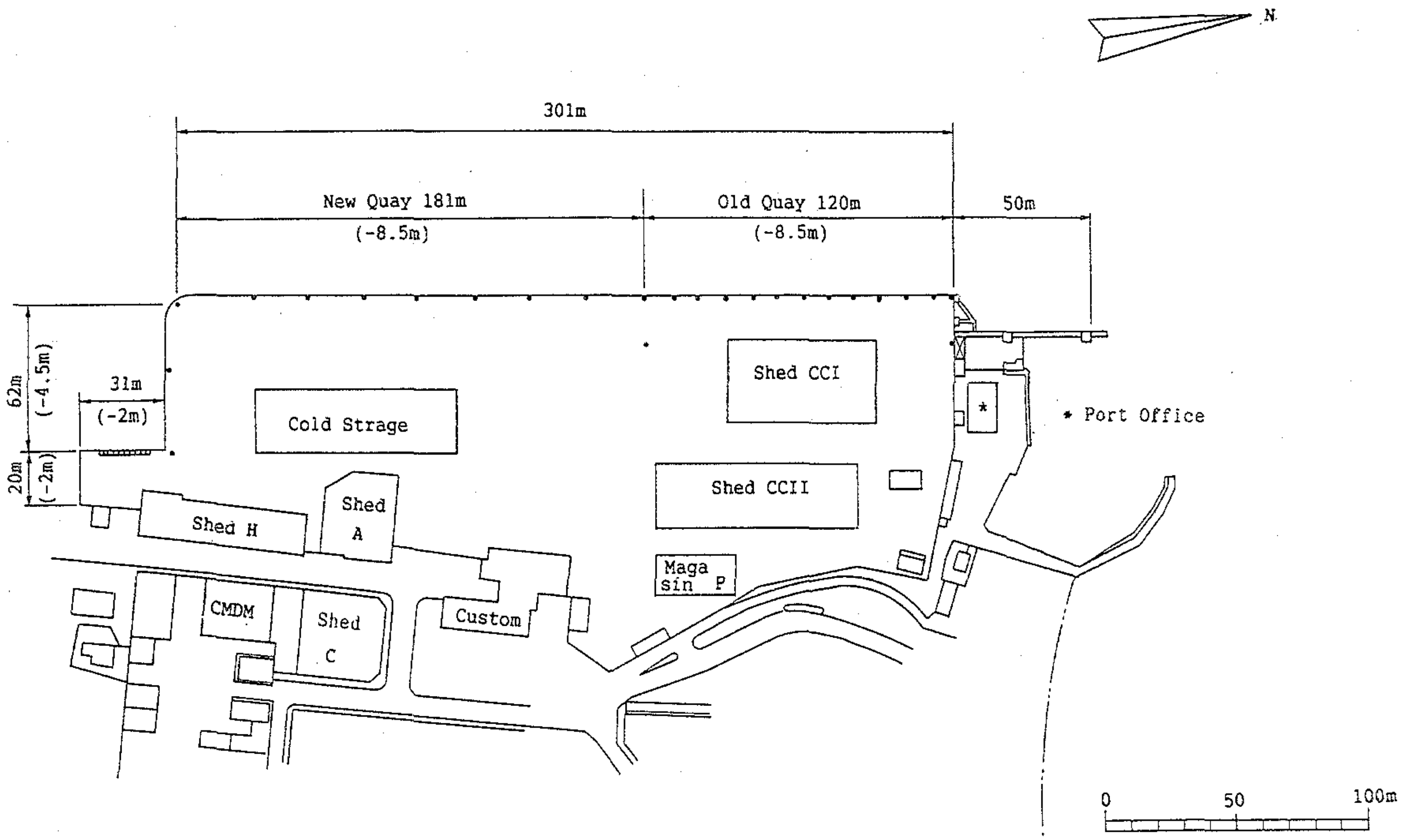


Figure 3-3-1 Existing Facilities of the Port of Antsiranana

Table 3-3-1 Berthing Facilities

Name	Length (m)	Depth (m)	Built
Ocean-going vessels quay Old quay New quay	301 (120) (181)	8.5 (8.5) (8.5)	 1932 1966
Coasters quay	62	4.5	1966
Small-boat quay	31 20	2.0	1966
Total	414		

(2) Shed, Magazine and Open Yard

The land area of the port is about 36,000 square meters, including 9,490 square meters of shed and magazine area, and 16,979 square meters of open yard. Dimensions of sheds and magazine are shown in Table 3-3-2.

Table 3-3-2 Dimension of Sheds and Magazine

Indication	Length*Width (m) (m)	Area (m^2)	Remarks (Owner)
Shed CC I	60.6*32.6 7.7*2.4 3.4*2.4 3.0*2.4	1,976 18 8 7	CCI
	Sub-total	2,009	
Shed CC II	80.2*25.7 2.8*1.9	2,061 5	CCI
	Sub-total	2,066	
Shed A	28.2*33.3 -10.1*0.7 -9.9*6.2/2	939 - 7 -31	CMDM
	Sub-total	901	
Shed H	65.0*16.9 -(1.7+1.4)*50.3/2	1,099 -78	CMDM
	Sub-total	1,021	
Shed C	31.0*30.0	930	CMDM
Magazine P	32.2*15.8	509	
Cold Storage	76.4*26.4 5.5*3.5 5.2*3.5	2,017 19 18	PFOI
	Sub-total	2,054	
	Total	9,490	
Open Yard	214.0*79.34	16,979	

Note : The area of open yard is the figure given from CMDM.

3.3.2 Superannuation and Deterioration of Facilities

(1) Old Quay

Old quay was constructed in 1932, and then in 1972 the slab of reinforced concrete was reconstructed. Recently, an overlay with asphalt concrete was executed (1989-1990). As-built drawings in 1932 were discovered. The detailed information of construction work in 1972 and 1989-1990 has not yet been collected.

Field survey was carried out with regard to the structural transformation, breakage and deterioration of the quay. The items of the field survey are shown as below.

1) Deterioration degree by visual observation.
2) Remaining quantities of the reinforcement.
3) Existing resistivity of the concrete.

The results of the visual observation are summarized as follows:

- Old quay is of reinforced concrete piled structure as shown in Figure 3-3-2. The total length of the quay is 120 meters. On a structural aspect, this quay is divided into 4 blocks with 30 meter length segments. Two blocks in the north and in the south which have the same structure are anchored with tie of used rails. As to the 2 blocks of the middle, the anchor is only installed on the common side(Figure 3-3-3).

- Deterioration is evident in the superstructure concrete. The situation of the concrete is very severe, in particular, the orthogonal reinforced beams for face line, the bottom of the slab and the front wall of the face line are severely damaged as shown in Photo 3-3-1 and 3-3-2.

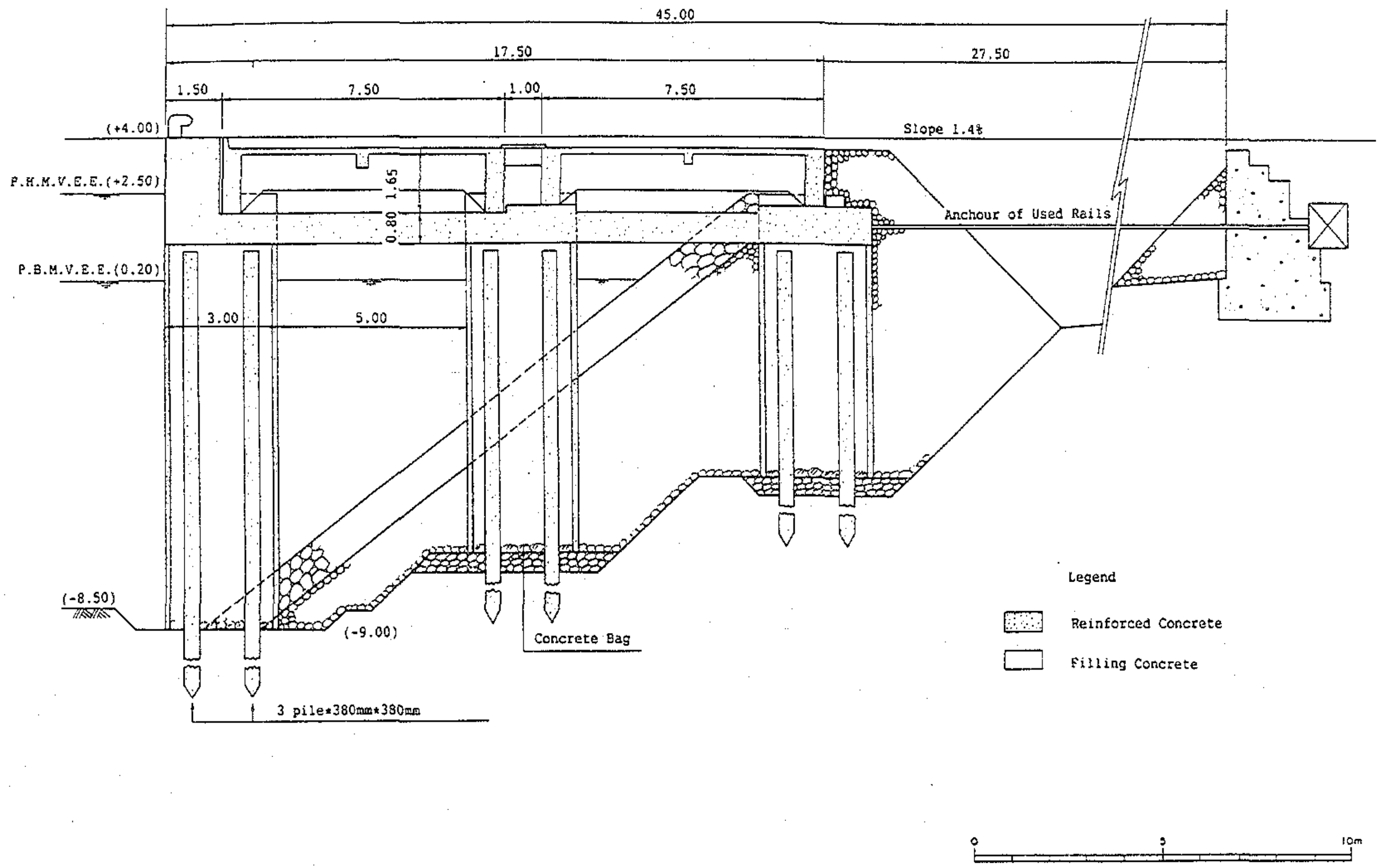


Figure 3-3-2 Cross Section View of the Old Quay

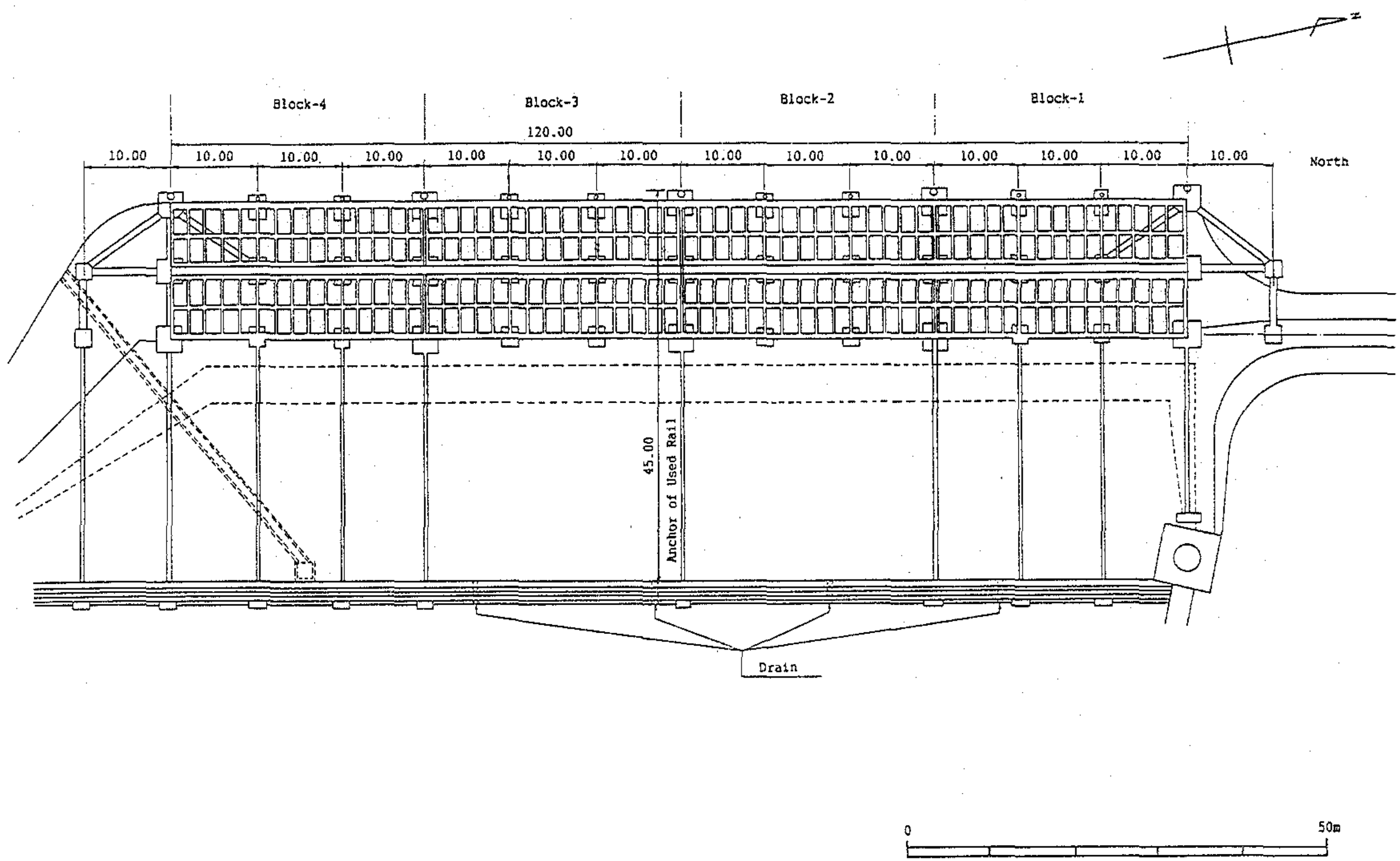
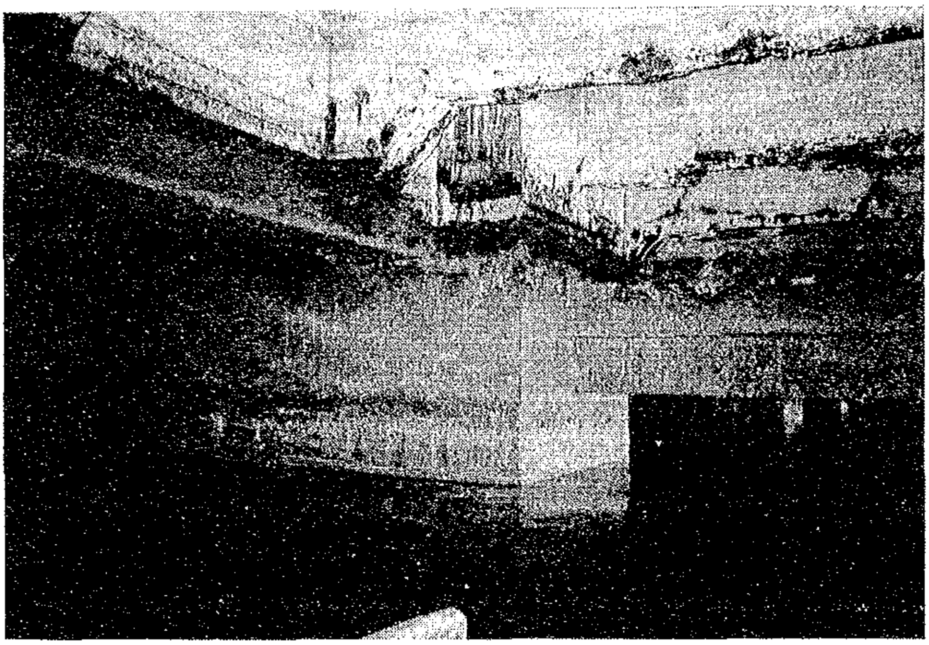


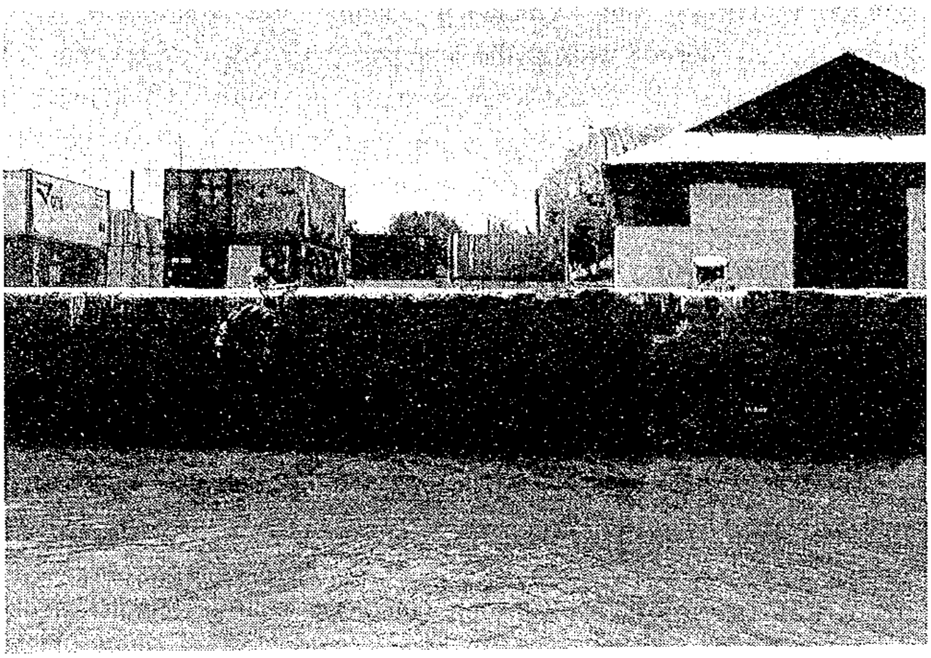
Figure 3-3-3 General Plan of Quay Structure



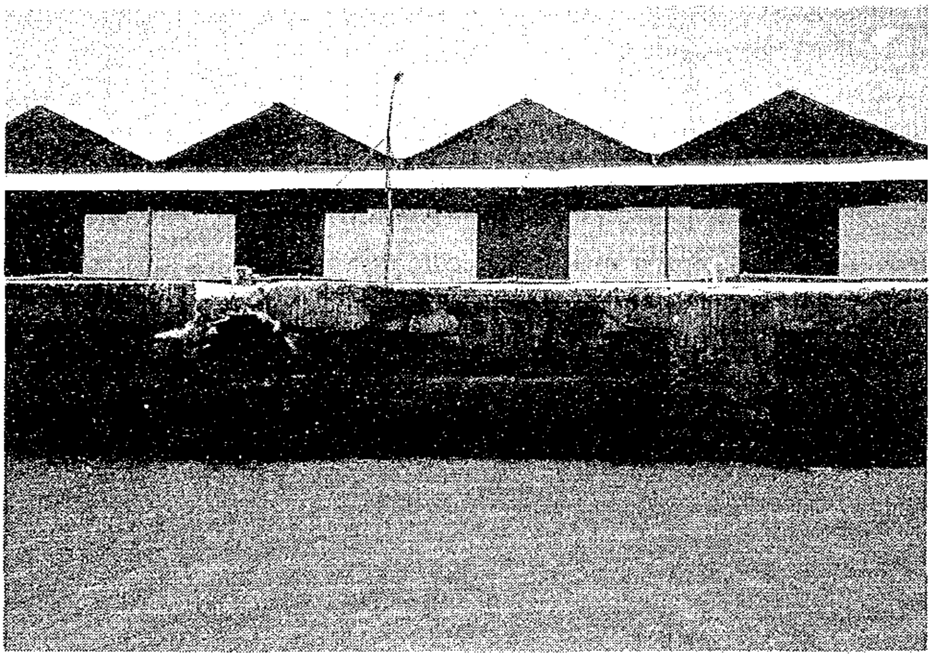
(a) Beam

(b) Slab

Photo 3-3-1　Deterioration of the Old Quay (1)



(a) Front Wall



(b) Front Wall

Photo 3-3-2 Deterioration of the Old Quay (2)

- The deterioration of the orthogonal beams and the slabs of the superstructure are observed during the low tide with small draft canoe. The deterioration condition of the old quay is shown in Figure 3-3-4(1)-(4). The description of deterioration degree is made with reference to the guidelines on the deterioration of the reinforced concrete shown in Appendix A-3.3.1.

- Fifth degree deterioration of the beam appears remarkably on block-4. On block-2, the deterioration degree 5 is rarely encountered compared to the other blocks.

- The deterioration of the slab concrete appears remarkably on the front side of the quay. Fifth degree deterioration is concentrated on both sides of the old quay, namely, block-1 and block-4.

- The front wall of the quay is severely damaged on the overall extension, as shown in Figure 3-3-5.

Main reinforcing bars located on the bottom of the beam are damaged in 50 percent of the orthogonal beams. Damage to the reinforcing bars located on the bottom of the slab is recognized on the front side of the quay. Racking of the reinforcing bars of the front wall is very severe.

Existing resistivity of the concrete was tested by concrete test hammer. The present compressive strength of the concrete is over 400 kgf/cm^2 for beam and slab, and around 370 kgf/cm^2 for front wall (See Table 3-3-3). For further study, concrete core sampling was executed at 6 points on the quay. The compressive strength of these core samples is from 225 to 324 kgf/cm^2, with or without the presence of reinforcing bar (See Appendix A-3.3.2).

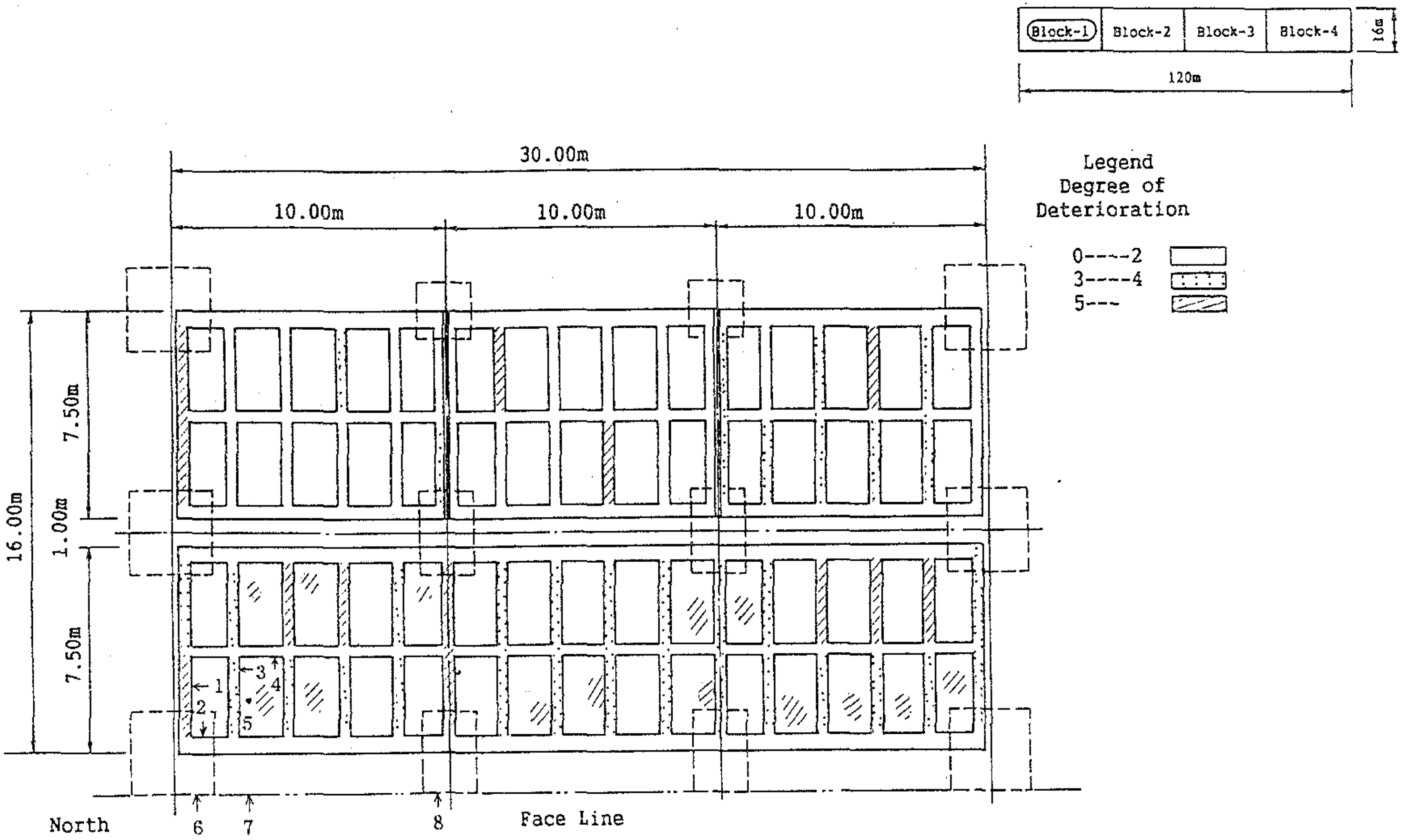


Figure 3-3-4(1) Degree of Deterioration of Beam and Slab

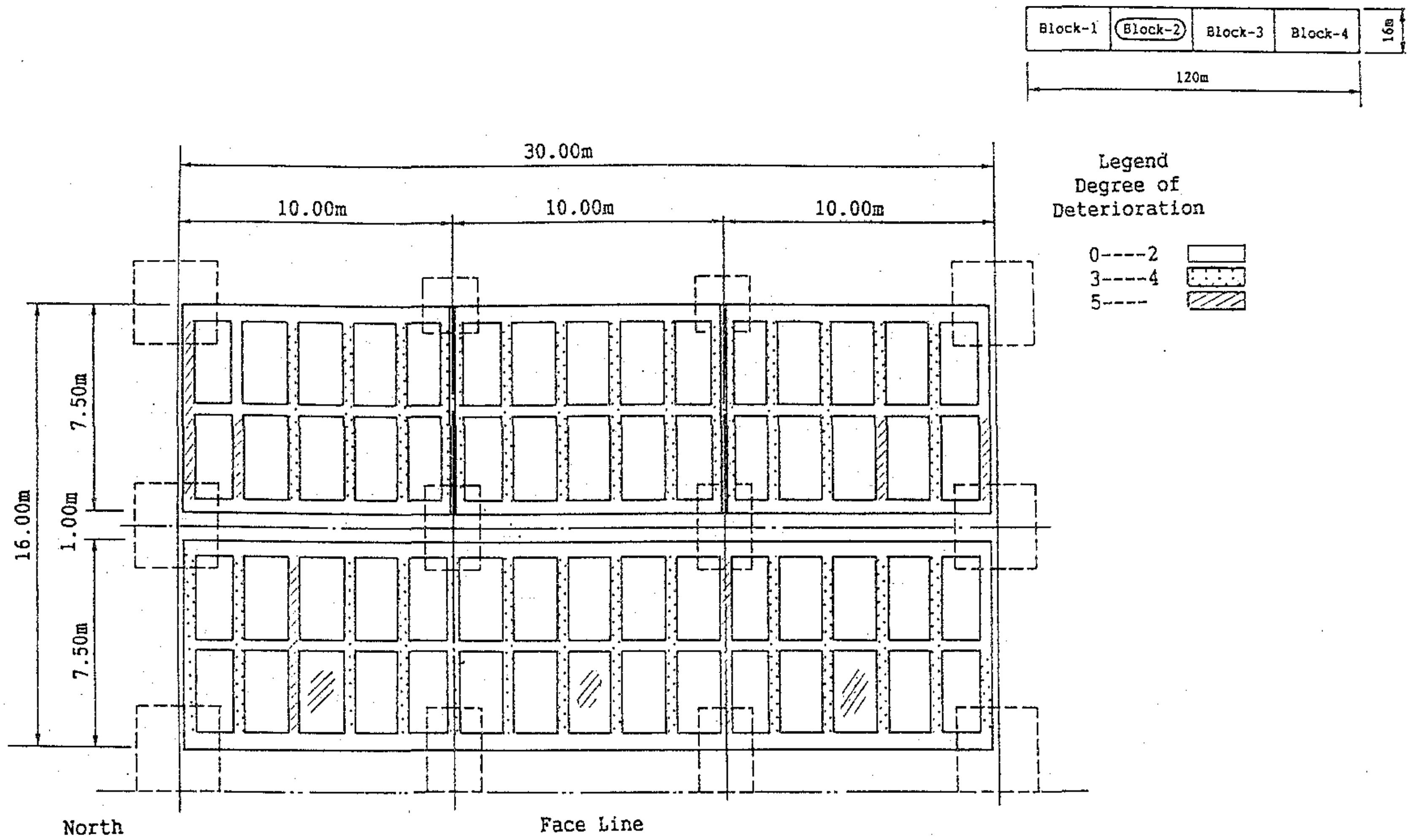


Figure 3-3-4(2) Degree of Deterioration of Beam and Slab

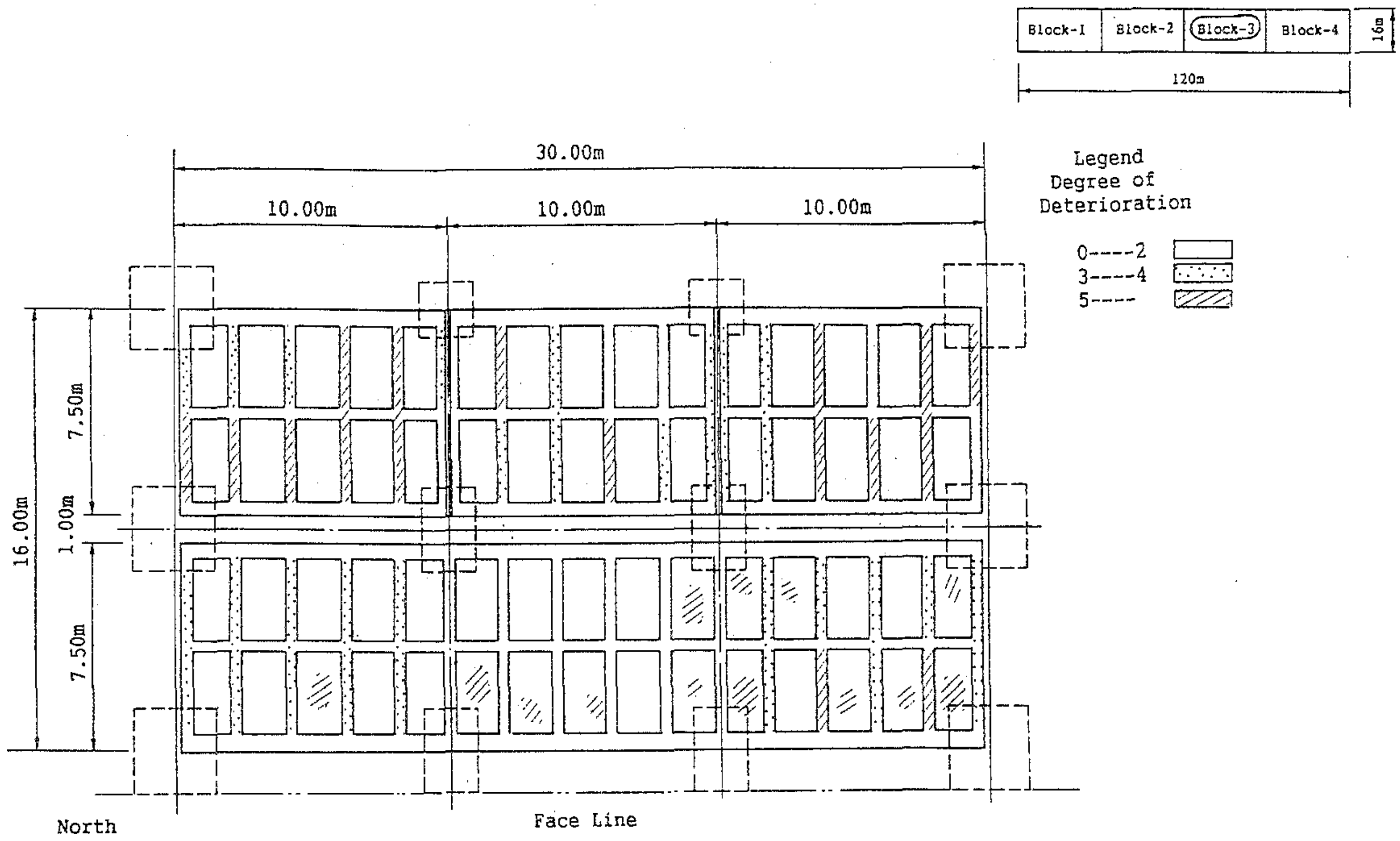


Figure 3-3-4(3) Degree of Deterioration of Beam and Slab

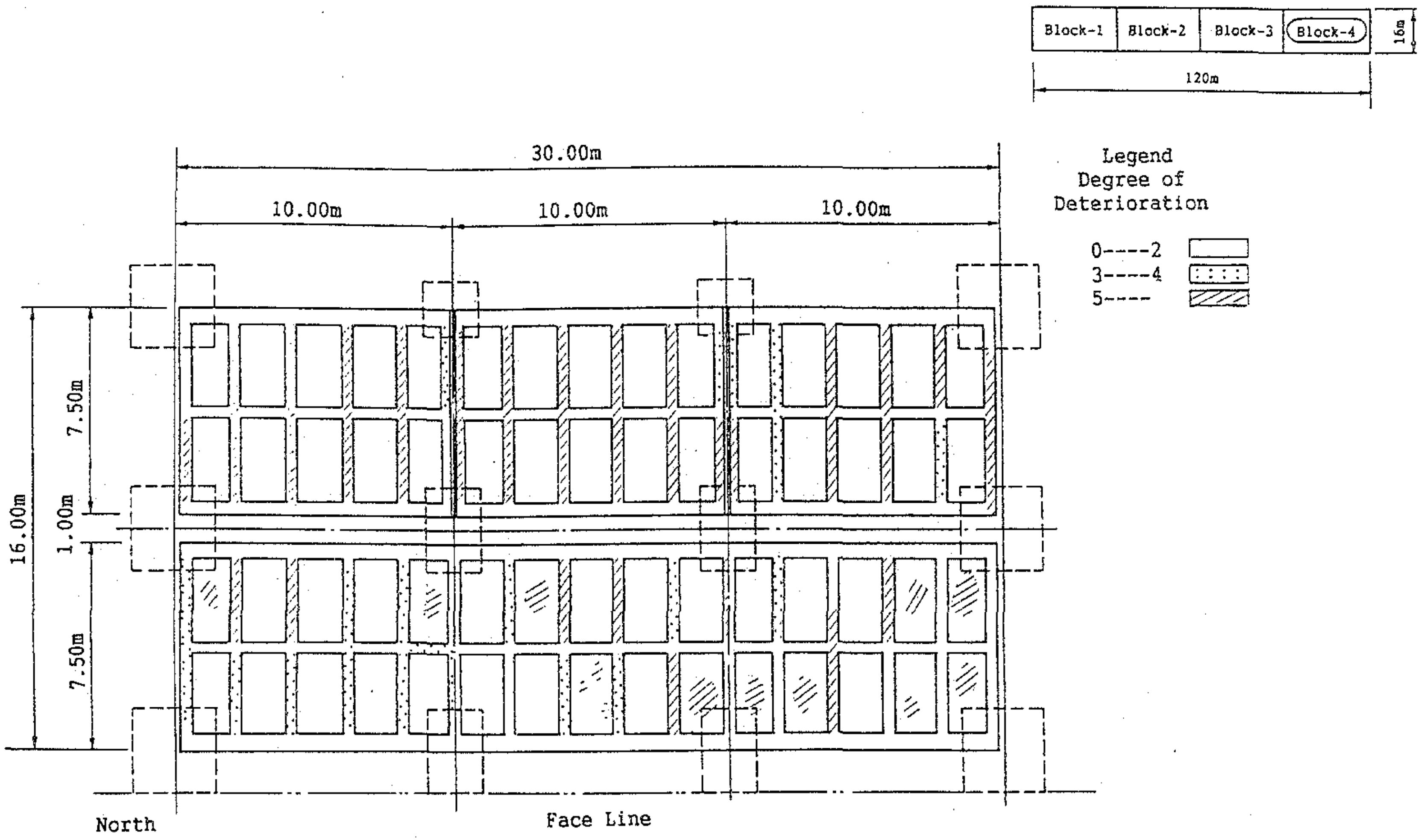


Figure 3-3-4(4) Degree of Deterioration of Beam and Slab

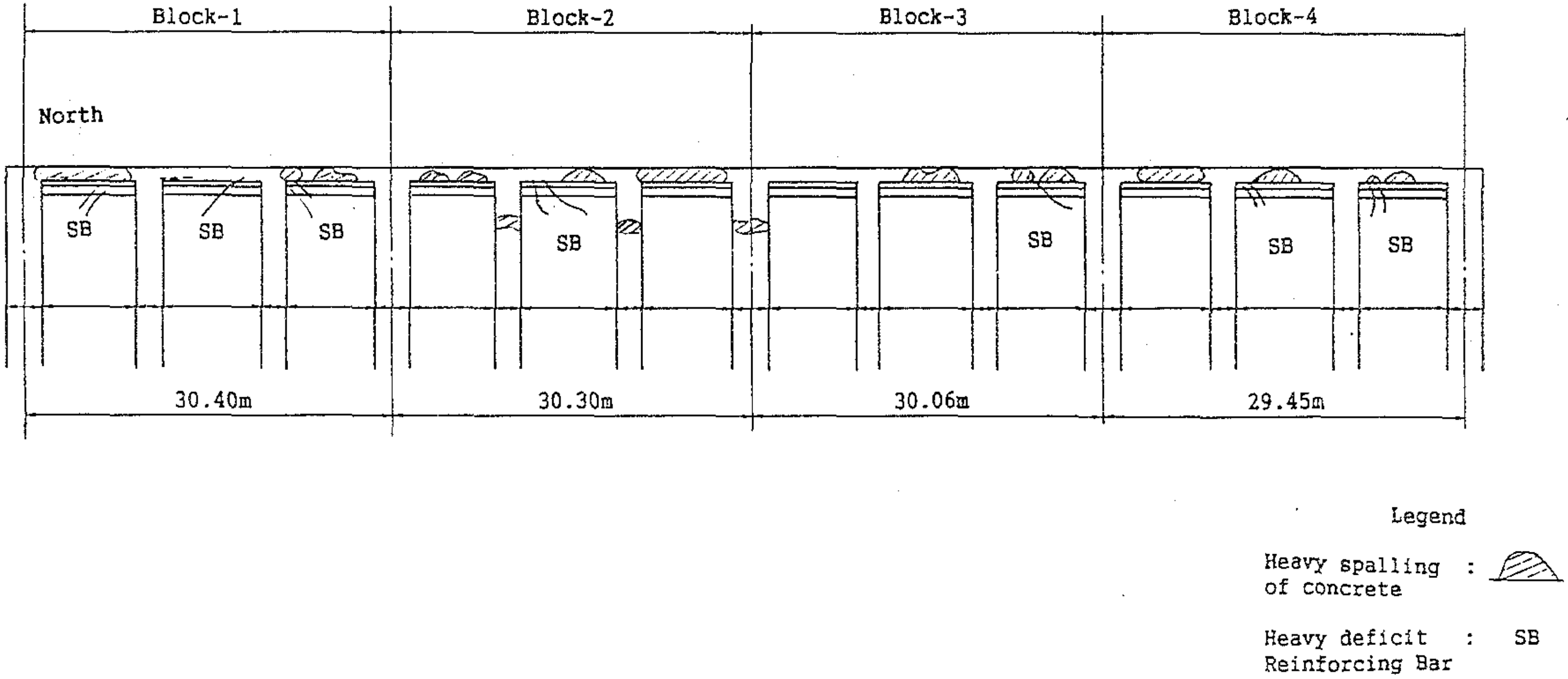


Figure 3-3-5 Degree of Deterioration of Front Wall

Table 3-3-3 Results of the Resistivity Measurement of Concrete

Measured Location No	Angle (°)	Hammer Rebound	Compressive Strength(kgf/cm²)	Remarks
1 : Beam	0	49.7	510 (462)	
2 : Beam	0	52.6	560 (500)	
3 : Beam	0	43.9	410 (387)	
4 : Beam	0	48.1	495 (441)	
5 : Slab	+90	55.4	600 (501)	effect of reinforcing bar
6 : Front Wall	0	40.9	365 (348)	
7 : Front Wall	0	41.6	375 (357)	
8 : Front Wall	0	34.8	275 (268)	a few swellings

Note : The measurement is executed at the end of block-1(Figure 3-3-4(1)). Figures in round brackets are based on the guideline of Japan Society of Materials.

Regarding the present bearing capacity, the examination on the slab(S1) and the orthogonal beam(BM) as a stiffener is essential for the evaluation.

The load-carrying capacity of the beam BM and the slab S1, which are heavily deteriorated, has been examined by structural calculation on the present load condition as shown in Figure 3-3-6. The present load condition is determined as follows:

- Surcharge : 2 tf/m²
- Forklift truck : 20 tf
- Truck crane : 40 tf

The resulting stress of these structural members has been compared to the values of the allowable stress at the initial design in 1932. The evaluation of the present capacity is outlined below.

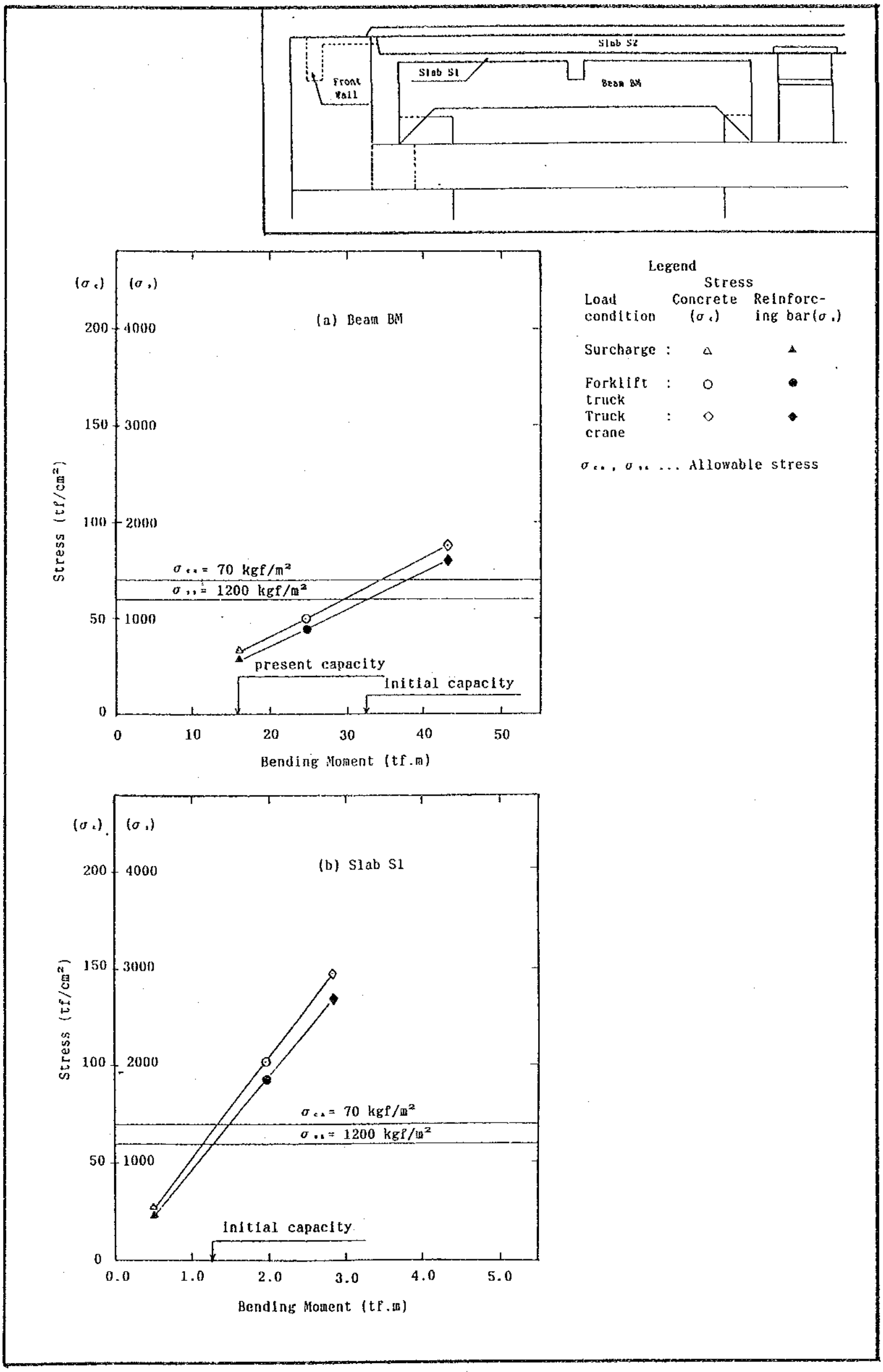


Figure 3-3-6 Relation between Bending Moment and Stress

- The present load-carrying capacity of the beam BM has dropped to approximately half of the original value while the stress reaches the allowable stress at the load condition of the surcharge. The capacity of the beam BM is not sufficient for the larger load condition of forklift truck and truck crane.

- The stress of the slab S1 reaches the allowable stress in the initial situation and it is evident that the present capacity of the slab S1 is also deficient for the present deteriorated condition.

Considering the structural stability and utilizable safety, the repair items are listed as follows:

- Stability : Beam BM, Slab S2*
- Safety : Front Wall, Fender, Bollard, Curbing.

* At present, it is necessary to repair due to lack of detailed structural data.

(2) New quay

New quay was constructed in 1966. As-built drawings and information of construction work have not yet been collected.

The survey items are shown as below.

1) Deterioration degree by visual observation
2) Remaining thickness of the steel sheet-pile

The results of the visual survey are summarized as follows:

- New quay is of steel sheet-pile cellular-bulkhead structure as shown in Figure 3-3-7. The total length of the quay is 181 meters. The number of cell and connection arc is 9 pieces and 7 pieces respectively.

- Deterioration appears in the superstructure concrete. The situation of the concrete is not so severe compared to the old quay but a part of the capping concrete of the quay is damaged as shown in Photo 3-3-3.

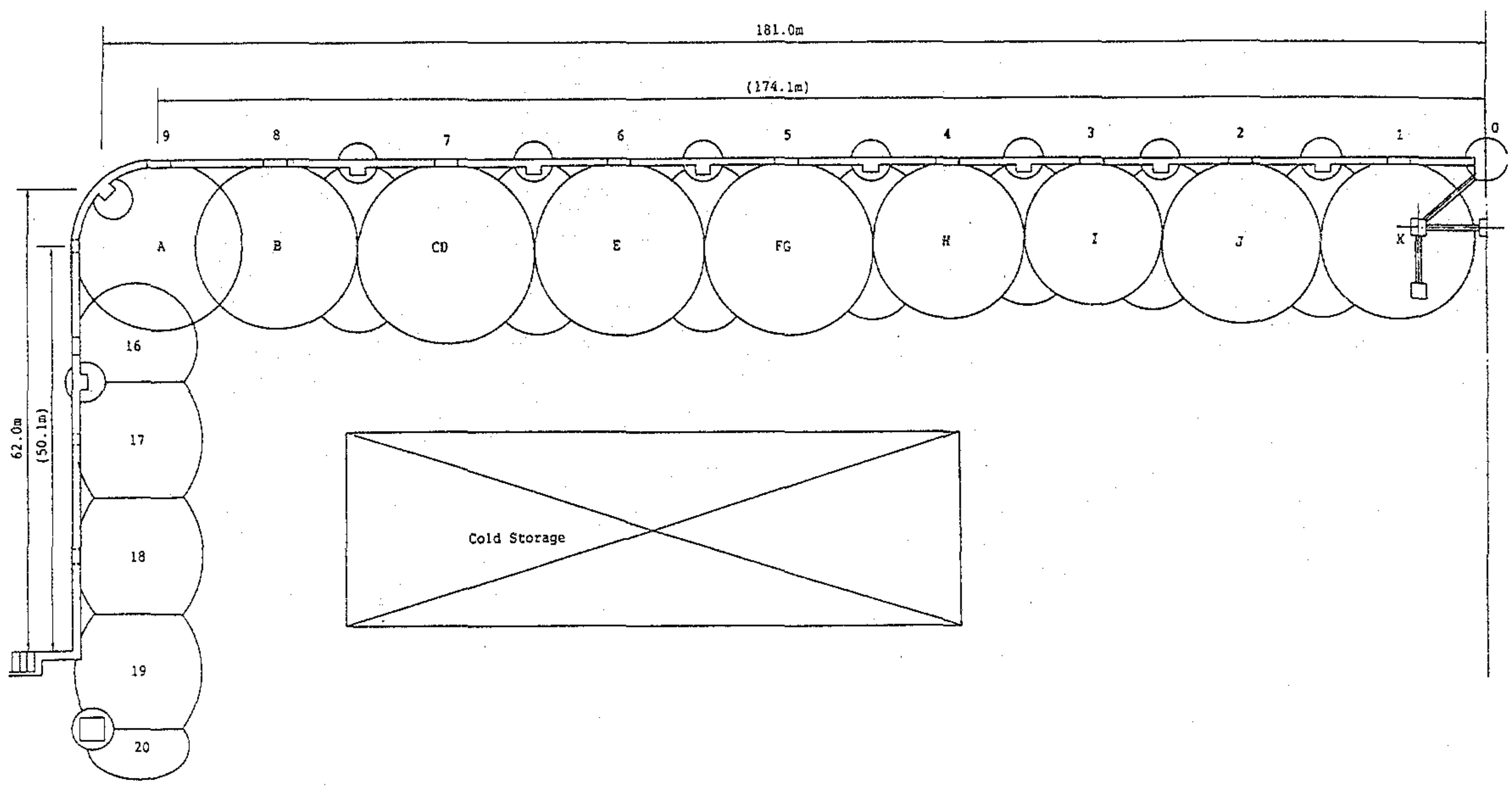
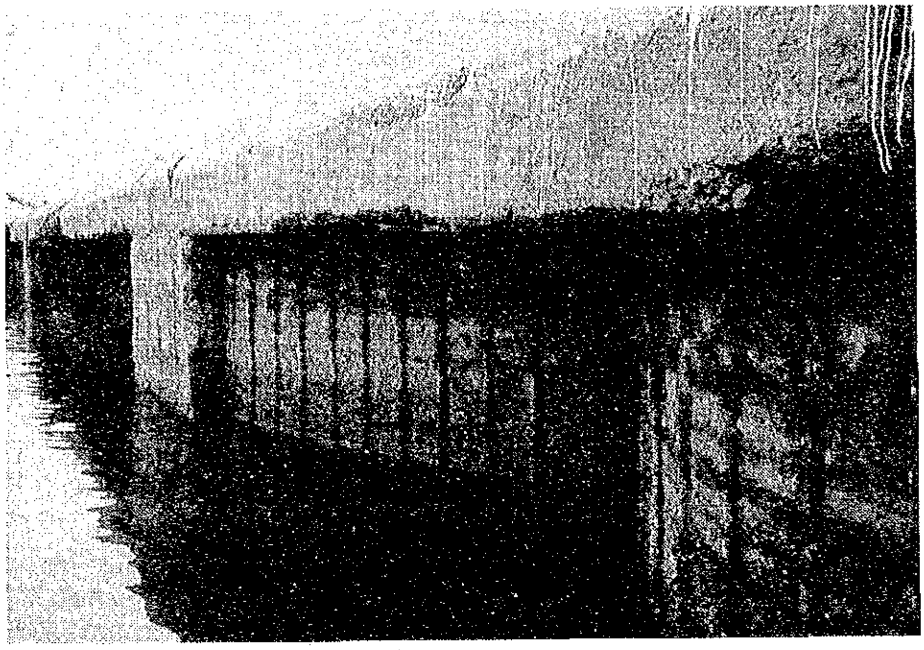
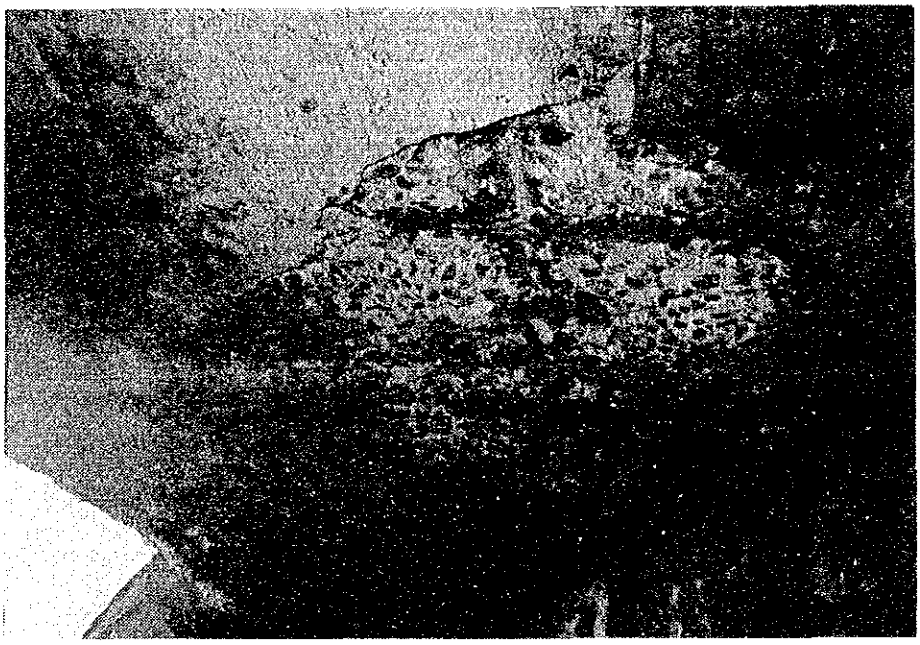


Figure 3-3-7 General Plan of the New Quay



(a) Capping Concrete and Cellular-Bulkhead



(b) Capping Concrete

Photo 3-3-3 Deterioration of the New Quay

Steel sheet-piles are corroded, particularly in the splash zone. Remaining thickness of the steel sheet-pile was examined based on the result of the survey with ultra sonic type thickness meter. The results of measurement are shown in Table 3-3-4. Remaining thickness is from 8 to 10 mm. Assuming the initial thickness is 12 mm, corroded thickness is from 2 to 4 mm and corrosion rate is about 0.1 mm/year (=3.0/27), which is the same as the ordinary value.

Table 3-3-4 Results of the Thickness Measurement of Steel Sheet-piles

Measured Location		Original Thickness T1(mm)	Measured Thickness T2(mm)	Corroded Thickness T1-T2(mm)	Remarks
No 1	+2.5m	12.0	8.9	3.1	Cell 19
	+0.5m	12.0	9.7	2.3	
	-1.5m	12.0	10.5	1.7	
No 2	+2.5m	12.0	8.2	3.8	Arc between
	+0.5m	12.0	9.5	2.5	Cell B and CD
No 3	+2.5m	12.0	10.0	2.0	Cell K
	+0.5m	12.0	10.4	1.6	

Note : The original thickness is assumed to be 12 mm.

Evaluation of load-carrying capacity has been executed by the following procedure.

- The stability of the cellular-bulkhead is assumed to be governed by the horizontal tension acting on the joint of straight steel sheet-pile, maximum horizontal tension is calculated on the present load condition (surcharge: 2 tf/m^2).

- Allowable tension of steel sheet-pile is estimated on the present corroded situation.

- Maximum horizontal tension is compared with allowable tension.

The results are shown in Figure 3-3-8 and described as follows:

- Maximum horizontal tension of the joint is about 60 tf/m on the line of coefficient of earth pressure Kr=0.3, considering that the deformation of the cellular-bulkhead has stopped and that filling sand was compacted completely since completion (1966).

- Allowable tension has decreased by 20 percent due to corrosion and is estimated at 120 tf/m.

- Horizontal tension is approximately half of the allowable tension. Therefore, the cellular-bulkhead is stable.

Considering the structure stability and utilizable safety, the repair items are listed as follows:

- Stability : Cellular-bulkhead*
- Safety : Capping concrete, Fender, Bollard, Curbing.

* It is considered that allowable tension will drop as corrosion of steel sheet-piles by rust progresses. To make clear the degree of repair work for sheet-pile, the drawings at the time of construction work are essential.

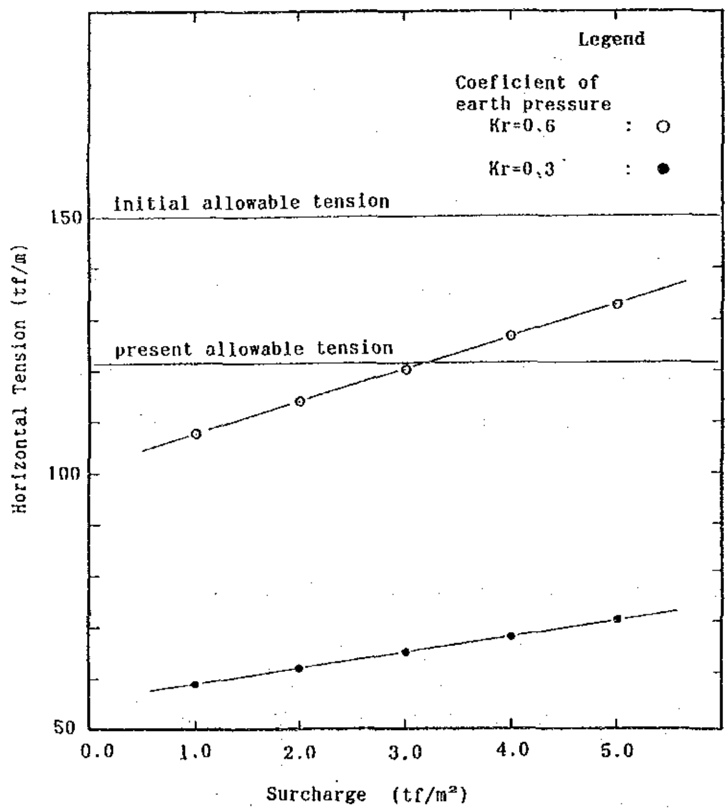


Figure 3-3-8 Relation between Surcharge and Horizontal Tension

3.4 Handling Equipment

The port of Antsiranana is not equipped with a large power crane such as gantry. In general, derricks or crawler cranes are used for loading/unloading of cargoes into/from vessels. To handle cargo including containers at the apron or open yard, fork lifts or yard tractors are used. The same is true for vanning/devanning into/from containers.

Cargo handling is carried out exclusively by CMDM, a private company founded with French capital. MTM supervises CMDM.

Cargo handling equipment owned by CMDM is shown in Table 3-4-1. In addition, CMDM has a program to purchase another HYSTER for handling 28-ton-containers by the end of 1993. The table shows also the state of each piece of equipment as evaluated by CMDM. As far as can be observed, the evaluation is accurate. A crane introduced in 1945 is still in use. That is amazing. This suggests that adequate daily maintenance is performed and supply of necessary spare parts is sufficient.

Considering the present cargo volume, it is thought that the capacity of handling equipment is not insufficient.

PFOI is a factory producing canned tuna, which began operations in March, 1993. PFOI has a refrigerator warehouse in the port. PFOI transports tuna from the warehouse to the factory just behind the port by themselves. PFOI owns 3 pieces of cargo handling equipment, two of which are forklifts and the other is a tractor. All of them were introduced in 1991 and are operating in good condition.

SOLIMA, the only enterprise in Madagascar having an oil refinery, transfers their products by pipeline between the port and their tanks in Antsiranana.

Table 3-4-1 Handling Equipment Owned by CMDM (1992)

NAME	No.	CHARACTERISTICS	YEAR	Con.
HYSTER	1	28T CONTAINER CARRIER	1986	TB
HYSTER	1	22T CONTAINER CARRIER	1991	TB
MC 80 MANITOU	2	8T FORK LIFT	1981	B
MC 25C MANITOU	3	2T 5 FORK LIFT	1981	B
MCE 25H MANITOU	1	2T 5 FORK LIFT	1990	TB
MCE 25H MANITOU	1	2T 5 FORK LIFT	1992	TB
MTL 625 MANITOU	1	2T 6 FORK LIFT	1992	TB
TRACTOR	1	32T SEMI TRAILER	1991	TB
TRACTOR	1	32T SEMI TRAILER	1991	TB
TRACTOR	1	MF 290	1986	TB
TRACTOR	1	MF 265	1986	TB
TRACTOR	1	RENAULT	1982	B
CRANE	1	NORDEST 5T	1972	B
CRANE	1	NORDEST 5T	1972	B
BONDY	1	CRANE	1945	AB
TRAILER	5	CONTAINER CARRIER	1991	B
TRAILER	2	CODERC 20T	1987	B
TRAILER	2	PNEU 5T		B
TRAILER	1	10 m		B

Note; (1)YEAR:starting year for use
(2)CON.:actual condition
(3)TB:very good
B:good
AB:poor

3.5 Cargo Handling Volume

With regard to cargo handling volume, DTM keeps the statistics of general merchandise cargo, and SOLIMA keeps the statistics of petroleum and its products. But there are no standardized statistics on cargo handling including both general merchandise and petroleum. Therefore it was necessary to study the handling of each type of cargo separately.

(1) General merchandise cargo

1) Loaded cargo

Trend of loaded cargo volume is shown in Table 3-5-1 and Figure 3-5-1. In the last decade, total loaded cargo volume including foreign and domestic cargos varied within the range of 33 thousand tons to about 72 thousand tons. The trend of foreign and domestic cargo volumes follows that of the total loaded cargo volume. Loaded commodities were classified into several categories to study the trend of loaded cargo.

Among these commodities, major cargoes are tuna and salt. Until 1990, tuna was mainly transhipped from fishing boats to refrigerator vessels for export. But since the tuna factory behind the port began its production in March 1991, a portion of tuna has been exported by container as canned food. Salt of Madagascar is mainly produced in Antsiranana and its export volume is comparatively stable according to the trade statistics.

Most of rice, flour, cement and fertilizer in the loaded cargoes are domestic cargoes and they are mainly imported for transhipment to other ports. The volume of these cargoes fluctuates.

Coffee, cacao, cashew nuts and canned foods are mainly exported and in the case of outbound cargo, most of them are transhipment cargo for export to other ports. As the contents of general merchandise and container are unavailable in the statistics of DTM. It seems that the volume of other items has been steadily increasing.

Table 3-5-1 Trend of Loaded Cargo Volume Excluding Petroleum Products

(Unit: ton)

	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992
Foreign cargo	24,482	9,718		26,157	31,879	17,379	39,705	57,803	64,183	66,309
Tuna	109	1,408		17,019	18,236	4,007	16,735	35,058	41,161	51,841
Salts	18,578	5,690		6,544	8,335	8,359	12,826	10,655	8,229	753
Rice	0	0		41	0	0	0	0	0	0
Flour	0	0		0	0	0	23	0	0	846
Cement	0	0		0	0	0	0	0	0	0
Fertilizer	0	0		0	0	0	0	0	0	0
Canned food	0	0		0	0	0	0	0	2,273	6,059
Others	5,798	2,620		2,553	5,308	5,013	10,121	12,090	12,520	6,810
Coffee	4,845	1,005		0	2,238	738	604	0	0	558
Cacao	100	0		0	866	1,059	143	0	0	785
Cashew nuts	0	0		0	0	637	1,354	1,159	2,018	0
General merchandise	17	4		230	32	298	477	604	1,050	1,505
Container	8	1,268		1,668	943	919	7,242	9,717	9,042	3,506
Empty container	558	145		652	307	711	213	405	410	195
Others	267	198		3	922	651	88	205	0	261
Domestic cargo	11,649	34,803		29,460	20,152	15,581	22,466	13,800	13,991	21,286
Tuna	565	537		293	211	0	0	0	0	0
Salts	2,025	23,392		26,415	16,528	13,444	17,906	12,747	12,751	10,163
Rice	0	5,050		425	0	1	0	0	0	2,001
Flour	30	35		0	52	189	158	66	0	22
Cement	3,353	957		0	23	0	224	200	0	31
Fertilizer	2,282	2,363		0	2,491	5	1,310	0	0	0
Canned food	0	0		0	0	0	0	0	0	0
Others	3,394	2,469		2,327	847	1,942	2,868	787	1,240	9,069
Coffee	80	40		0	0	182	1,111	0	0	0
Cacao	51	0		0	0	102	0	0	0	0
Cashew nuts	0	0		351	0	0	0	0	0	163
General merchandise	408	249		593	248	716	406	138	1,198	6,509
Container	438	223		29	108	75	392	0	13	3
Empty container	54	72		51	17	4	49	71	17	6
Others	2,363	1,885		1,303	474	863	910	578	12	2,388
Total	36,131	44,521	46,718	55,617	52,031	32,960	62,171	71,603	78,174	87,595
tuna(tranship)	674	1,945	4,629	17,312	18,447	4,007	16,735	35,058	41,161	51,841
Salts	20,603	28,982	30,299	32,959	24,863	21,803	30,732	23,402	20,980	10,916
Rice	0	5,050	1,688	466	0	1	0	0	0	2,001
Flour	30	35	270	0	52	189	181	66	0	868
Cement	3,353	957	553	0	23	0	224	200	0	31
Fertilizer	2,282	2,363	1,408	0	2,491	5	1,310	0	0	0
Canned food	0	0	0	0	0	0	0	0	2273	6059
Others	9,189	5,189	7,871	4,880	6,155	6,955	12,989	12,877	13,760	15,879
Coffee	4,925	1,045	1,932	0	2,238	920	1,715	0	0	558
Cacao	151	0	639	0	866	1,161	143	0	0	785
Cashew nuts	0	0	0	351	0	637	1354	1159	2018	163
General merchandise	425	249	1,228	823	280	1014	883	742	2248	8014
Container	446	1,491	2,150	1697	1051	994	7634	9717	9055	3509
Empty container	612	217	640	703	324	715	262	476	427	201
Others	2,630	2,187	1,282	1306	1396	1514	998	783	12	2649

Original source: DTM
NOTE: Tuna data in 1991, 1992 are based on PFOI data and others

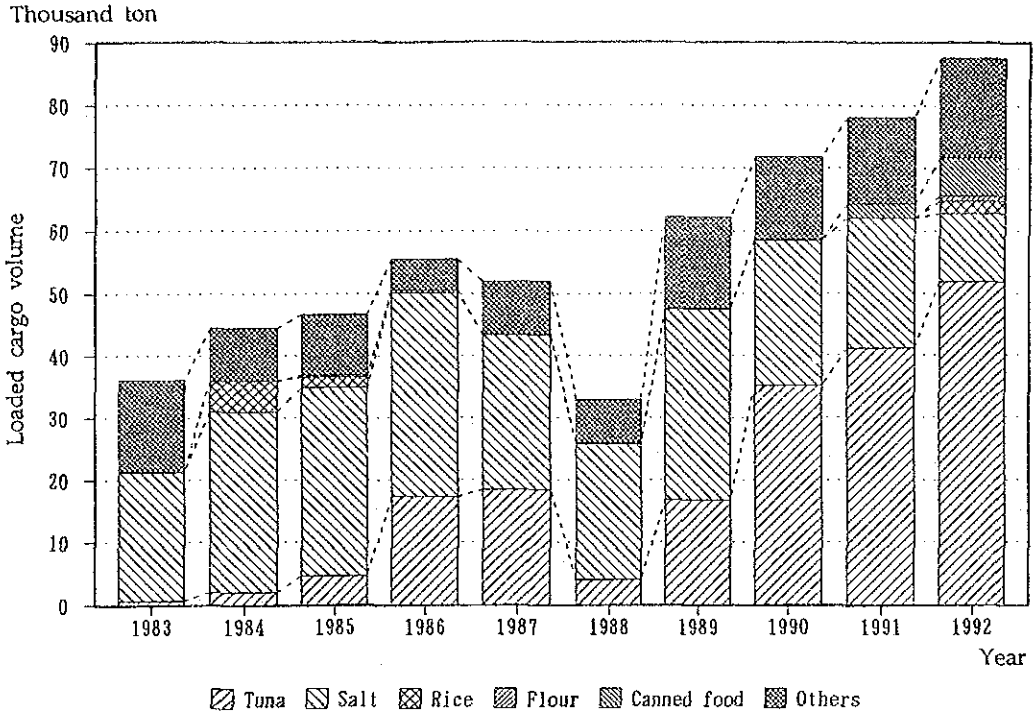


Figure 3-5-1 Trend of Loaded Cargo Volume

2) Unloaded cargo

Trend of unloaded cargo volume is shown in Table 3-5-2 and Figure 3-5-2. Among these commodities, major cargoes are rice, flour, tuna, cement and fertilizer. In the statistics of trade in Madagascar, the import volume of rice decreases, while that of flour and cement increases. For several years, the unloaded volume of rice, flour and cement at the port of Antsiranana has been comparatively stable.

An import cargo before 1984, rice became a domestic unloaded cargo between 1985 and 1991, but reverted to an import cargo again in 1992. Most flours in the unloaded cargoes are domestic cargoes and constitute transhipment cargo from other ports. In the unloaded volume of cement, the proportion of import for inbound is different each year. Before 1989, fertilizer was mainly an import cargo, but since this year fertilizer has not been handled. Most tuna was transhipment cargo for export before 1990, but since this year part of it is unloaded for the canning factory.

The majority of coffee is transhipment cargo for export from other ports, and the volume is not stable. For several years, the volume of other items has been comparatively stable with the exception of 1991.

Table 3-5-2 Trend of Unloaded Cargo Volume Excluding Petroleum Products

(Unit:ton)

	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992
Foreign cargo	29876	10663		1,056	4,571	5,923	12,675	14,614	20,704	11,337
Rice	13,105	2,337		0	0	0	0	0	0	4,000
Flour	0	0		0	0	0	91	60	0	0
Tuna	0	0		0	0	0	0	0	0	0
Cement	11,152	2,600		0	0	54	6,132	5,140	7,118	2,195
Coffee	0	0		0	0	0	30	0	0	0
Fertilizer	3,277	1,872		0	2,237	118	1,494	0	0	0
Animal & Vegetable oil	0	0		0	2	5	1	1,090	0	437
Metal products	557	1,052		416	116	201	994	1,342	1,222	877
Others	1,785	2,802		640	2,216	5,545	3,933	6,982	12,364	3,828
General merchandise	703	735		0	369	3,319	1,576	2,431	7,479	1,562
Container	73	628		156	389	1,275	943	1,819	3,207	1,204
Empty container	378	278		474	383	338	1,225	1,637	1,171	887
Others	631	1,161		10	1,075	613	189	1,095	507	175
Domestic cargo	17,199	21,494		22,565	32,272	18,858	33,009	48,822	59,159	78,542
Rice	2,750	9,509		0	3,130	3,939	5,609	4,868	4,044	872
Flour	1,124	1,275		1,626	2,328	2,295	1,298	1,957	2,041	1,053
Tuna	1,446	1,265		19,518	19,172	4,007	16,735	35,058	47,036	66,537
Cement	68	1,537		175	2,433	3,672	575	2,722	0	4,752
Coffee	4,753	803		0	0	0	1,938	1,383	0	303
Fertilizer	66	281		0	0	0	134	0	0	0
Animal & Vegetable oil	1,208	1,602		0	1,171	1,400	587	355	0	45
Metal products	617	594		102	322	748	559	324	0	334
Others	5,167	4,628		1,144	3,716	2,797	5,574	2,155	6,038	4,646
General merchandise	976	1,406		0	2,207	1,411	2,712	1,641	5,153	2,236
Container	155	473		357	278	266	399	38	381	783
Empty container	213	71		172	45	2	161	128	0	392
Others	3,823	2,678		615	1,186	1,118	2,302	348	504	1,235
Total	47,075	32,157	37,940	23,621	36,843	24,781	45,684	63,436	79,863	89,879
Rice	15,855	11,846	10,637	0	3,130	3,939	5,609	4,868	4,044	4,872
Flour	1,124	1,275	1,528	1,626	2,328	2,295	1,389	2,017	2,041	1,053
Tuna	1,446	1,265	4,128	19,518	19,172	4,007	16,735	35,058	47,036	66,537
Cement	11,220	4,137	9,951	175	2,433	3,726	6,707	7,862	7,118	6,947
Coffee	4,753	803	1,557	0	0	0	1,968	1,383	0	303
Fertilizer	3,343	2,153	1,938	0	2,237	118	1,628	0	0	0
Animal & Vegetable oil	1,208	1,602	1,131	0	1,173	1,405	588	1,445	0	482
Metal products	1,174	1,646	952	518	438	949	1,553	1,666	1,222	1,211
Others	6,952	7,430	6,118	1,784	5,932	8,342	9,507	9,137	18,402	8,474
General merchandise	1,679	2,141	2,713	0	2,576	4,730	4,288	4,072	12,632	3,798
Container	228	1,101	1,528	513	667	1,541	1,342	1,857	3,588	1,987
Empty container	591	349	533	646	428	340	1,386	1,765	1,171	1,279
Others	4,454	3,839	1,344	625	2,261	1,731	2,491	1,443	1,011	1,410

Original source: DTM

Note: Tuna data in 1990, 1991 are based on PFOI data and others

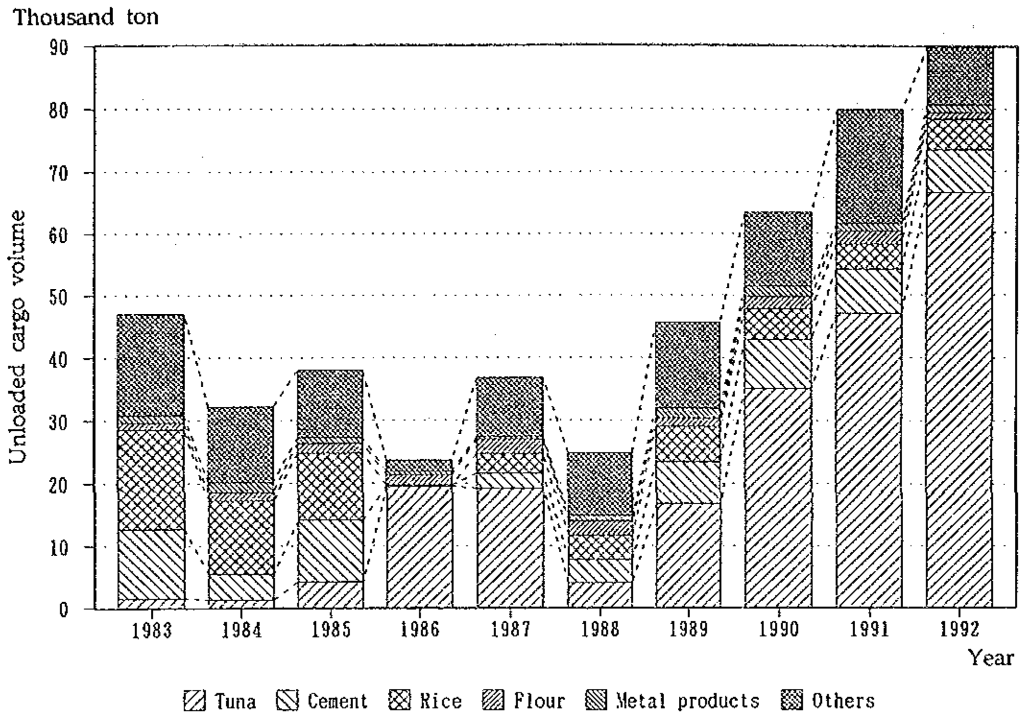


Figure 3-5-2 Trend of Unloaded Cargo Volume

3) Container cargo handling

Trend of container cargo volume is shown in Table 3-5-3. Number of handled containers has been increasing steadily.

Table 3-5-3 Trend of Container Cargo Volume

	Volume of cont. cargo (ton)	Number of cont. (TEU)	Number of empty cont. (TEU)	Ave. volume per cont. (ton/TEU)
1983	2,322	479	103	4.85
1984	3,163	325	265	9.73
1985	3,678	616	388	5.97
1986	3,559	550	288	6.47
1987	2,471	563	286	4.39
1988	3,250	135	76	24.07
1989	10,624	775	666	13.71
1990	9,717	887	815	10.95
1991	16,514	710	945	23.26
1992	16,879	816	924	20.69

Source: DTM

(2) Petroleum products

SOLIMA deals exclusively with most refining, transportation and sales of petroleum and its products in Madagascar. SOLIMA has only one refinery in Toamasina. About 45 % of petroleum products refined there are transported by ship from the port of Toamasina to other ports and the rest is mainly transported by railway to inland capital areas. To make up for a deficiency, complementary petroleum products are imported mainly through the port of Antsiranana. Trend of petroleum cargoes in the port of Antsiranana is shown in Table 3-5-4 and Figure 3-5-3. About 70 % of imported volume in 1992 was transhipped off shore from an ocean tanker to coastal tankers and then transported to other ports.

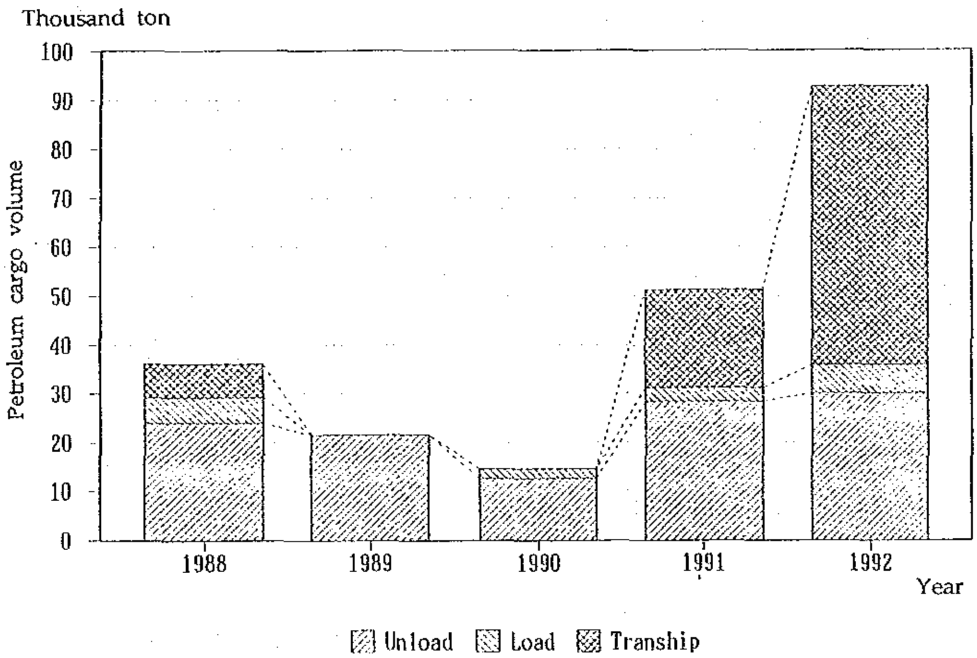


Figure 3-5-3 Trend of Petroleum Cargo Volume

Table 3-5-4 Trend of Petroleum Cargo Volume

(Unit:ton)

	Import			Cabotage	Total	Cabotage	Grand Total			
	Total	Unload	Tranship	Unload		Load	Unload	Load	Tranship	Total
1988	16674	9792	6882	14171	30845	5200	23963	5200	6882	36045
1989	6676	6676	0	14952	21628	0	21628	0	0	21628
1990	0	0	0	12579	12579	2030	12579	2030	0	14609
1991	29887	9732	20155	18609	48496	2840	28341	2840	20155	51336
1992	81122	24269	56853	5770	86892	5890	30039	5890	56853	92782

Source: *SOLIMA*

3.6 Calling Vessels

As to calling vessels at the port of Antsiranana, three different sets of numbers have been obtained, one by DTM, another by Coutoms (DIRECTION GENERALE DE LA BANQUE DES DONNEES DE L'ETAT), the other by the Port Office. It is difficult to determine which figures are most reliable.

The most detailed data come from the Port Office, which include such items as gross tonnage, net tonnage, overall length of calling vessels, arrival and departure time, origin and destination of navigation, shipping agency etc. This data spans from 1990 to 1993. They are the most useful and thus have been applied for the analysis. However, much of the data are not reliable or contain many omissions. It has been necessary to disregard data having problems and analyze what remains. Therefore each item has been analyzed using a unique set of date (See Appendix 3.6).

3.6.1 Frequency of Calling Vessels

The number of calling vessels from 1990 to 1993 per month is shown in Table 3-6-1 and Figure 3-6-1.

The number of calling vessels highly fluctuates not only per month but also per year. It is guessed that the former mainly reflects by fishery boats calling and the latter the economic situation. In particular the decline seen in the late half of 1991 is influenced by the political and economical confusion in Madagascar.

Table 3-6-1 Number of Calling Vessels

	1990		1991		1992		1993
Month	Total No.	Fishery No	Total No.	Fishery No	Total No.	Fishery No	Total No.
January	31	4	43	6	24	1	24
February	20	1	24	0	13	3	24
March	19	3	40	17	18	8	22
April	50	19	68	49	29	17	53
May	65	37	32	12	19	16	38
June	29	7	34	13	20	8	24
July	29	5	16	7	15	1	26
August	25	3	17	1	9	0	14
September	14	2	10	0	17	3	15
October	13	0	16	3	11	1	22
November	32	5	21	1	13	0	36
December	65	3	42	1	16	0	13
Total	392	89	363	110	204	58	311
Average	33	7	30	9	17	5	26

Note: 1. Fishery No. means the estimated calling number of fishery boats.
2. The calling number of fishery boats in 1993 cannot be estimated.

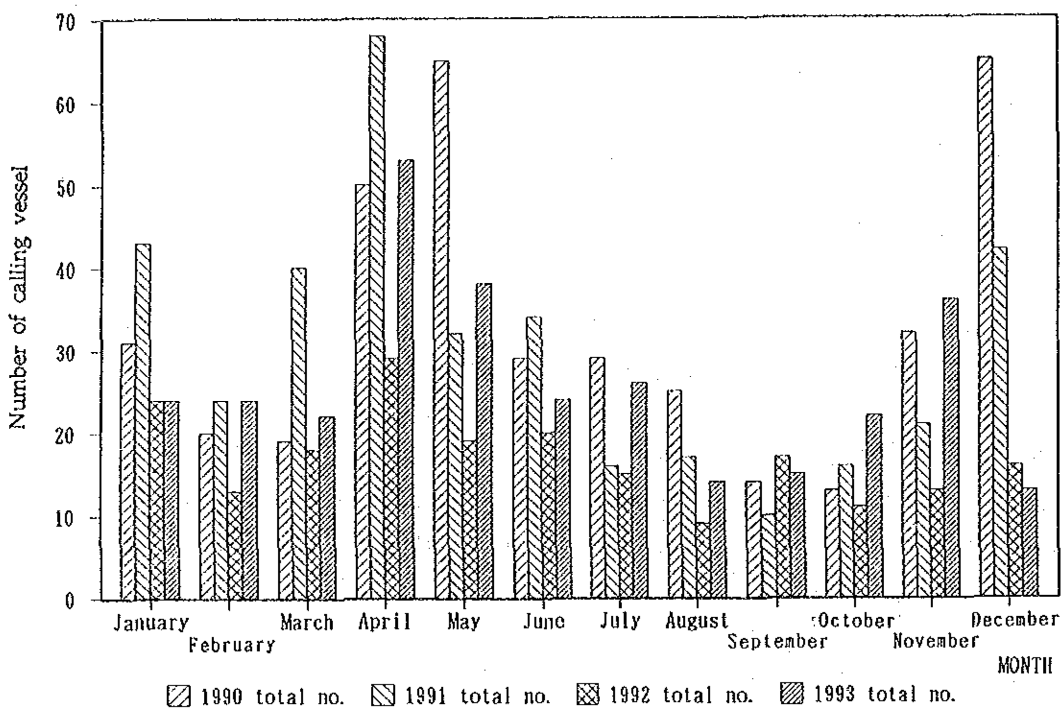


Figure 3-6-1 Total Number of Calling Vessels

3.6.2 Category of Vessel Type

There are various types of vessels calling the port of Antsiranana. In order to know properly the present port activities and formulate a practical port plan, it is necessary to categorize by type. By examining the data, the Study Team has been able to categorize the vessels into ocean-going cargo vessels, coastal cargo vessels, fishery boats and others. Here, other vessels are calling for the purpose other than handling cargoes. Furthermore, they are divided into two types. One is related to calling and waiting to be repaired by SECREN and the other is for refuge or rest.

As will be mentioned in detail later, characteristics by vessel type such as staying time at the port, vessel size are fairly different from one another.

The data in 1990 are analyzed for they are the most reliable and complete.

3.6.3 Staying Time by Vessel Type

The Study Team was able to analyze 328 vessels. Average staying time by vessel type is as follows:

- Ocean-going cargo vessel (75 vessels)	1.62 days
- Coastal cargo vessel (75 vessels)	2.33 days
- Fishery boat (80 vessels)	5.25 days
- Vessels related to SECREN (70 vessels)	3.02 days
- Others (28 vessels)	17.38 days

The results for the upper three categories of vessels are rational and they are almost coincident with another survey or common sense, but those of the two lower categories seem to defy belief.

The average staying time of vessels related to SECREN seems to be practical but the number of calling vessels is rather large. If this figure is accurate, it must be assumed that almost all vessels are calling before going to SECREN's docks. It is an odd situation. However, with the growth of the fishing industry, particularly tuna fishing in the Indian Ocean, many fishery boats not only in Madagascar but also from nearby countries come to be repaired or docked because SECREN is a shipyard with a long history and a good reputation for its excellent technology. Therefore it is plausible that a relatively large number of vessels, typically fishing boats, are calling.

It is surmised that the majority of vessels from the "Others" category are calling for refuge or rest, because the port of Antsiranana is naturally sheltered and located at the northern end near Cape d'Ambre, where it is very difficult to maneuver vessels because of the sea conditions etc. For that reason, the number of vessels is not in question, but the average staying time is too long. In the analysis, several vessels are recorded as having stayed for about one month. It could not be confirmed that many vessels were staying that long, and thus a correction may be required.

3.6.4 Vessel Size by Vessel Type

Following categorized vessel types, distributions of gross tonnage and overall length by each vessel type are shown in Fig 3-6-2, 3-6-3, 3-6-4.

Maximum and average gross tonnage and overall length are shown in Table 3-6-2.

For ocean-going cargo vessels, except two vessels, gross tonnage and overall length do not exceed 25,000 GRT and 200 m respectively. While there are several 20,000 GRT class vessels calling, the predominant vessel size is 12,000 GRT class and under 5,000

GRT class. The distribution of overall length is characterized by two convex-shaped patterns.

For coastal cargo vessels, 72 % of all are under 2,000 GRT but over 2,500 GRT vessels are continuously calling. The maximum vessel is the same one. As to overall length, a distinct feature cannot be seen but it is noted that the 100 m class accounts for more than one-third of the total.

For fishery boats, both ship size and overall length do not have vast distributions. The maximum-sized vessel, only one, would seem to be an exception, but according to the report of ASSOCIATION THONIERE, a fishery cargo vessel with freezers is 4,000 GRT class, larger than that abovementioned. So, it is perhaps not an exception. Other than that one, predominant vessel size is from 700 GRT to 1,800 GRT and overall length is from 50 m to 80 m.

Table 3-6-2 Vessel Size by Vessel Type

	Ocean	Coastal	Fishery
Maximum tonnage (GRT)	26,409	4,205	2,775
Average tonnage (GRT)	5,645	1,522	1,141
Maximum overall length (m)	205	108	101
Average overall length (m)	110	68	65

Note : Ocean, Coastal and Fishery mean ocean-going cargo vessel, coastal cargo vessel and fishery boat respectively.

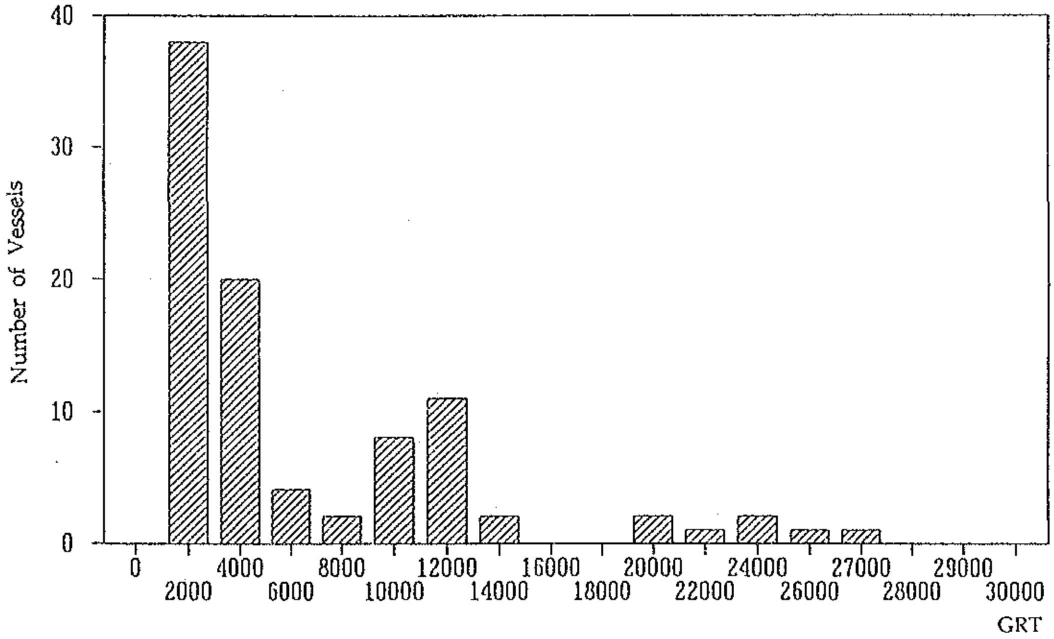


Figure 3-6-2(1) Distribution of Ocean-going Vessels (GRT)

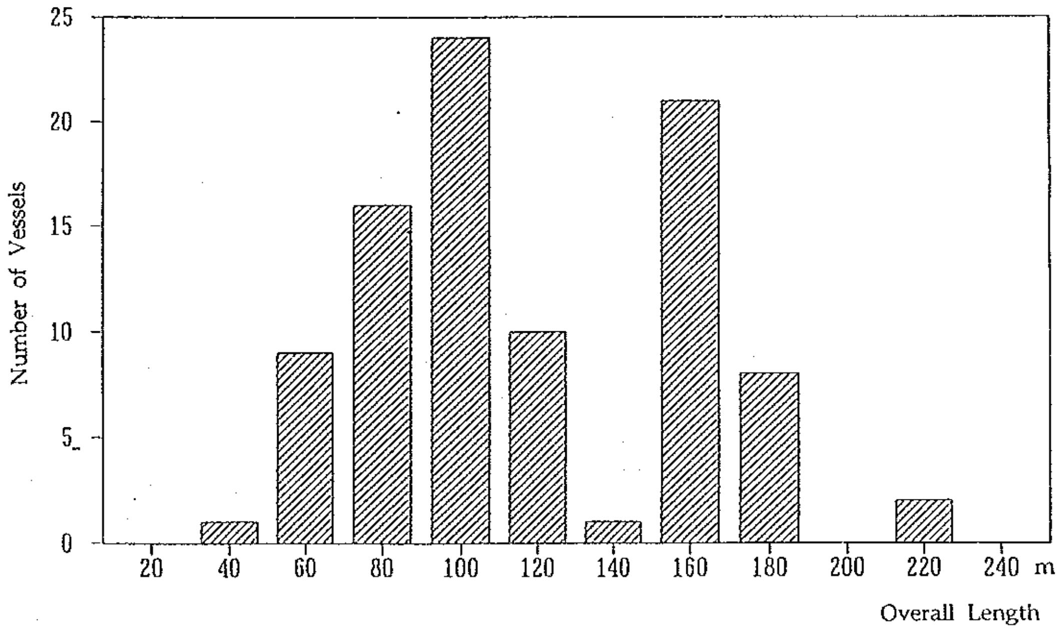


Figure 3-6-2(2) Distribution of Ocean-going Vessels (Overall Length)

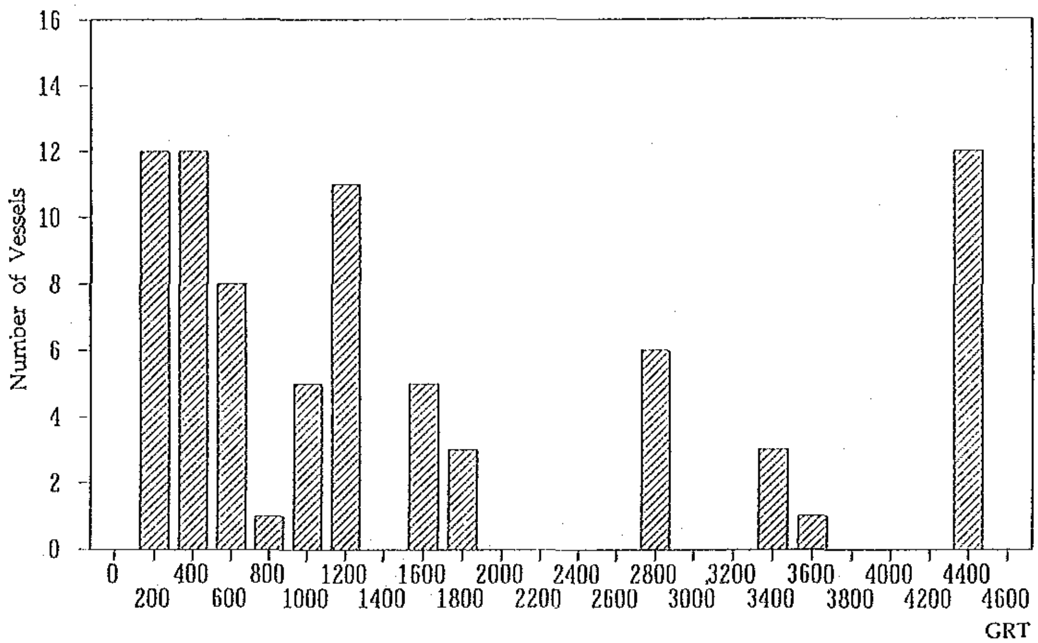


Figure 3-6-3(1) Distribution of Coastal Cargo Vessels (GRT)

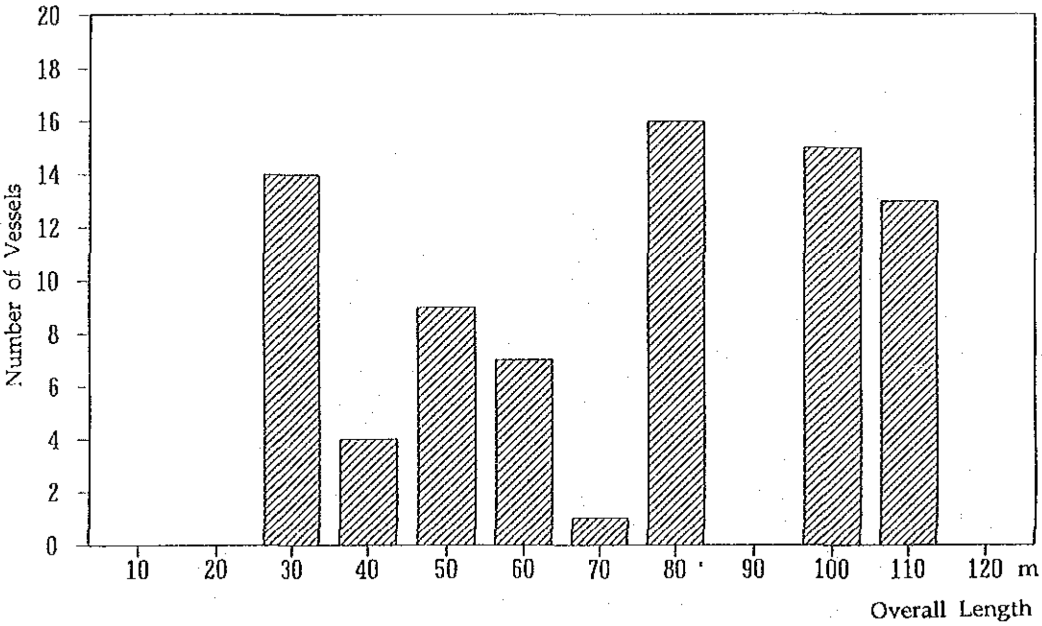


Figure 3-6-3(2) Distribution of Coastal Cargo Vessels (Overall Length)

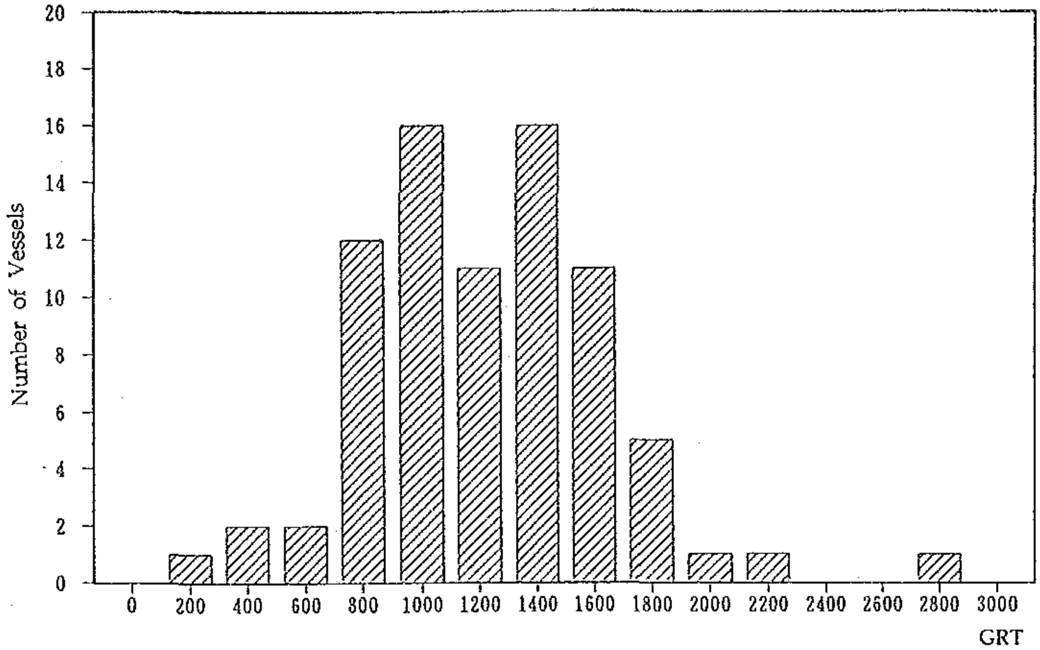


Figure 3-6-4(1) Distribution of Fishery Boats (GRT)

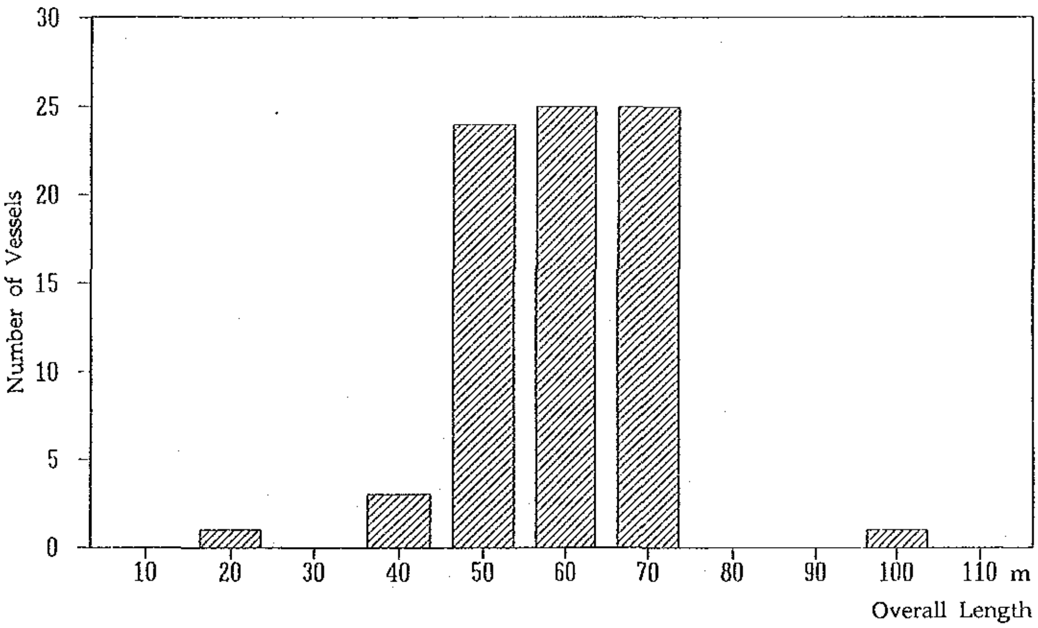


Figure 3-6-4(2) Distribution of Fishery Boats (Overall Length)

3.7 Administration, Management and Operations

(1) Administration

Organization chart of Antsiranana Port is shown in Figure 3-7-1. There are 28 staffs.

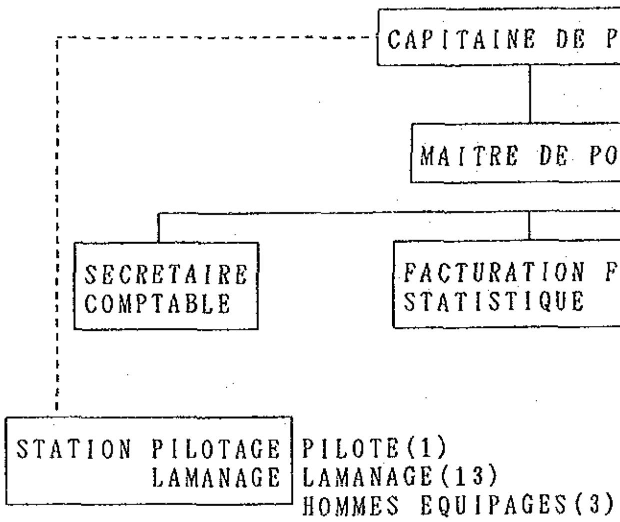


Figure 3-7-1 Organization Chart of the Port of Antsiranana

(2) Management and operation

At Antsiranana Port, Port Master grants permission for port use and berth assignment and levies appropriate port charges such as entering the port, wharfage and cargo handling charge etc.

All cargo handling operations are conducted by COMPANIE MALAGACHE DE MANUTENTION(CMDM) which is a private company created by French capital. However, so far as hydrocarbons are concerned, SOLITARY MALAGASY(SOLIMA), a private company created by government funds, handles its own products. Organization chart and number of employees of CMDM are shown in Figure 3-7-2.

ORGANIZATION CHART OF CMDM ANTSIRANANA

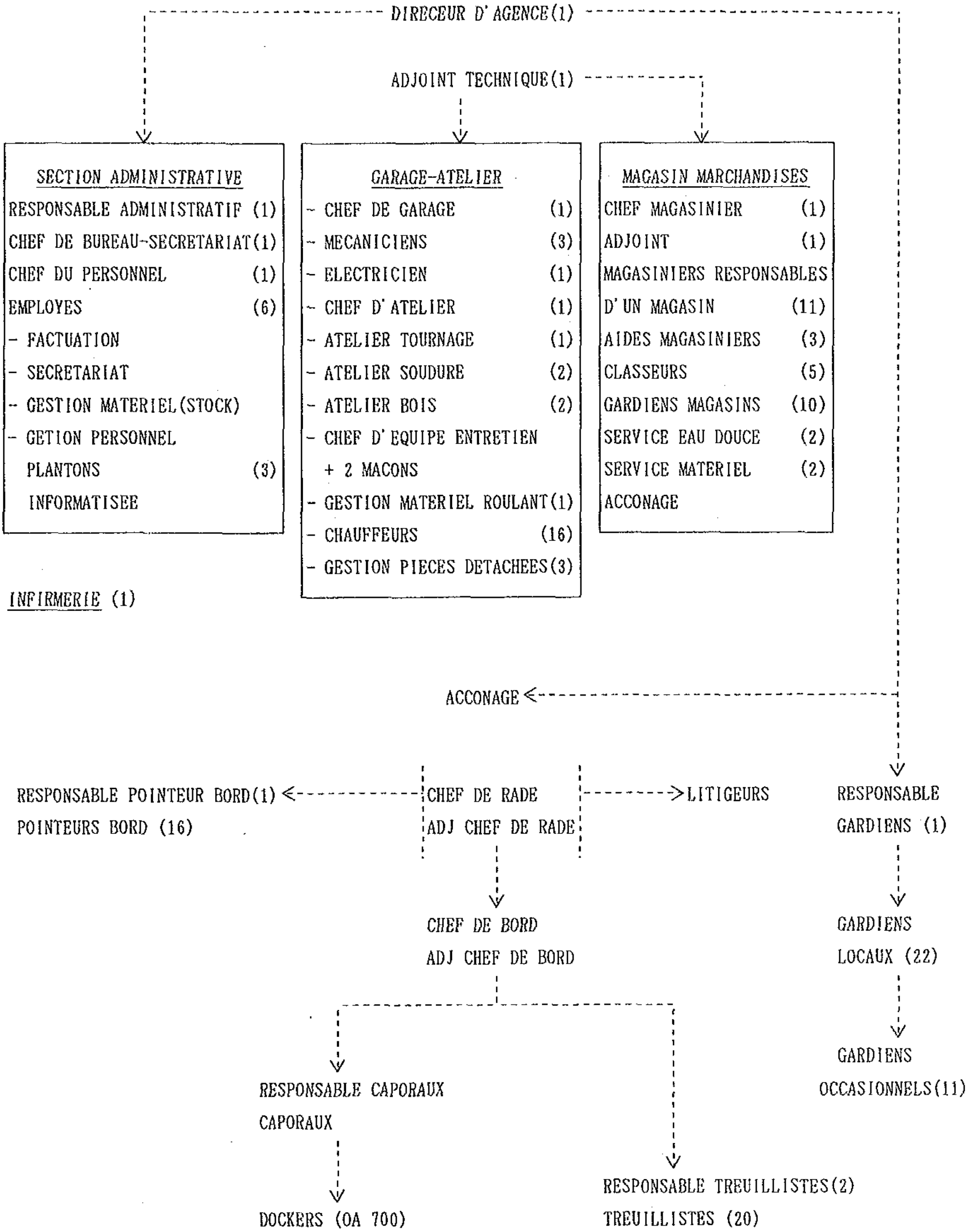


Figure 3-7-2 Organization Chart and Number of Employees of CMDM

CHAPTER 4

MASTER PLAN OF THE PORT OF ANTSIRANANA

4. MASTER PLAN OF THE PORT OF ANTSIRANANA

4.1 Background of the Port Development

While the port of Antsiranana, which plays very important roles in serving cargo traffic, is expected to be developed for the regional and national prosperity, the existing port facilities face a number of serious problems.

The port development may, therefore, be categorized into two phases; one is to solve the present problems and the other is to prepare to deal with the future needs.

(1) Problems to be solved with the existing facilities

- Superannuation or deterioration of facilities

The port of Antsiranana has two quays for large vessels and other mooring facilities for small vessels, whose total length is 414 m. It has been a long time since construction and all quays are superannuated or deteriorated more or less. In particular, "the Old Quay", constructed in 1932, is in bad condition. The surface concrete is detached in most parts and some reinforcing bars of the reinforced concrete are exposed. Old rubber tires are used as fenders, but their number is insufficient and their effectiveness is questionable. The hull of vessels may be damaged and efficiency of cargo handling will be jeopardized. If necessary rehabilitation works are not carried out, these facilities will be out of use in the near future.

- Shortage of quay length and depth

The length of "the Old Quay" is insufficient for mooring of ocean-going vessels. On the other hand, ocean-going vessels do not usually use "the New Quay" because of its water depth. They are often moored out of "the Old Quay", about 50 m northwards using mooring dolphins. From March to June, when many tunny boats come, the port gets congested. At that time, the quay length is often insufficient for all vessels to be berthed. Seasonal congestion by tunny boats is inevitable to some extent because of the timing of the tunny catch. Relevant organizations are reportedly making efforts to alleviate the situation.

As to the water depth of the quay, it is not sufficient for 10,000 DWT class vessels to call in full load. Some of SOLIMA's tankers are forced to handle oil products off the quay in the bay. In consideration of shippers, shipping companies etc., it is better to have a longer and deeper quay.

- Containerization

Containerization has made remarkable progress in maritime transport throughout the world. Container cargo traffic volume in the port of Antsiranana is gradually increasing and it is expected that this trend will not change at least for a while. In order to handle a lot of container cargoes, equipment and facilities such as gantry crane, container freight station, open yard etc. should be provided. This requires an enormous amount of investment and maintenance cost. Considering the present situation, specialized container facilities will not be necessary in the near future. However, even now, the port of Antsiranana is not well accommodated to receive containers because open yard is unpaved and undulated with improper layout of the transit sheds.

(2) Development required to support the regional and national prosperity

The region that includes the port of Antsiranana, i.e. Diego-Suarez Faritany and its surroundings, is blessed with natural resources and highly valued agricultural products (refer to section 1.7). Excellent and modern industries such as SECREN and PFOI are already working around the port. The region will become prosperous if it is able to realize its full potential.

So as to meet the expectations, development of infrastructure such as port, road and communication system is a most important and urgent matter. In particular, considering the geographical and topographical features, socio-economic activities or financial situation, the role of the port of Antsiranana will become more important in future.

The major purpose of the Master Plan for the port of Antsiranana is thought to be as follows:

- to be a guideline for long-term investment and operational improvement scheme of the target port

- to be a base for short-term development plan, the contents of which are required to be consistent with total development scheme

- to provide port users, investors and other business entities concerned with the prospect of a sound business environment and to serve as a guideline for the future development of those business

- to promote harmonized development of other infrastructures necessary to realize the proposed port development scheme

- to assist various financing agencies in their investment or financial assistance plans

In order to secure applicability and practicability of the proposed plan, a long period of time and a large scale of investment are required. Moreover, understanding and cooperation by people and organizations related to the port are necessary.

Taking the above, it is necessary to formulate the Master Plan of the port of Antsiranana as soon as possible, which includes an urgent improvement plan and a rational implementation program.

4.2 Concept of the Port Development

4.2.1 The Roles and Functions of the Port

One of the objectives of this Study is to formulate the Master Plan with the target year of 2010.

In general, a port master plan is formulated, coordinating the future plans on socio-economy, regional development, land use and so on related to the hinterland and the nation. However, there are no such future plans for the port. Therefore, the Master Plan is mainly drafted as a reasonably foreseen expansion of the present role and functions of the Port.

The present roles and functions of the port of Antsiranana are summarized as follows:

- to deliver daily necessities to the hinterland
- to collect goods to be supplied to other districts in Madagascar or to be exported
- to support the industrial activities of the hinterland
- to supplement the port of Toamasina, for example, by importing oil products
- to provide an appropriate water area for vessels to refuge, rest or wait to be repaired by SECREN

A brief explanation for the each point of view follows.

The first and second point are closely concerned with the socio-economic activities of the hinterland. The present hinterland is rather small mainly due to the defective road network and communication system. However, there is a large potential for prosperity in future which would possibly cause the area of the hinterland to be enlarged. When this potential is realized, cargo volume of the port of Antsiranana will greatly increase.

The third point is the issue which is the most relevant to the port activities both at present and in future. The cargo traffic generated by the industrial activities of PFOI and CSM accounts for over 40 % of the total excluding oil products in 1992. CSM produces about 95 % of all salt in Madagascar, supplies it throughout the country, and also exports some to neighboring countries. In addition, they have an expansion plan according to the interview. The major commodities of the port of Antsiranana consist of their products and materials, and this situation will not change in future. This is one of the most important points in formulating the Master Plan.

The fourth point is one which should not be forgotten when examining the future roles and functions of the port of Antsiranana. The reason is as follows: The port of Toamasina is the largest and the most important port in Madagascar, having over half of the total population in its hinterland. It has been functioning as the core of maritime transport. This structure will not change, in other words, the relative relationship between the port of Toamasina and others will remain as it is. Toamasina, the only port with connections all over the world, is sometimes hit by cyclones because it faces the Indian Ocean. So as to secure the lifeline and to bring about prosperity to the regions and the nation, ports to supplement Toamasina would be necessary. The port of Antsiranana has one of the most favorable sites from the viewpoint of natural and geographical conditions. Although, at present, the port of Antsiranana rarely supplements or substitutes the port of Toamasina except for import of oil products by SOLIMA, this important role or function must be taken into consideration when formulating the Master Plan.

The last point needs to carefully be considered in formulating the Master Plan since future function for such water area will become vital according to increasing number of vessels calling of the port.

4.2.2 Orderly and Efficient Management and Operation of the Port

There are many different types of activities according to different requirements of commercial general cargo vessels, tankers, fishery boats and others. For example, vessel size, staying time, the peak and off peak period of calling and so on differ largely by the types of vessels. The appropriate principles need to be established for orderly and efficient operation and management of the port facilities. One of the possible measures for this purpose may be to assign the special berths or wharves according to the