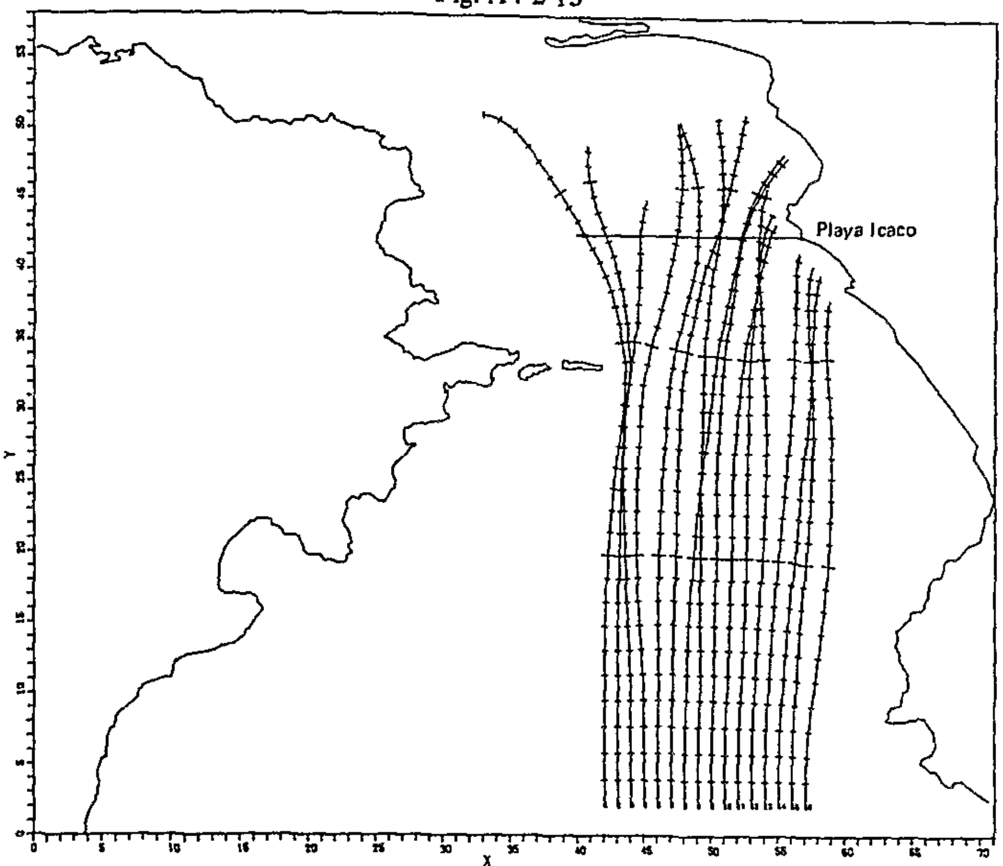
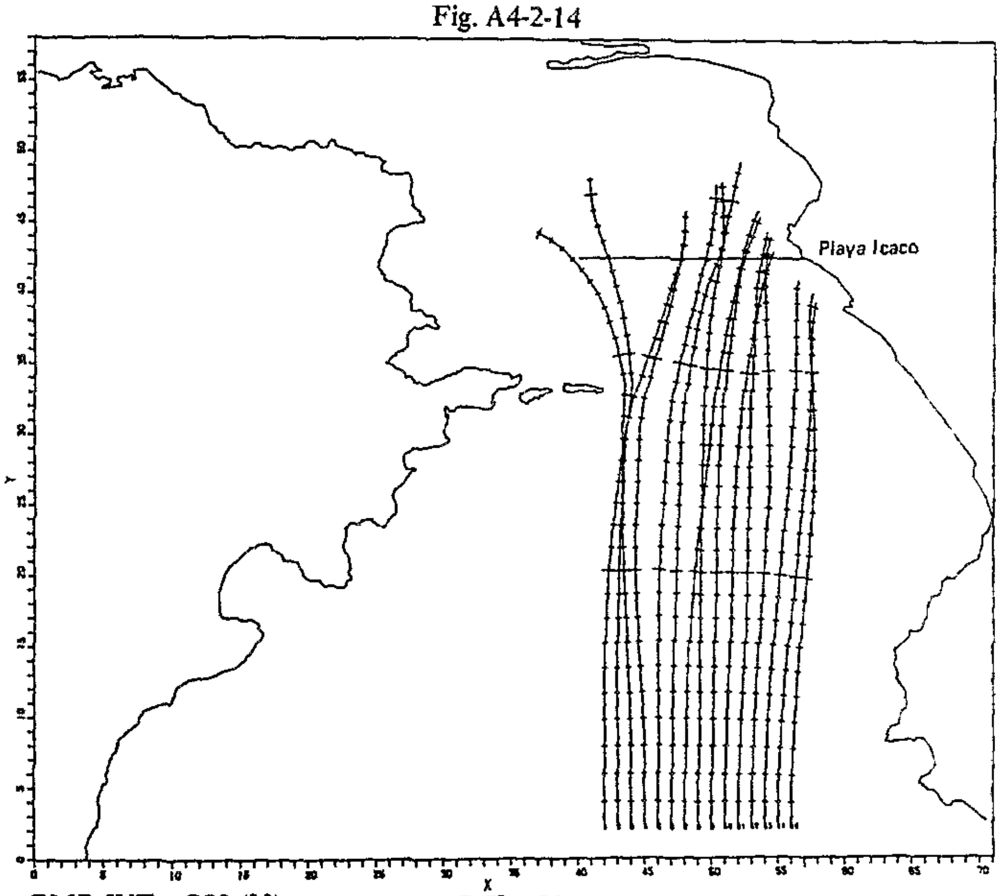
Fig. A4-2-13



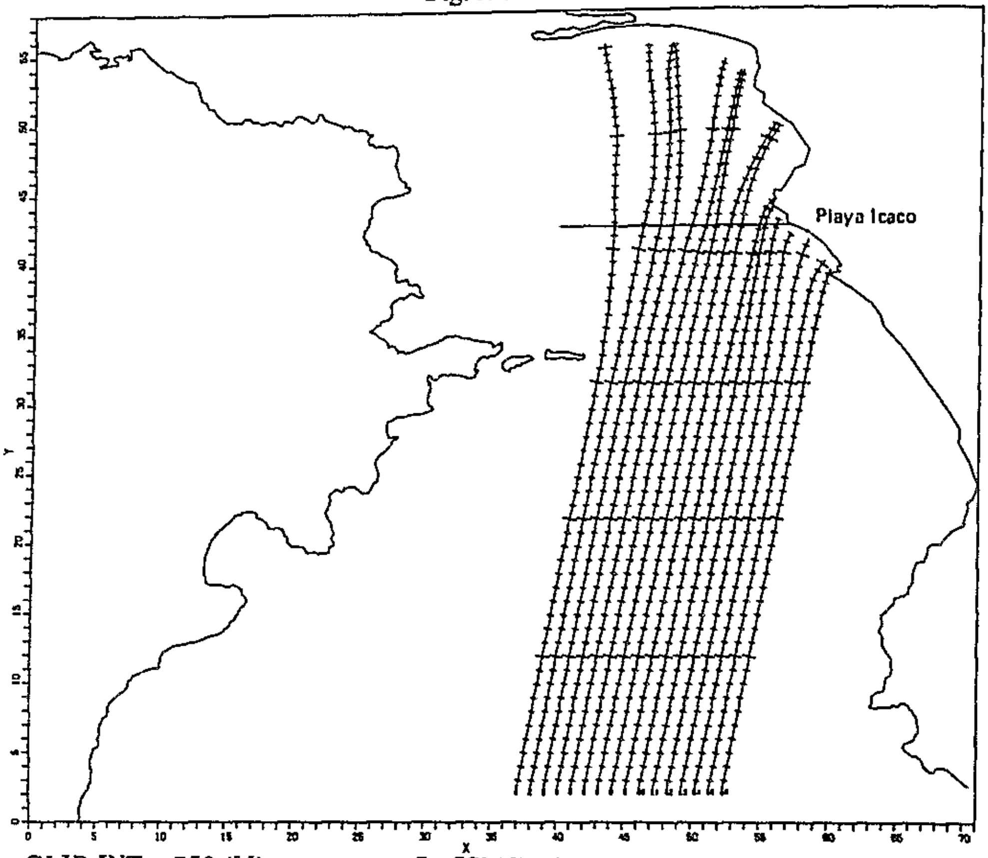

GLID INT = 750 (M) S T = 18s

Fig. A4-2-14



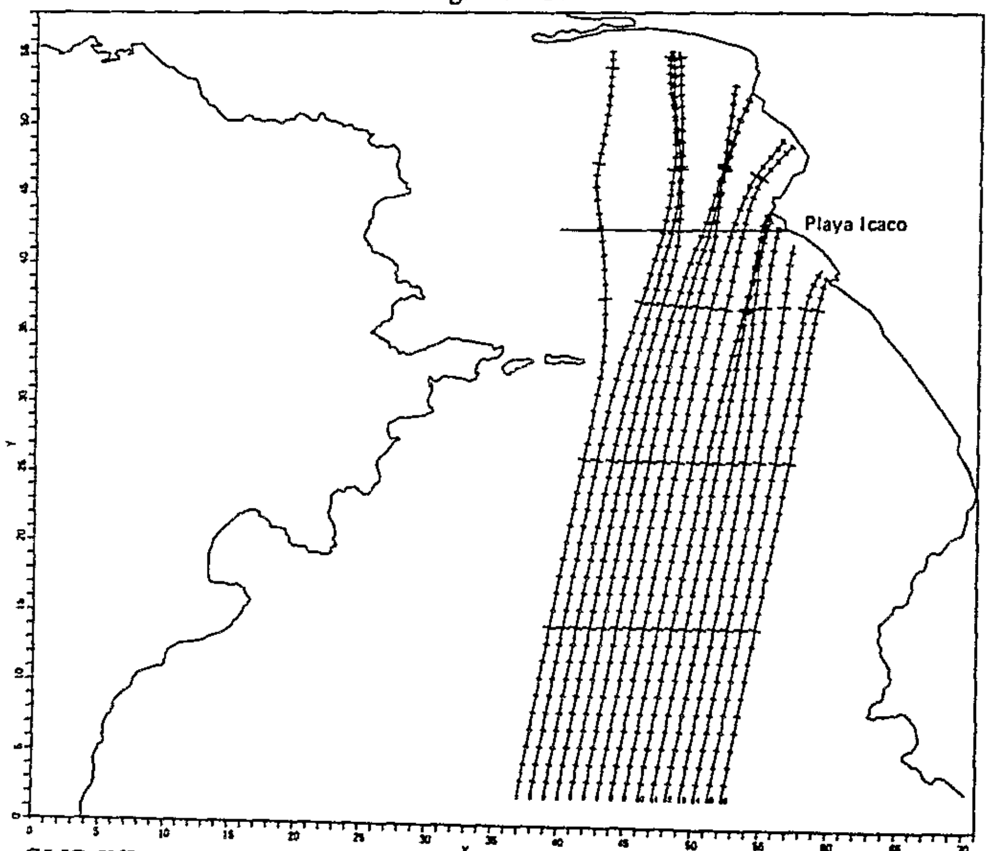

GLID INT = 750 (M) S T = 20s

Fig. A4-2-15



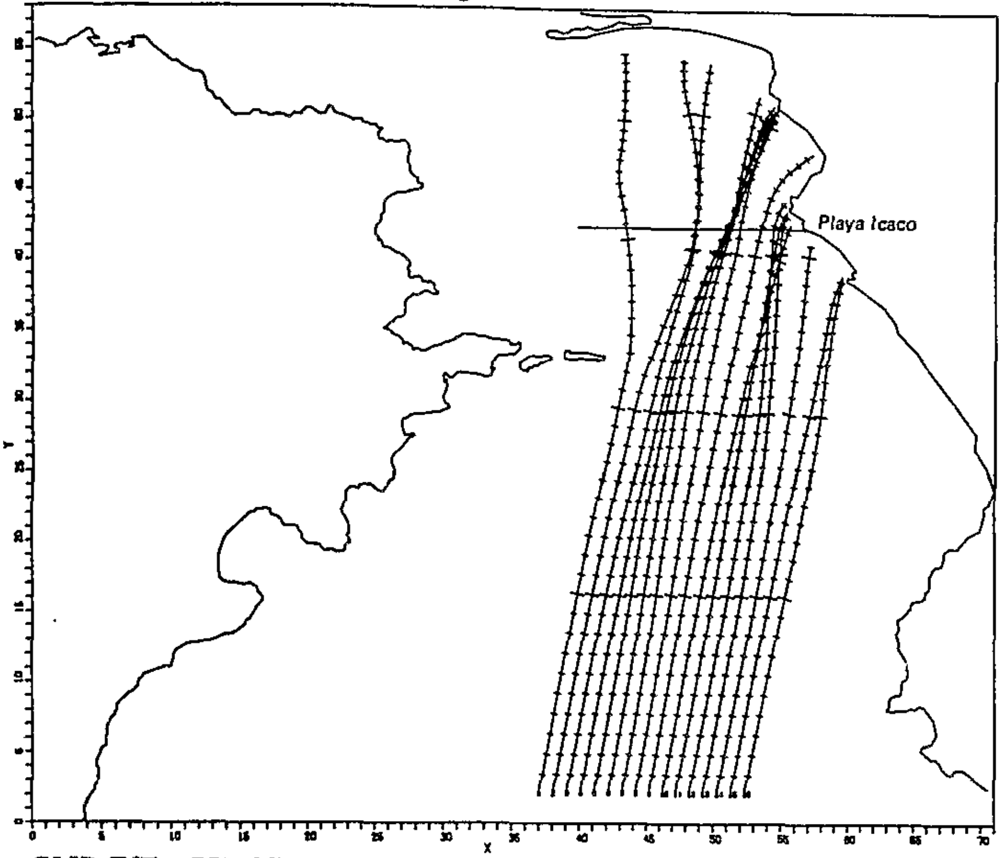

GLID INT = 750 (M)  S · SSW T =8s

Fig. A4-2-16



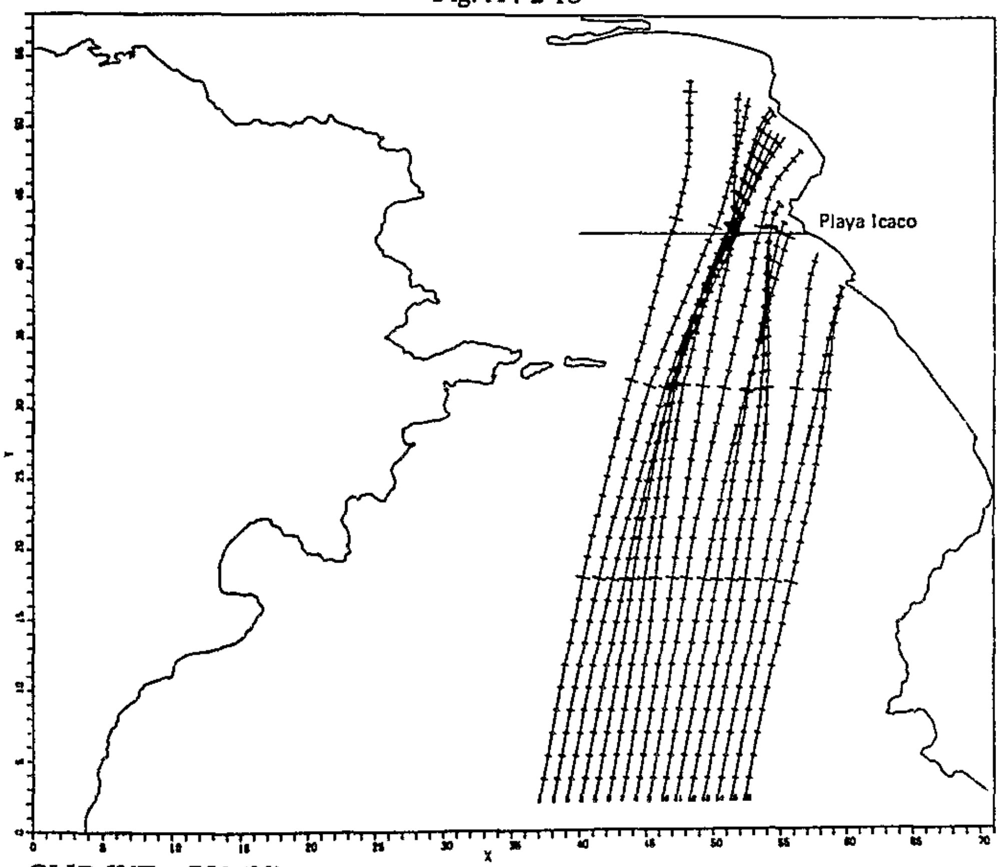

GLID INT = 750 (M)  S · SSW T = 10s

Fig. A4-2-17



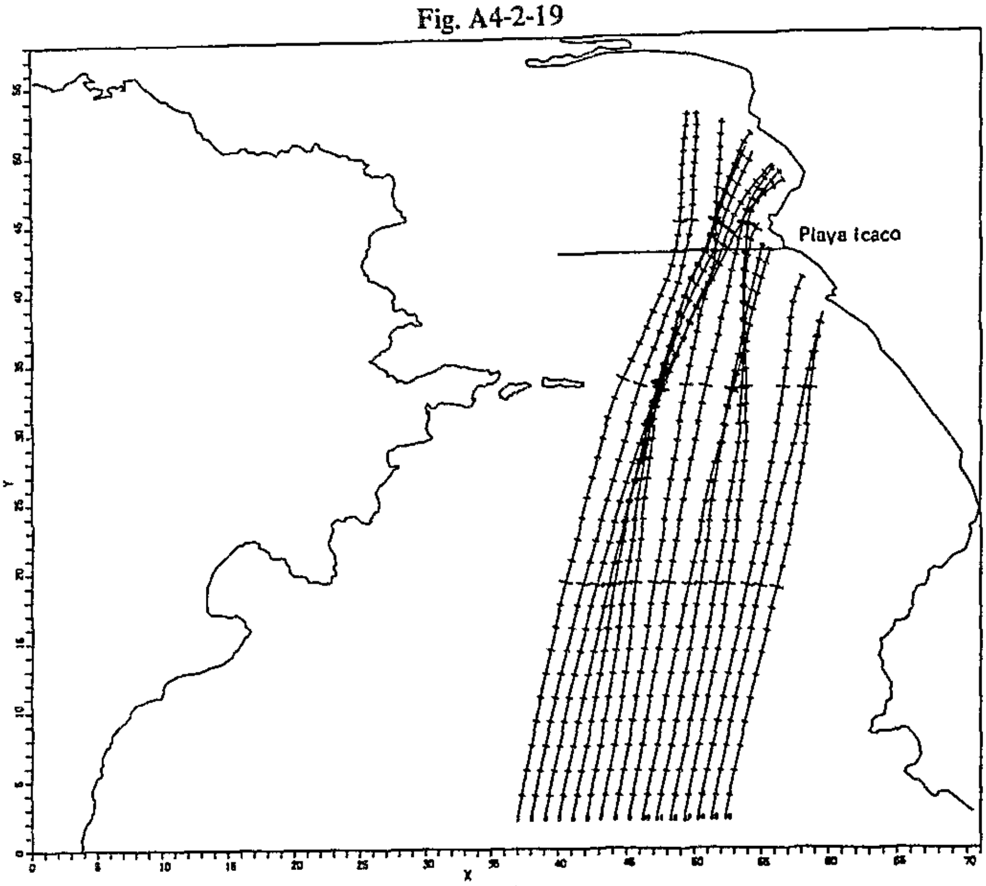

GLID INT = 750 (M) S · SSW T = 12s

Fig. A4-2-18



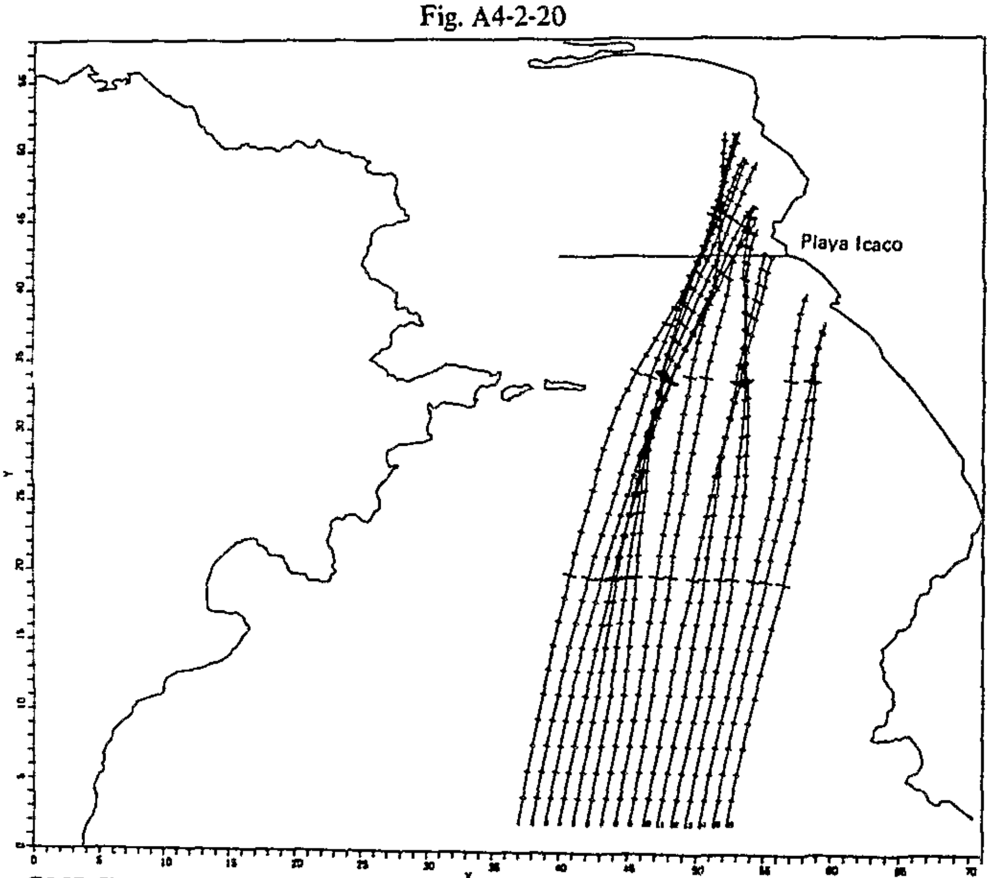

GLID INT = 750 (M) S · SSW T = 14s

Fig. A4-2-19



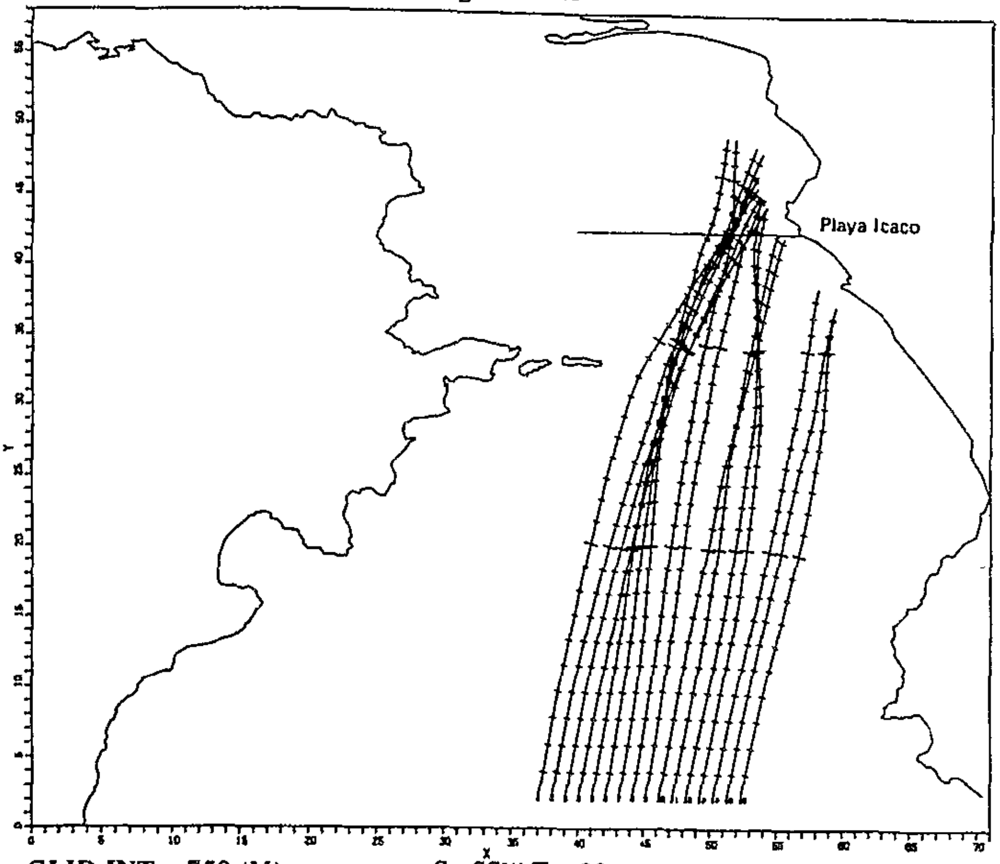

GLID INT = 750 (M) S · SSW T = 16s

Fig. A4-2-20



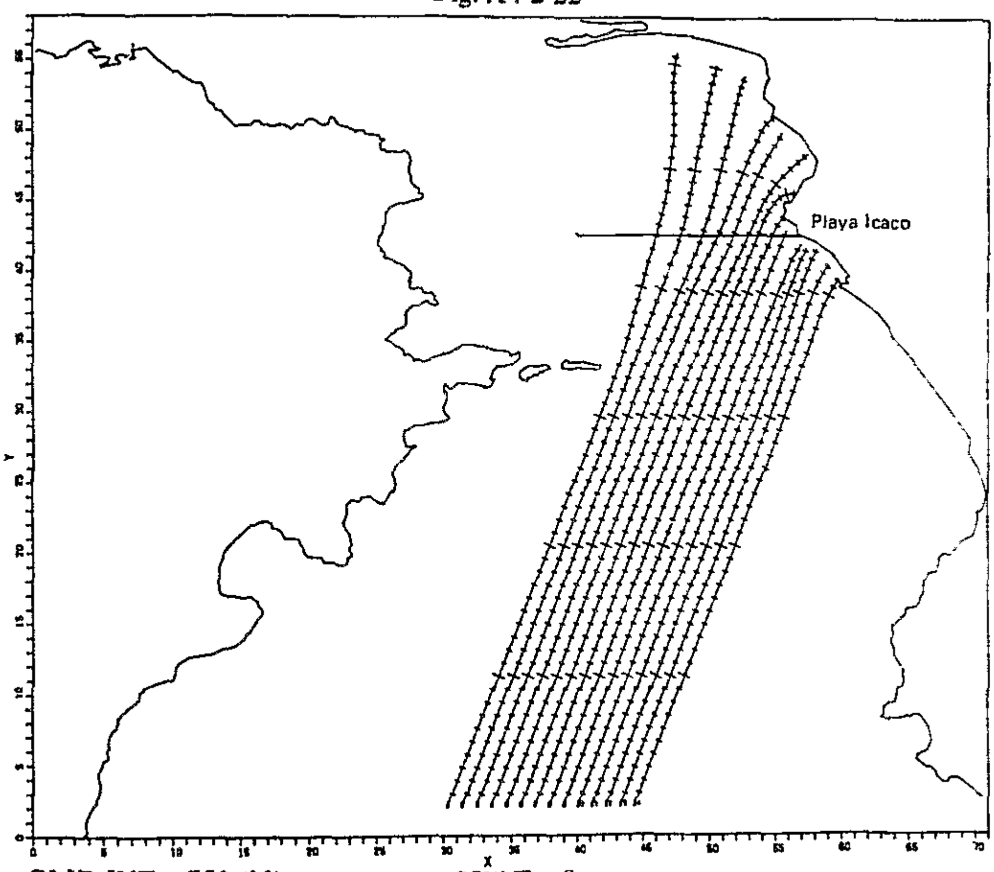

GLID INT = 750 (M) S · SSW T = 18s

Fig. A4-2-21



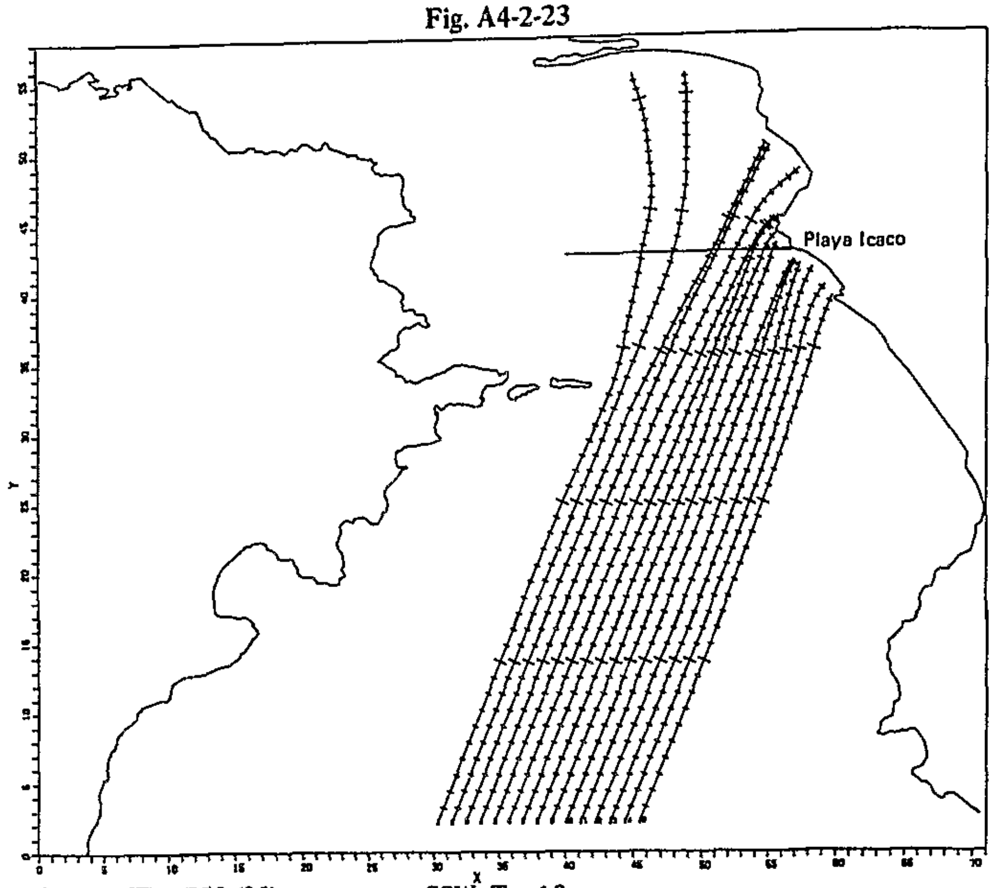

GLID INT = 750 (M)        S · SSW T = 20s

Fig. A4-2-22



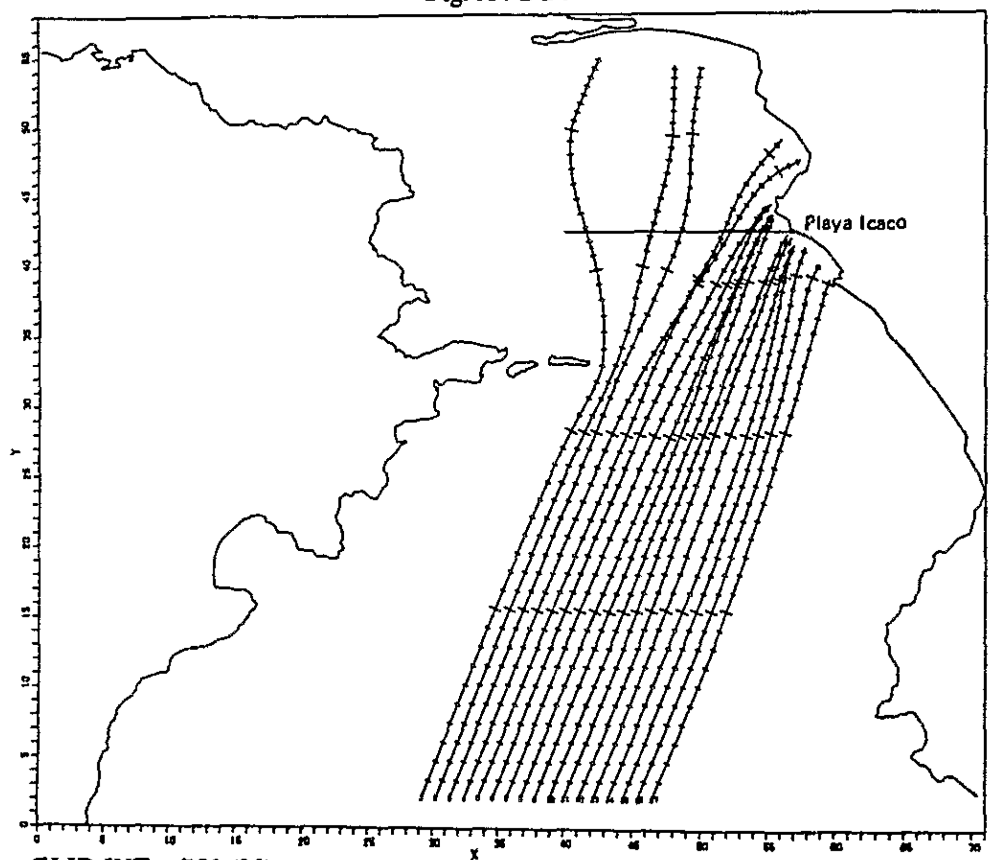

GLID INT = 750 (M)        SSW T = 8s

Fig. A4-2-23



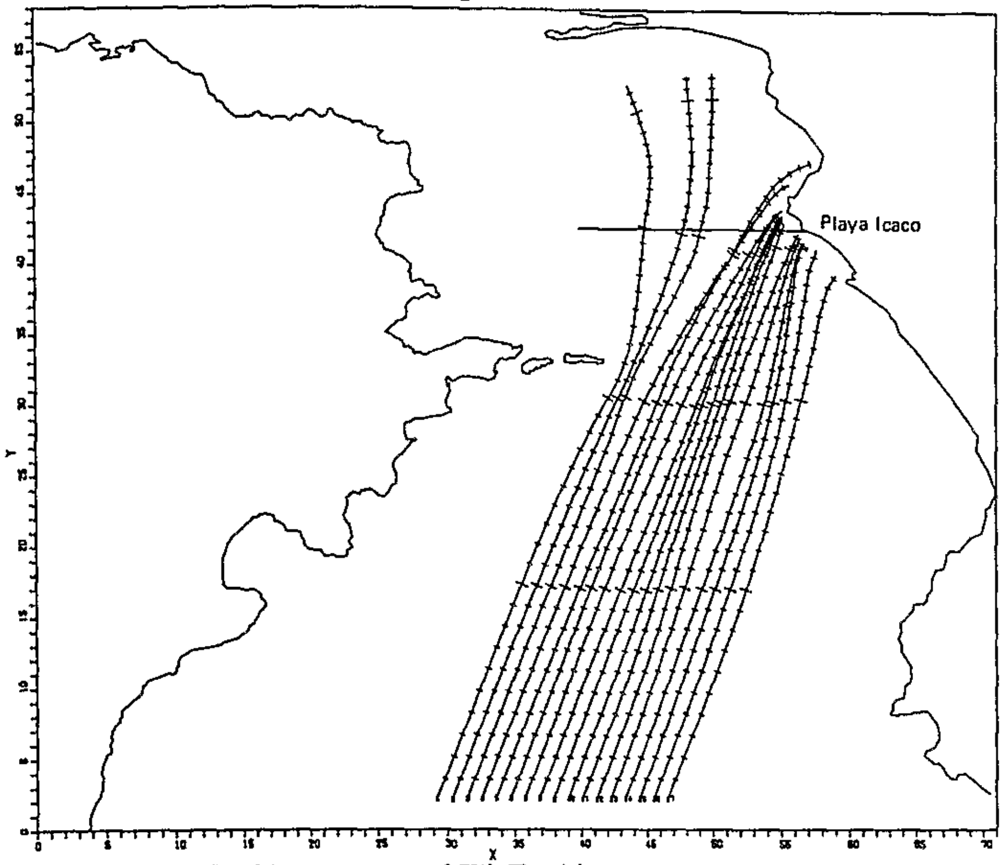

GLID INT = 750 (M) SSW T = 10s

Fig. A4-2-24



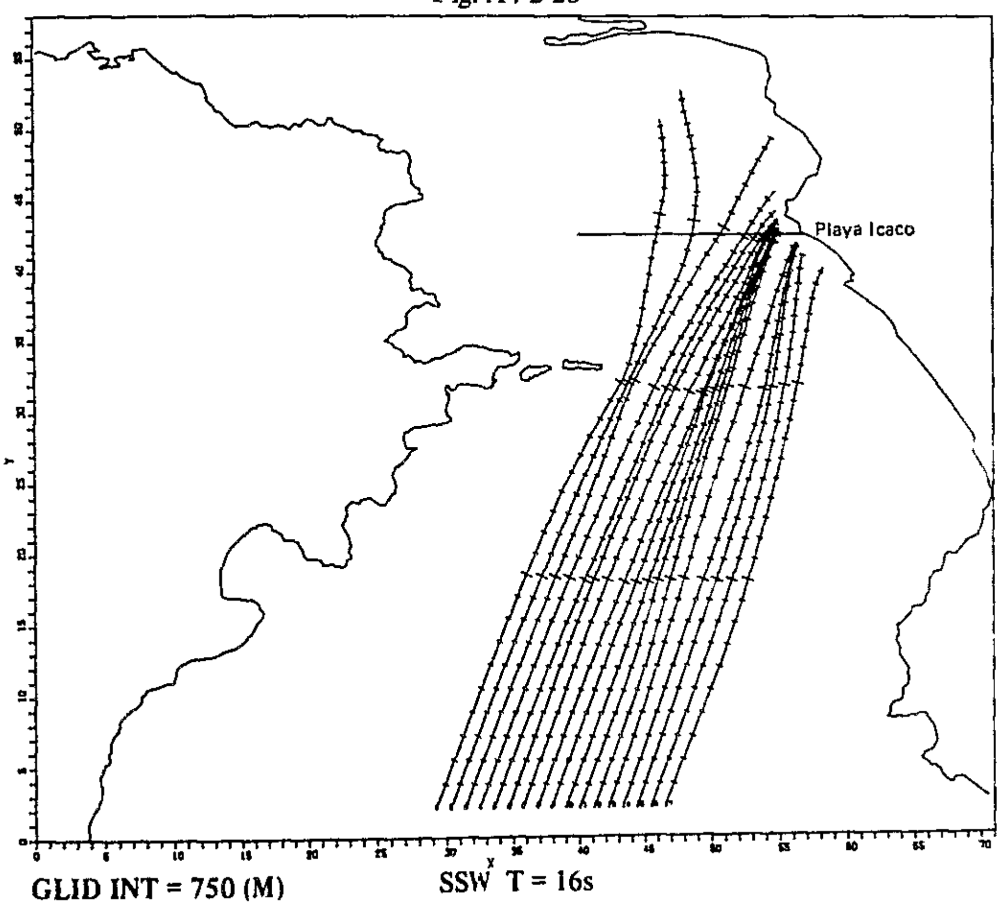

GLID INT = 750 (M) SSW T = 12s

Fig. A4-2-25



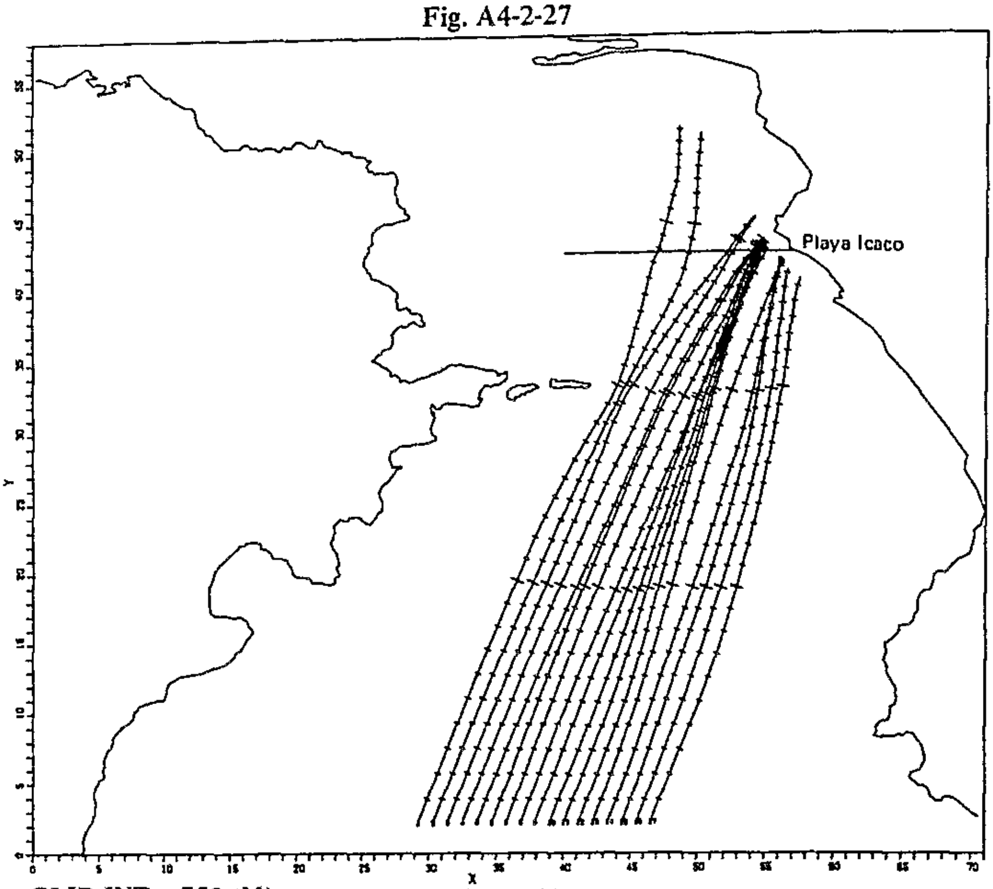

GLID INT = 750 (M) SSW T = 14s

Fig. A4-2-26



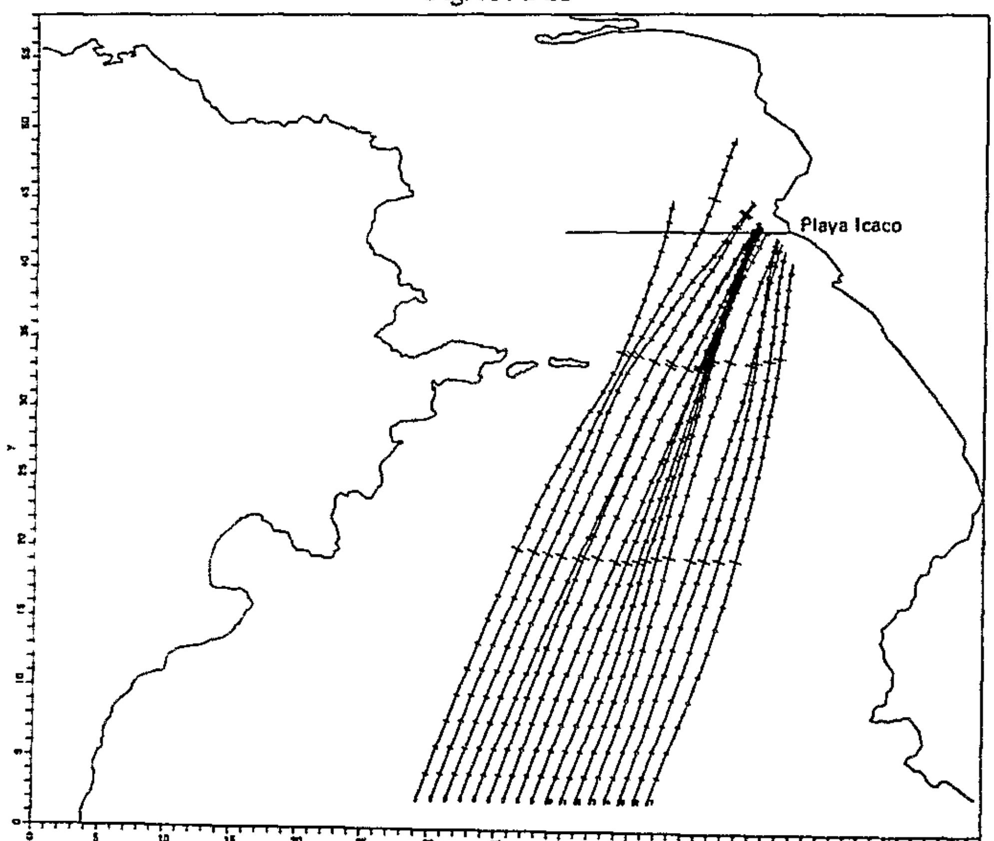

GLID INT = 750 (M) SSW T = 16s

Fig. A4-2-27



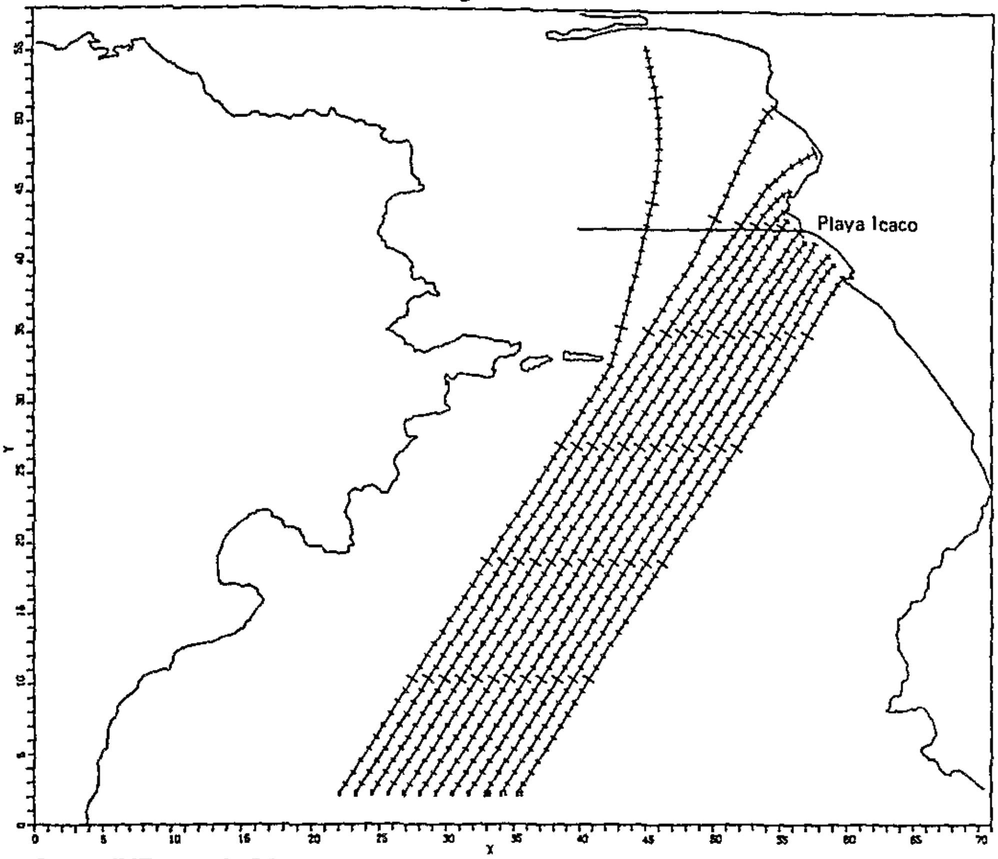

GLID INT = 750 (M) SSW T = 18s

Fig. A4-2-28



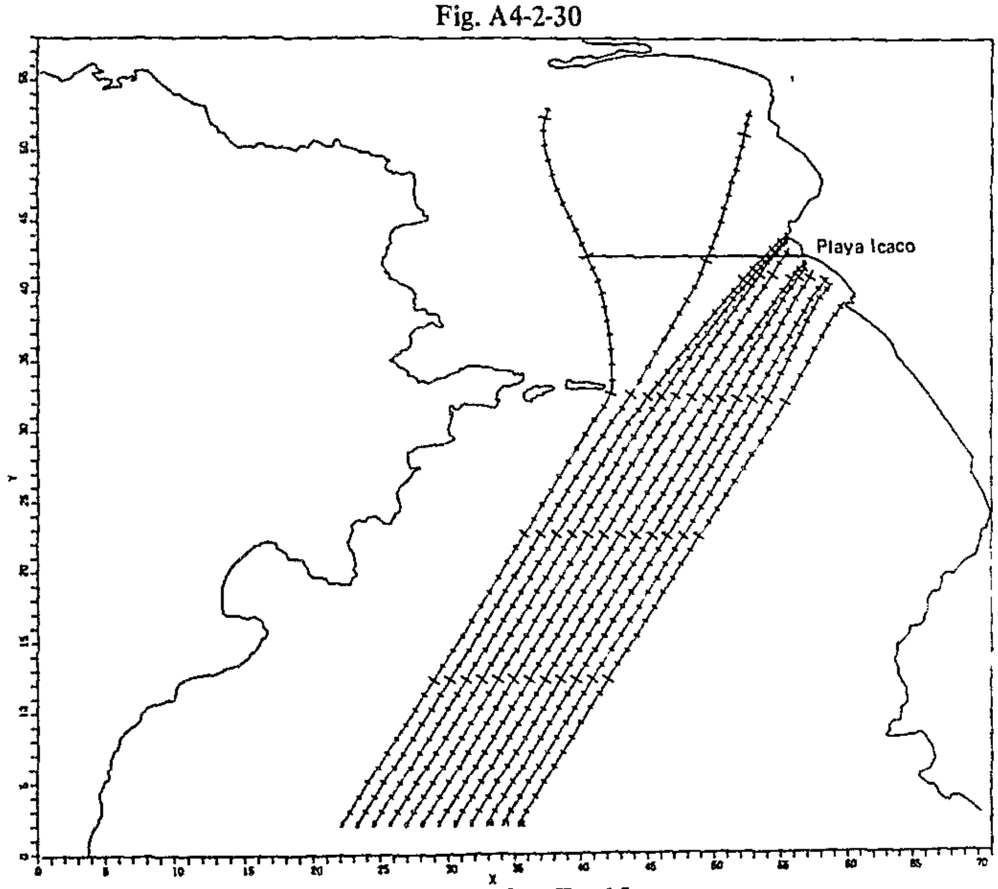

GLID INT = 750 (M) SSW T = 20s

Fig. A4-2-29



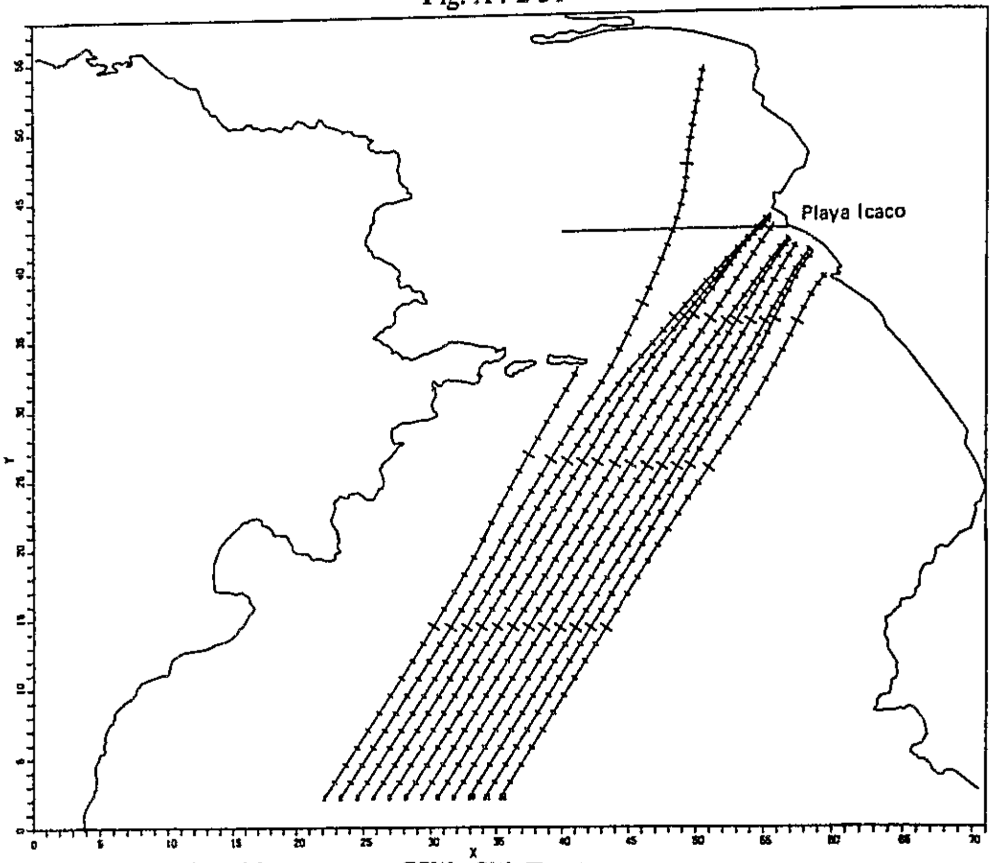

GLID INT = 750 (M) SSW · SW T=8s

Fig. A4-2-30



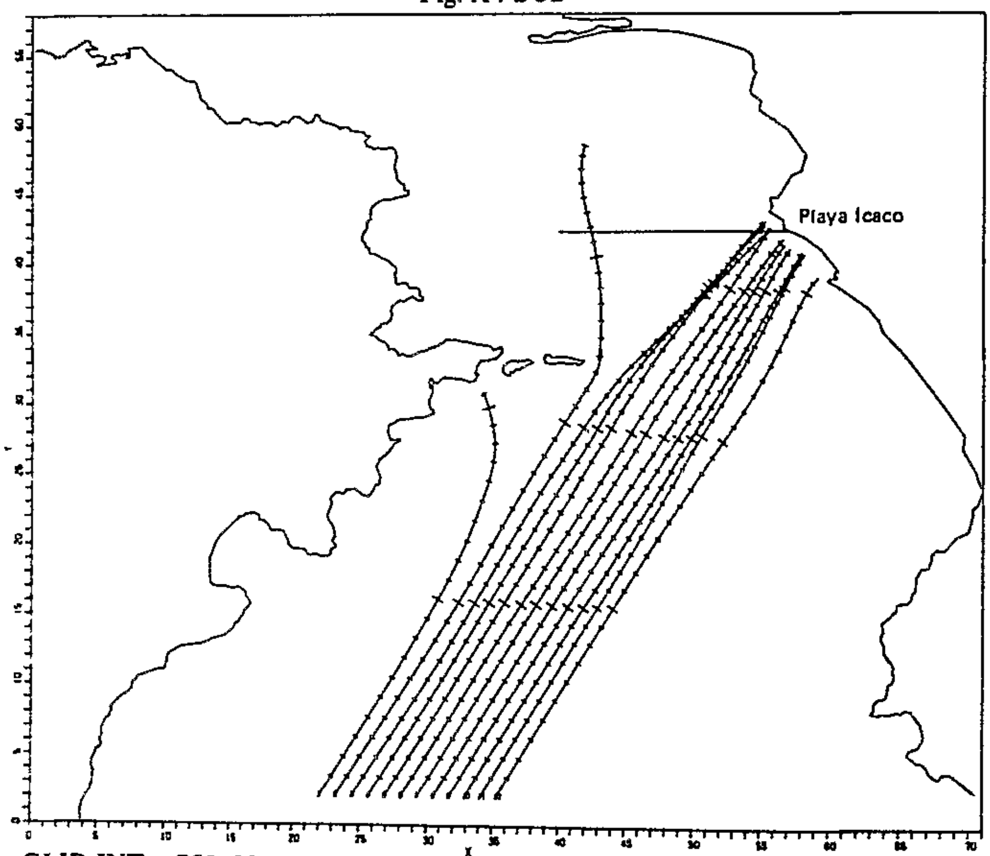

GLID INT = 750 (M) SSW · SW T = 10s

Fig. A4-2-31



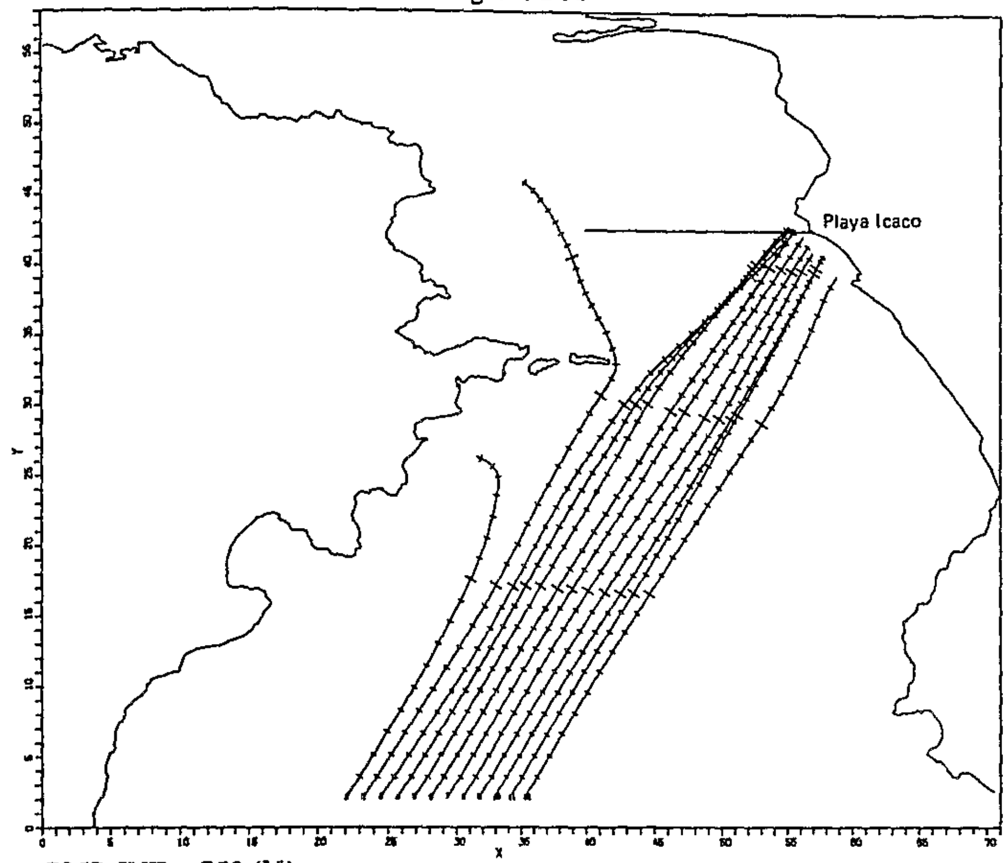

GLID INT = 750 (M) SSW · SW T = 12s

Fig. A4-2-32



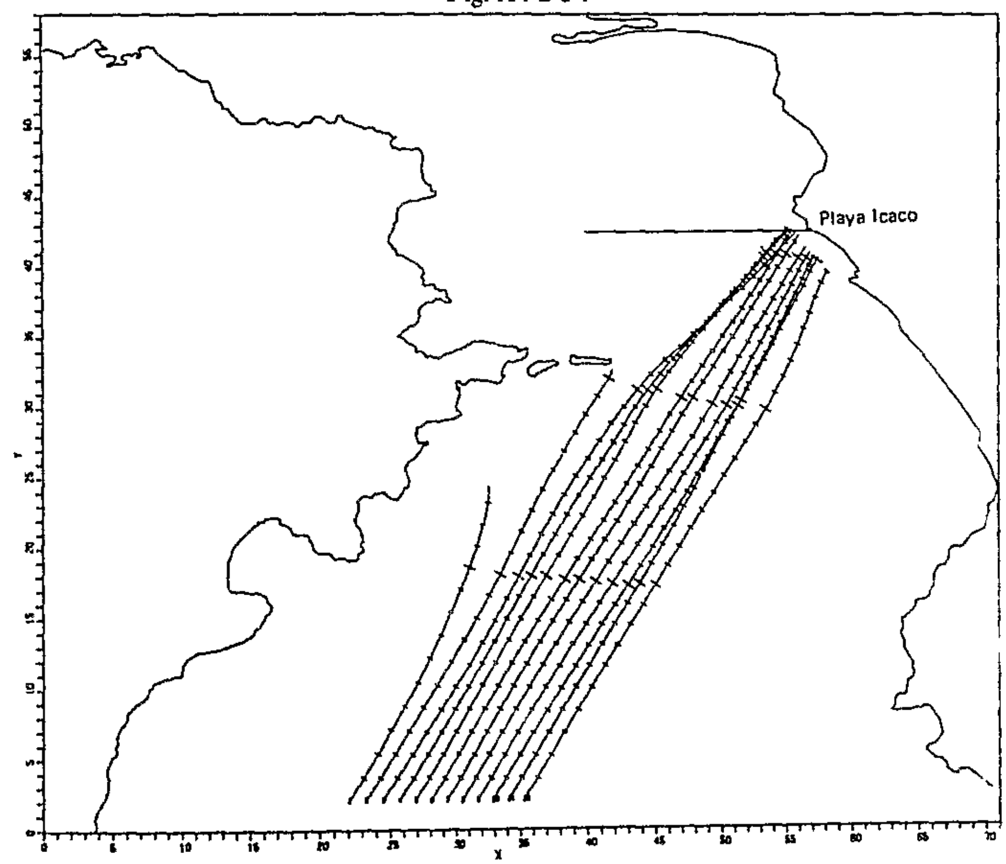

GLID INT = 750 (M) SSW · SW T = 14s

Fig. A4-2-33



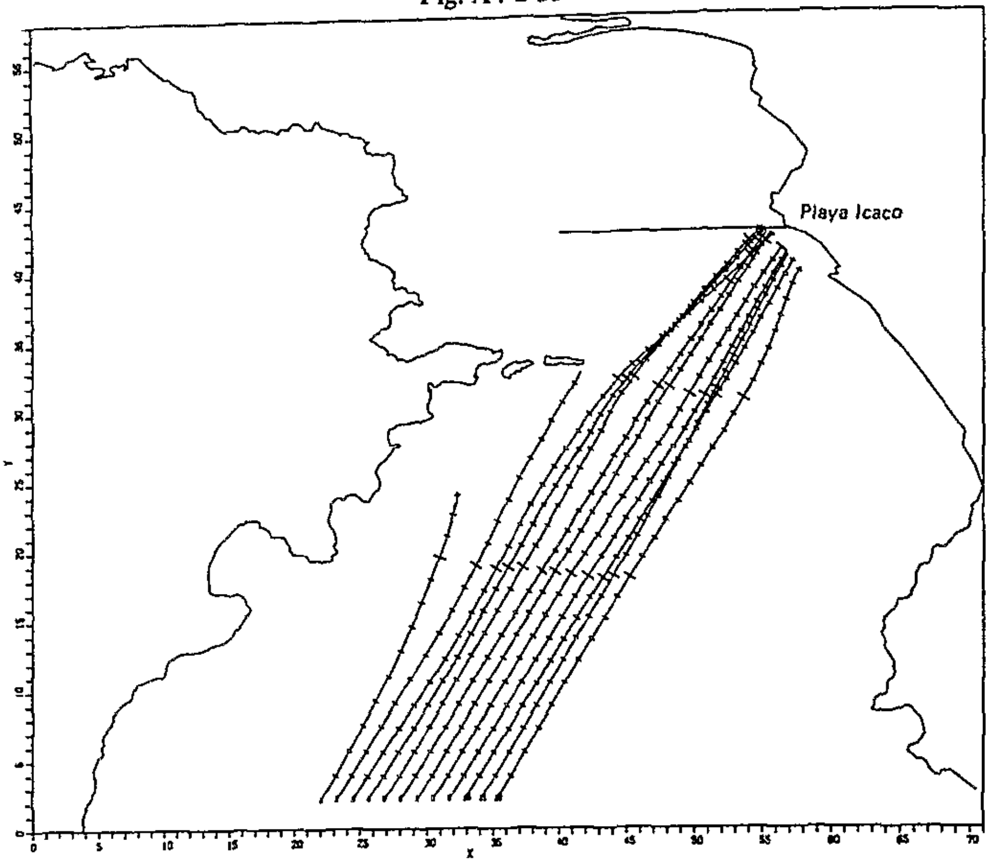

GLID INT = 750 (M) SSW · SW T =16s

Fig. A4-2-34



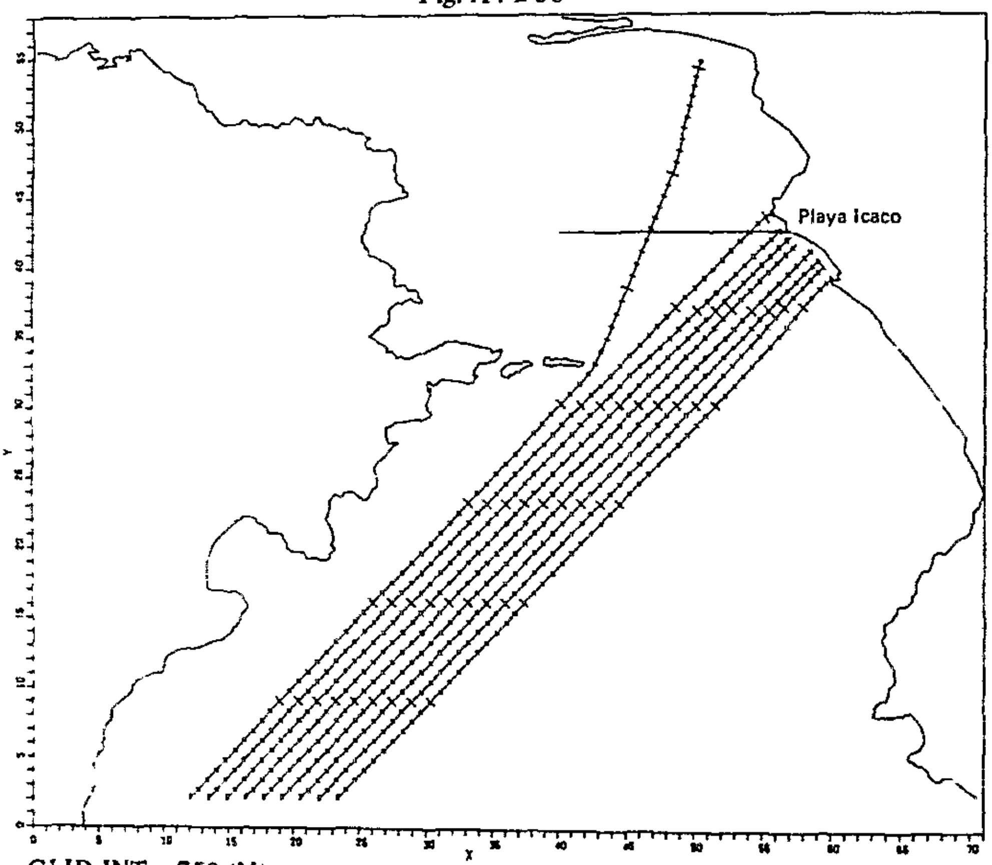

GLID INT = 750 (M) SSW · SW T = 18s

Fig. A4-2-35



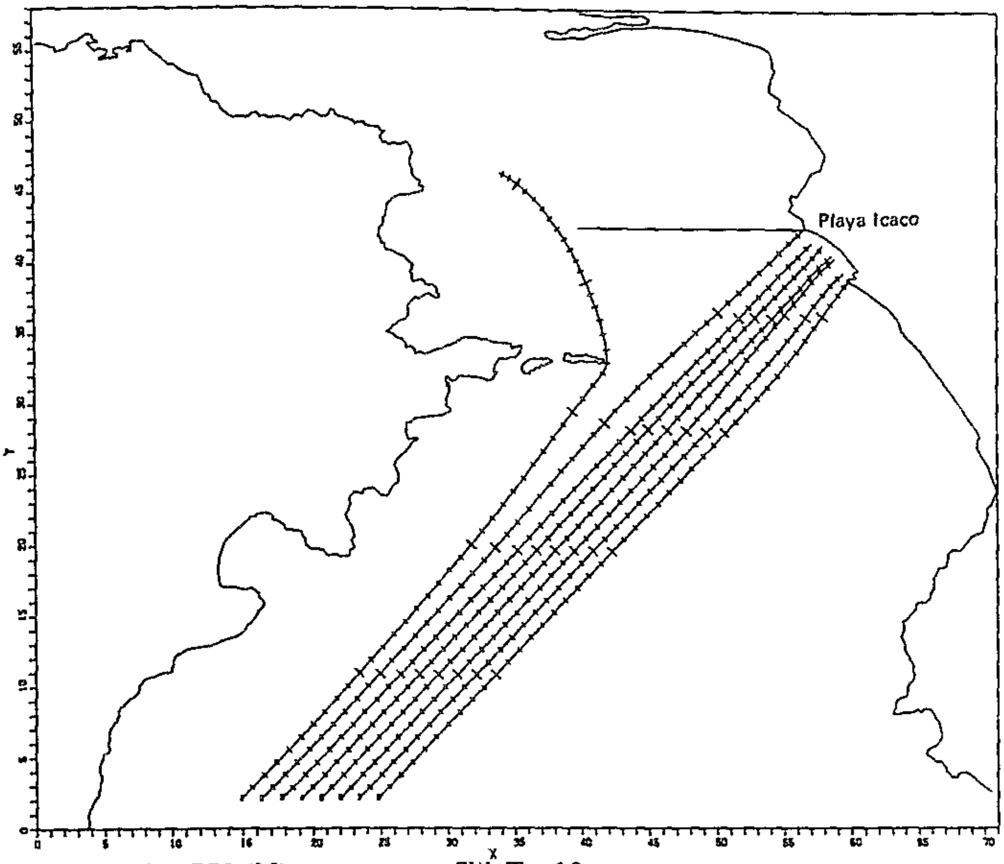

GLID INT = 750 (M) SSW · SW T = 20s

Fig. A4-2-36



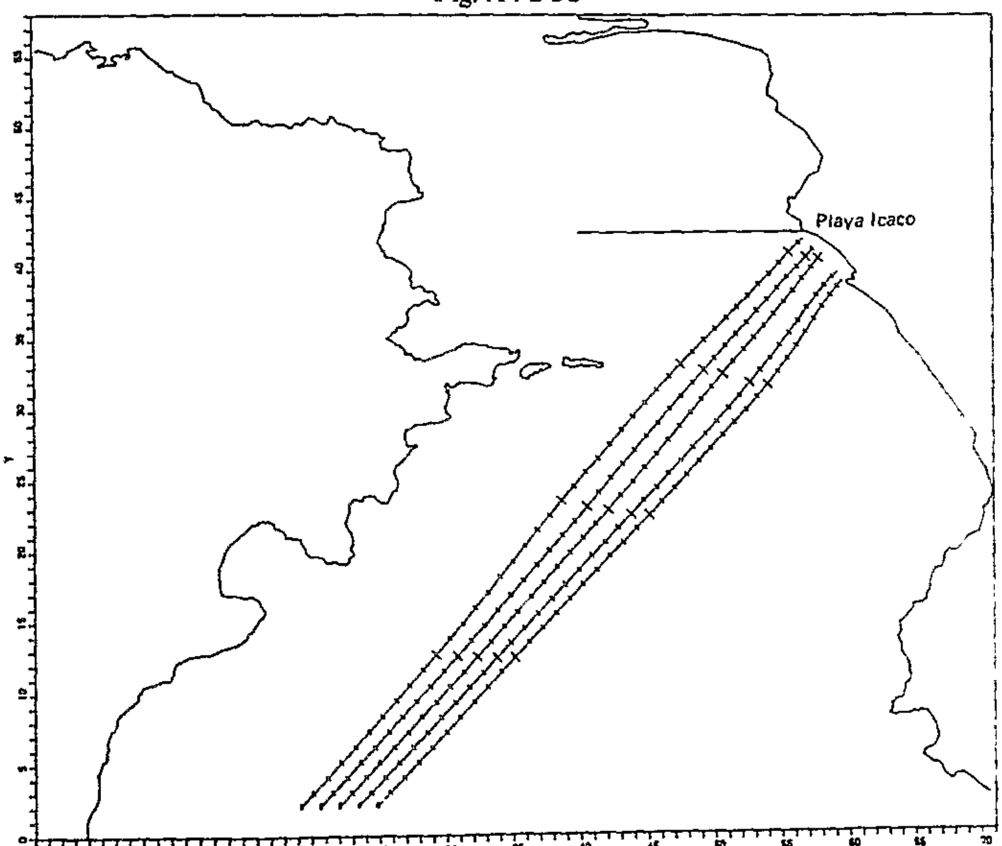

GLID INT = 750 (M) SW T = 8s

Fig. A4-2-37



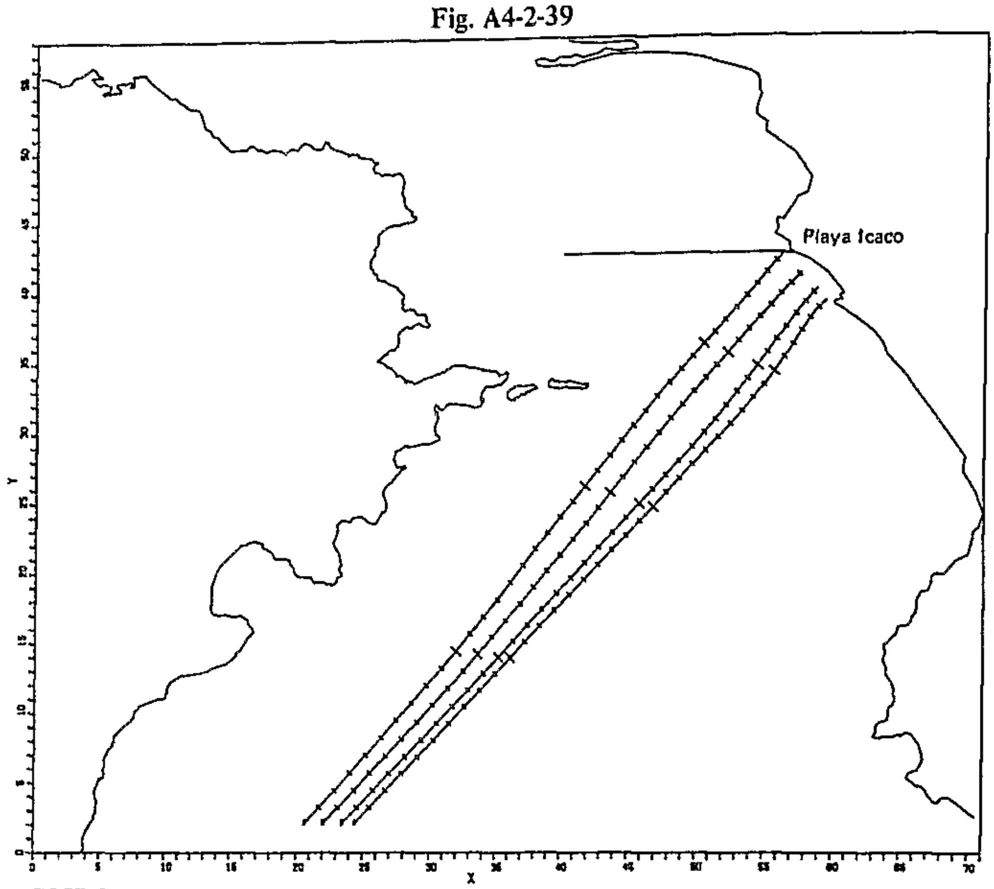

GLID INT = 750 (M) SW T = 10s

Fig. A4-2-38



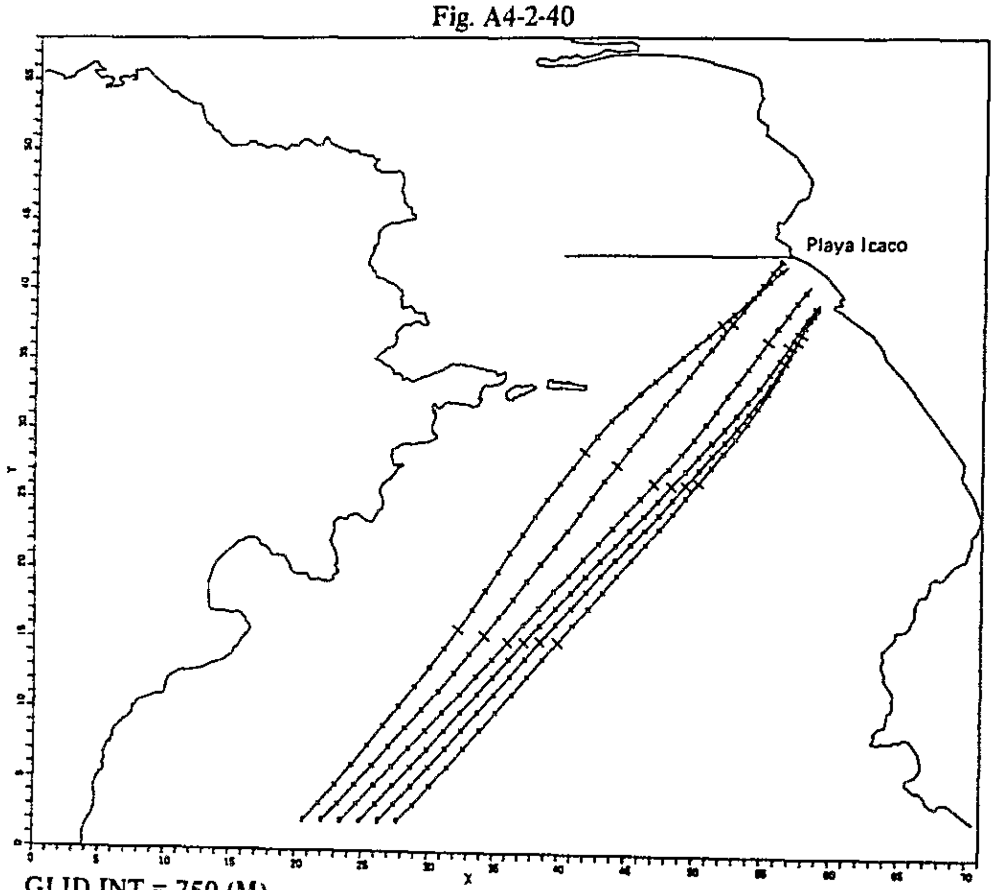

GLID INT = 750 (M) SW T = 12s

Fig. A4-2-39



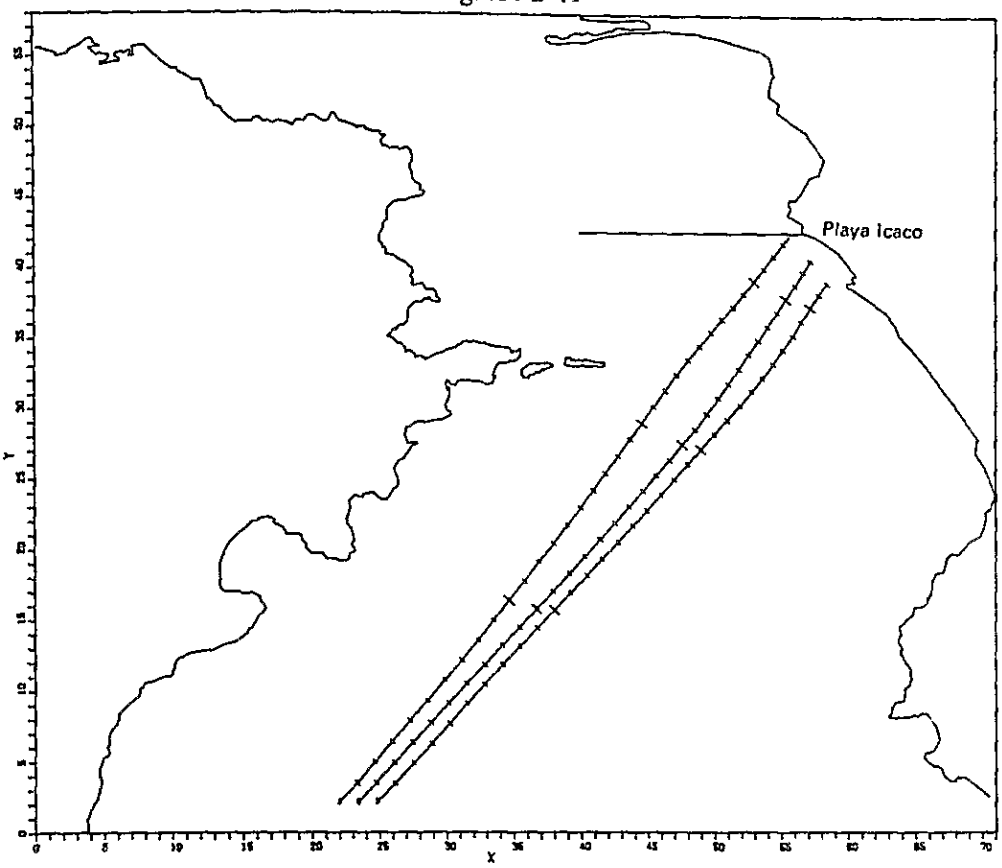

GLID INT = 750 (M)      SW T = 14s

Fig. A4-2-40



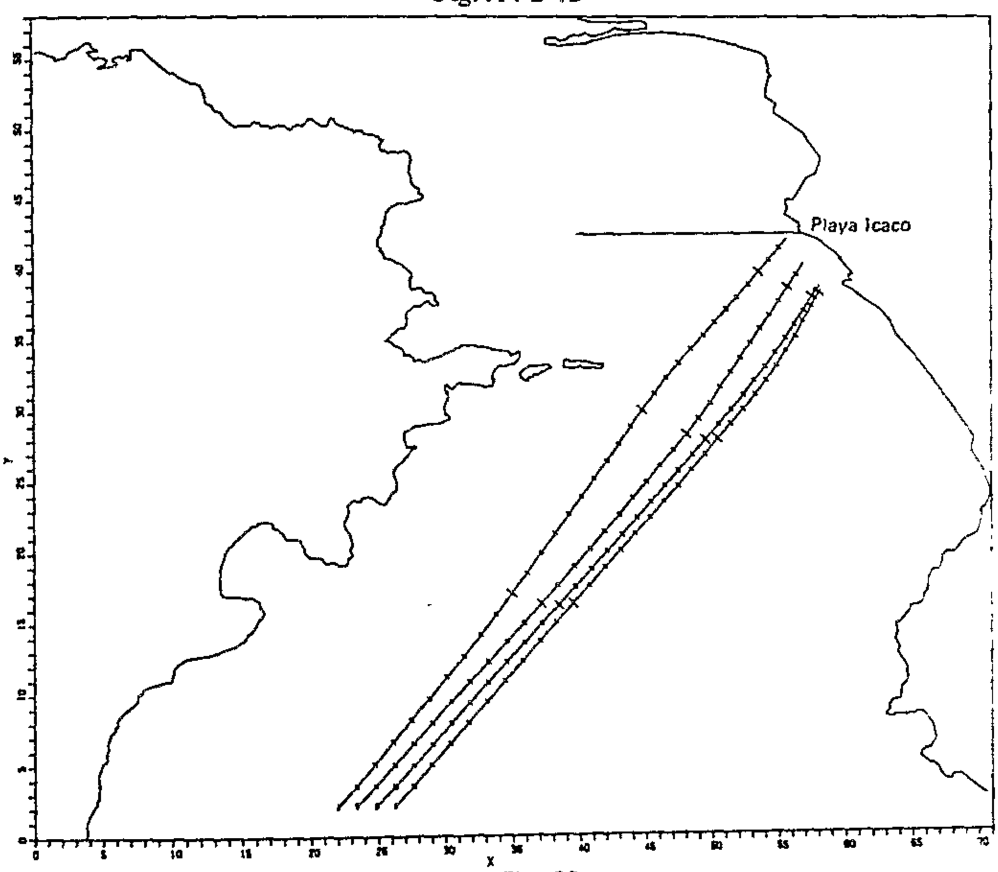

GLID INT = 750 (M)      SW T = 16s

Fig. A4-2-41



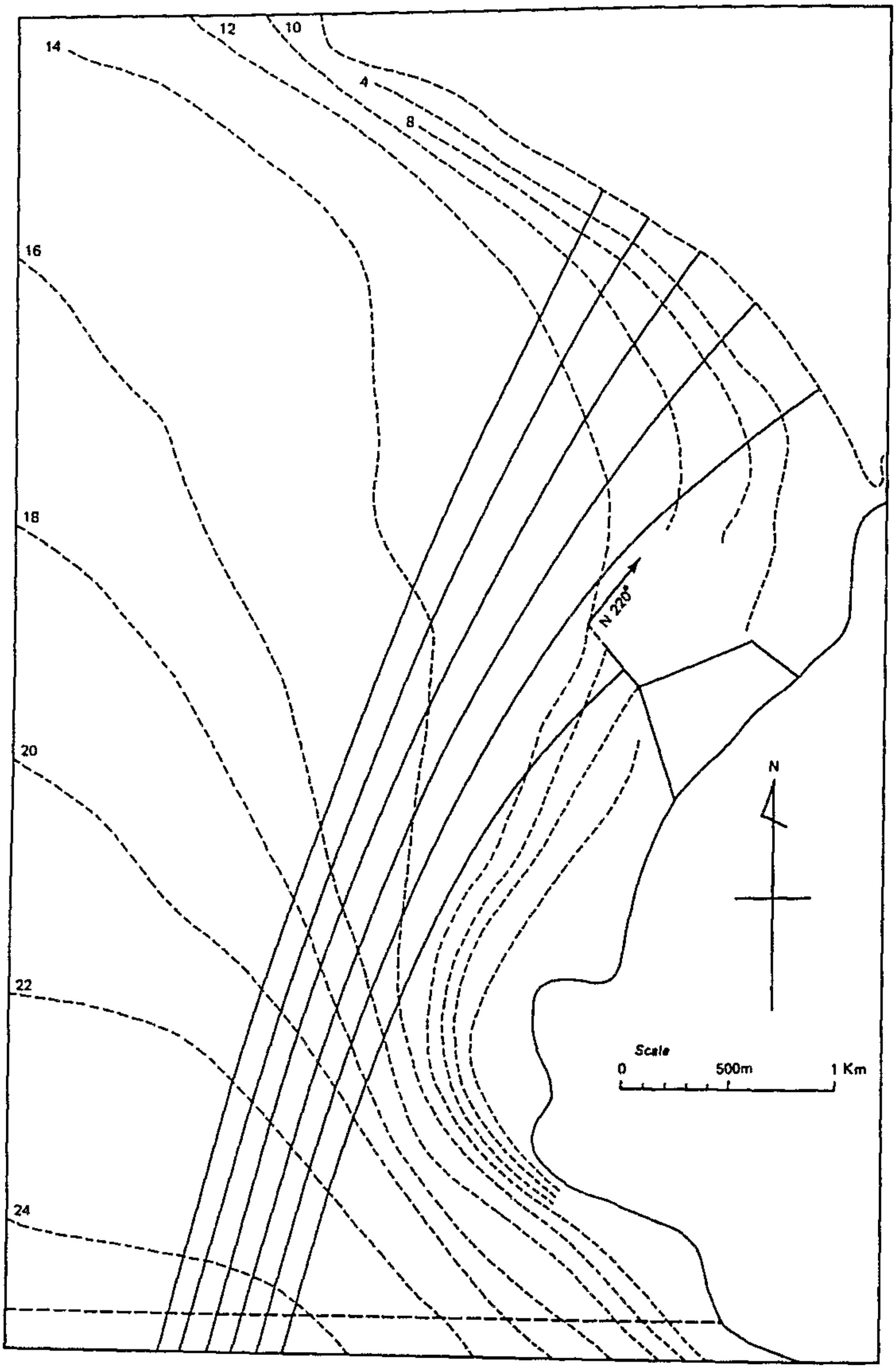

GLID INT = 750 (M) SW T = 18s

Fig. A4-2-42



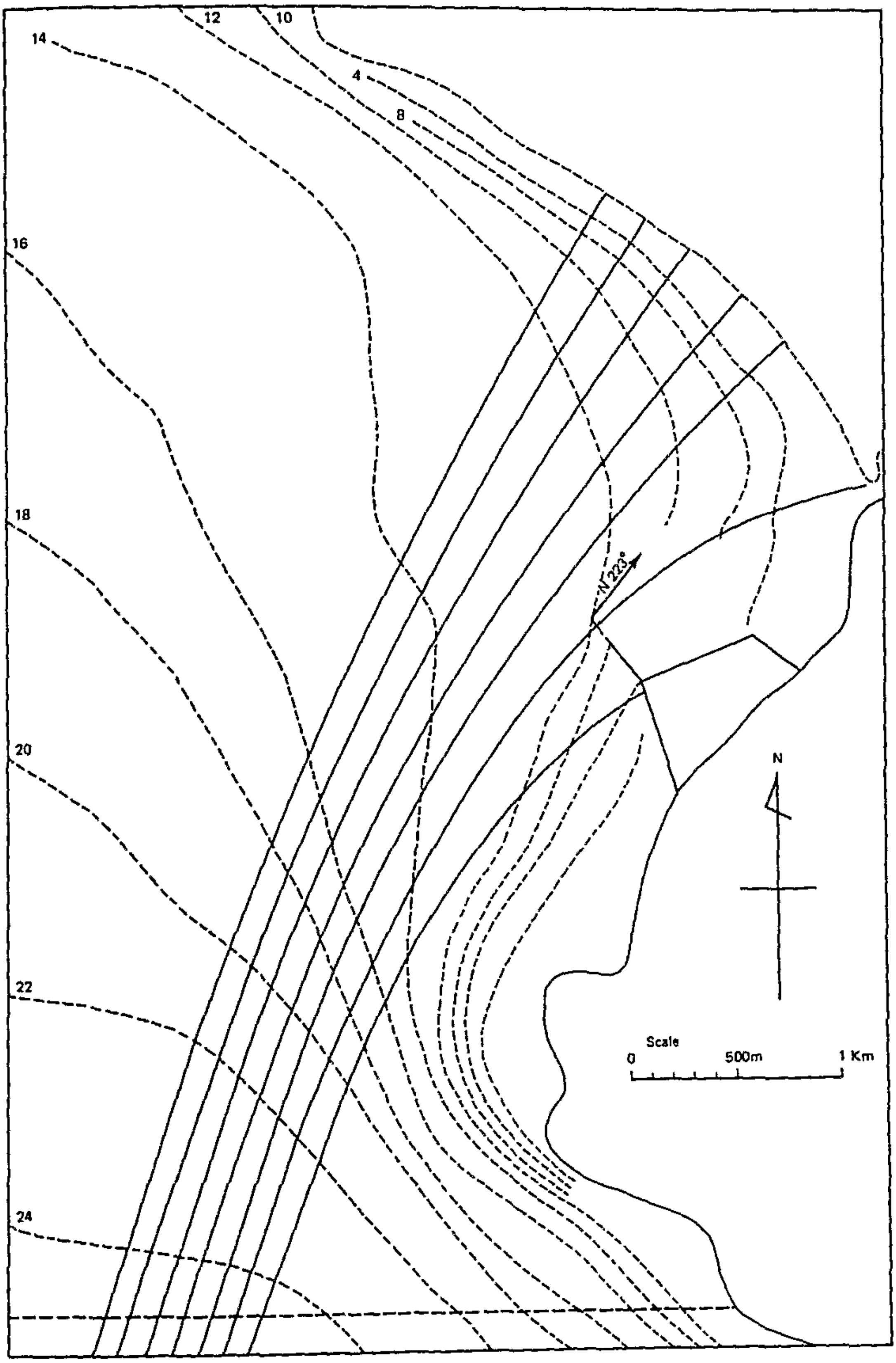

GLID INT = 750 (M) SW T = 20s

Fig. A4-2-43



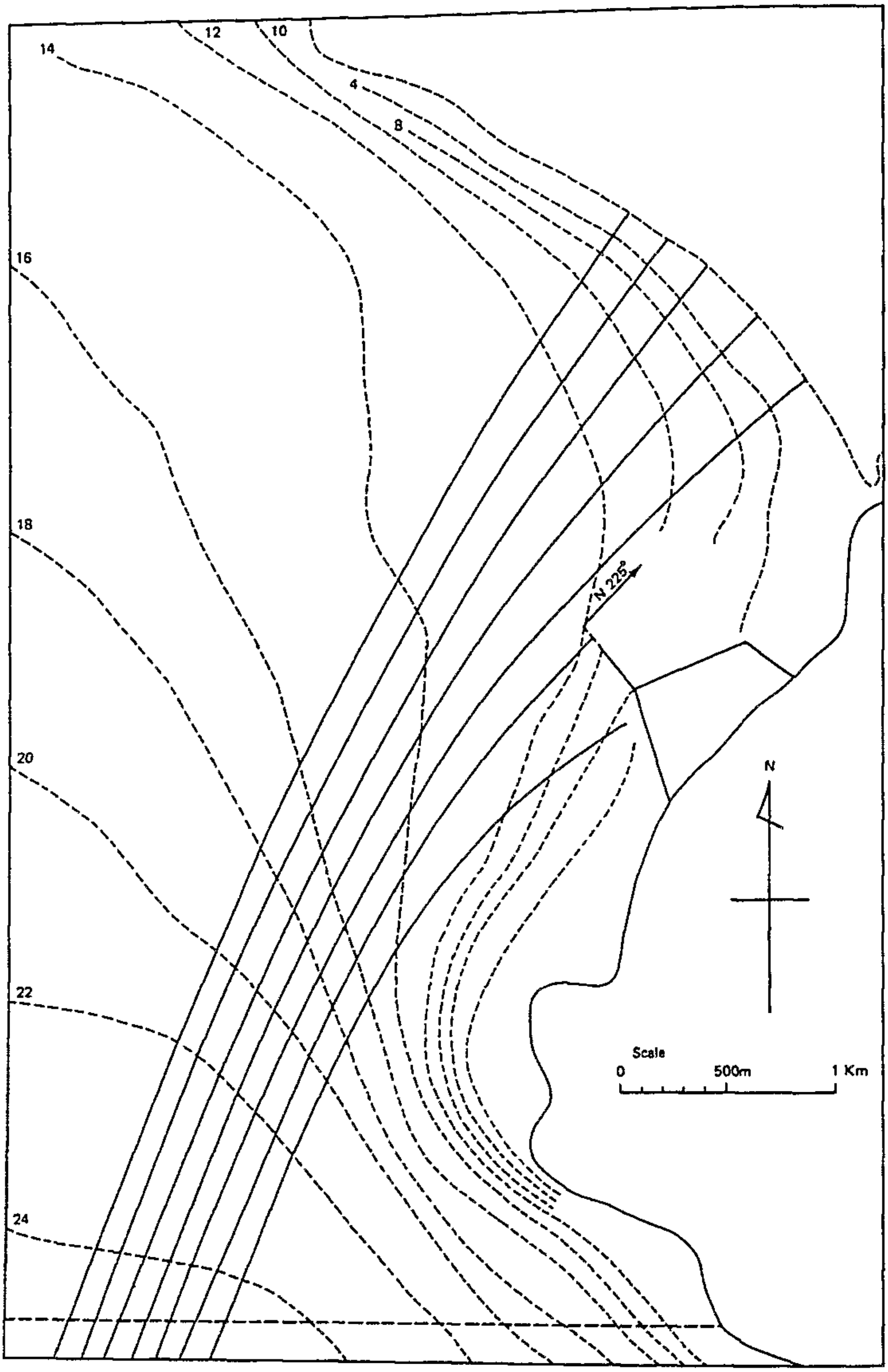

N 196° T = 12s

Fig. A4-2-44



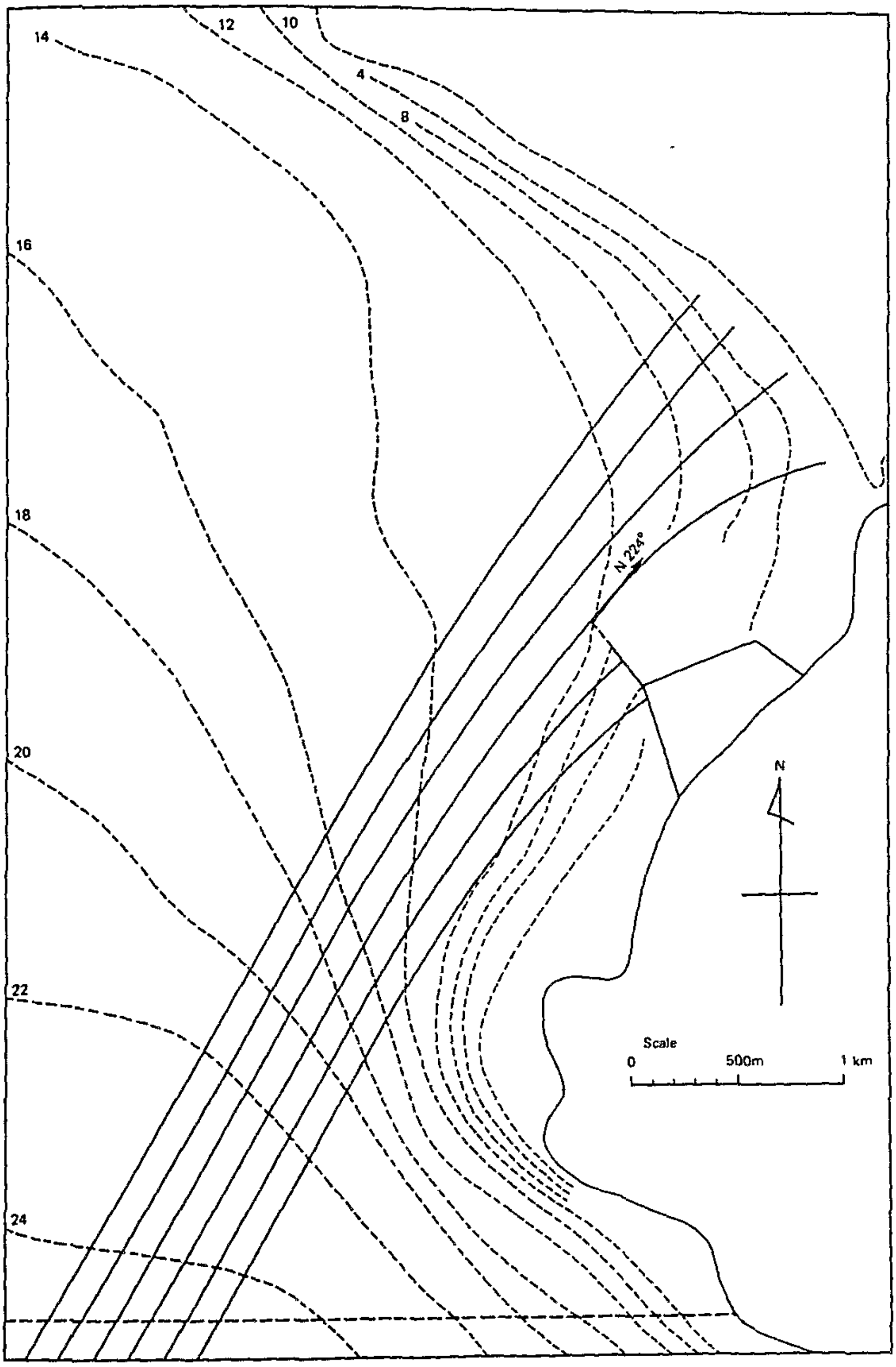

N 199° T = 16s

Fig. A4-2-45



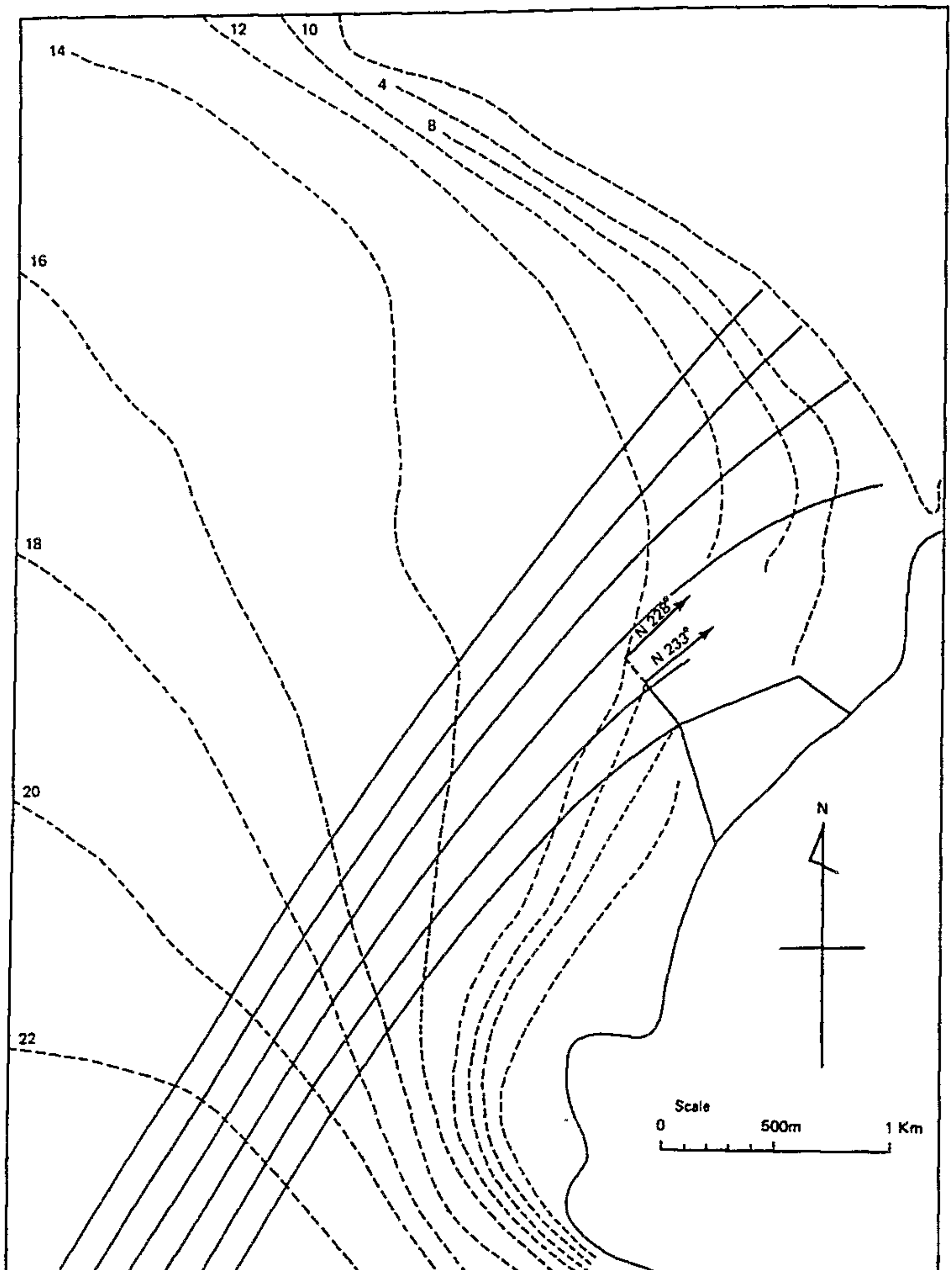

N 204° T = 20s

Fig. A4-2-46



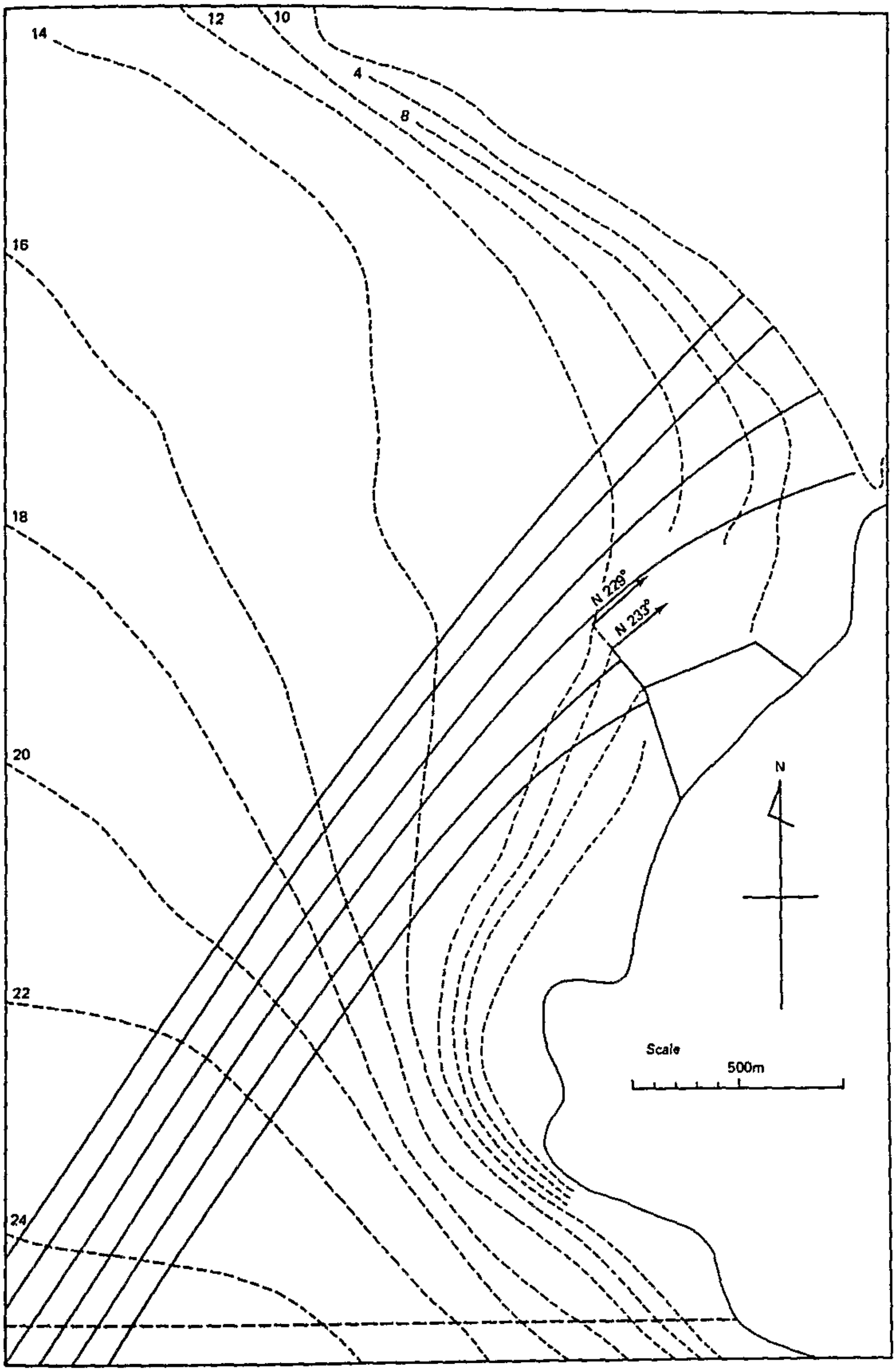

N 210° T = 12s

Fig. A4-2-47




N 212° T = 16s

Fig. A4-2-48




N 215° T = 20s

4-2-5 Tide

Tide observation is being done at the pier of the Port of Puntarenas. Fig. 4-2-10 shows the relation between the tides and datum level. Tidal constants at Puntarenas are shown in Table 4-2-8. The tide at Caldera has been measured by a temporary installed tide guage since June 1979. Small differences are seen in the time and height of the tide at Caldera and Puntarenas. However, the tide observation at Caldera is insufficient, being much influenced by waves, so the exact comparison of tides between Caldera and Puntarenas should be carried out after observations have been made at the permanent tide station in the Port of Caldera.

Table 4-2-8 Tidal Constants at Puntarenas

| | Height above datum of soundings (m) | | | |
|---|---|---|---|---|
| | High Water | | Low Water | |
| | Mean Springs | Mean Neaps | Mean Springs | Mean Neaps |
| Puntarenas | 2.84 | 2.23 | -0.04 | 0.58 |

4-2-6 Littoral Drift

(1) Characteristics of Littoral Drift in Vicinity of the Port of Caldera

The coast extending for about 20 km to the north and south of the Port of Caldera can be divided into the following three sections from the view-point of drift sand characteristics:

1 Coast from Puntarenas to Rio Barranca ... (Punteranas area)

2 Coast from Roca Carballo to Rio Jesus Maria ... (Caldera area)

3 Coast from Punta Loros to Rio Grande Tárcoles ... (Tárcoles area)

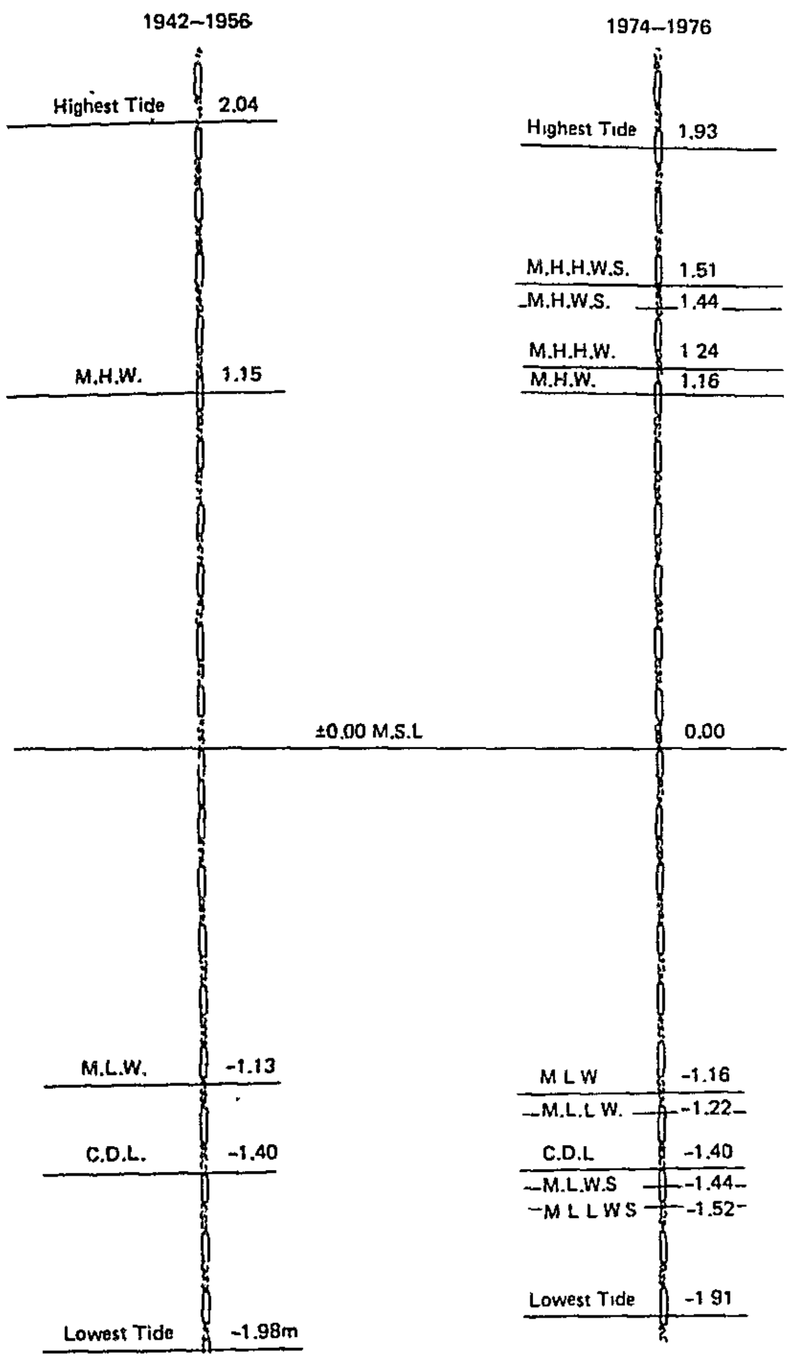
The Port of Caldera is in the above Caldera area and differs from the other two areas in coastal characteristics. The movement of littoral drift in the Caldera area is quite unlikely. The differences of coastal characteristics between the Caldera area and the Puntarenas area are as follows:

i) The two areas have different foreshore slopes. The foreshore slope in the Puntarenas area is only about 3°~5° but that in the Caldera area is 10° or more.

ii) In the Puntarenas area, some "black sand" exists in the vicinity of the estuary of the Rio Barranca but, in the area as a whole, black sand can hardly be seen. However, in the Caldera area considerable black sand exists on all seashores from about the flow-tide level of the foreshore to the front of the backshore.

iii) The shape of the long sand spit in the Puntarenas area provides a clue that the direction of the local drift sand is from east to west. Roca Carballo located on the boundary between the two areas is heavily eroded by waves and forms a source of supply of drift sand for the seashores in the vicinity. The shore about a kilometer south of Roca Carballo has long been known as "the place where limitless sand comes from the sea" and FECOSA has collected 10,000~20,000 $m^3$ every year since 1938. Sand at this sand collecting point and its vicinity is of rather large grain size (approximately $d_{50}$ = 1 mm) and the grain size is increasingly small in the south direction from this point. These facts indicate that sand supplied from Roca Carballo moves in the direction of Playa Caldera.

Fig. 4-2-10 Tide at Puntarenas



The distinction between Caldera area and Tárcoles area is based on the following points of view:

i) Sand from Rio Jesus Maria does not move south because Punta Loros protrudes as if to cover up the estuary of this river.

ii) Punta Loros protrudes sharply into the sea. In addition, two rocks rise from the sea 200~300 m off this cape. So even if sand from Rio Grande Tárcoles moves north to reach this point, it is likely to move out to the offing without going round Punta Loros.

iii) Comparison of aerial photographs taken in 1944 and 1979 shows that large quantities of sand have accumulated at the estuary of Rio Grande Tárcoles and on the shore from this estuary to the vicinity of Guacallo. So it seems that sand from Rio Grande Tárcoles stays mostly in this area. Thus there is little likelihood that this river sand has moved north to Punta Loros.

If the entire coast is thus divided into three areas with different drift sand characteristics, each area includes a large river. Furthermore, these rivers are each located at the south of east end of the area. This fact indicates that the prevailing direction of littoral drift in the three areas is all toward the recesses of Nicoya Bay.

(2) Littoral Drift Characteristics of Caldera Area

Sand in Playa Caldera is supplied from Roca Carballo located at its northwest end, and littoral drifting prevails in the southeastern direction. This can be proven by the fact that the sandbar at the Mata de Limón estuary extends from northwest to southeast. Fig. 4-2-11 shows the characteristics of foreshore sand in order from Roca Carballo to the Mata de Limón estuary and from the estuary towards upstream. The points from which these samples were taken are as indicated in Fig. 4-2-12. The samples show that the central grain size ($d_{50}$) is large (1.0 mm) in the vicinity of Roca Carballo and increasingly small from the Mata de Limón estuary towards upstream. Also, the sieve analysis coefficient is increasingly small from Roca Carballo to the Mata de Limón estuary and the upstream direction. This fact indicates that the prevailing direction of littoral drift is southeast.

The Mata de Limón estuary itself has such a small catchment area that it seems to supply little sand to the sea. However, there are signs that silt and clay washed down by heavy rain has descended at ebb tide and settled as soft mud in the calm waters of the anchorage in front of the wharf.

The grain size characteristics of sand on the foreshore from the Port of Caldera to Rio Jesus Maria are shown in Fig. 4-2-13. The points from which sand was collected are shown in Fig. 4-2-14. The sieve analysis coefficient of this sand is increasingly small in the northern direction on both the north side and the south side of Punta Caldera. This fact suggests that northward sand drift prevails. But the grain size ($d_{50}$) of sand on the Tivives shore suddently increases in the direction from Rio Jesus Maria toward Punta Caldera. This can be explained as follows: Sand supplied from Rio Jesus Maria moves north and reaches Punta Caldera. Punta Caldera comprises three capes: Punta Corralillo, Punta Torre and Punta Icaco. Since waves in front of these capes are larger than those on the seashore in the vicinity, sand brought to Punta Caldera reaches Playa Corralillo, going round the front of each cape. In the process, sand with smaller grain size readily goes round the capes but sand with larger grain size tends to be left behind on the south side of the capes. It is probably for this reason that, in Fig. 4-2-13, grain size differs between the shores

Fig. 4-2-11 Beach Materials of Caldera (1)

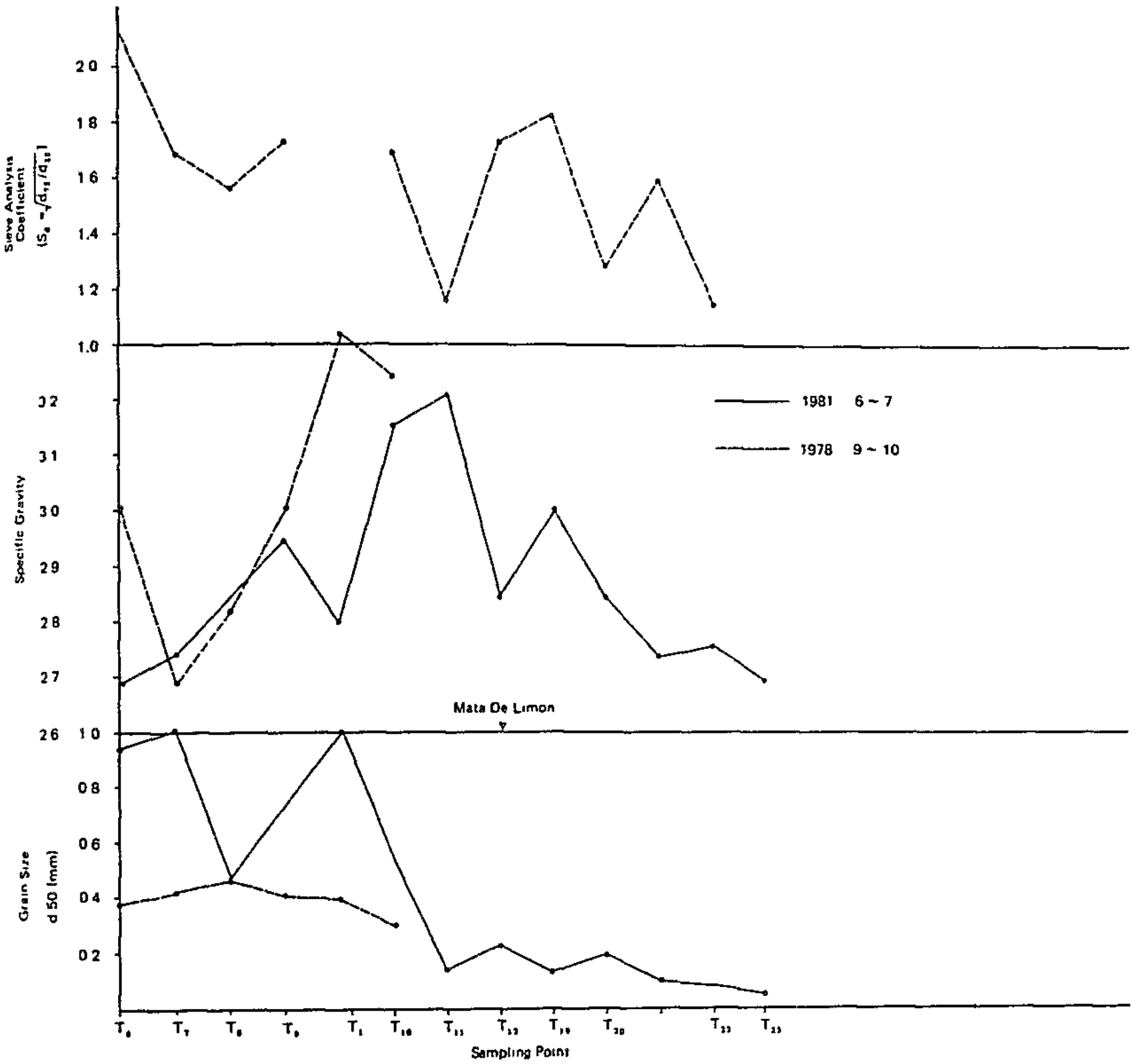


Fig. 4-2-12 Sampling Points of Beach Materials (1)

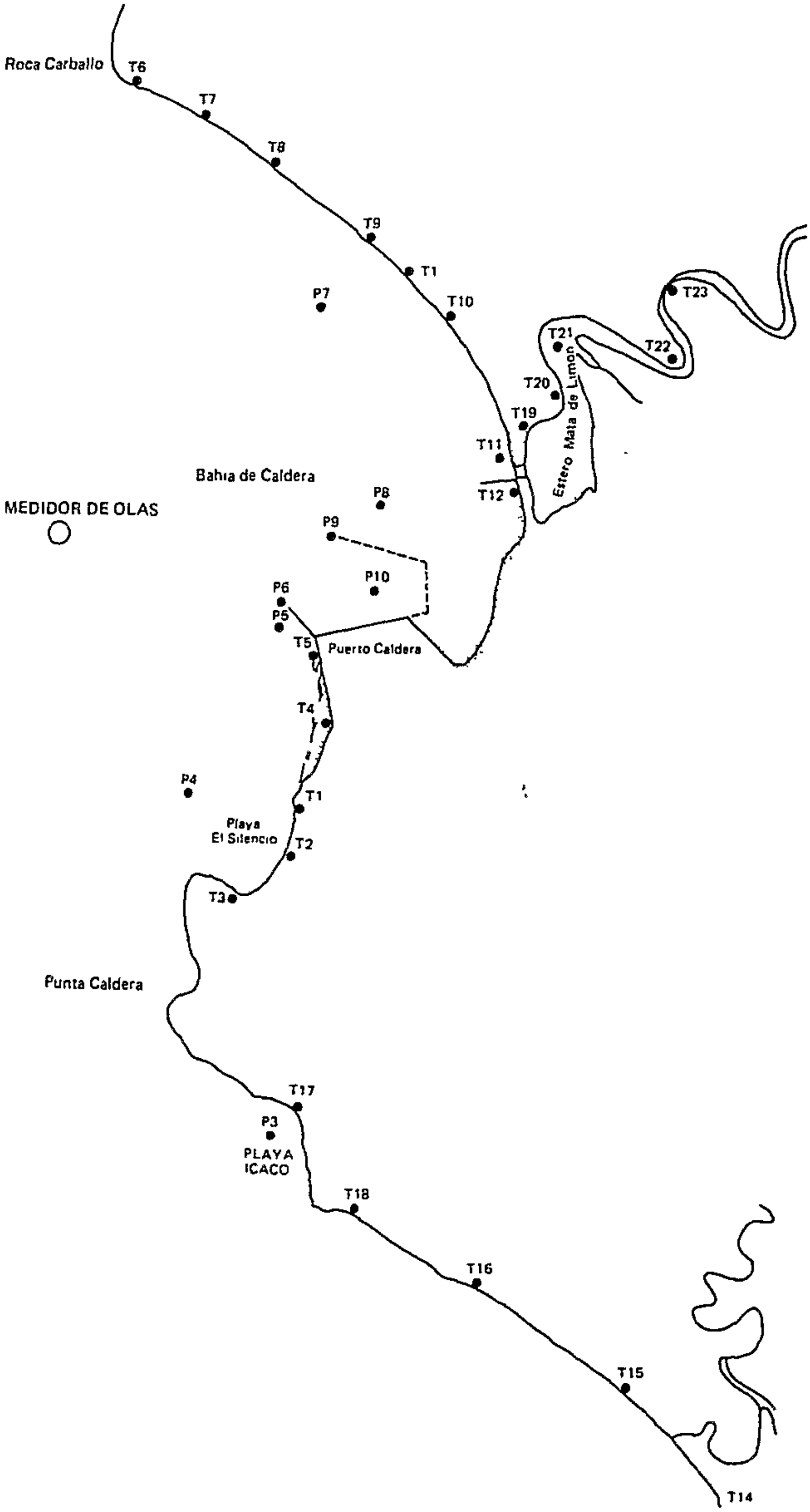


Fig. 4-2-13 Beach Materials of Caldera (2)

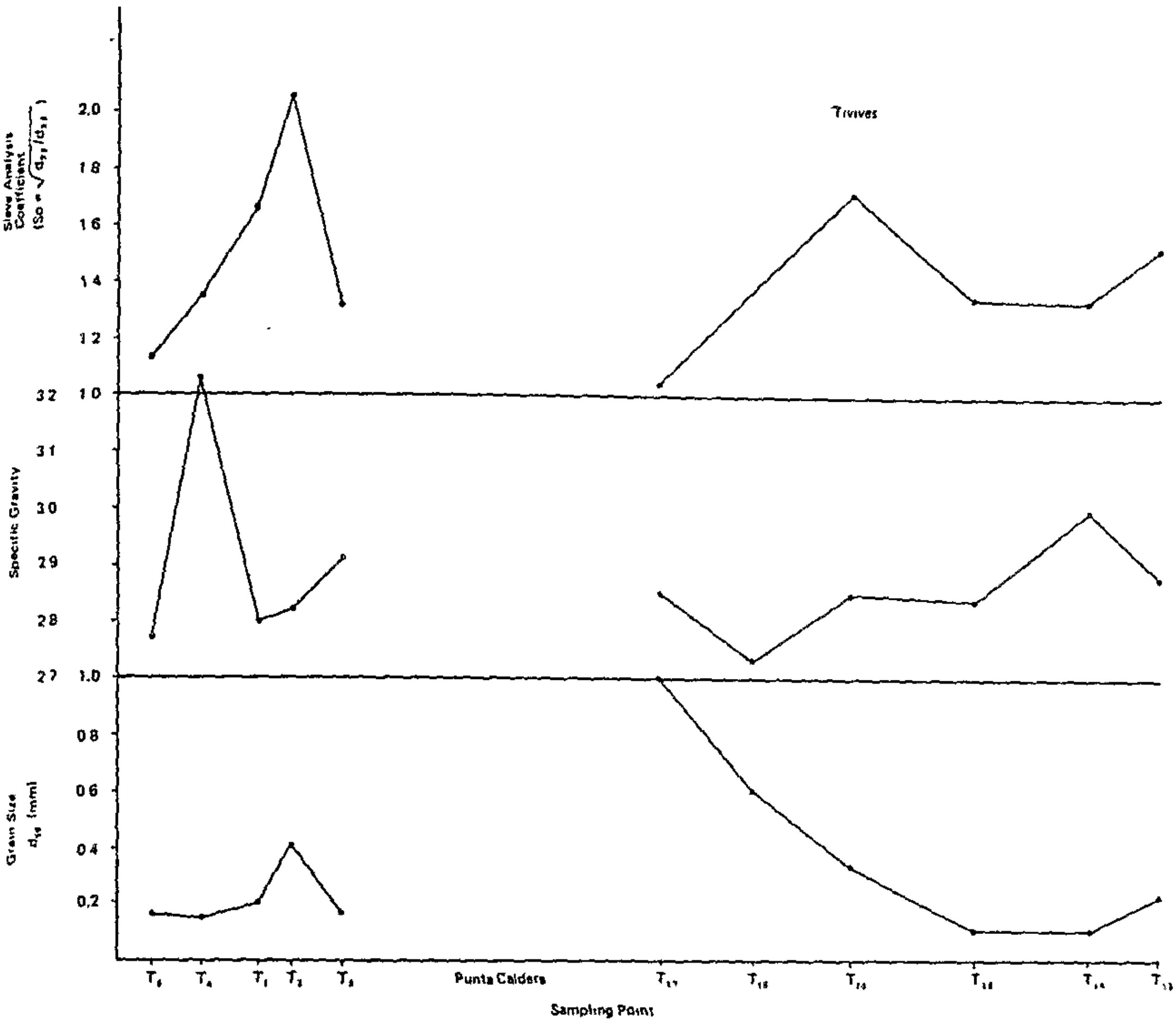
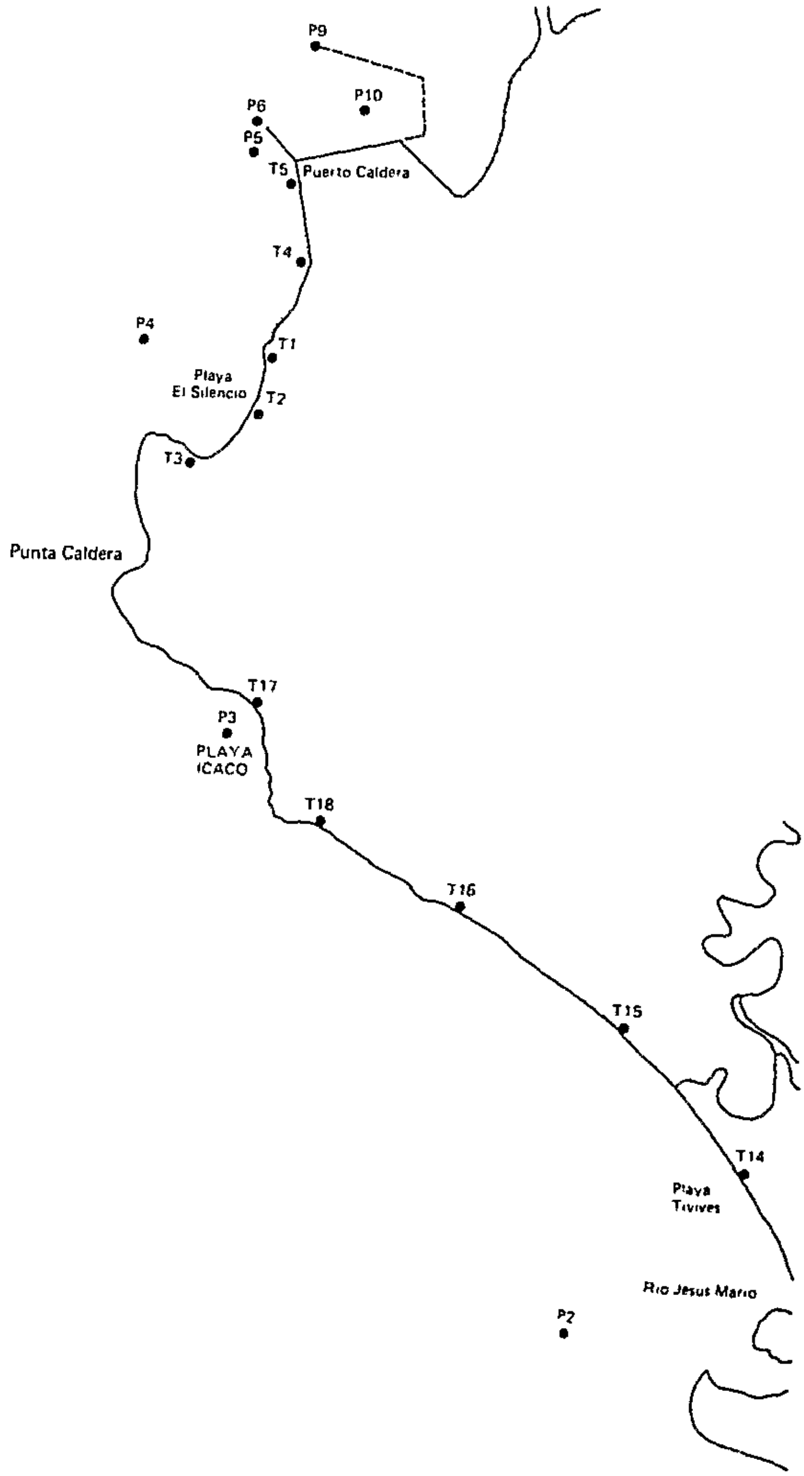


Fig. 4-2-14 Sampling Points of Beach Materials (2)



north and south of Punta Caldera, being smaller on the northern shore (Playa Corralillo and the shore south of the Port of Caldera). So, it is considered that it is due to the difficulty of sand with larger grain size to go round the capes that sand with larger grain size exists on the south side of Punta Caldera.

In connection with this littoral drift going round Punta Caldera, divers who having been fishing for lobsters at this punta for the past 10 years made a statement to the following effect: Rocks were formerly exposed at the sea bottom in front of Punta Caldera but the sea bottom in this general area has begun to be covered with sand since one or two years ago. Indeed, in the survey depth of about –7.5 m between Punta Corralillo and Punta Torra.

From the above littoral drift phenomenon, the sand accumulation now in progress on the coast south of the Port of Caldera seems to be due to the arrival of sand from Rio Jesus Maria which comes round Punta Caldera.

### 4-2-7 Earthquake

Figs. 4-2-15 and 16 are iso-acceleration maps of 50 years and 100 year return periods, prepared on the basis of past earthquake records ("A study of Seismic Risk for Costa Rica" by the John A. Blume, Earthquake Engineering Center-Stanford University) As seen from these maps, peak ground accelerations are comparatively small in Caribbean Coast areas, while comparatively large in the Golfito area on the Pacific coast. PGAs in other areas present roughly equal values. PGAs in Caldera are 0.15g for the 50 year return period and 0.175 – 0.20g for the 100 year return period.

The relationship between activating seismic coefficients obtained from damage examples of earthquakes at various ports in Japan and PGAs obtained from seismic response computation of the ground are summarized in Fig. 4-2-17. The straight and curved lines appearing on the figure are drawn by connecting approximate upper-limit values of activating seismic coefficient. Further, since activating seismic coefficients corresponding to PGA for 75 year return periods are applied in Japan, it will be appropriate to apply 0.15 as the design seismic coefficient.

Fig. 4-2-15 Iso-Acceleration Map (% of G)
Return Period 50 Years

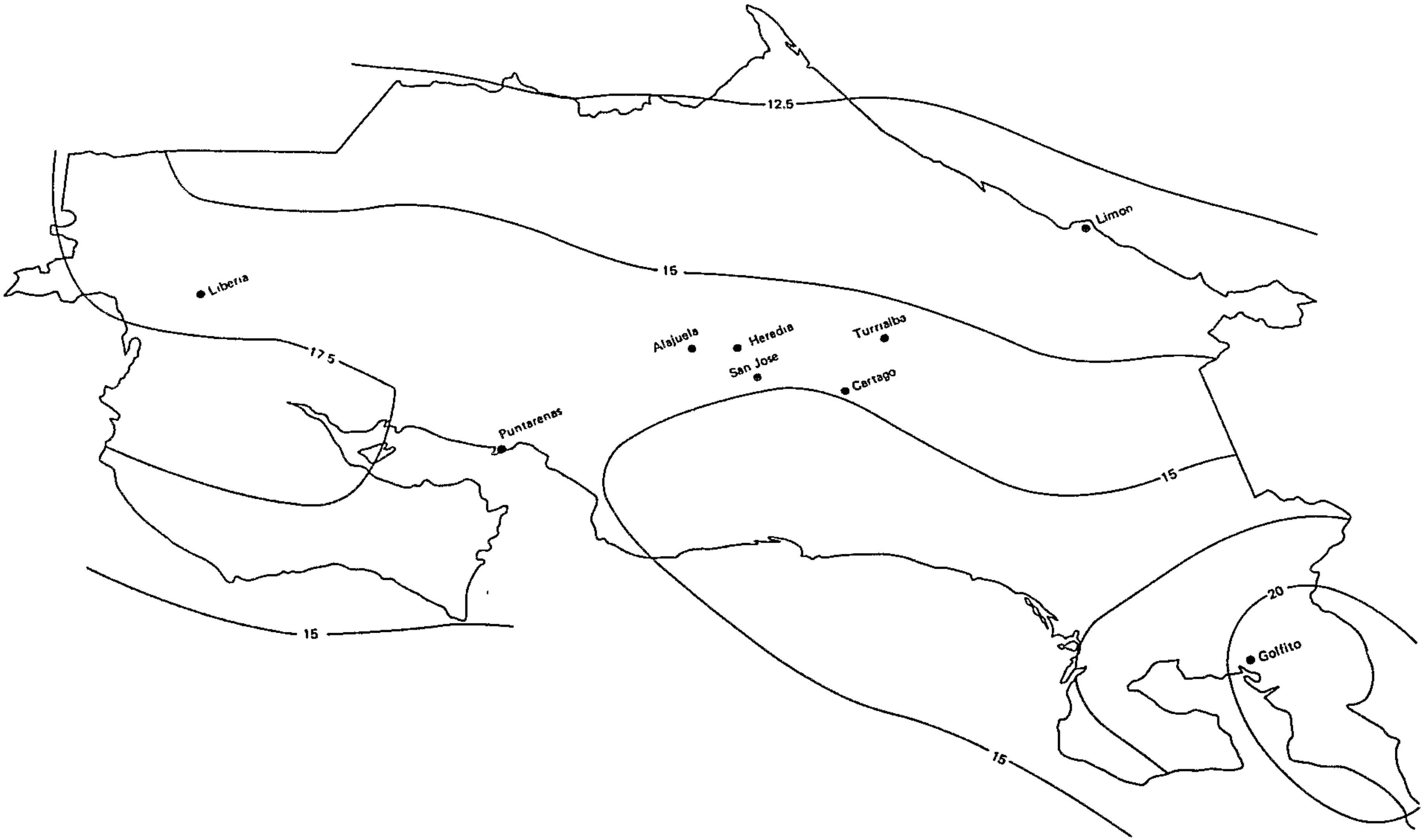


Fig. 4-2-16 Iso-Acceleration Map (% of G)
Return Period 100 Years

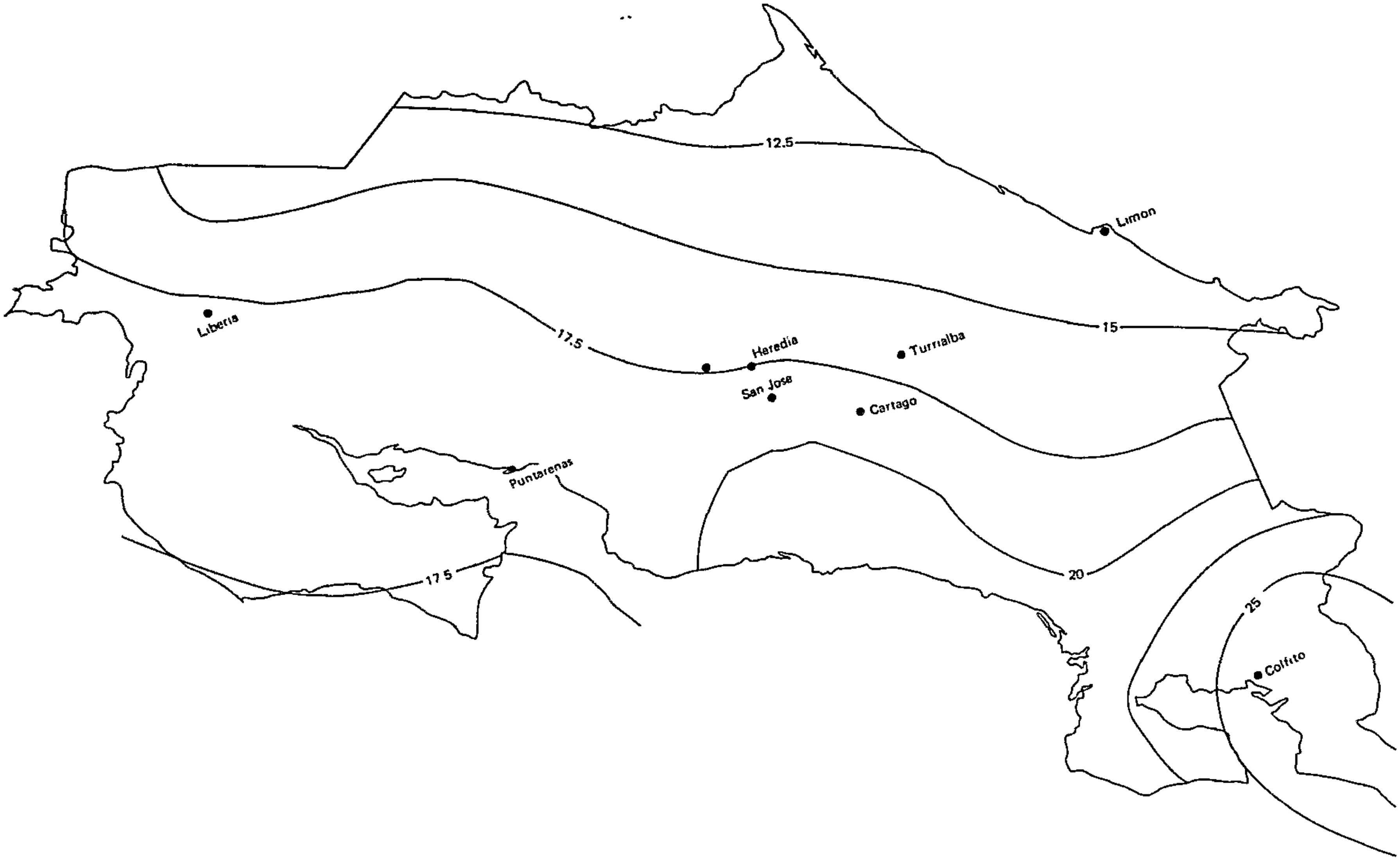
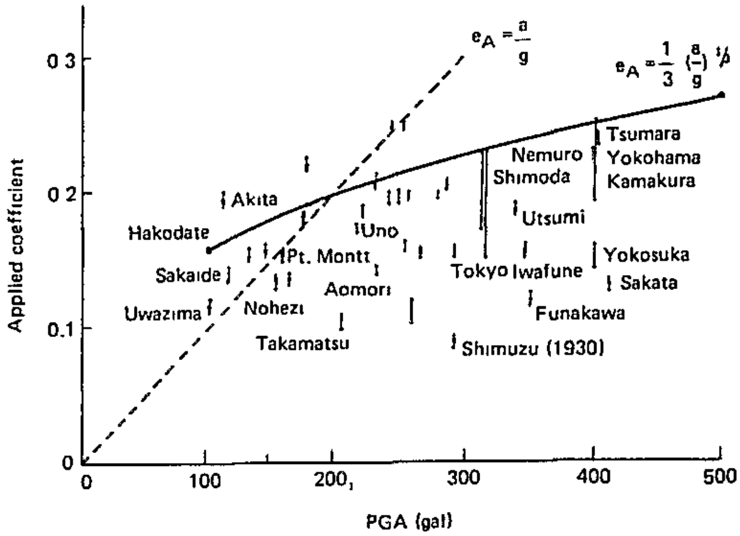


Fig. 4-2-17 Relation between PGA and Coefficient




## 4-2-8 Soil Condition

The soil exploration for the foundation engineering of the Second Stage Expansion Project of the Port of Caldera has been carried out by MOPT.

Consequently the outline of the soil conditions and the soil properties at the planning areas of the wharf and the breakwater of the project are understood. Investigations consisted of exploratory drillings with the Standard Penetration Tests and undisturbed samplings, and laboratory soil tests of samples obtained from the bore holes. 14 Bore holes were drilled, to depth of the surface of bedrock, and the total drilling length was about 400 m. The location of the bore holes are shown in Fig. 4-2-18.

The wash boring method was adopted for drilling, and the operation was carried on a barge (dredger) or boring tower framed by steel pipe ($\phi$50 cm). The Standard Penetration Tests and soil tests were practiced under the Standards of the American Society for Testing and Materials (ASTM). For undisturbed sampling, BX Shelby tubes ($\phi$50 mm open drive sampler) were used.

### (1) Topography and Geology

The Port of Caldera is located at the east coast of Nicoya Gulf. As it is shown in Fig. 4-2-19, the planning wharf area of the Second Stage Expansion Project is situated on the east side of the wharf constructed by the First Stage Project. The front (northern side) of these wharfs is Caldera Bay and beyond it Puntarenas can be seen. On the southern side of the wharfs, low but steep flat-top mountains of about 200 meters can be seen ranging across the narrow plain. On the east there is an estuary called Estero Mata de Limon flowing through a thick Mangrove forest. The estuary is separated from the bay by a small spit.

The geology around the site has been reported by Rodolfo Madrigal (1970)* et al. According to his report, the region is occupied by Tertiary and Quaternary rocks and deposits shown as follows.

| Period | Epoch | Formation |
| --- | --- | --- |
| Quaternary | Holocene | Alluvium |
| | Pleistocene | Diluvium |
| | | Orotina Formation<br>Tivives Formation |
| Tertiary | Pliocene | |
| | Miocene | Punta Carballo Formation |
| | Pre-Eocene | Nicoya Group |

Nicoya Group, the basement of this region consists of silicious limestone and basalt, but their outcrops can not be found near the project site.

Punta Carballo Formation is mainly composed of greyish blue sandstone and conglomerate with shell fossiles. Brown tuffacious sandstone and mudstone alternated with basaltic pyroclastic layers are also found. It is widely distributed in almost all the area and is locally exposed in the mountain skirts at the back of the project site and around the Mata de Limon station.

Tivives Formation consists of massive basaltic agglomerate and lava flows, intercalating tuff and tuff-breccia.

Orotina Formation consists of welded tuff and is widely distributed around the mountains of the left bank of the Jesus Maria River.

Dilivuum and Alluvium are composed of soft clay, loose sand and gravel. They are distributed in the alluvial plain, river side and sea bottom.

Several faults with NE or NW trends are found in the area. Dengo (1960) says that these faults are restricted in distribution to the Punta Carballo Formation and he ascribes their origin to the Central American Orogenic Movement.

* Rodolfo Madrigal G. (1970), Geologia de Mapa Basico "Barranca", Costa Rica, Informes Techicos y Notas Geologicas, Ciudad Universitaria "Rodorigo Facio", Costa Rica, America Central.

Fig. 4-2-18 Location Map of Bore Holes

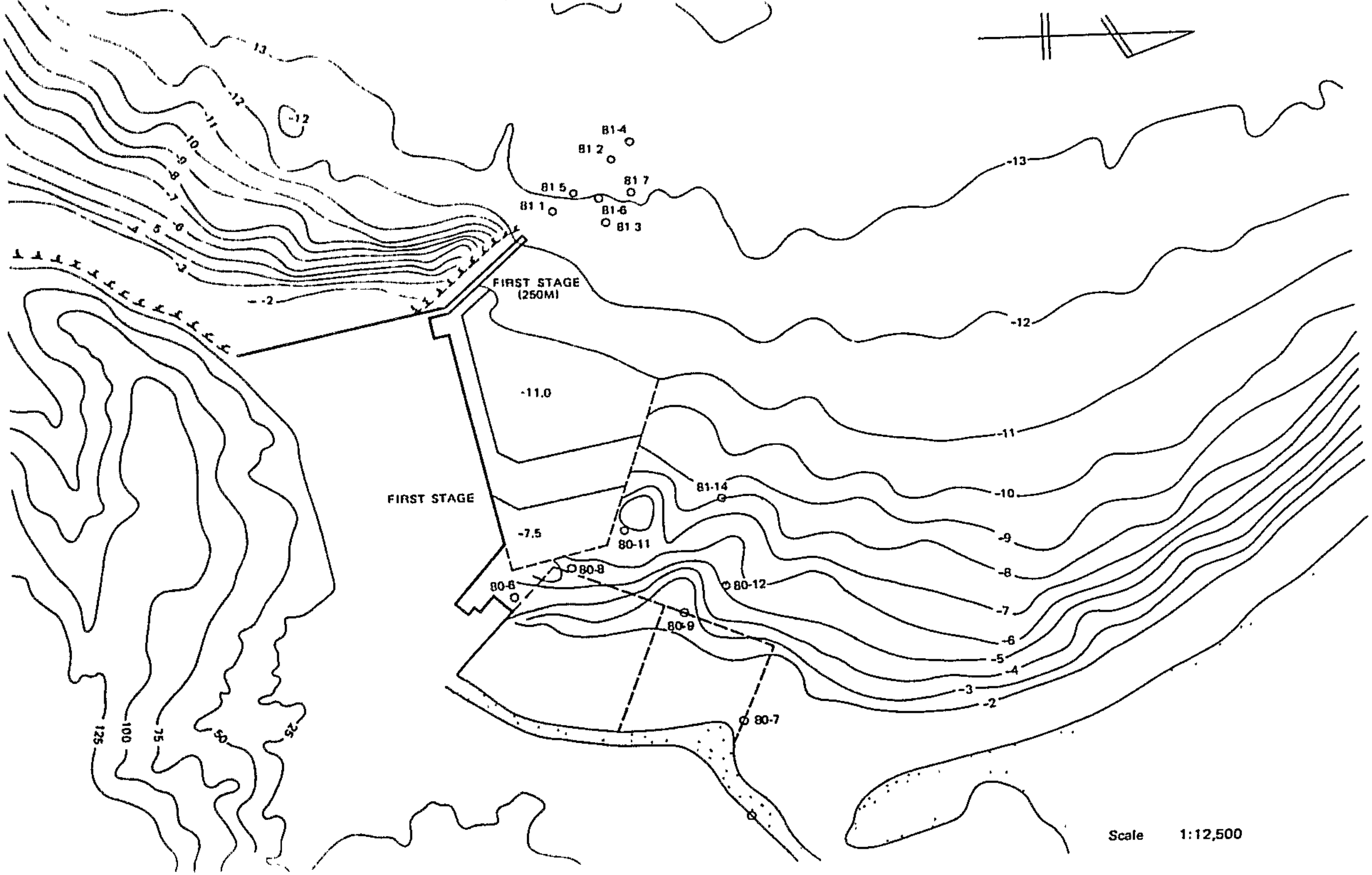
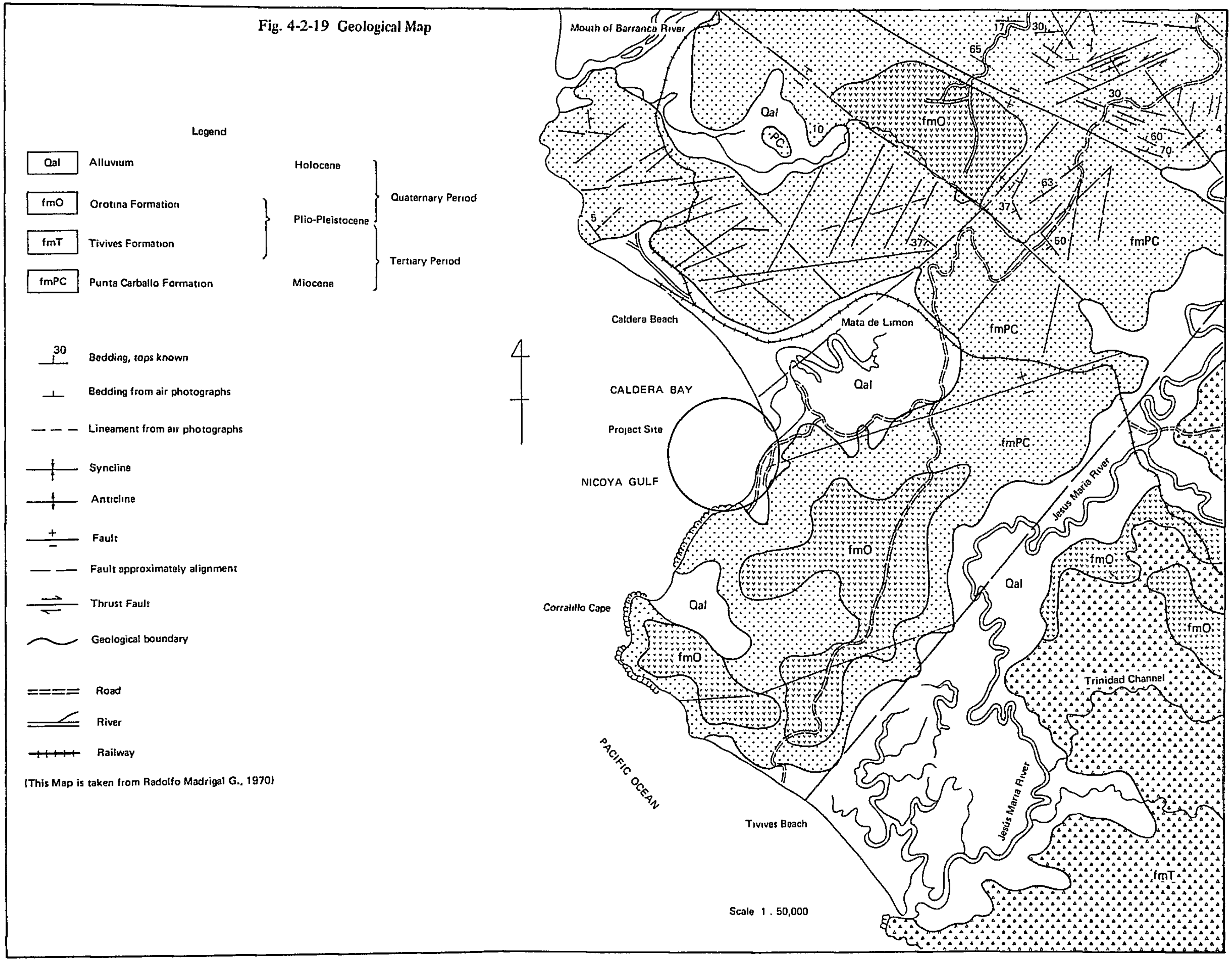


Fig. 4-2-19 Geological Map



(2) Soil Conditions at the Wharf Site

The location of bore holes is shown in Fig. 4-2-20. The drilling logs of each hole are shown in Figs. 4-2-21(1) to 4-2-21(7)

① Soil Stratigraphy

The soil stratigraphy at the wharf area is presented in Figs. 4-2-22(1) to 4-2-22(3). Four beds, $S_A$, $S_B$, $M_C$ and $S_D$ are distinguished in descending order from the sea bottom. The beds are Quaternary loose deposits and the bedrock is Tertiary Punta Carballo Formation in.

a. $S_A$ bed

$S_A$ bed about 2 meters in thickness, consists of black fine to very fine sand with colored minerals and fine shell fragments.

b. $S_B$ bed

$S_B$ bed is composed of coarse to fine sand. Some shell fragments and fine gravel are found in a scattered patern, and trace silty sand in the lower part of this bed at the point of 80-12. The thickness is from 10 to 20 meters and thins to the west and to the offing. N value is 25 to 40, therefore the relative density is almost dense, and in some upper parts and silty parts N value is about 10.

c. $M_C$ bed

$M_C$ bed consists of almost homogeneous stiff silt with some shell fragments locally. The bed becomes thinner, 2 to 8 meters and coarser grained toward the shore, thicker, 10 to 16 meters and finer grained toward the offing.

d. $S_D$ bed

$S_D$ bed is restricted to the points of 80-6, 80-8, 80-11 and 81-14 in the west of the area, and consists of silt with some sands, gravels, and shell fragments. The bed faces vary at different points and the thickness changes from 2 to 10 meters. Therefore N value varies between 12 and 50.

② Soil Property

The soil properties of each bore hole were obtained by laboratory soil test. Their results are illustrated in Figs. 4-2-21(1) to 4-2-21(7).

The soil properties of the above-mentioned beds are as follows.

a. $S_A$ bed

By the grain-size analysis, the sand contains 5 to 20 percent cohesive soil and is classified into SM or SP based upon the Standard Test Method for Classification of Soils for Engineering Purposes (ASTM D248). The specific gravity (Gs) is about 2.8.

b. $S_B$ bed

The soil is coarse to fine sand with cohesive soil of about ten percent and a few gravels in part. Therefore the soil is classified into SM or SP. The specific gravity (Gs) is 2.7 to 2.85.

c. $M_C$ bed

The soil is silt including 5 to 10 percent sand and 15 to 20 percent clay. The liquid limit (Ll) is 50 to 60 percent and the plastic limit (Pl) is 42 to 45 percent. The classification is largely equivalent to MH or CH, and partly to ML or CL. The moisture content (Wn) is 42 to 45 percent and is between the value of Ll and Pl. The total unit weight ($\gamma t$) is 1.68 to 1.84 $g/cm^3$. The void ratio (e) is 1.1 to 1.35.

The shear strength is as follows.

Unconfined compressive strength (qu)
1.2 to 2.6 $kg/cm^2$

Cohesion (C)* 0.7 to 1.0 $kg/cm^2$

Friction angle ($\phi$)* 2 to 5°

*data from triaxial compression test (uu)

The consolidation property is as follows.

Preconsolidation pressure (Py)** 2.0 $kg/cm^2$

Compression index (Cc)** 0.43

**data from the test of only one sample

d. $S_D$ bed

This sand and sand with silt are classified into SM or SC. The specific gravity (Gs) is 2.76 to 2.83.

③ Soil Condition

Fig. 4-2-22(3) shows the geologic profile along the pier head line of this project and the soil condition for the wharf foundation as follows.

a. $S_B$ bed is suitable for the foundation of a wharf, because it consists of compacted coarse to fine sand, the N value is 25 to 40, and the thickness is more than 10 meters. From the N value the friction angle is calculated at about 40 degrees.

b. $S_A$ bed, composed of loose fine sand with an N value of about 10, extends from the sea bottom to approx four meters in thickness.

c $M_C$ bed consisting of homogeneous stiff silt, is 2 to 15 meters in thickness and thickens to the east. The elevation of it's surface is −20 to −22 m.

The shear strength of triaxial compression test (uu) is

Cohesion (C) 0.7 to 1.0 $kg/cm^2$

Friction angle ($\phi$) 2 to 5°

d. The bedrock, Punta Carballo Formation which is made up of Tertiary sedimantary rocks, has biggest bearing capacity in this area.

The shape of the bedrock surface is shown in Fig. 4-2-23.

Fig. 4-2-20 Location Map of Bore Holes at Wharf Site

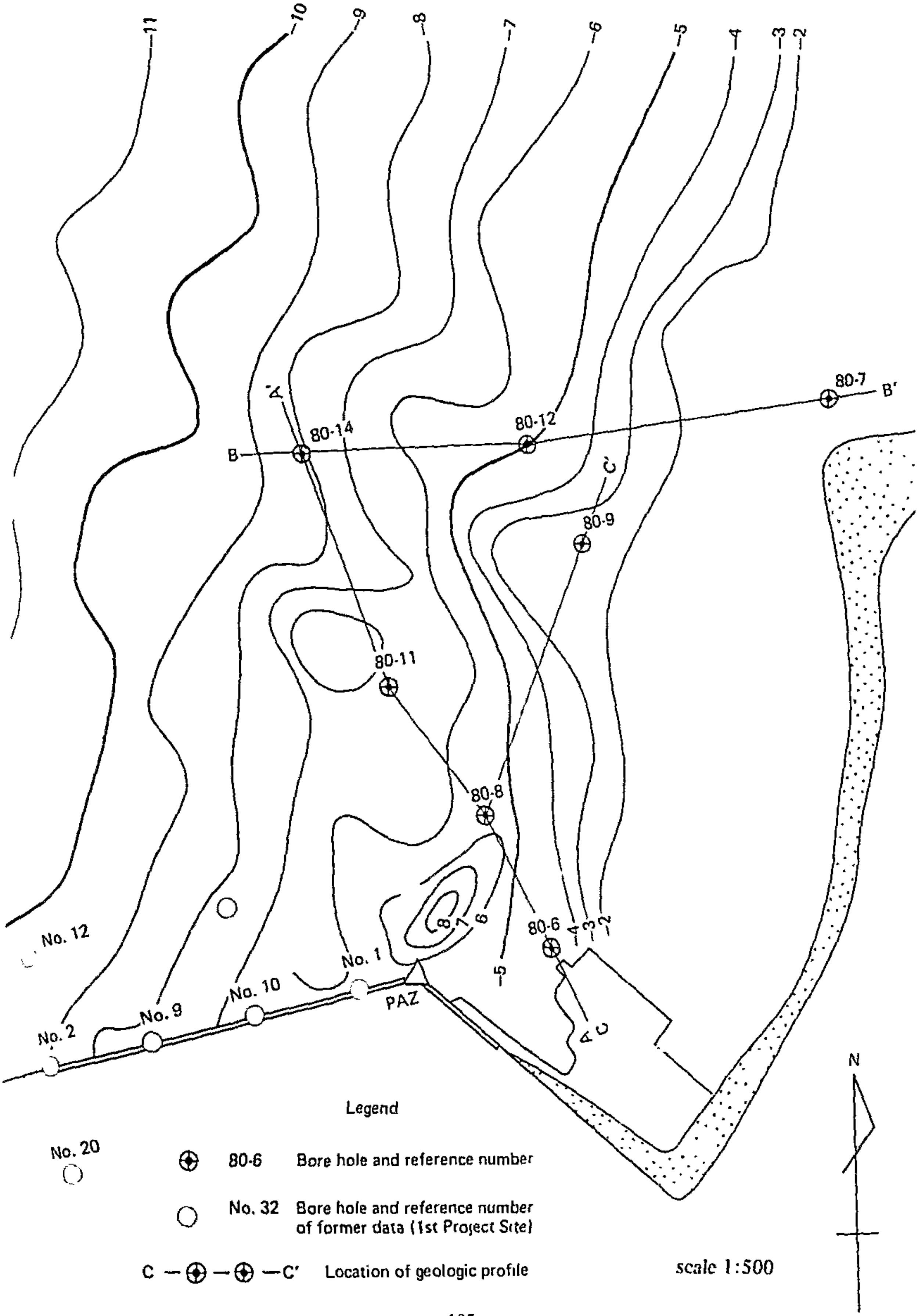
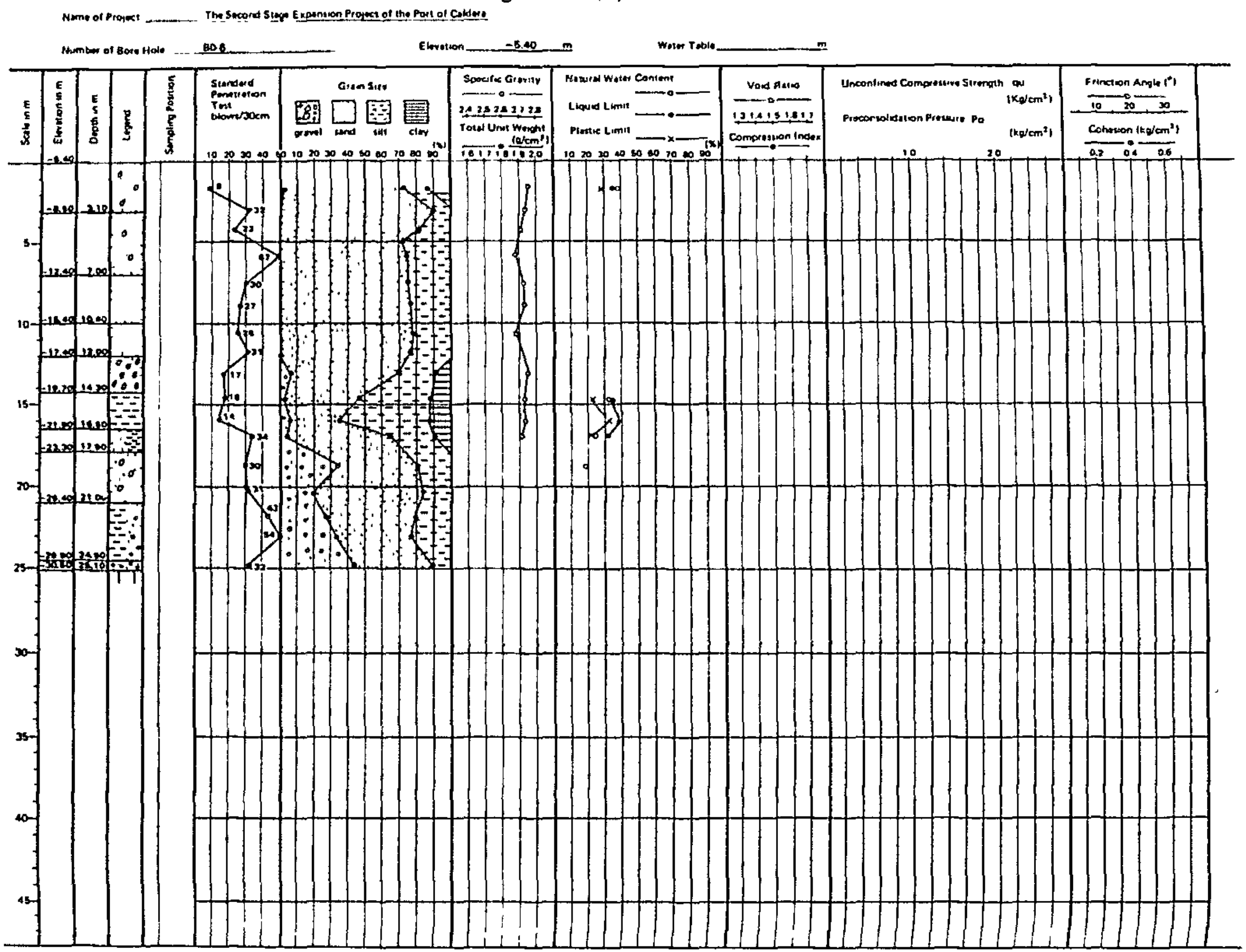
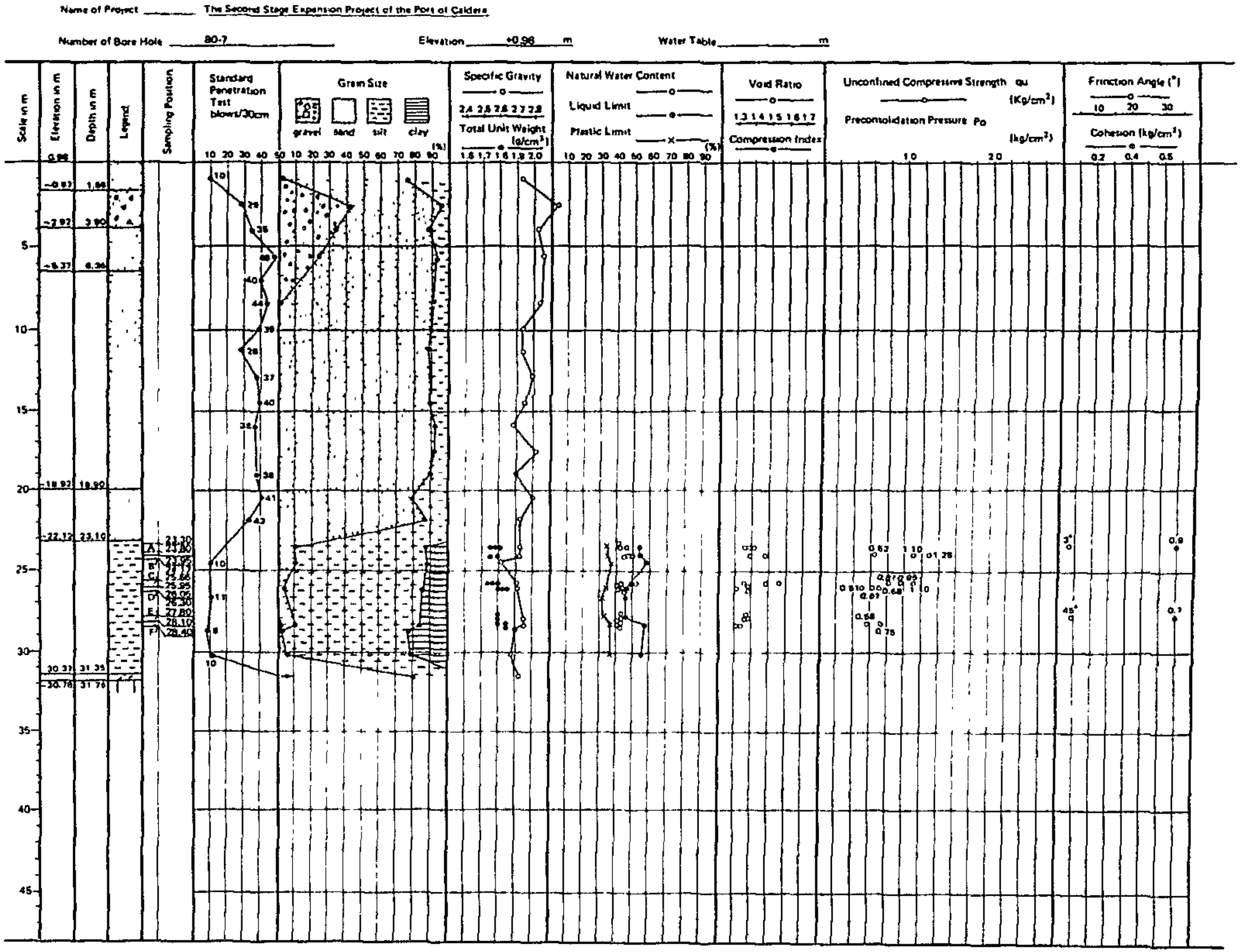


Fig. 4-2-21 (1) Soil Profile



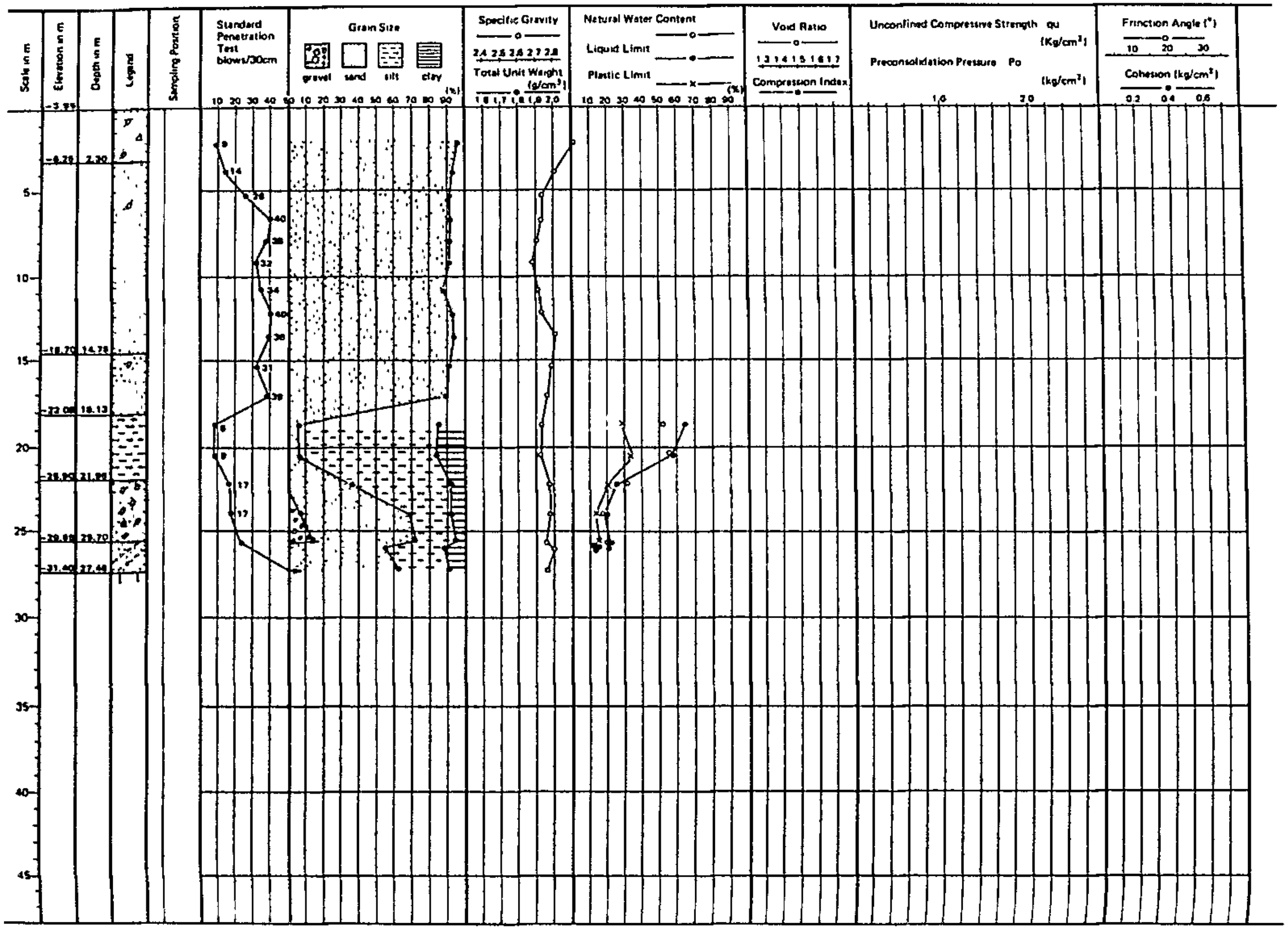
# Fig. 4-2-21 (2) Soil Profile



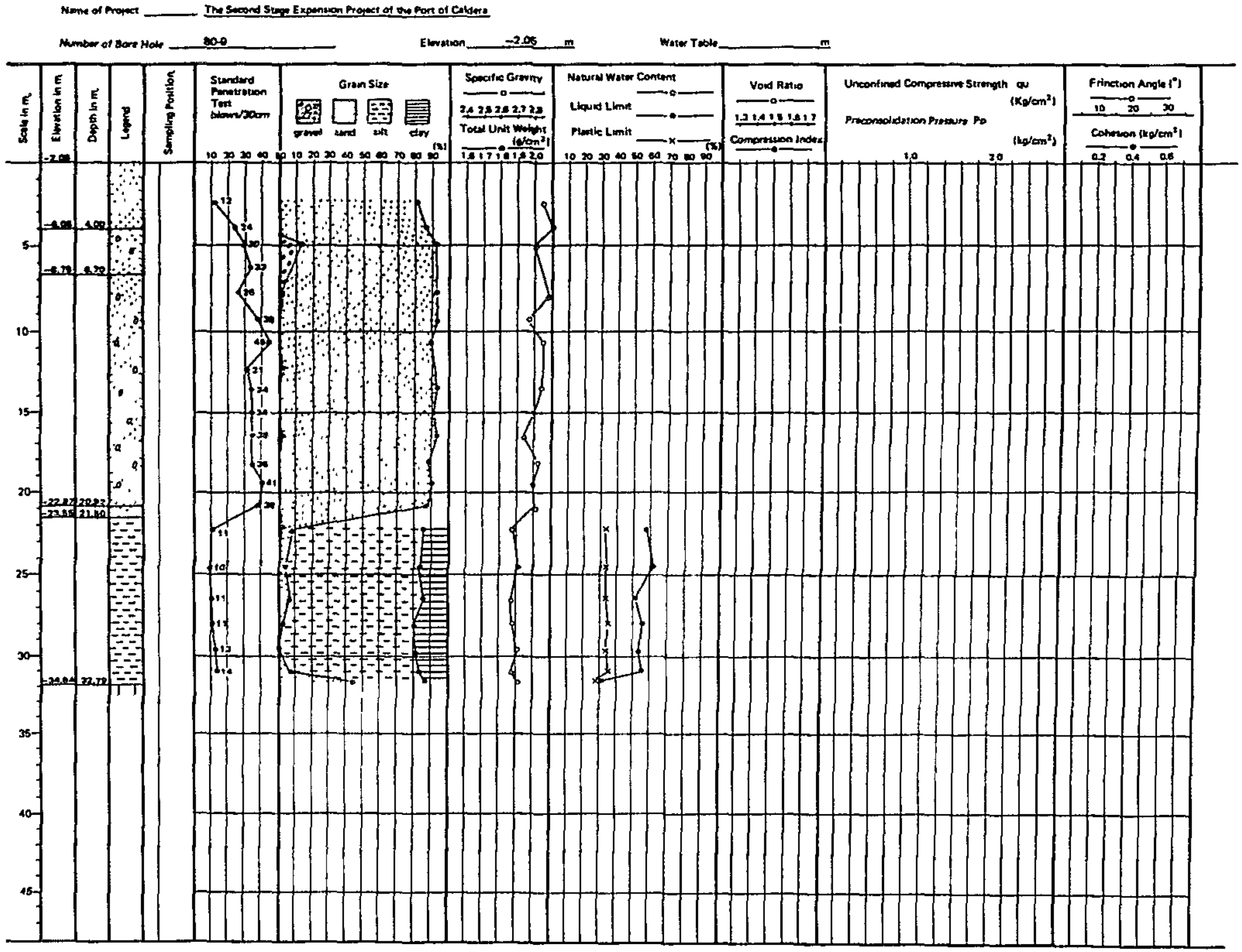
# Fig. 4-2-21 (3) Soil Profile

Name of Project: The Second Stage Expansion Project of the Port of Caldera

Number of Bore Hole: 80-8    Elevation: -3.95 m    Water Table: ____ m



## Fig. 4-2-21 (4) Soil Profile



## Fig. 4-2-21 (5) Soil Profile

Name of Project: The Second Stage Expansion Project of the Port of Caldera

Number of Bore Hole: 80-11 Elevation: -6.95 m Water Table: ____ m

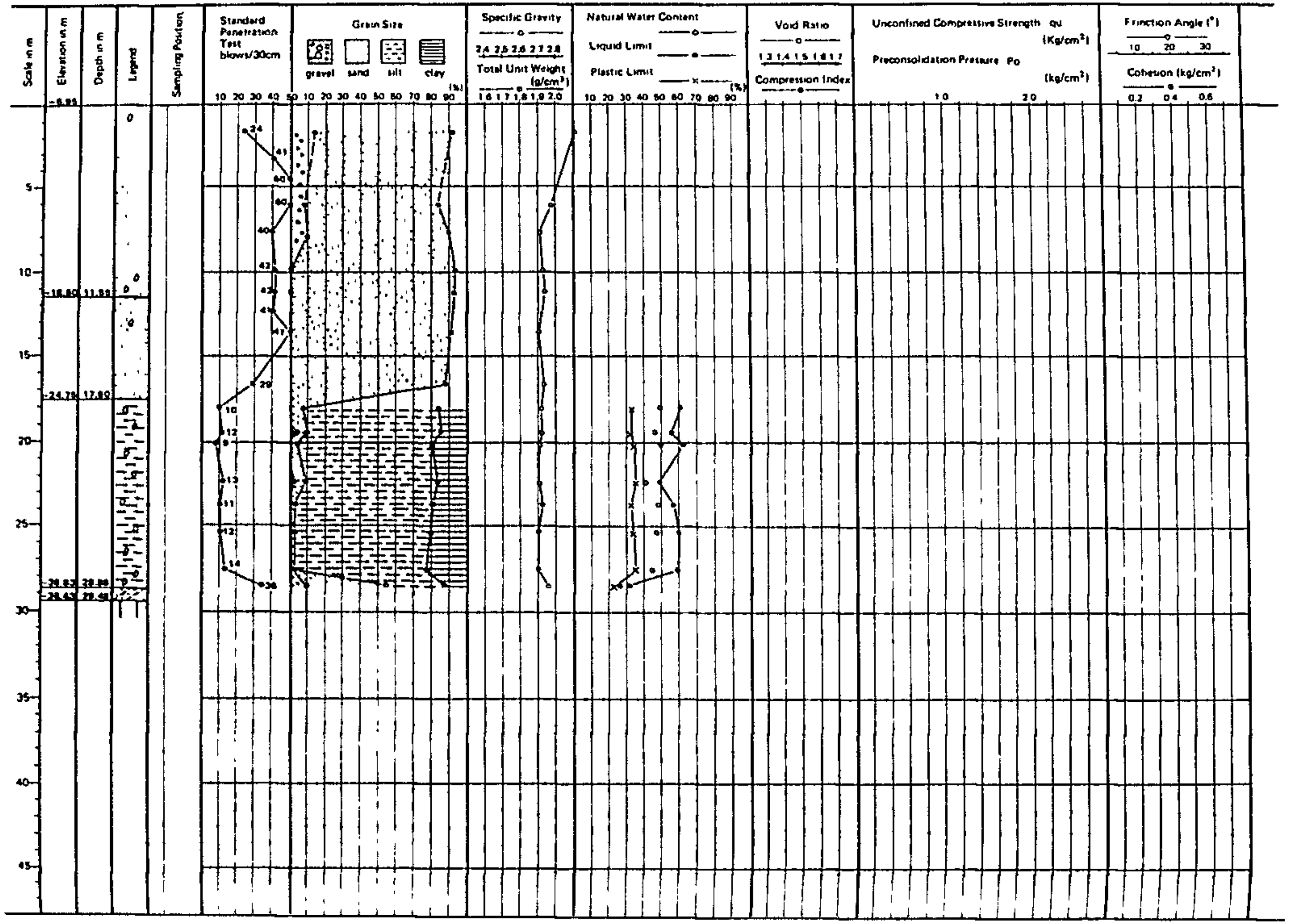
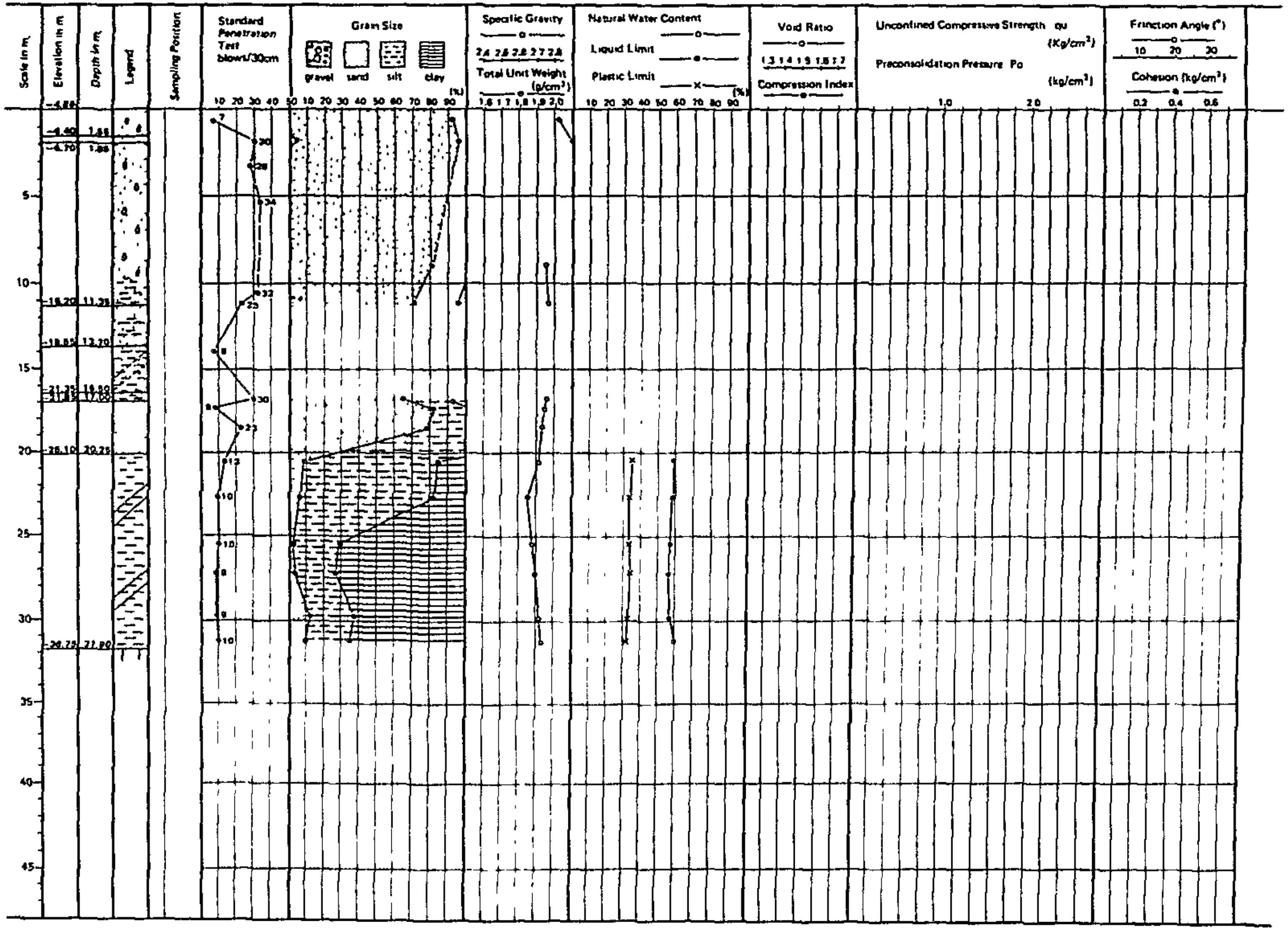


Fig. 4-2-21 (6) Soil Profile

Name of Project: The Second Stage Expansion Project of the Port of Caldera

Number of Bore Hole: 80-12    Elevation: -4.85 m    Water Table: ____ m



# Fig. 4-2-21 (7) Soil Profile

Name of Project: The Second Stage Expansion Project of the Port of Caldera

Number of Bore Hole: 81 14    Elevation: -7.90 m    Water Table: m

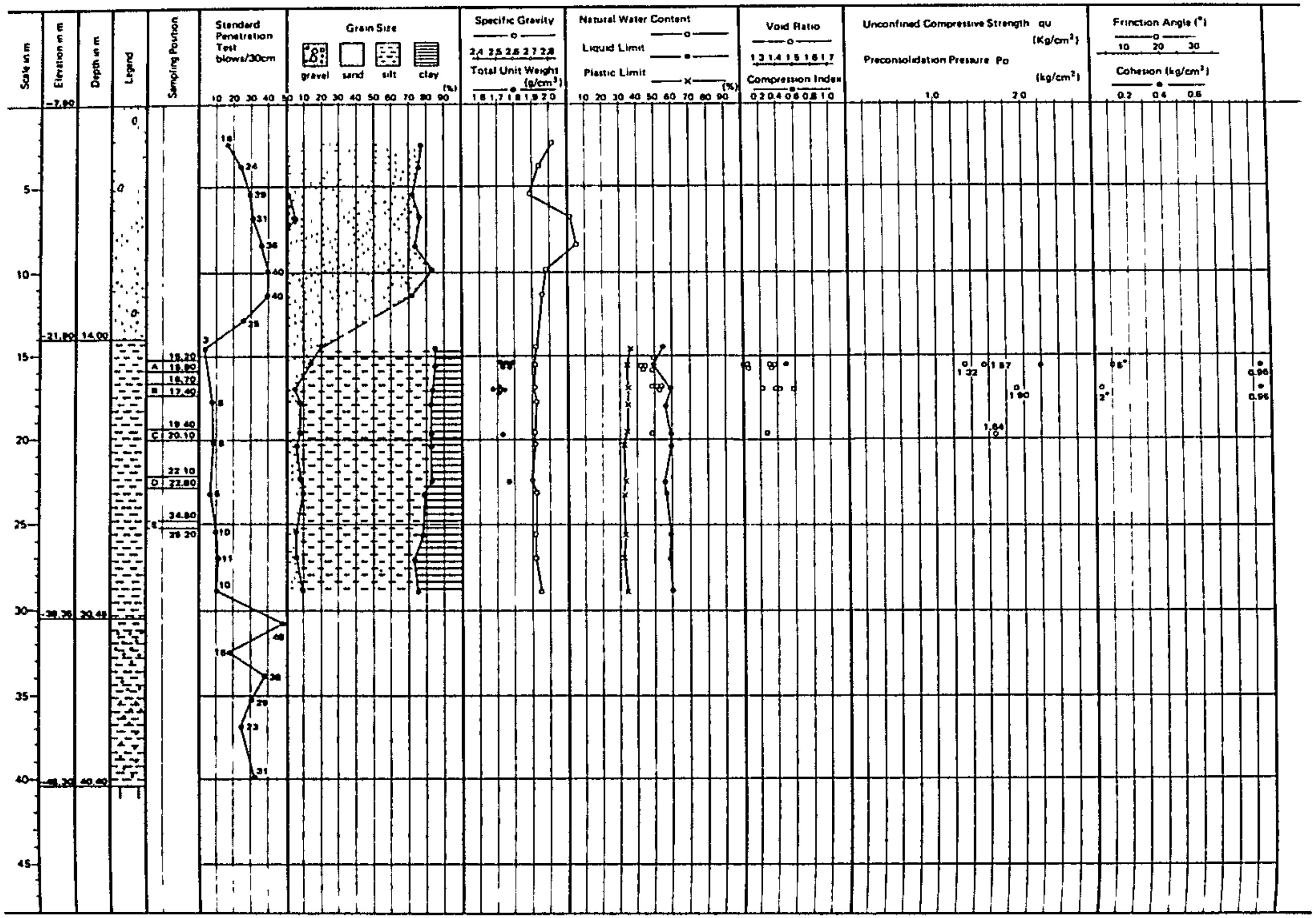


Fig. 4-2-22 (1) Geologic Profile at Wharf Site (A-A' Section)

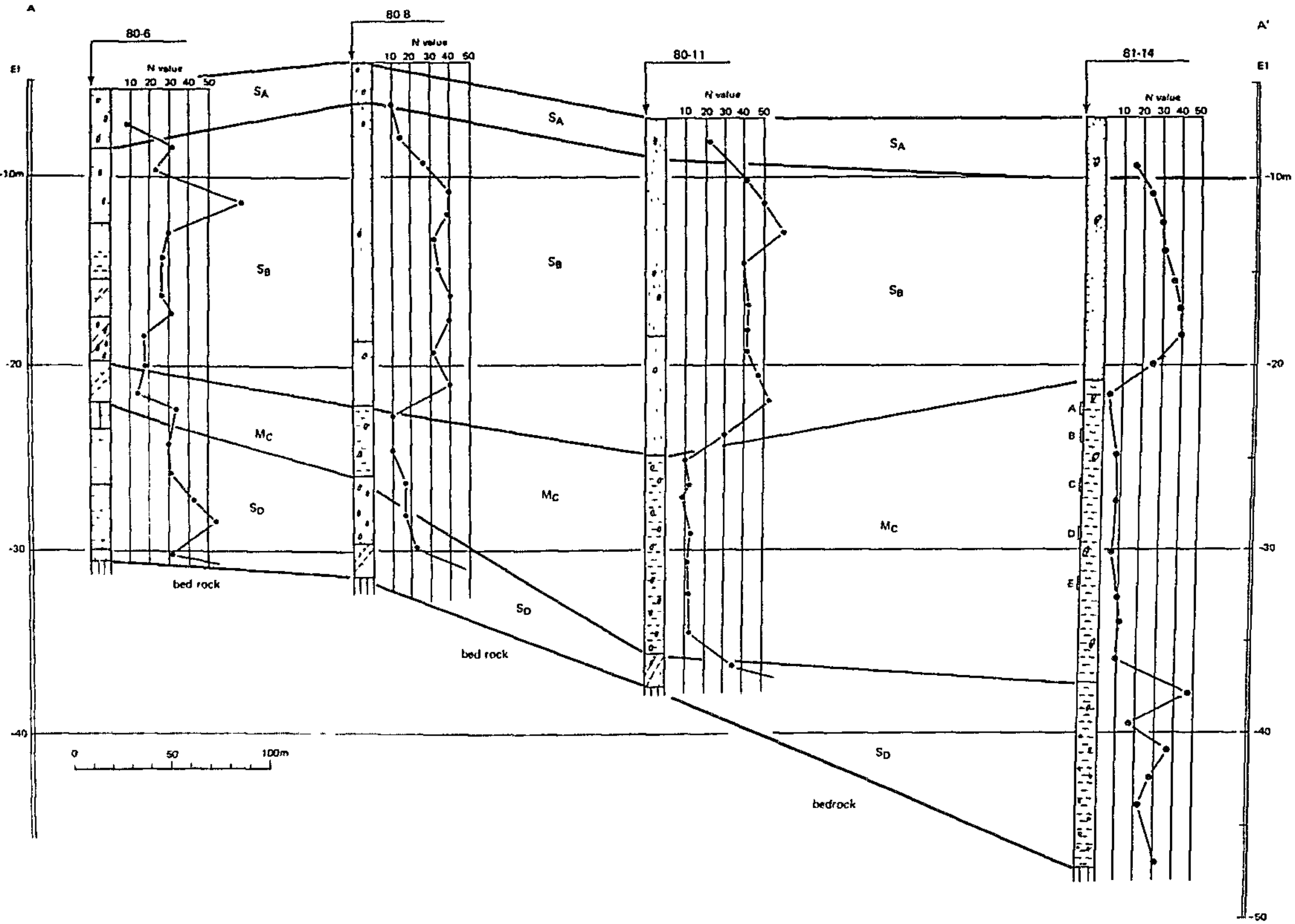


Fig. 4-2-22 (2) Geologic Profile at Wharf Site (B-B' Section)

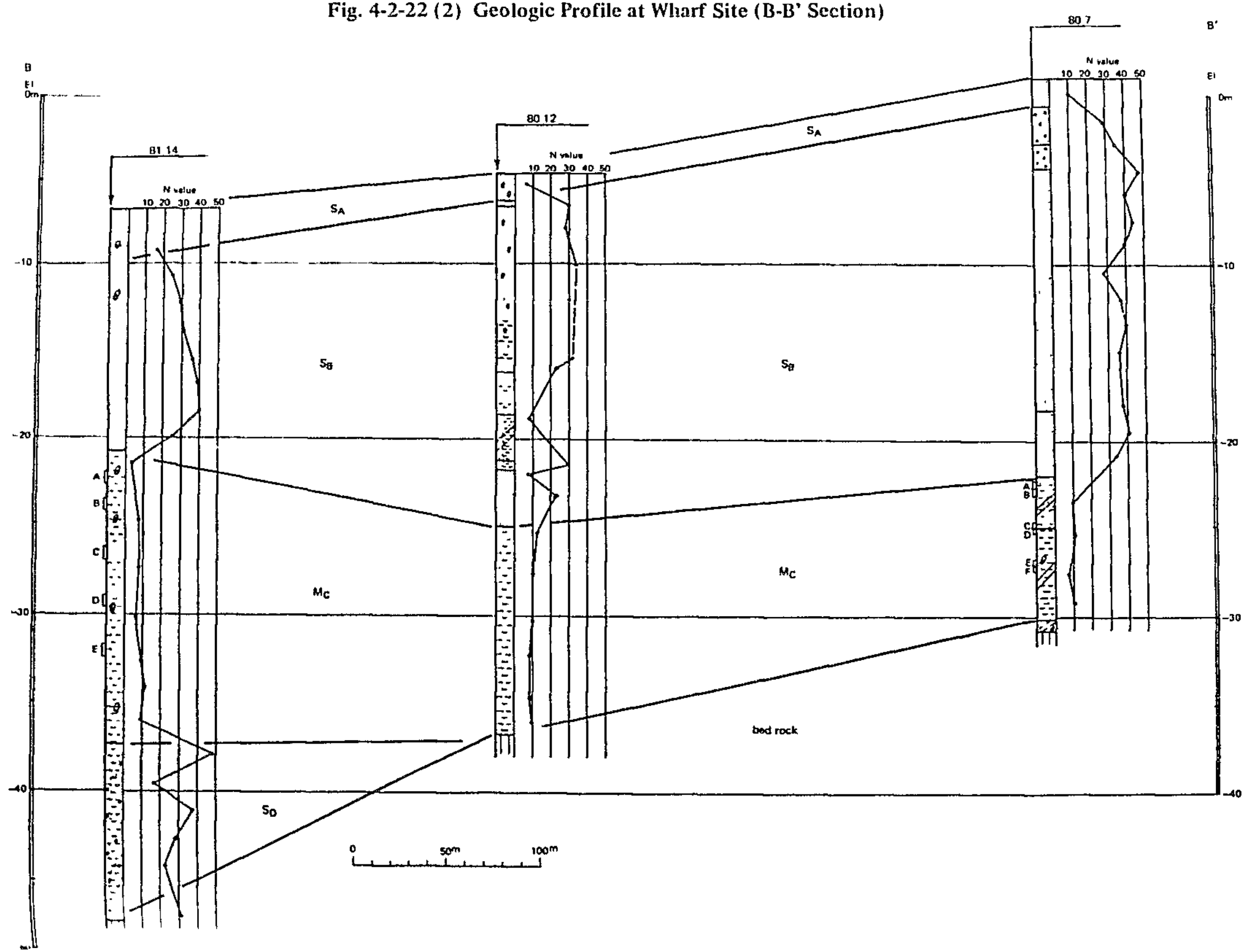


Fig. 4-2-22 (3) Geologic Profile at Wharf Site (C-C' Section)

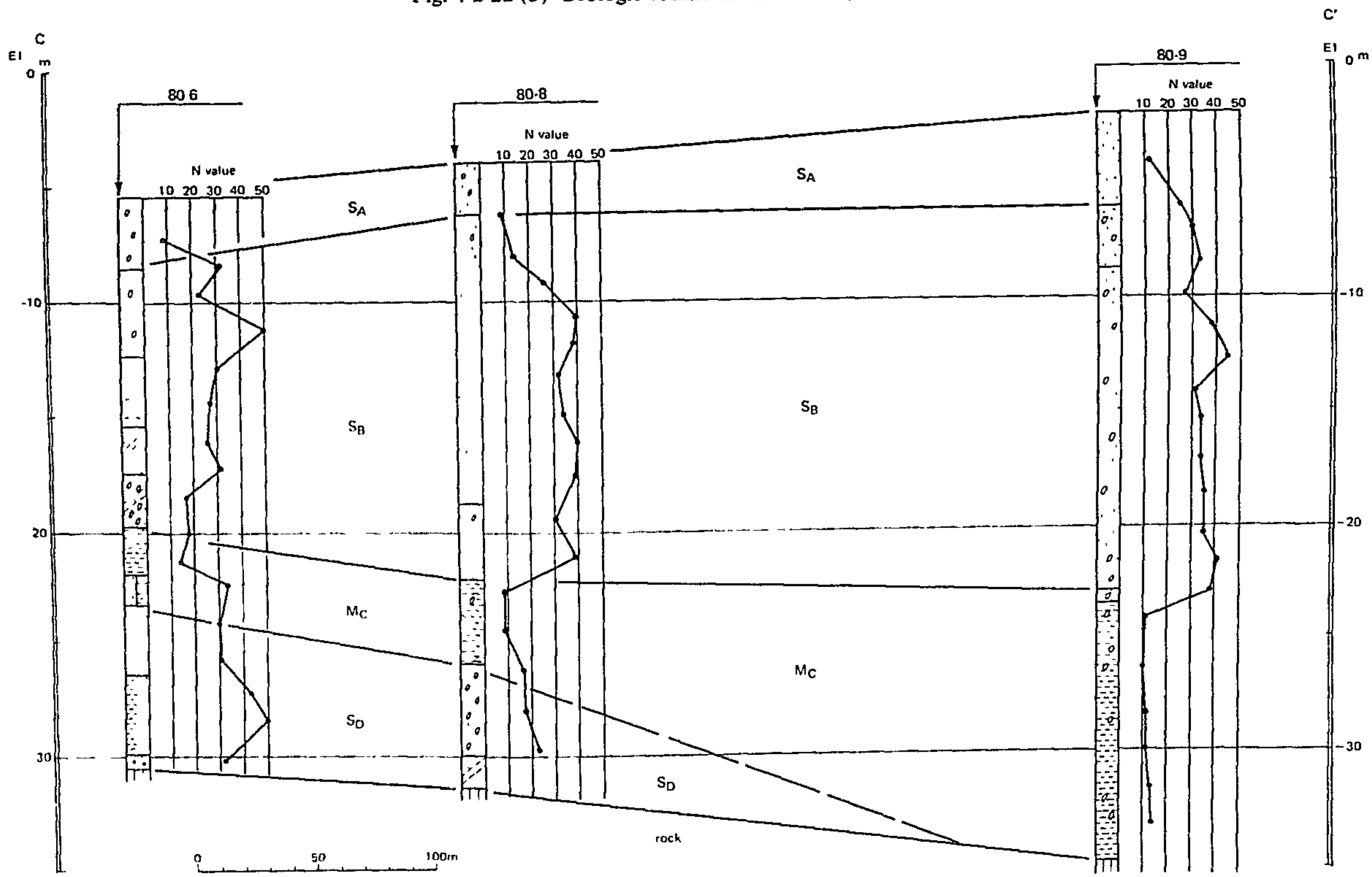
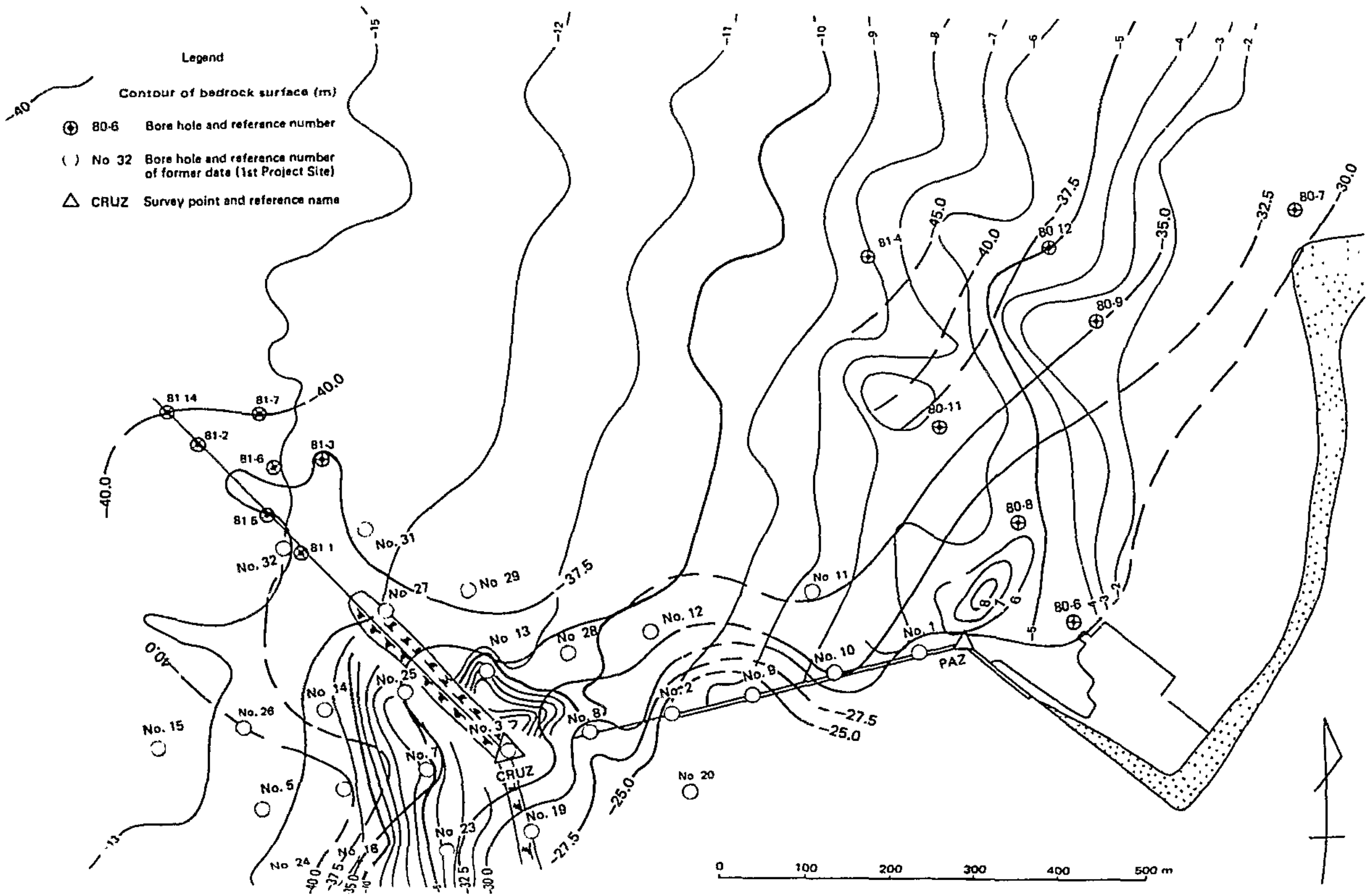


Fig. 4-2-23 Contour Map of Bedrock Surface



(3) Soil Condition at the Breakwater Site

Fig. 4-2-24 shows the location of the bore holes at the breakwater site. The water depth of the extension breakwater site of the project is about 12 meters.

The drilling logs of the site are shown in Figs. 4-2-25(1) to 4-2-25(7).

① Soil Stratigraphy

The geologic profiles are shown in Figs. 4-2-26(1) and 4-2-26(2). The sub-surface sediments, composed of the Quaternary soft and loose deposits can be divided into 3 layers, namely sa, mb, and mc in ascending order.

a. sa bed

sa bed consists of black fine to very fine sand with little fine shell fragments. Some silty sand are included and thin sand layers are intercalated in the lower part. The bed is 7 to 10 meters in thickness and the N value is 10 to 20, and in some parts where it is very loose or silty, N value is below 10.

b. mb bed

mb bed consists of very soft sandy silt mainly and silt with sand partly. Sand layers are intercalated at the point 81-7. The bed is 2.5 to 7 meters in thickness, and the N value is 1 to 4 except sandy parts.

The plasticity is medium and the moisture content is medium to high.

c. mc bed

mc bed is composed of homogeneous silt with little shell fragments. Plasticity and moisture content of the silt are high. Thin gravel layers with silt are found in the lowest part at the points of 81-2 and 81-4.

The above mentioned beds are inferred to be Alluvium and the underlying bedrock is Tertiary Punta Carballo Formation.

② Soil Property

Figs. 4-2-25(1) to 4-2-25(7) show the soil properties of each bore hole and the general properties of the above-mentioned beds as follows.

a. sa bed

By the grain-sized classification, this is fine sand with 5 to 40 percent cohesive soil. The soil is classified into SM.

The specific gravity (Gs) is 2.7 to 2.8.

b. mb bed

Sandy silt and silt with sand, that contain 20 to 40 percent sand and about 20 percent clay. The liquid limit (Ll) is 40 to 55 percent and the plastic limit (Pl) is 30 to 35 percent. Therefore this is classified as ML, CH, or MH. The moisture content (Wn) is 45 to 55 percent and near the value of Pl. The specific gravity (Gs) is 2.65 to 2.85 and mean value is about 2.7.

The total density ($\gamma t$) is 1.7 to 1.75 g/cm$^3$. The void ratio (e) is 1.35 to 1.45. Fig. 4-2-27 shows the relations of $\gamma t$ and e to Wn, and $\gamma t$ and e varies markedly in each specimen.

Unconfined compressive strength (qu)
0.44 to 0.68 kg/cm²

Cohesion (C)* 0.43 to 0.55 kg/cm²

Friction angle*($\phi$) 0 to 3°

*data from triaxial compression tests (uu)

c. mc bed

The soil is silt including 10 to 30 percent clay and 2 to 15 percent sand. And the upper part is sandy, the lower silty. The liquid limit (L1) is 52 to 62 percent and the plastic limit (P1) is 30 to 35 percent. The soil is generally equivalent to MH by classification of soil.

The moisture content (Wn) is 45 to 60 percent and near the value of L1. The specific density (Gs) is 2.65 to 2.75, the total density ($\gamma t$) is 1.65 to 1.75 g/cm³ and the void ratio (e) is 1.3 to 1.6.

Fig. 4-2-27 also shows the relations of $\gamma t$ and e to Wn of the mc bed and these values shows some variation.

The shear strength which is dotted in Fig. 4-2-28 and 4-2-29 is shown as follows:

unconfined compressive strength (qu) 0.5 to 1.7 kg/cm²

Cohesion (C)* 0.2 to 0.7 kg/cm²

Friction angle ($\phi$)* 0 to 5°

*data from triaxial compression test (uu)

The consolidation property is as follows:

Preconsolidation (Py)** 1.3 to 1.75 kg/cm²

Compression index (Cc)** 0.45 to 0.47

**data from the tests of 3 samples

③ Soil Condition

From the above-mentioned data, the soil conditions of the breakwater site are as follows.

a. sa bed is fine sand including some silty sand and a thin silt layer in the lower part. N value is in the range of 2 to 30 and generally 10 to 20. Therefore the friction angle of this sand bed will be about 30 degree. The bed is only 7 to 10 meters in thickness.

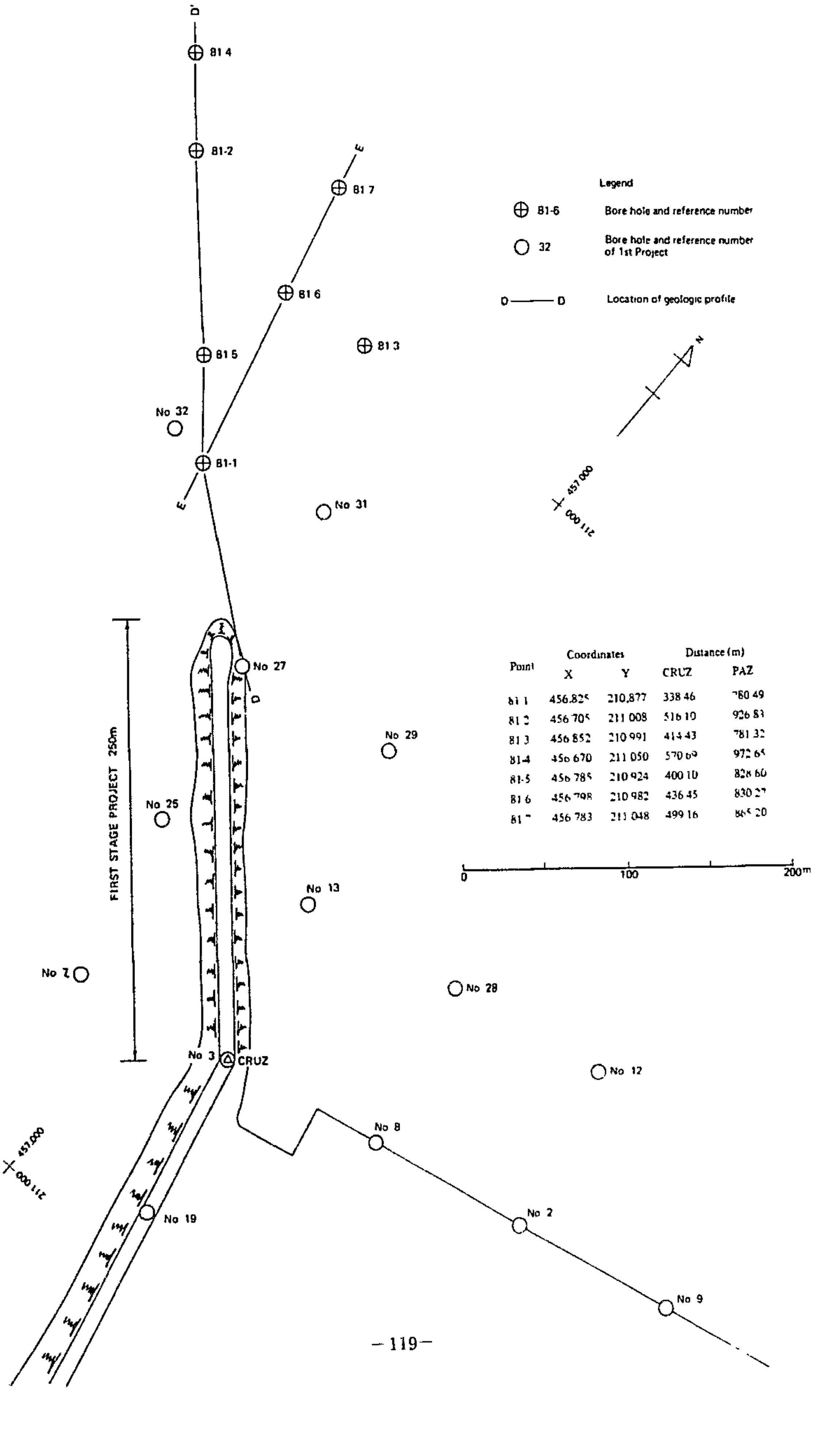
b. The cohesive soil of mb and mc beds consists mainly of soft silt and the N value is 1 to 9. The bed is 16.3 to 21.5 meters in thickness. Fig. 4-2-29 shows the profile of the total unit weight and the cohesion obtained from triaxial compression test (uu).

c. The boundary between the sand bed and the cohesive soil bed is estimated to be El. −20 meters depending on grain size analysis.

According to the Fig. 4-2-29, the following soil properties are inferred on the inshore side of 81-1, 81-5, 81-3 and 81-6 points in the breakwater site.

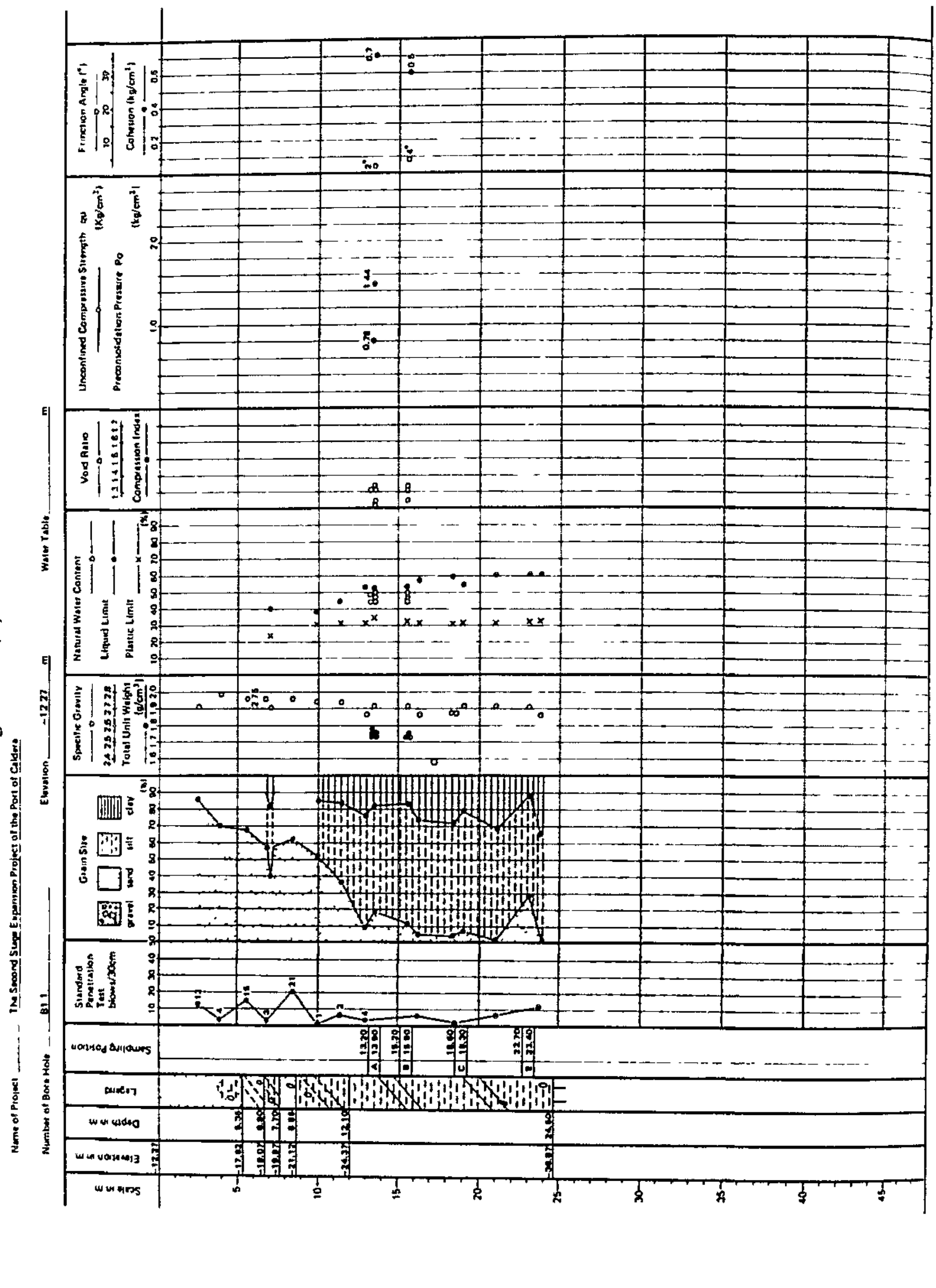
| Elevation Z | Soil | Total unit weight ($\gamma t$) (t/m³) | Choesion C (t/m²) | Friction angle $\phi$ (degree) |
|---|---|---|---|---|
| | sand | 2.0 | 0 | 30 |
| -20m | silt | 1.7 | $C = 0.3Z + 4.0$ ($Zo = -20m$) | 0 |

## Fig. 4-2-24 Location Map of Bore Holes at Breakwater Site




| Point | Coordinates X | Coordinates Y | Distance (m) CRUZ | Distance (m) PAZ |
|---|---|---|---|---|
| 81 1 | 456.825 | 210,877 | 338 46 | 780 49 |
| 81 2 | 456 705 | 211 008 | 516 10 | 926 83 |
| 81 3 | 456 852 | 210 991 | 414 43 | 781 32 |
| 81-4 | 456 670 | 211 050 | 570 69 | 972 65 |
| 81-5 | 456 785 | 210 924 | 400 10 | 828 60 |
| 81 6 | 456 798 | 210 982 | 436 45 | 830 27 |
| 81 7 | 456 783 | 211 048 | 499 16 | 865 20 |

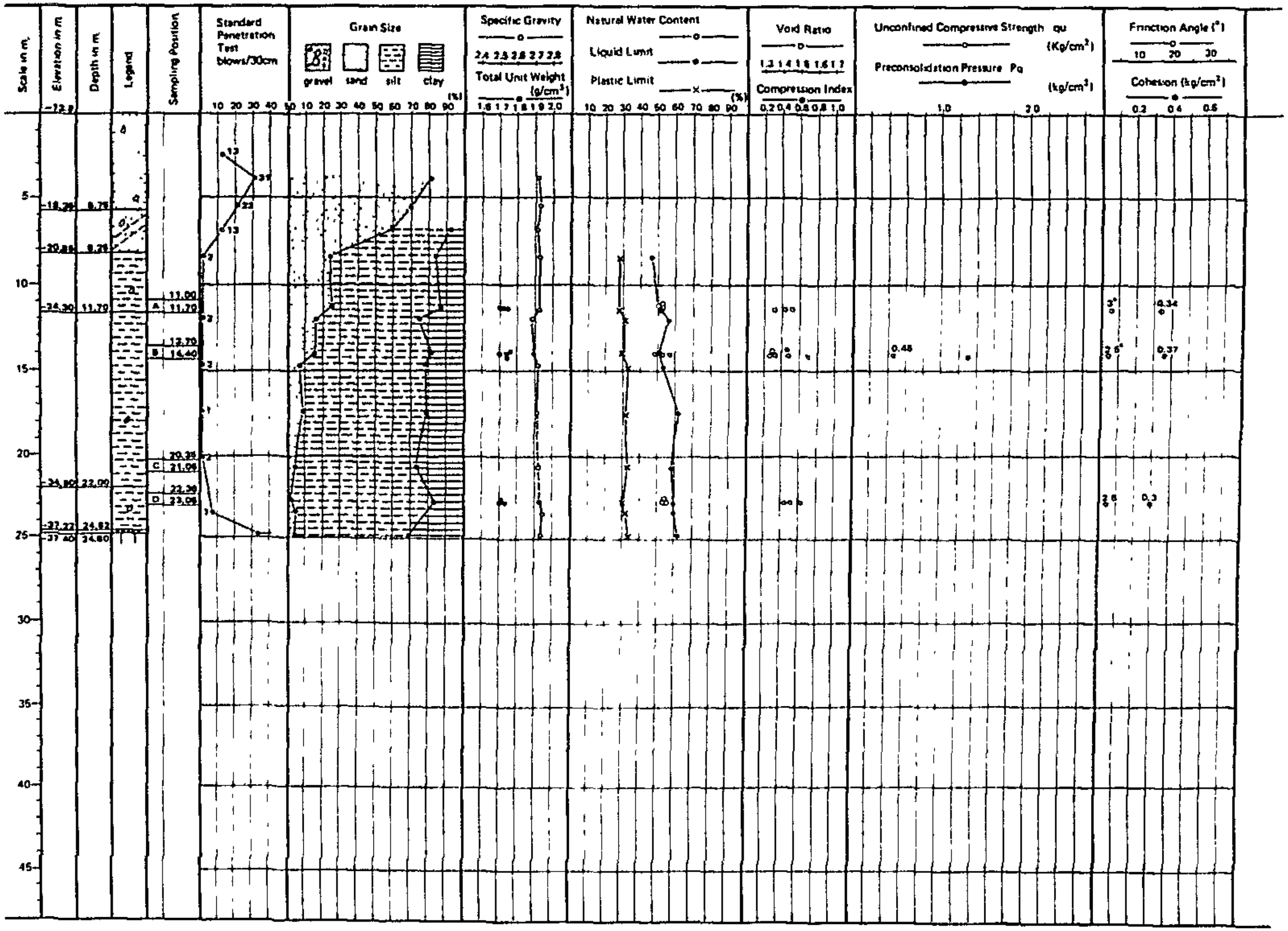
Fig. 4-2-25 (1) Soil Profile



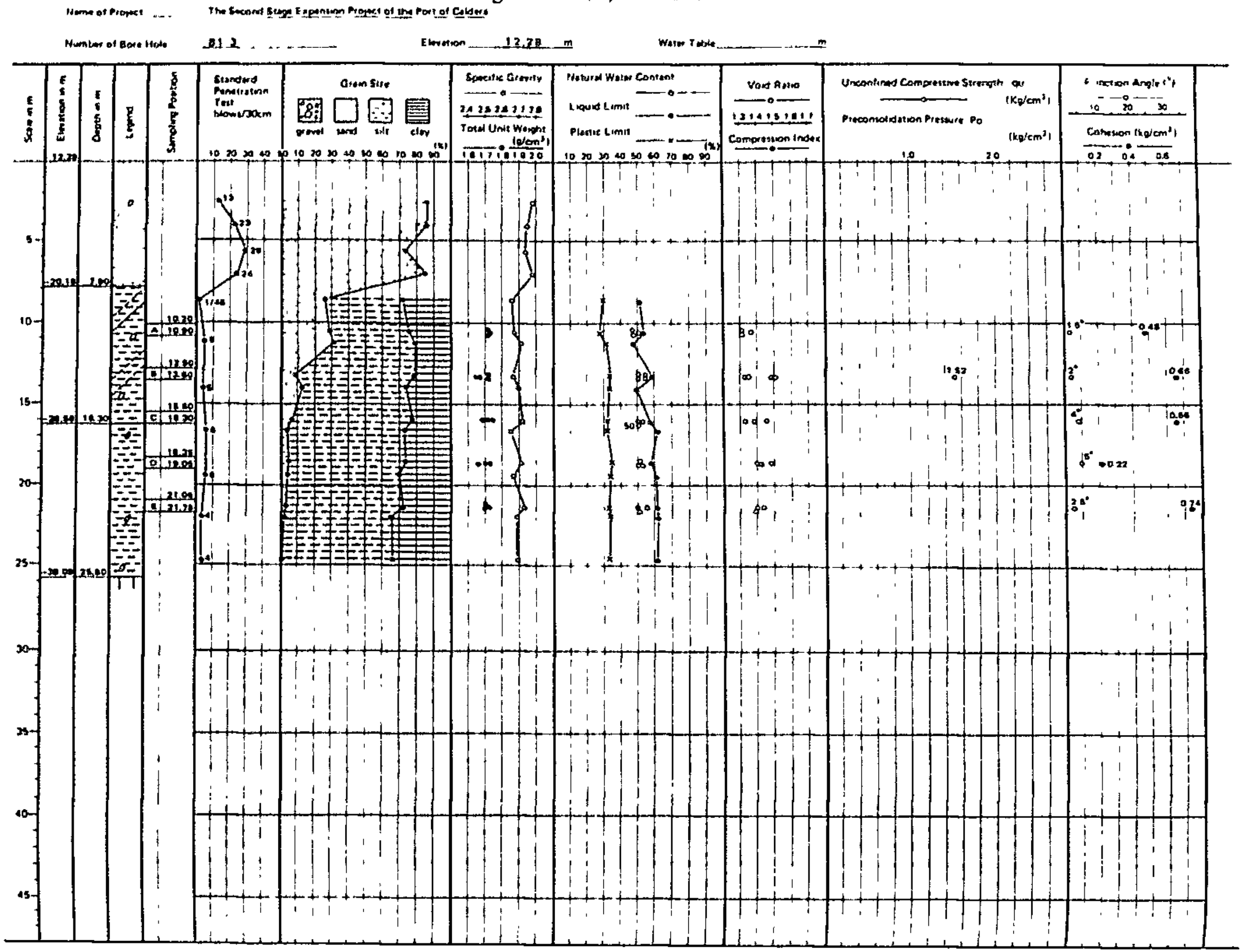
# Fig. 4-2-25 (2) Soil Profile

Name of Project ______ The Second Stage Expansion Project of the Port of Caldera

Number of Bore Hole ______ B1-2 ______ Elevation ______ -12.6 ______ m ______ Water Table ______ m



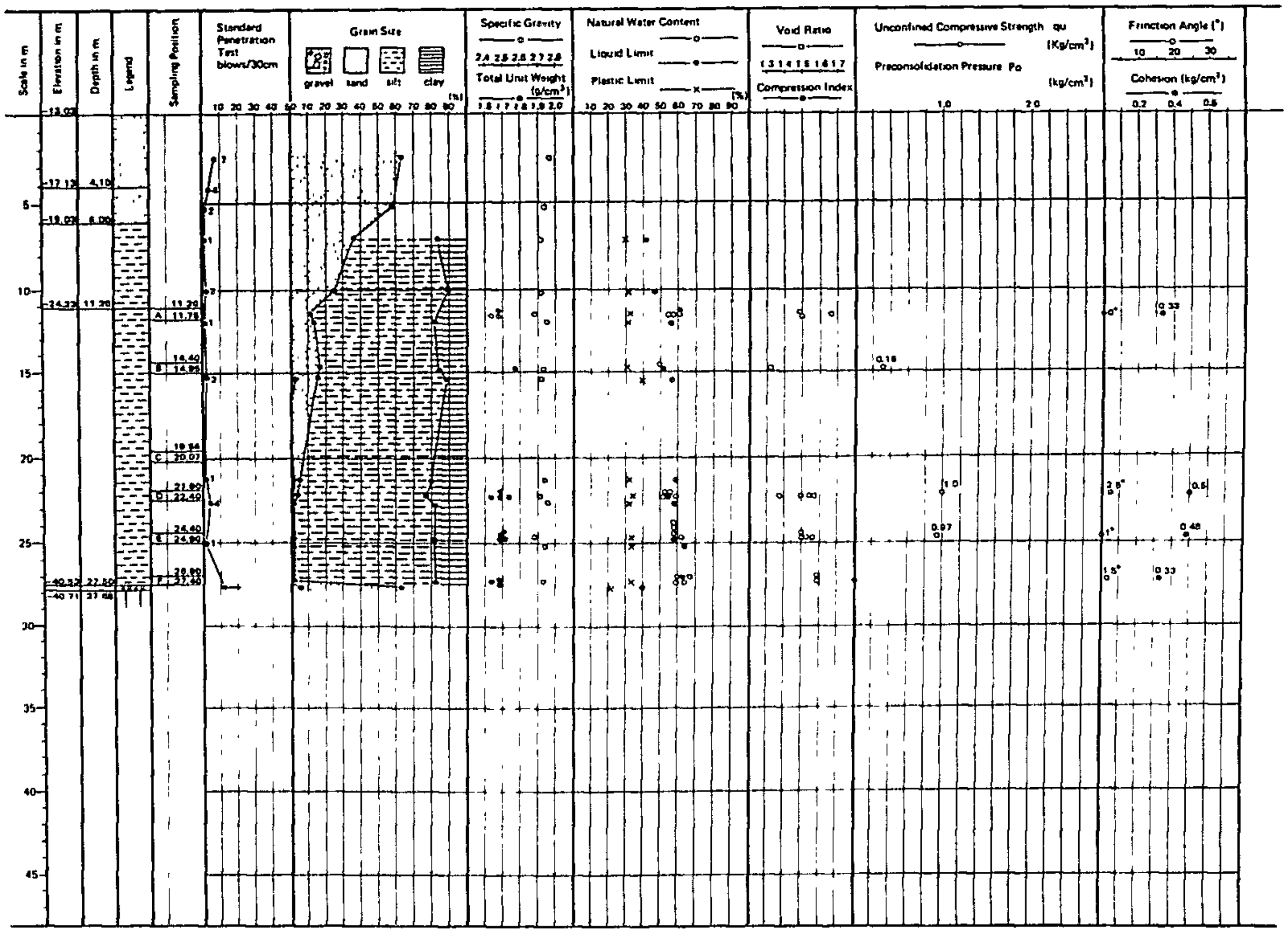
# Fig. 4-2-25 (3) Soil Profile



# Fig. 4-2-25 (4) Soil Profile

Name of Project ______ The Second Stage Expansion Project of the Port of Caldera

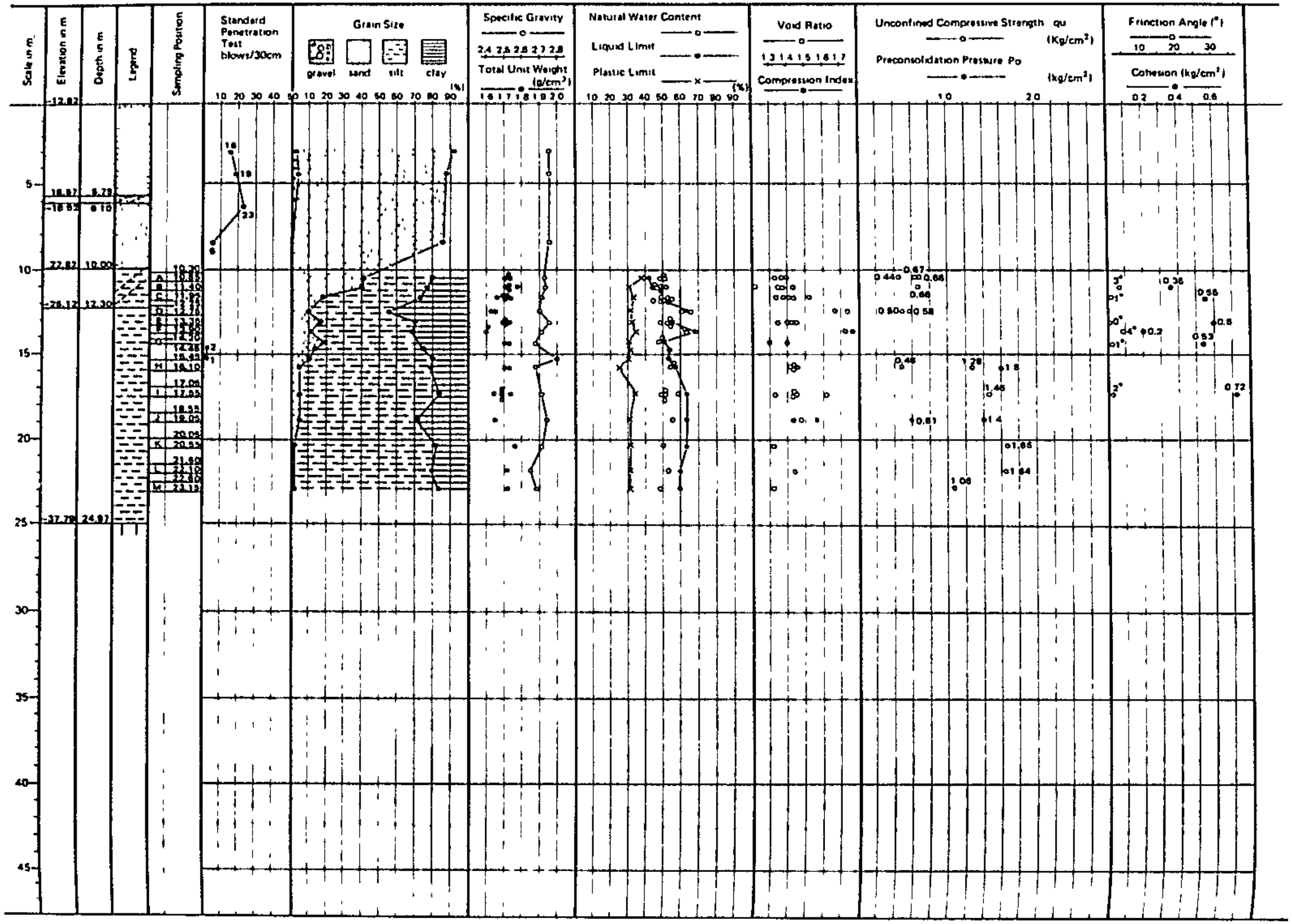
Number of Bore Hole ___81-4___ Elevation ___-13.03___ m Water Table ________ m



# Fig. 4-2-25 (5) Soil Profile

Name of Project The Second Stage Expansion Project of the Port of Caldera

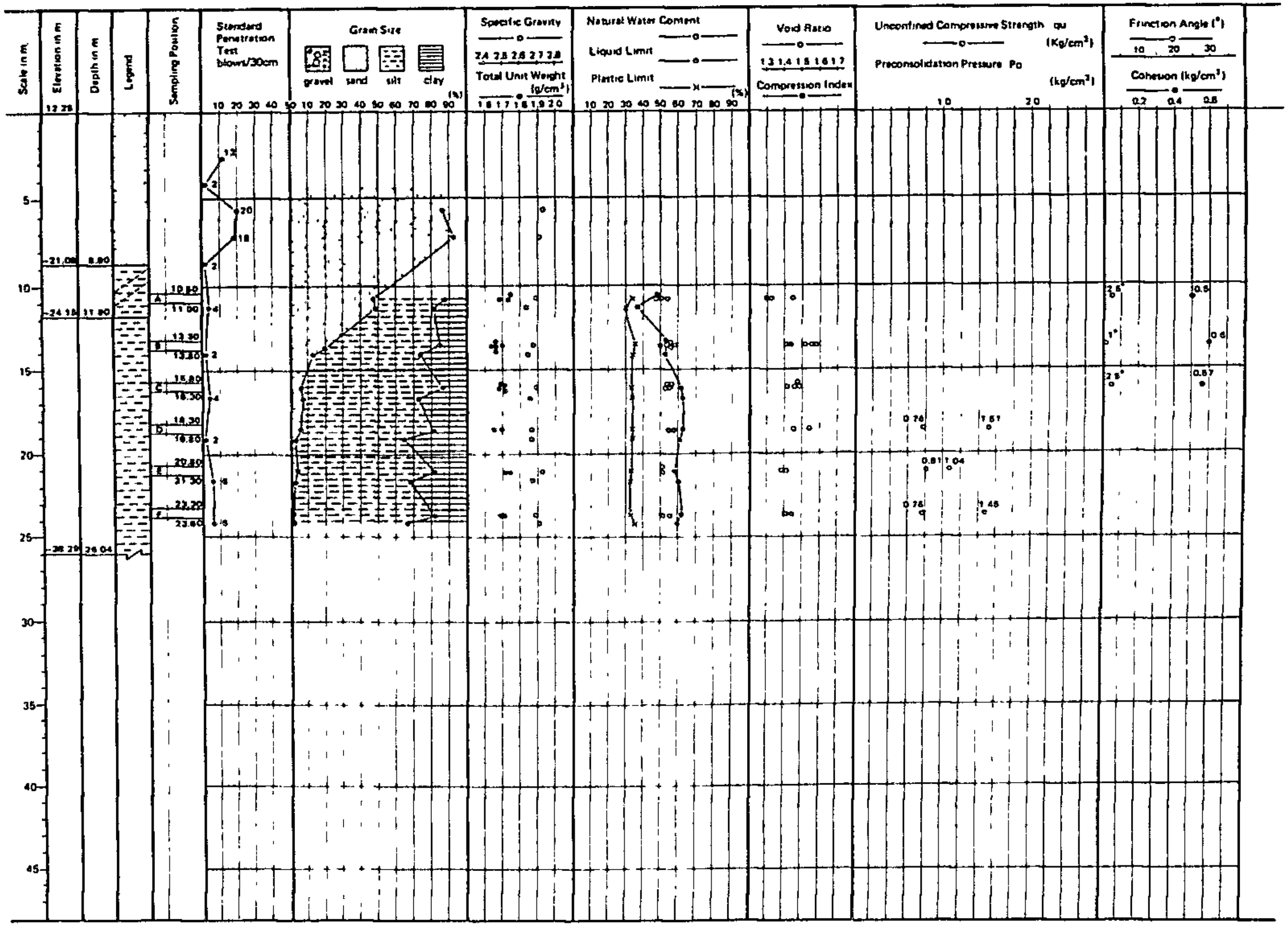
Number of Bore Hole 81-5 Elevation -12.82 m Water Table m



# Fig. 4-2-25 (6) Soil Profile

Name of Project: The Second Stage Expansion Project of the Port of Caldera

Number of Bore Hole: B1-6 Elevation: -12.25 m Water Table: m



# Fig. 4-2-25 (7) Soil Profile

Name of Project: The Second Stage Expansion Project of the Port of Caldera

Number of Bore Hole: B1 7

Elevation: -12.23 m

Water Table: m

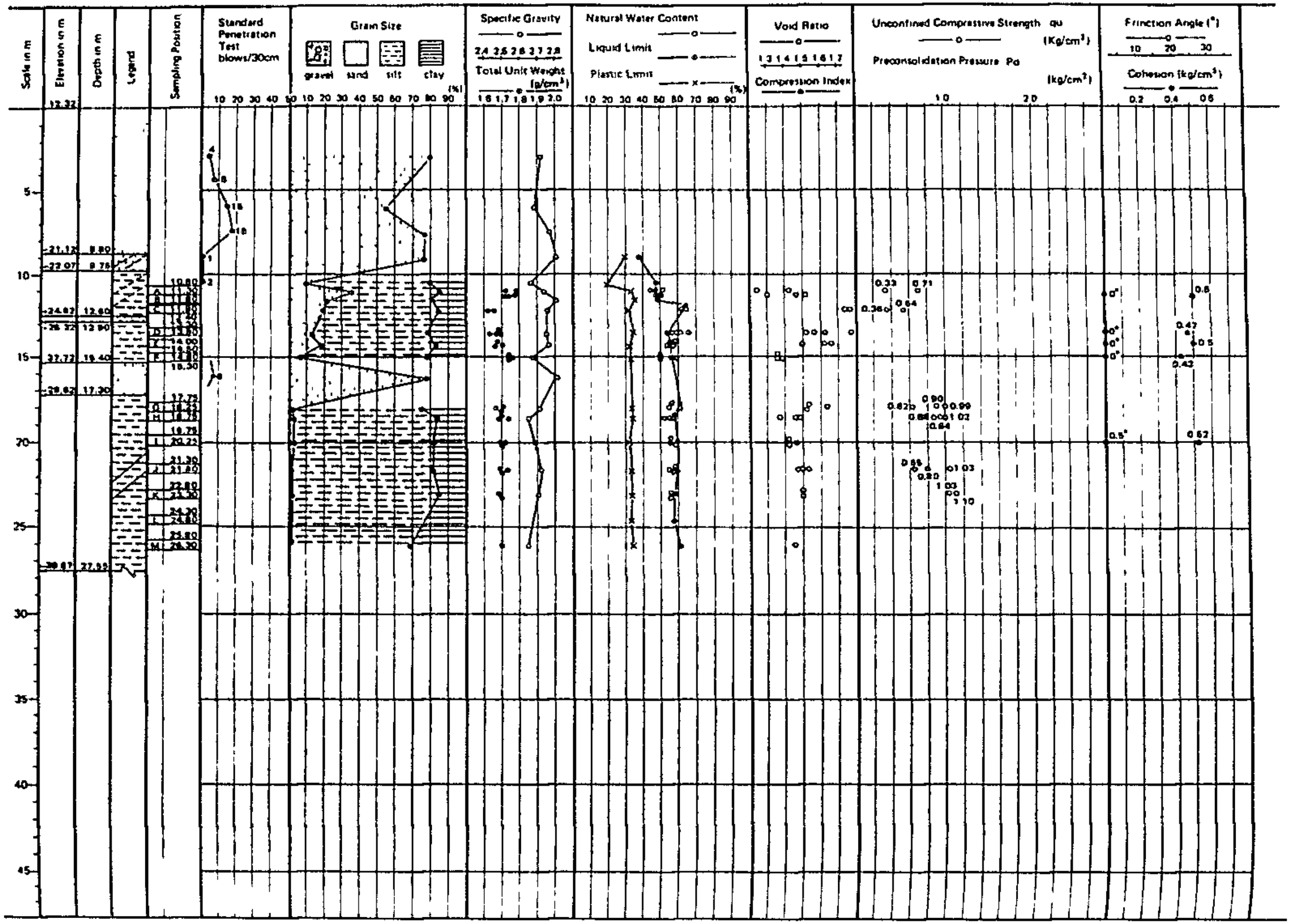


Fig. 4-2-26 (1) Geologic Profile at Breakwater Site (D-D' Section)

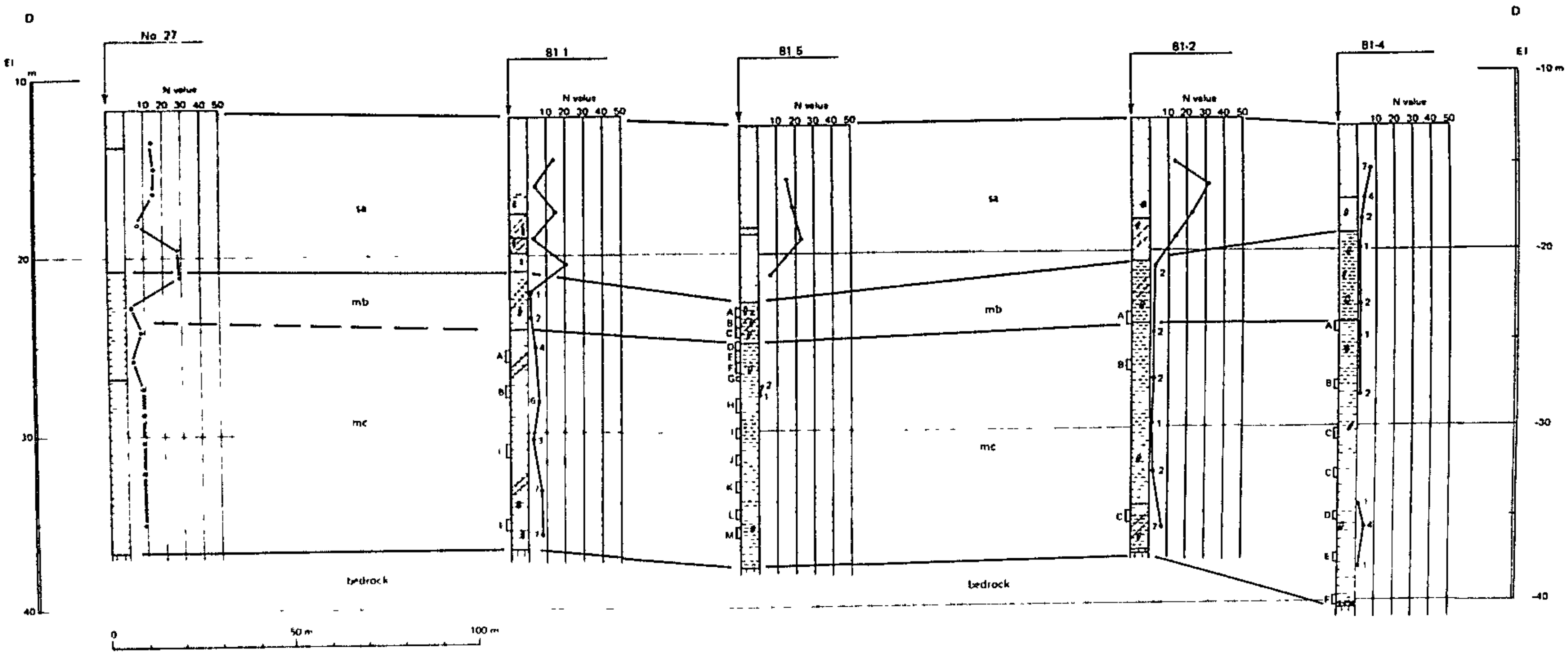


Fig. 4-2-26 (2) Geologic Profile at Breakwater Site (E-E' Section)

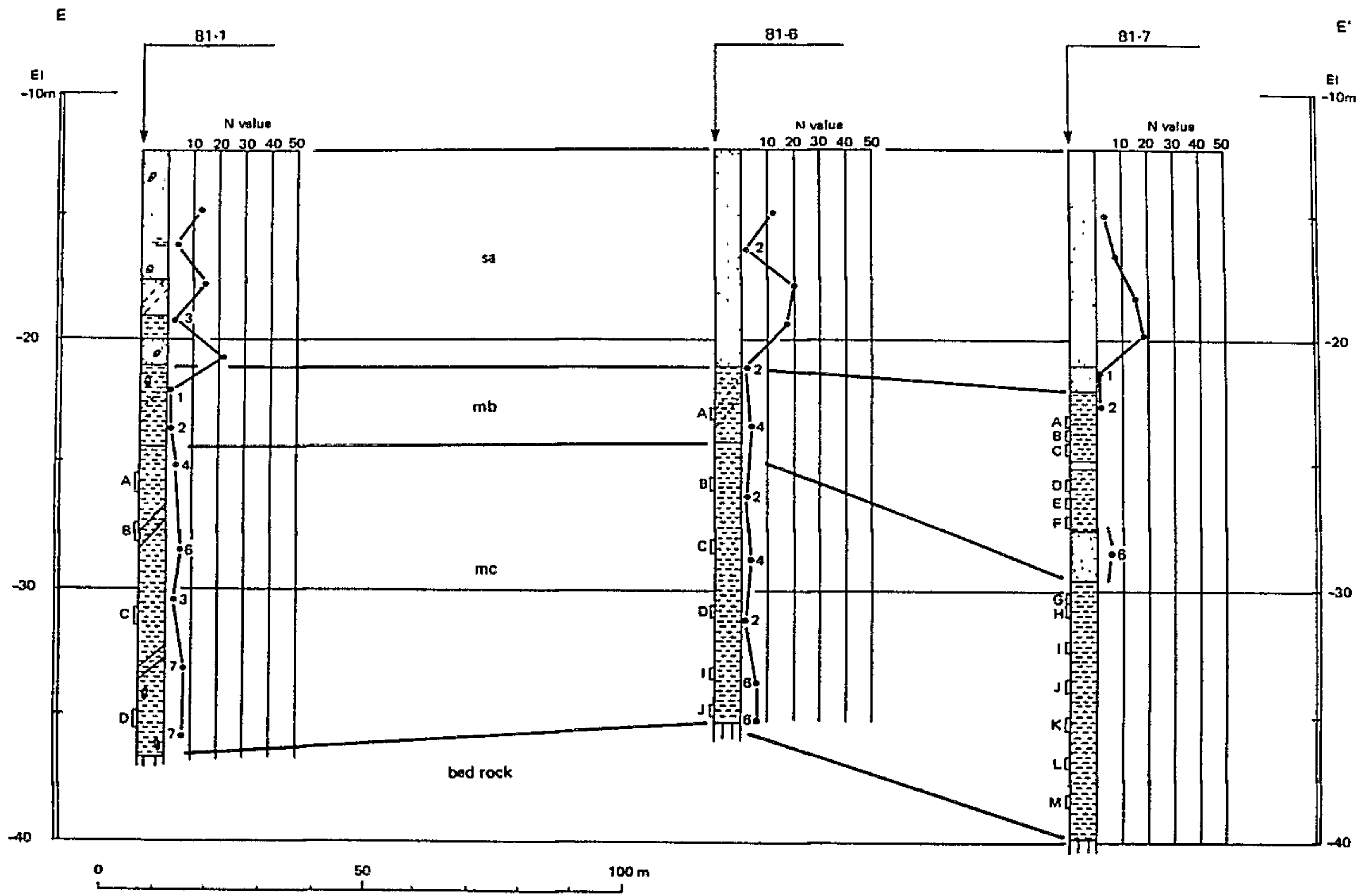
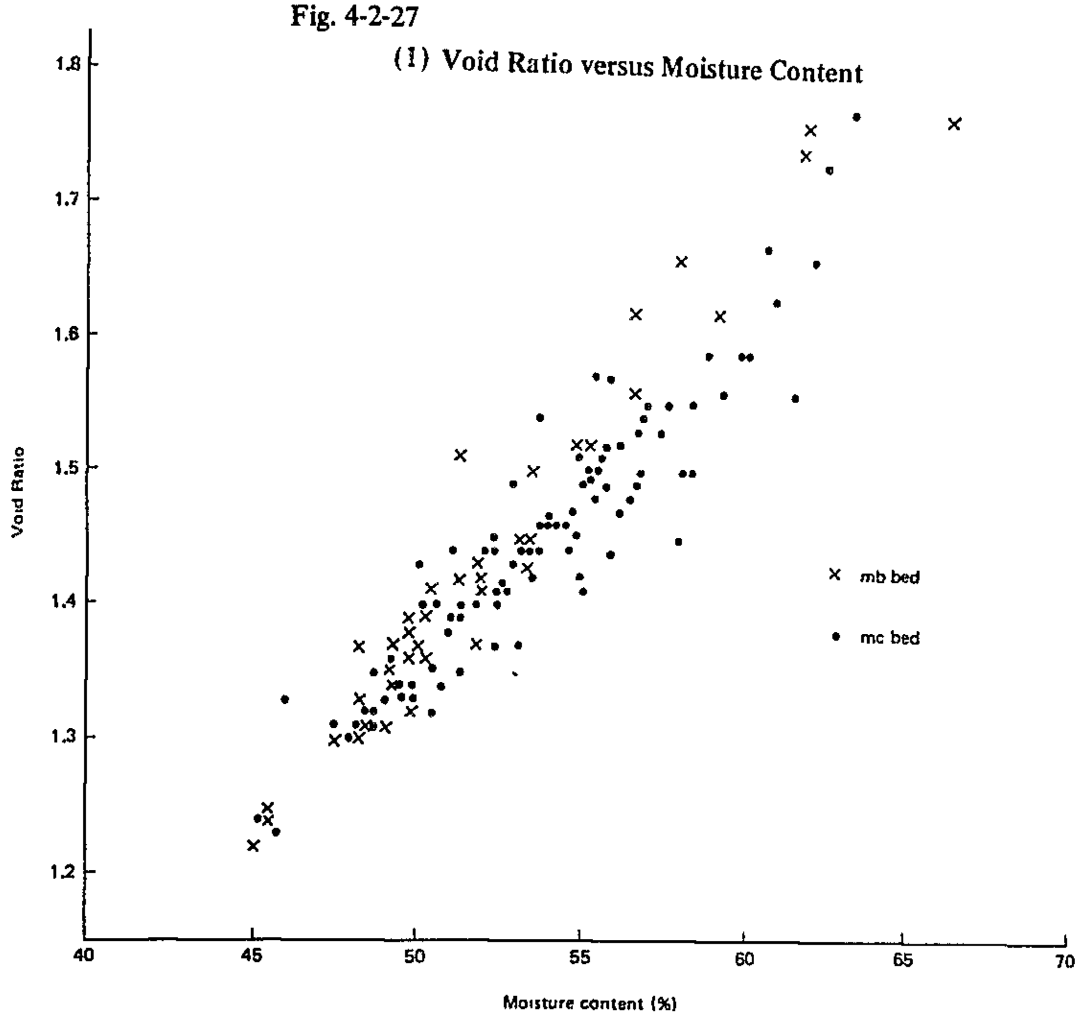


Fig. 4-2-27

(1) Void Ratio versus Moisture Content




(2) Total Unit Density versus Moisture Content

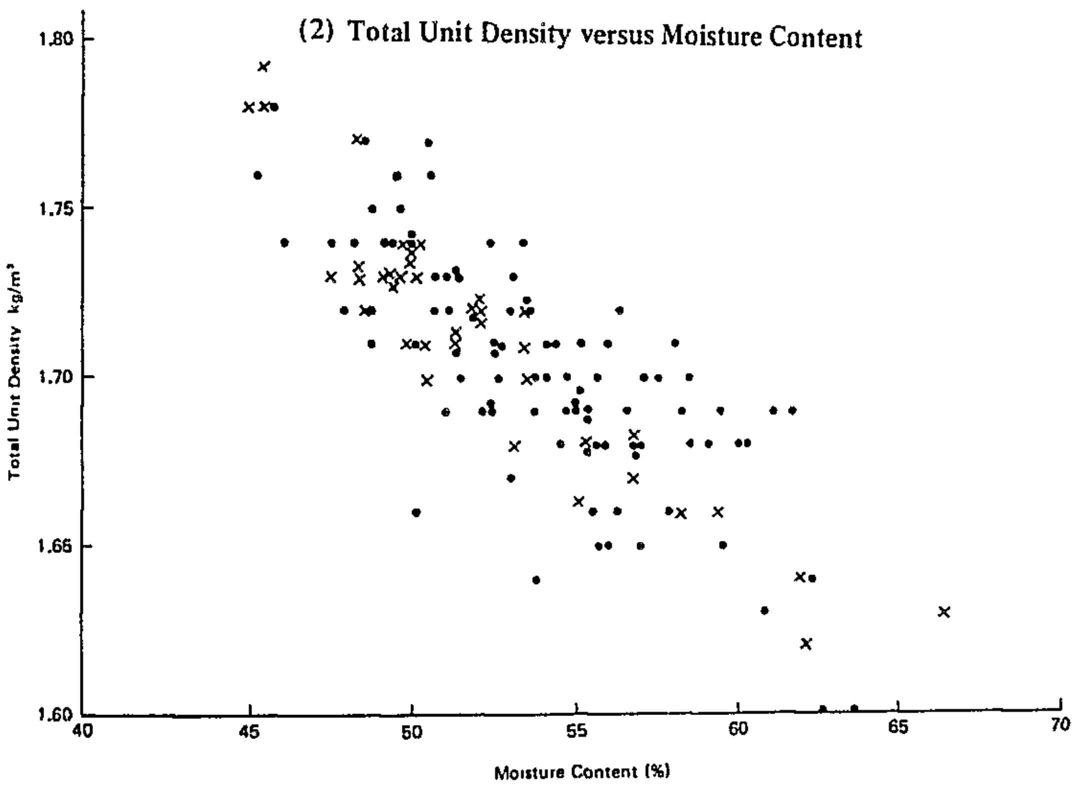


Fig. 4-2-28 Unconfined Compression Strength at Breakwater Site

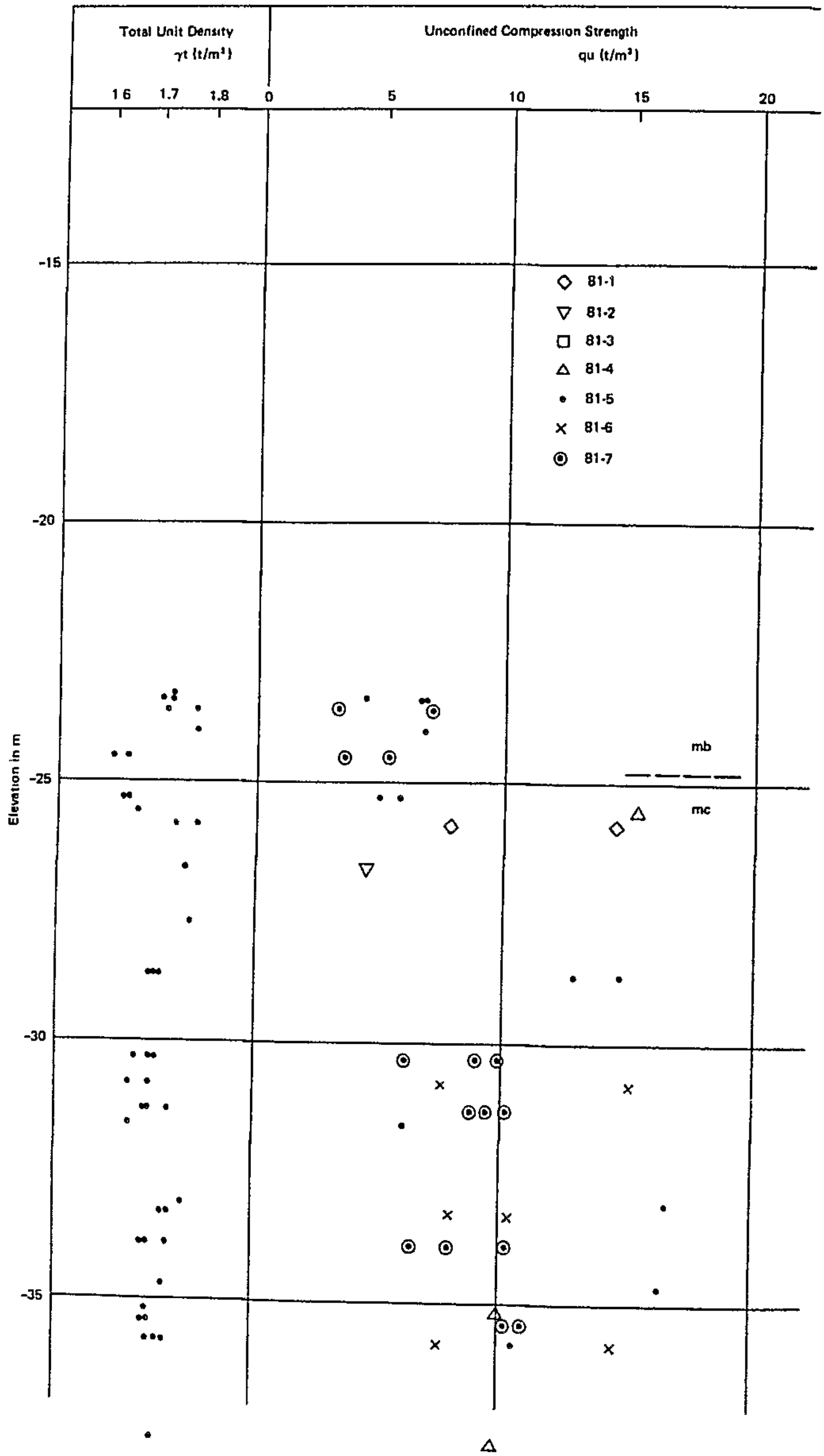
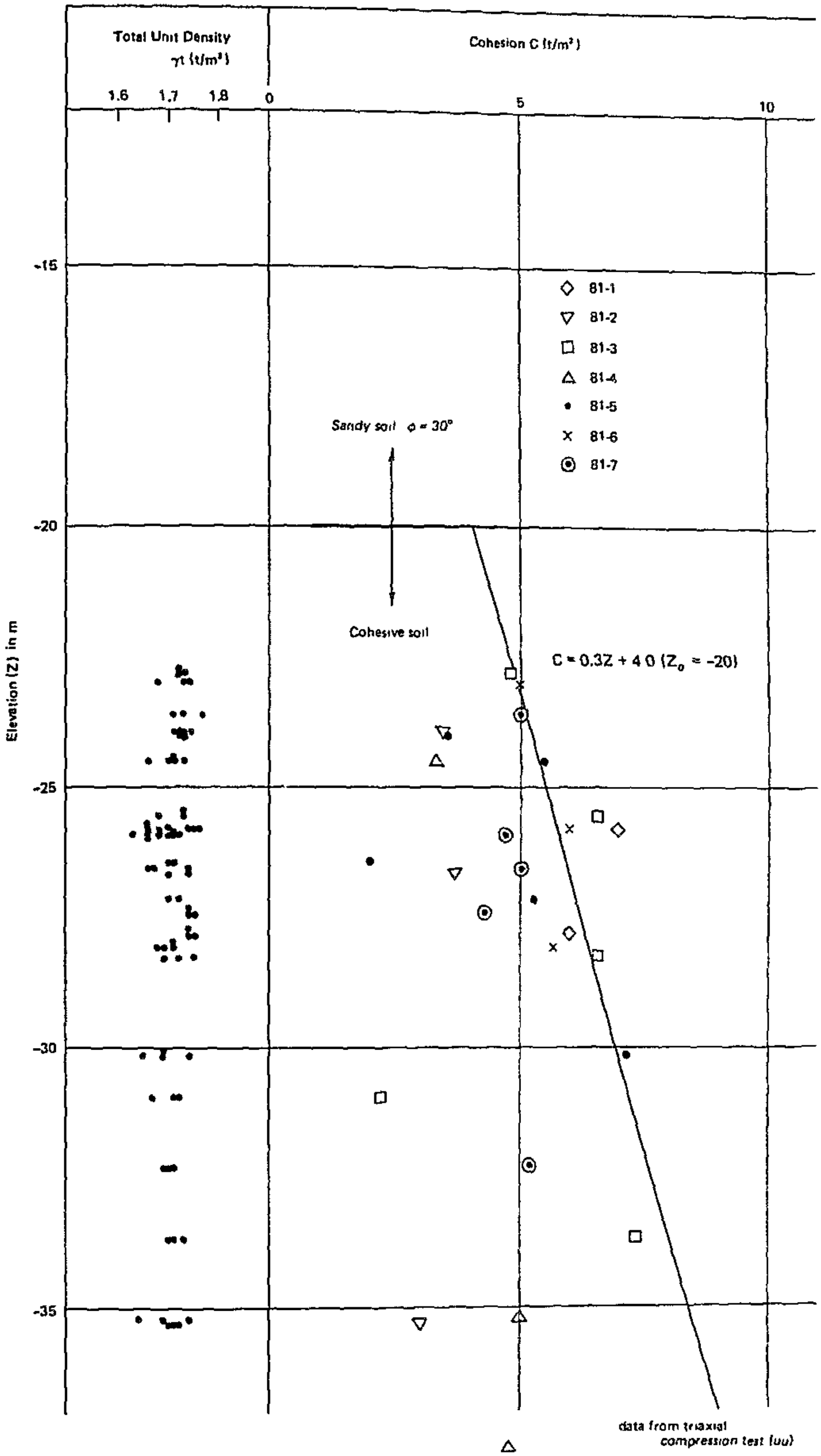


Fig. 4-2-29 Soil Strength Profile at Breakwater Site



(4) Future Subject

The investigation involved the outline of the soil condition in the wharf and breakwater areas of the project. The following investigation should be conducted before the detail design.

① The Wharf Area

This investigation was performed around the planning area and there are only three bore hole points along the face line.

For the detail design some drillings should be performed at the intervals of 50 to 100 meters on the face line.

② The Breakwater Area

Thick soft cohesive bed is distributed on the breakwater site and it is very important to ascertain the soil properties, especially subsoil profiles, shear strength and consolidation properties.

The investigation was far from sufficient about the data of shear strength and particularly consolidation of the soft cohesive soil. Besides, some samples were disturbed a bit and were weakened somewhat in strength.

Therefore the investigation should be performed with the following views for the detail design.

a. The interval of drilling holes should be from 25 meters to 50 meters and the interval of undisturbed sampling depth 1.5 meters. For the sampling, a stationary piston thin wall sampler ($\phi$75 mm) should be used.
b. Laboratory soil tests, especially shearing tests and consolidation tests should be performed The shearing tests should be triaxial compression (uu) tests and also (cu) tests for getting consolidated-undrained shear strength.
c. On the planning extension breakwater site, it looks like that the shear strength of the soil on the seashore is weaker than on the offshore. Therefore, accurate investigation should be performed for ascertaining the limit of the breakwater extension.

# CHAPTER 5
# THE FIRST STAGE PROJECT OF THE PORT OF CALDERA

## CHAPTER 5. THE FIRST-STAGE PROJECT OF THE PORT OF CALDERA

Land reclamation on the Port of Caldera by MOPT started in November, 1974 and wharf construction by Carrez started in 1978. The plan is shown in Fig. 5-1. Facilities involved in the First Stage Project are as follows:

### 5-1 Breakwater and Revetment

(a) Breakwater

The first 200 meters were completed in April 1980 and a 50 meter extension is almost finished except the outer stone armour.

| | | |
|---|---|---|
| Type | Rubble slopping breakwater | |
| Length | 250 m | |
| Top elevation | +8.20 m | |

(b) Revetment

| | | |
|---|---|---|
| Type | Rubble sloping revetment | |
| Length | 500 m (outside of the port) | To be completed by October, 1980 |
| | 340 m (inside of the port) | To be completed by October. 1980 |
| Top elevation | +7.5 m ~ +5.0 m | |

### 5-2 Wharf

| | | |
|---|---|---|
| Type | Steel sheet pile wharf | |
| −11 m wharf | 210 m | Scheduled to be completed by August 1981, although it will be used as a −10 m wharf for a while. |
| −10 m wharf | 150 m | Completed in July, 1980 |
| −7.5 m wharf | 130 m | Completed in June, 1980 |

### 5-3 Dredging

| | |
|---|---|
| Completion: | August, 1980 |
| Volume of Dredged Material: | 355,535 $m^3$ |

### 5-4 Cargo Handling Equipment

The basic patterns of the present cargo handling at the port of Puntarenas is to unload cargo once on the flatcar waiting on the front track on the pier and then load it on the freight car parked on the second track. But the port of Caldera, when completed, will introduce the following method.

Ship ——► Apron ——► Forklift ——► Transit Shed

Also, "Containerization" will be rushed. And for bulk cargo, introduction of mobile pneumatic unloaders is being considered.

The cargo handling equipment included in the First Stage Project of the Port of Caldera has been partially determined and it is described as follows:

(1) Equipment already decided and being considered

Buying institution· MOPT

| Kind of Machine | Capacity | Number |
|---|---|---|
| Forklift | 3 tons | 10 |
| 〃 | 5 tons | 5 |
| 〃 | 6 tons | 3 |
| 〃 | 15 tons | 1 |
| 〃 | 35–40 tons | 1 |
| 〃 | 40 tons | 1 |
| Tractor | | 5 |
| Trailer (Heads) | | 3 |
| 〃 (Chassis) | 40 tons | 6 |
| Diesel Engine | | 1 |
| Attachment for Forklift | | 1 |
| 〃 | | 1 |
| Spreader | for 20' | 1 |
| 〃 | for 40' | 1 |
| Scale | 50 tons | 4 |
| 〃 | 3 tons | 2 |
| Pallet (wooden) | 1.2m x 1.8m | 5,000 |

(2) Container crane

MOPT is now studying the feasibility of installing a container crane with a capacity of 35 tons, but it has not yet decided such details as when to order it and when to install it.

(3) Pneumatic unloaders

Buying instituion: CNP

Three 40 t/h pneumatic unloaders are presently in operation at the port of Puntarenas to unload grains. The tender close for four pneumatic unloaders was done in October, 1981. Its capacity will be 60 t/h each.

As for the storage of grains, it was decided in September 1980 to relocate the grain silos presently located in San Jose City to the Caldera Port site. Preparing necessary land will take one to five months and the completion of the relocation is scheduled for February 1982. The storage capacity is about 10,000 tons.

## 5-5 Freight Handling Facilities (Fig. 5-1)

Cargo storage facilities for the First Stage Project of the Port of Caldera are the following:

| | area | |
|---|---|---|
| Transit shed | 7,200 $m^2$ | 1 |
| Warehouse | 5,400 $m^2$ | 1 |

Fig. 5-1 First Stage Plan of Port of Caldera

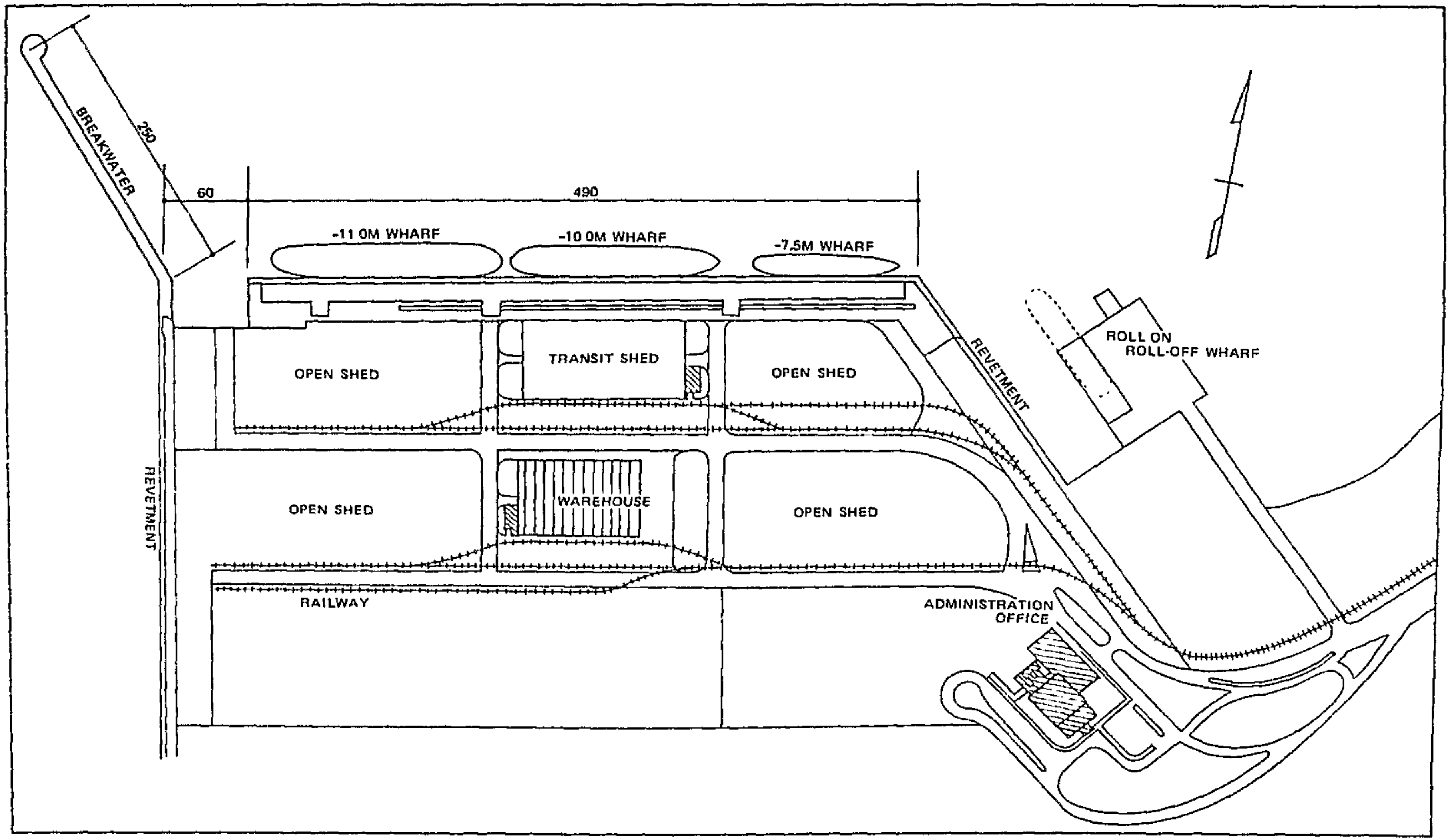


Fig. 5-1-1 Breakwater

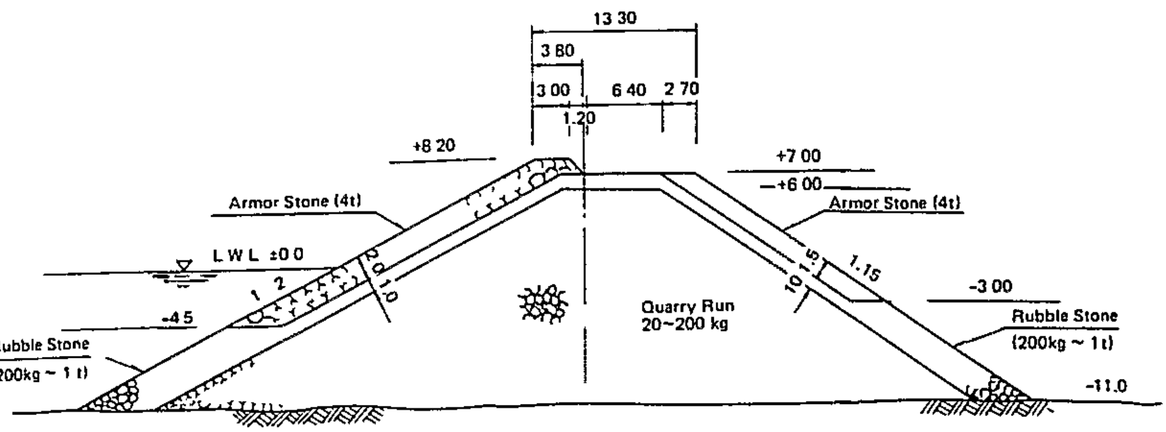



Fig. 5-1-2 Revetment (Outside of the Port)

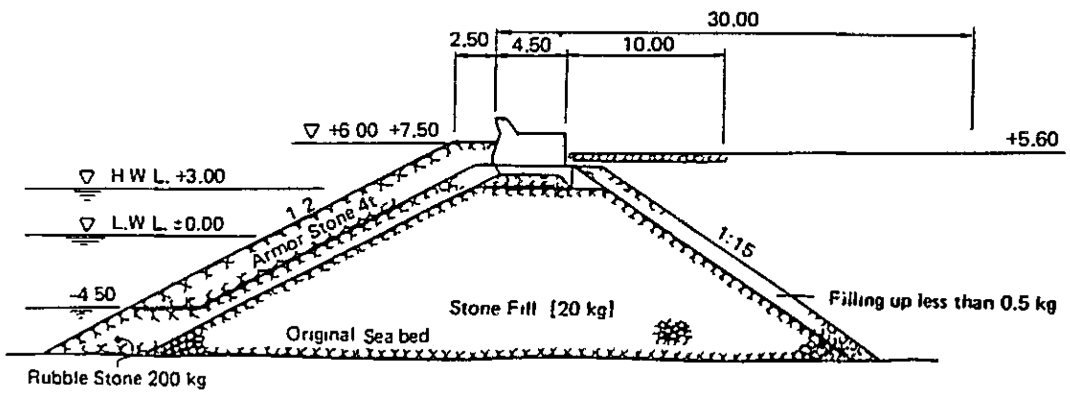


Fig. 5-2-1 (1) -11.0 m Wharf

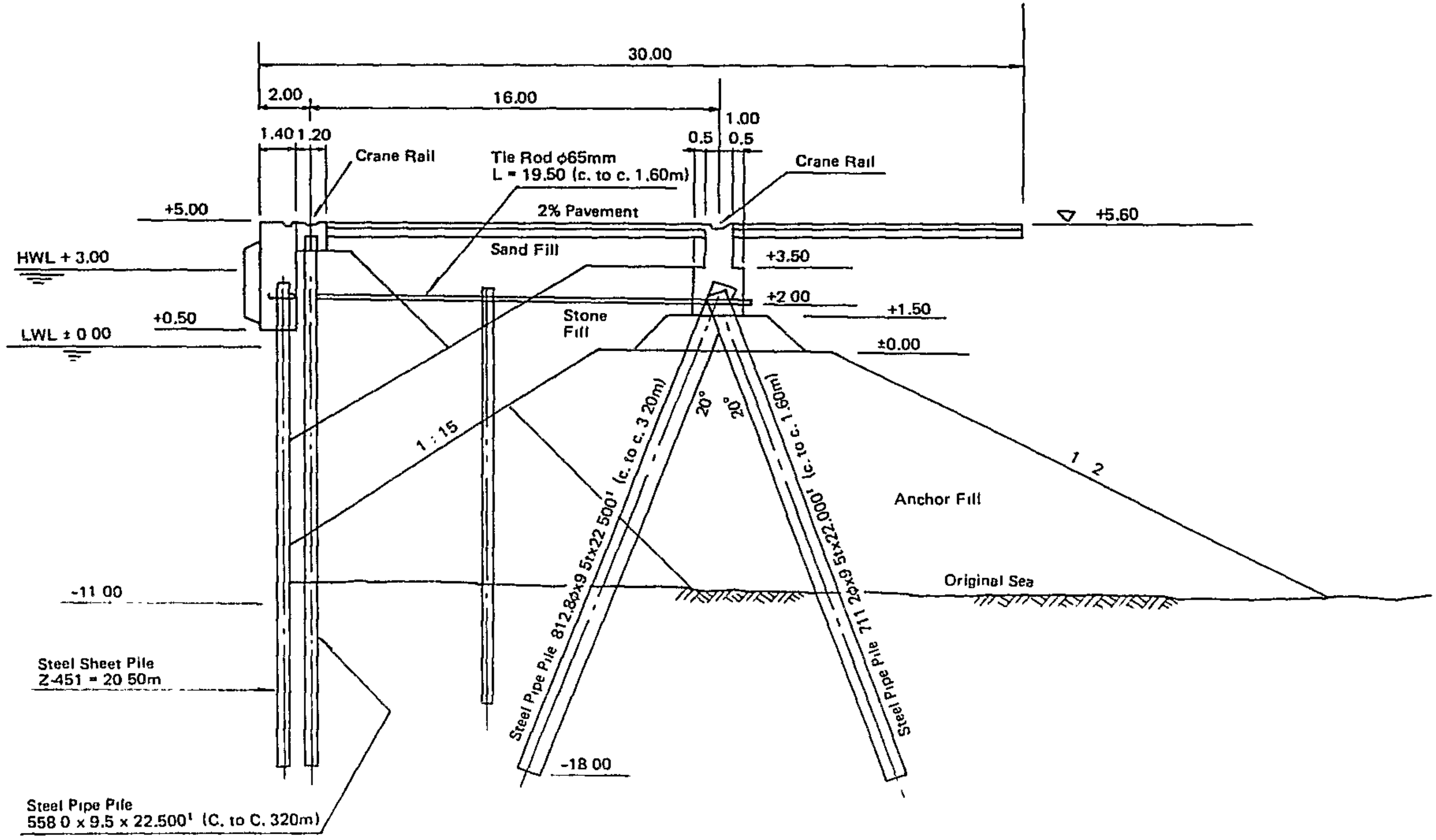


Fig. 5-2-1 (2) −11.0m Wharf

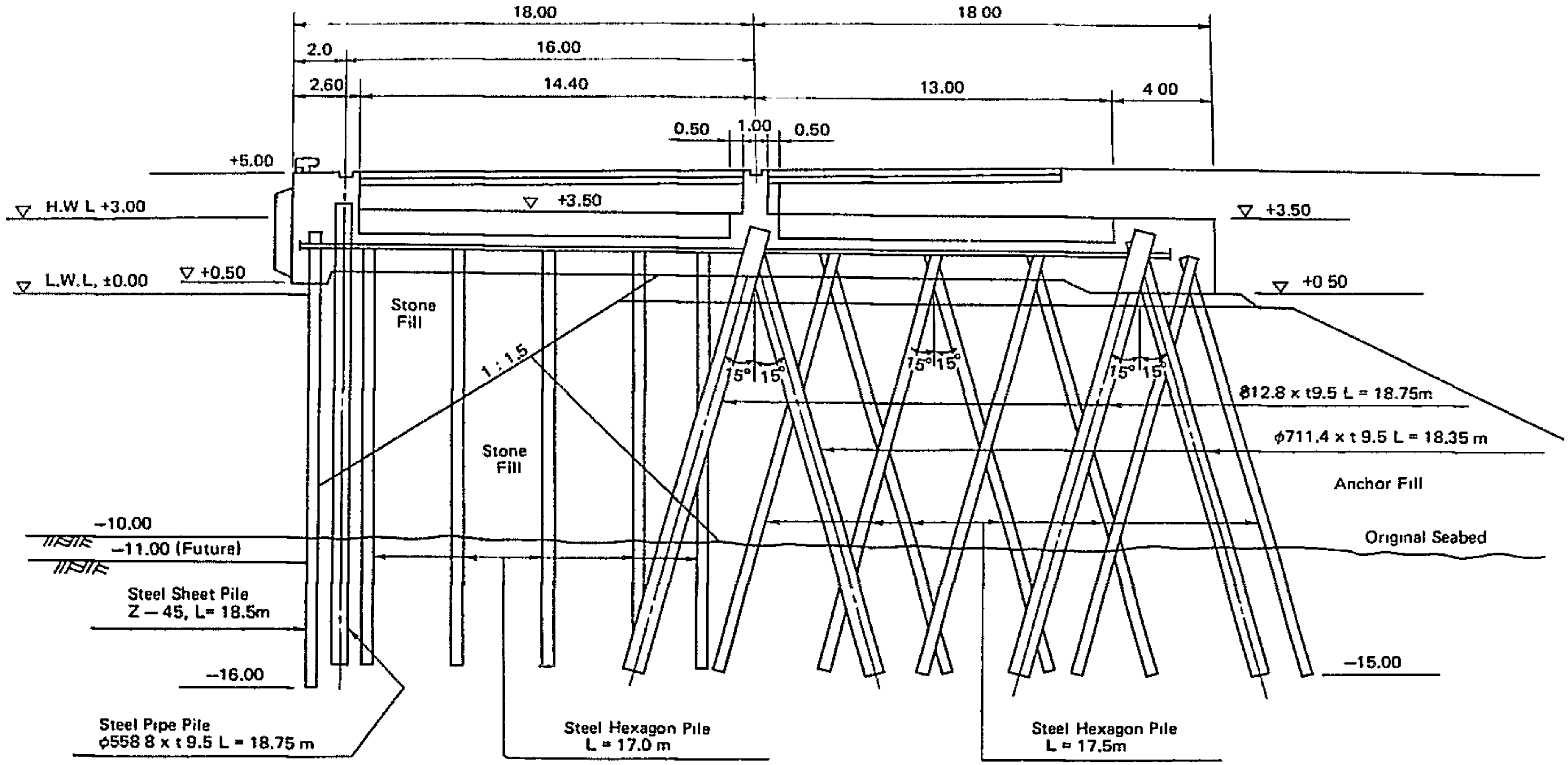


Fig. 5-2-2 -10.0m Wharf

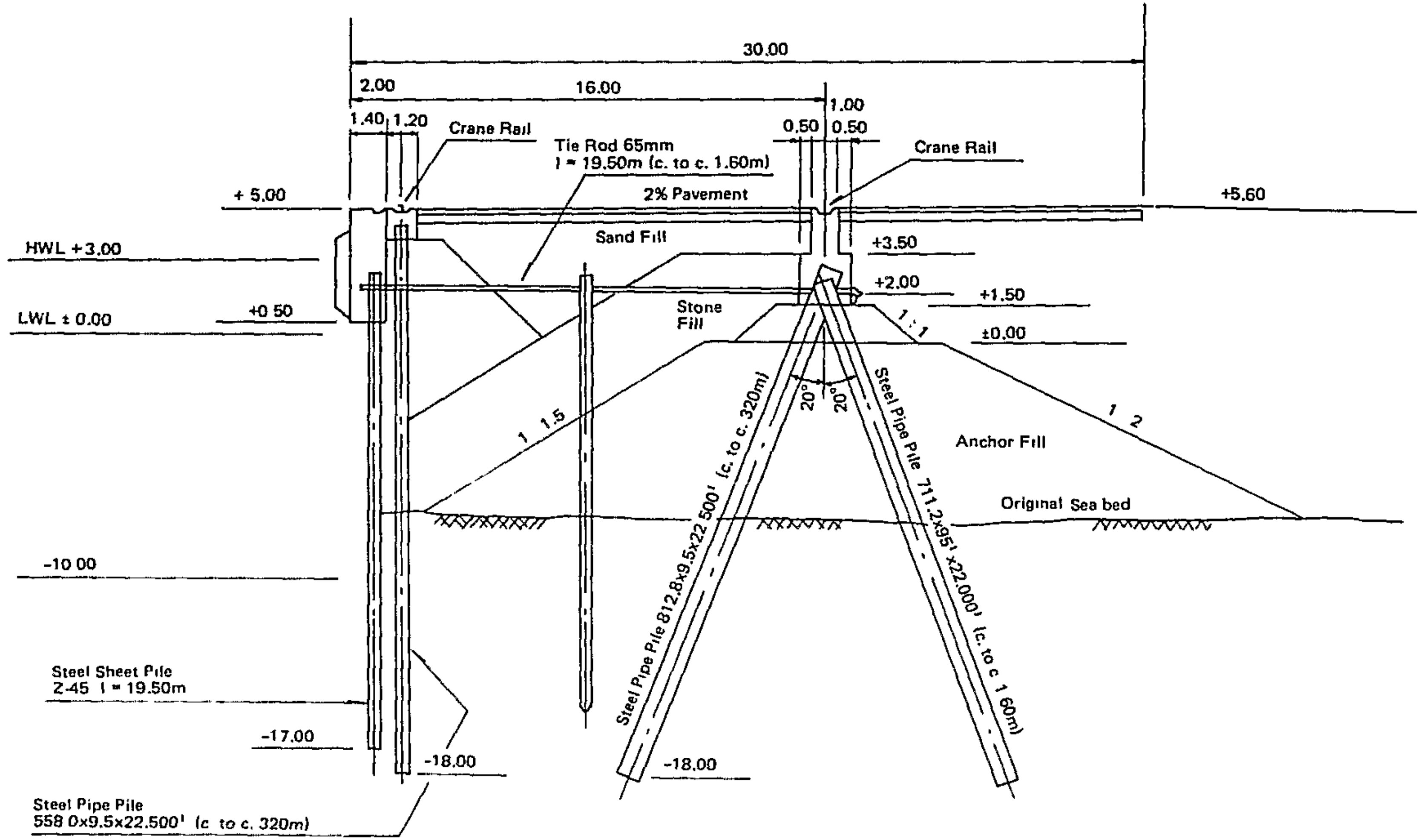


Fig. 5-2-3 -7.5m Wharf

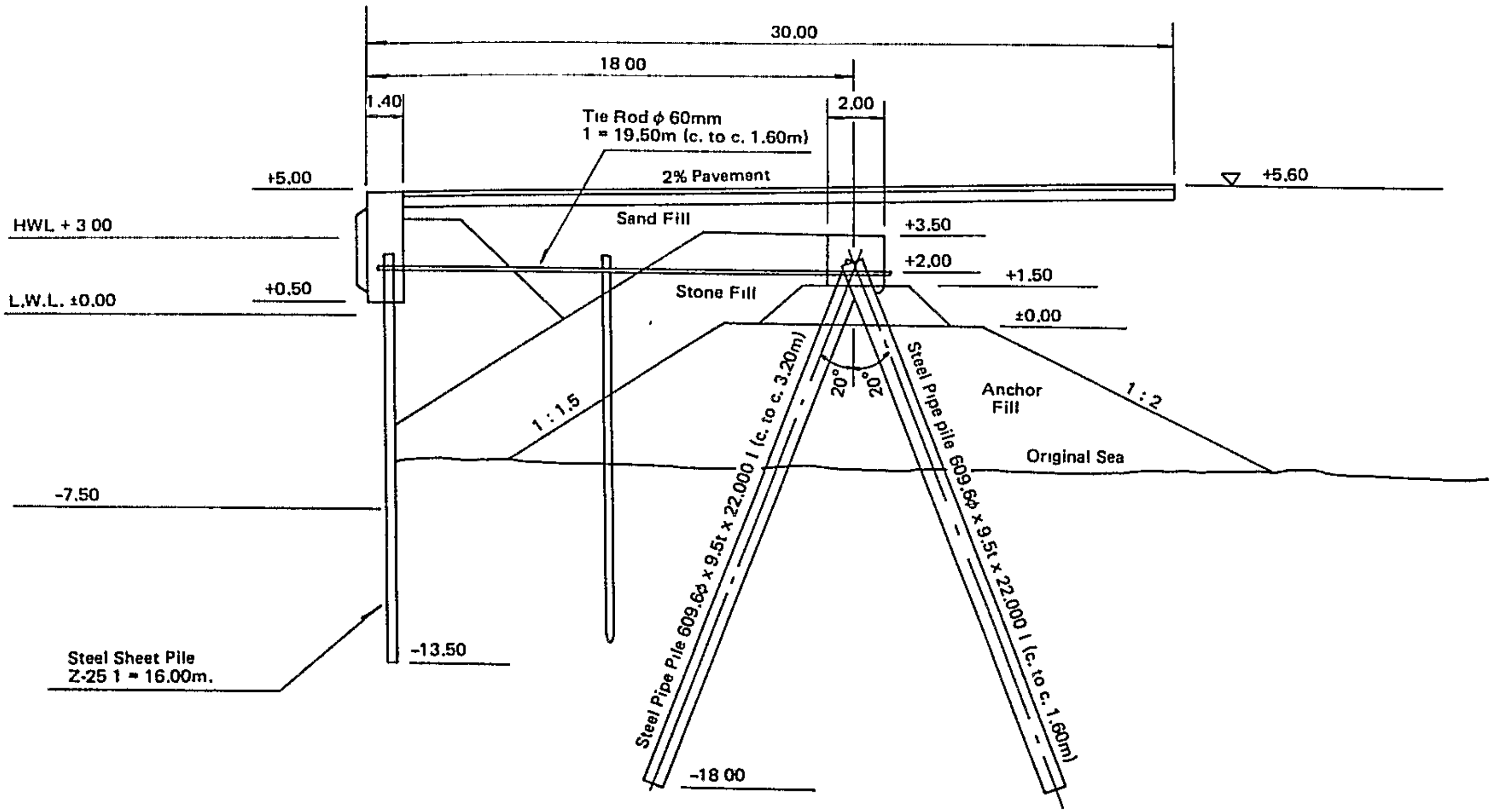
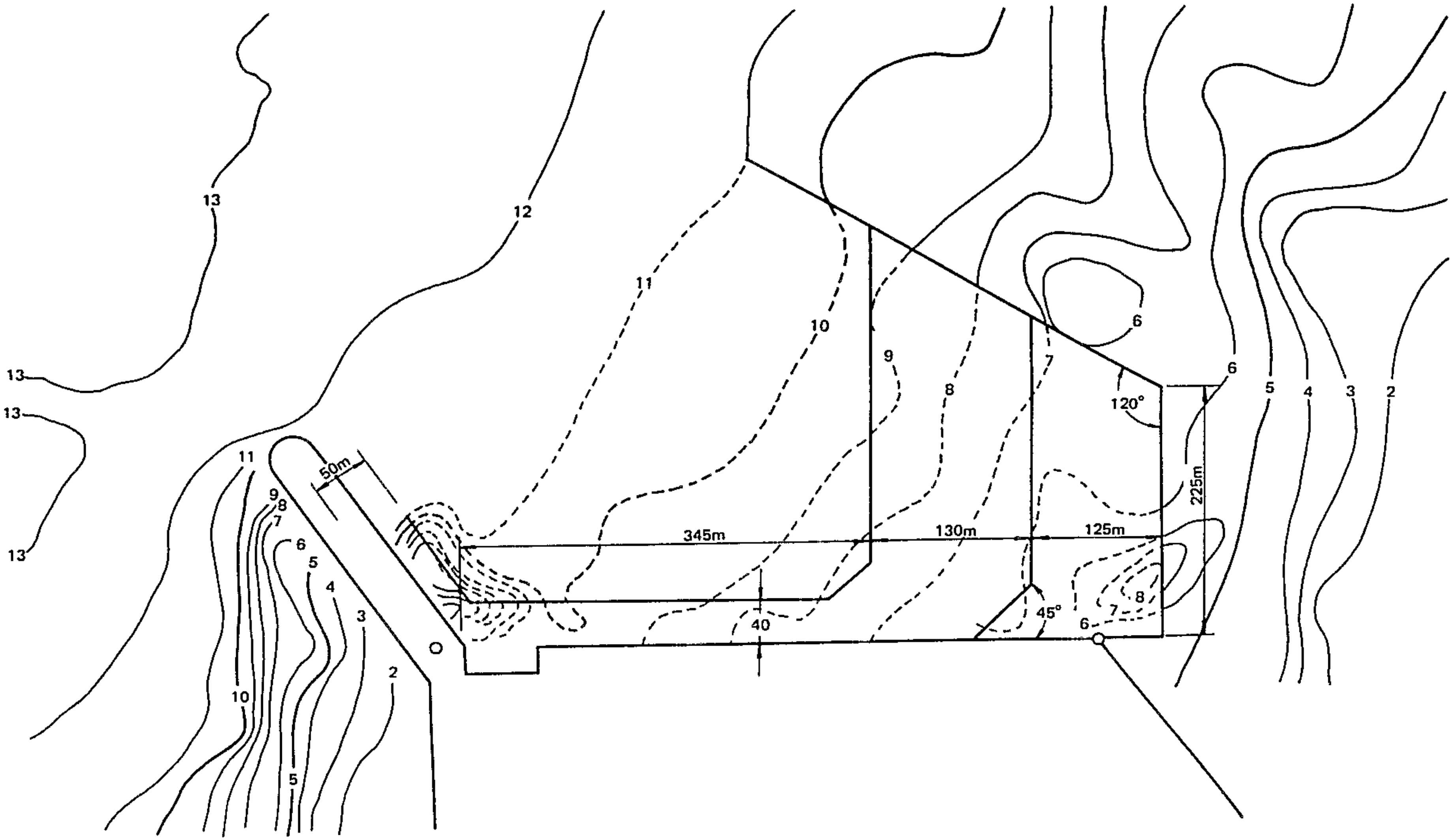


Fig. 5-3-1 Dredging Plan



## 5-6 Port Traffic Facilities

For transportation of cargo there are railway lines reaching behind the transit shed and the warehouse, and connected to an existing railway line at Salinas. Their rail span is 1.07 m.

The harbor road with a width of 12 m, is connected to the roads between Caldera and San Jose and between Caldera and Salinas.

## 5-7 Salinas Cargo Terminal

Salinas is expected to become Caldera's cargo terminal after the start of operations. Situated approximately 4 km North – East of Caldera, Salinas will be connected with the Port by road and a railway line. Salinas' Zone A (with an area of some 10 ha.) will handle all the cargoes bound directly for San Jose. Zone B (with an area of 56 ha.) will handle the cargoes which go to destinations other than the Central High Lands. The scheme plan is shown in Fig. 5-7-1.

Construction of a railway terminal is proposed at Santo Domingo and this terminal will also handle containers (for both the Pacific and Atlantic sides). Necessary land is now being purchased by MOPT and the terminal will be ready in two or three years. (See Fig. 5-7-2)

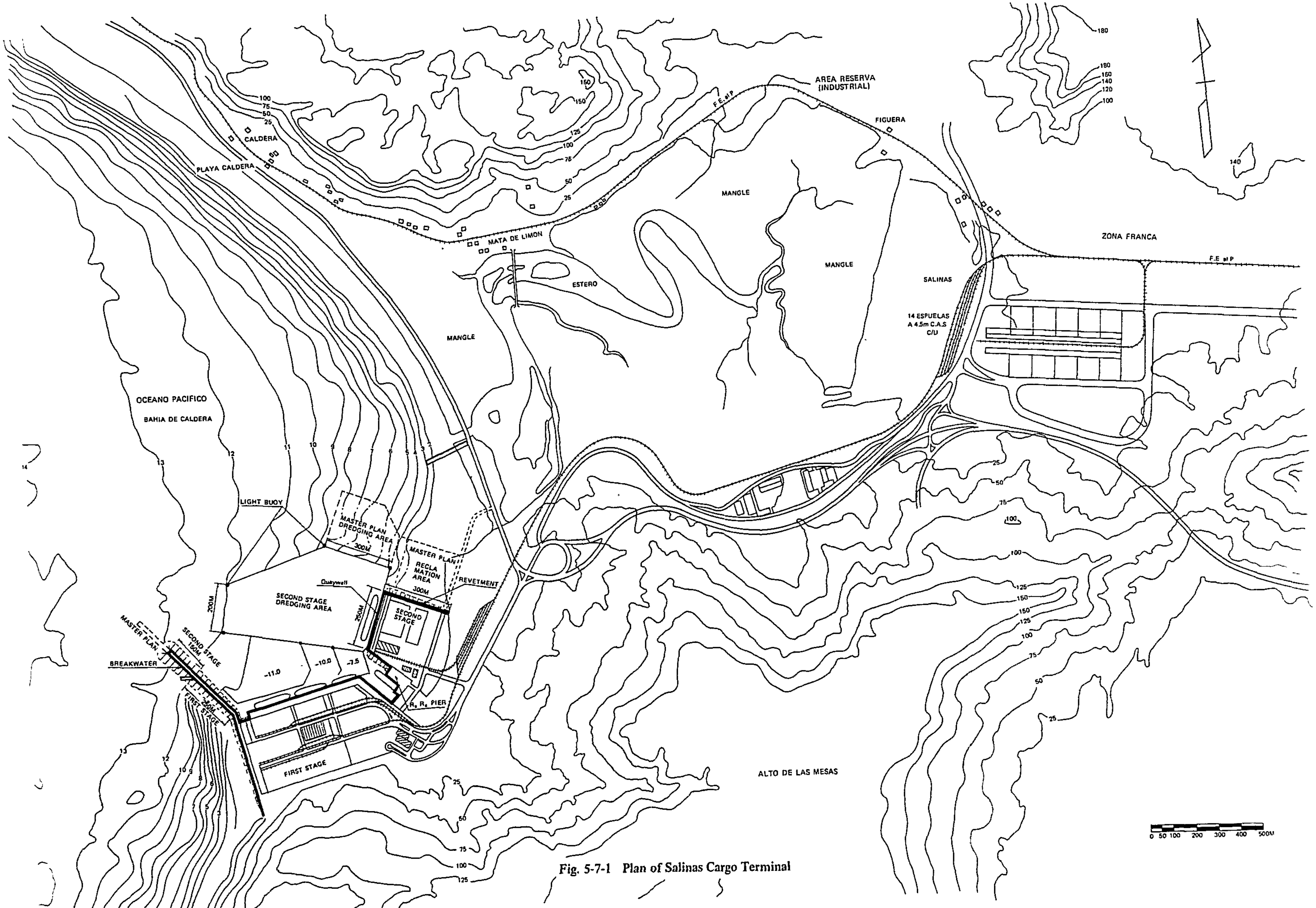
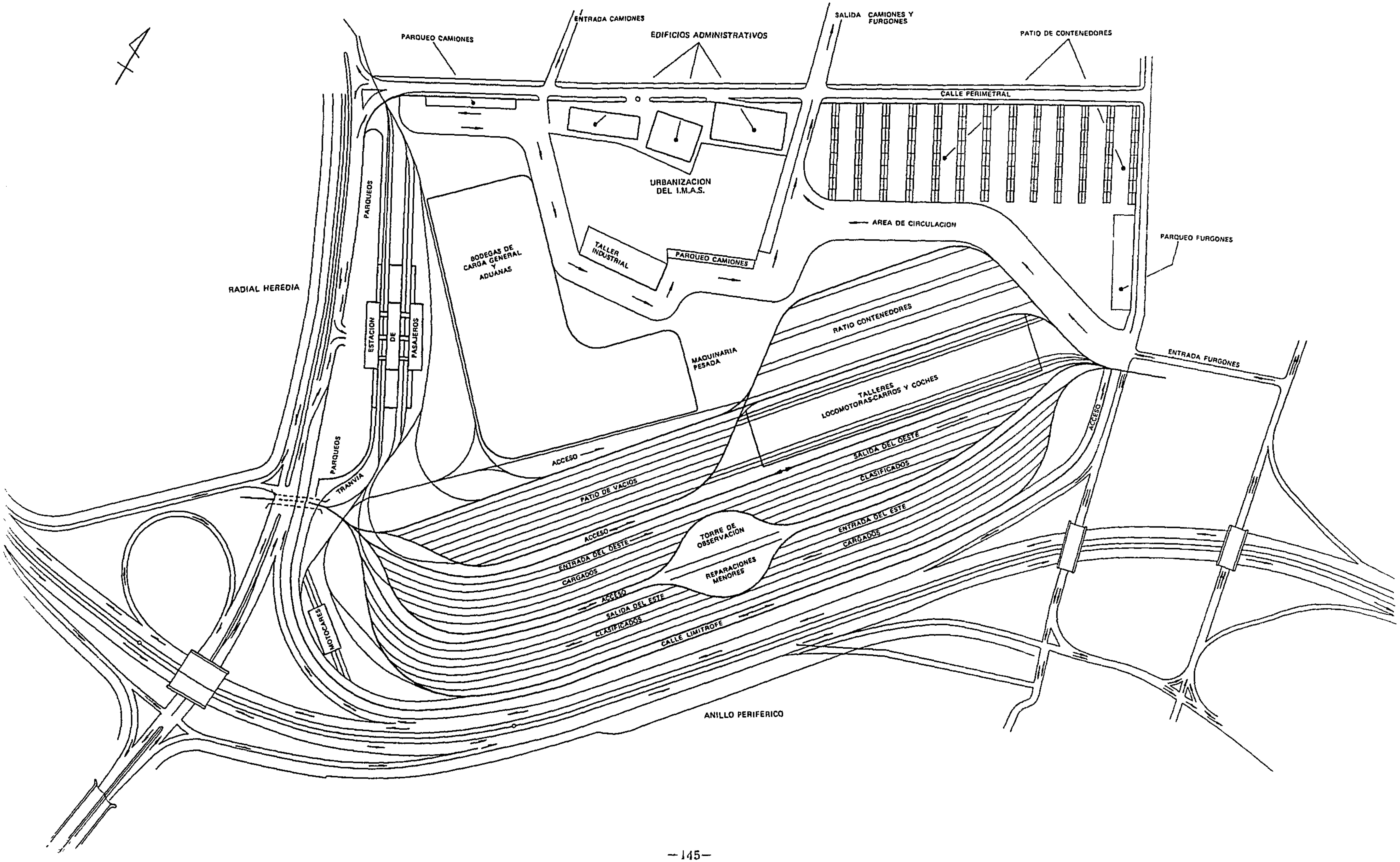



Fig. 5-7-1 Plan of Salinas Cargo Terminal

Fig. 5-7-2 Santo Domingo Railway Terminal



## 5-8 Construction Cost and Results of Funding

Construction cost and results of funding for the First Stage Project are as follows;

### 5-8-1 *Construction Cost*

Construction cost of each facility is shown in Table 5-8-1.

**Table 5-8-1 Construction Cost**

Unit: colones 1,000

| Description | Amount | The life |
|---|---|---|
| Reclamation and dredging | 98,991 | |
| Breakwater | 33,590 | 100 year |
| Wharf and seawall | 316,020 | 50 |
| Control tower | 47,710 | 50 |
| Related equipment | 116,150 | 35 |
| Warehouse and office building | 40,430 | 35 |
| Beacon | 2,460 | 25 |
| Railway | 29,960 | 20 |
| Pavement | 43,920 | 15 |
| Electric power, water supply and sewerage | 26,920 | 15 |
| Material handling equipment | 24,590 | 10 |
| Total | 780,741 | – |

### 5-8-2 Results of Funding

Results of funding are as follows;

The conditions of borrowing are shown in Table 5-8-2.

(Funding)

| | |
|---|---|
| Borrowing from Japanese Government | ¢485.711,000 |
| Borrowing from Venezuela Government | 142.030,000 |
| Government fund | 153,000,000 |
| Total | 780.741,000 |

**Table 5-8-2 Conditions of borrowing**

Unit: colones 1,000

| | Lender | Amount | Interest | Date of borrowing | Term | Grace period | Maturity |
|---|---|---|---|---|---|---|---|
| 1 | Japan | 307,141 | 4.75% | 1974.3.5 | 20 year | 7 year | 1994.3.10 |
| | 〃 | 178,570 | 〃 | 1976 8 18 | 〃 | 〃 | 1996.7.7 |
| | Sub total | 485,711 | | | | | |
| 2 | Venezuela | 37,633 | 8.0% | 1975.10.3 | 19 year | 6 year | 1994.12.30 |
| | 〃 | 53,213 | 〃 | 1977.1.6 | 17 〃 | 4 〃 | 〃 |
| | 〃 | 51,184 | 〃 | 1978.2.27 | 16 〃 | 3 〃 | 〃 |
| | Sub total | 142,030 | | | | | |
| Total | | 627,741 | | | | | |

## 5-9 Administration and Operation

### 5-9-1 System of Administration and Operation

Studies concerning the Administration and operation of the Port of Caldera are now being consolidated mainly by the Direccion de Transport port Agua of MOPT. The draft plan is ready as the Sistema de Operacion en el Puerto de Caldera (Borrador) and MOPT is coordinating with related agencies on this plan. The borrador (draft) recommends the following:

Analysis of different systems (Analisis de los diferentes sistemas)
Attention to ships (Atencion a la nave)
System of operation of pilots (Sistema de operacion de los practicos)
Stevedoring system (Sistema de manipulacion a bordo carga y descarga)
Cargo handling equipment (Utileria)
Transfer and loading and unloading equipment (Transferencia y equipo de carga y descarga)
Warehousing (Almacenamiento)
Delivery of cargoes (Entrega de mercaderias)
Container terminal (Terminal de contenedores)

### 5-9-2 Organization of Administration and Operation

The personnel assigned to the administration and operation of the Port of Caldera is planned as follows:

| | AMOUNT |
|---|---|
| Board of Directors | |
| Directors | 6 |
| Other management employers | 4 |
| Executive President | |
| President | 1 |
| Other management employers | 6 |
| General Audit | |
| Auditor | 1 |
| Other management employers | 8 |
| General Manager | |
| Manager | 1 |
| Other management employers | 5 |
| Legal Affairs | 6 |
| Port Operation Division | |
| Administration | |
| – Director | 1 |
| – Other Personnes | 9 |
| Port Police | 25 |
| Operation Program and documentation (SHIP PAPERS) | 3 |
| Marine Department and Pilotage | 43 |

| | |
|---|---|
| Cargo Handling Department | |
| – Loading and unloading section | 224 |
| – Equipment of Transfer Section | 54 |
| – Warehouse and Open Storage Section | 97 |
| Supervision of Operations Dept. | 10 |
| Containers Departments | 15 |
| Management Division | |
| Director | 1 |
| Secretary | 2 |
| Data Processing Center | 8 |
| General File | 2 |
| Financial Dept. | 28 |
| Labour affair Dept. | 21 |
| Supplying Depart. | 5 |
| Planning and Development Division | 7 |
| Engineering and Mantenance Division | 97 |
| | 690 |
| Casual stevedores | 150 |
| | 840 |

### 5-9-3 Port Fees and Charges

The fees and charges for using the Port of Caldera have not yet been decided but, in the MOPT draft, they are as follows:

| CODIGO | CONCEPTO | | ₡ | UNIDAD |
|---|---|---|---|---|
| 1010 | Ayudas Navegación | | 4,8 | TRB |
| 1020 | Pilotaje | | 1,2 | " |
| 1030 | Remolcaje | | 7,5 | " |
| 1040 | Anclaje | | | |
| 1050 | Estadía | | 300,0 | m-día (eslora) |
| 1060 | Amarres | | 2,25 | TRB |
| 1070 | Servicios | | – | – |
| 1080 | Limpieza muelle nave | | 0,55 | TRB |
| 1080 | Limpieza muelle merc. | | 0,80 | Ton-Mtr. |
| 1210 | Descarga | M.G. | 80 | " |
| 1220 | Descarga | Conten. | 70 | " |
| 1230 | Descarga | Ro-Ro | 52 | " |
| 1240 | | Gr. S. | 60 | " |
| 1250 | | Gr. L. | 32 | " |
| 1260 | | Refrig. | 52 | " |
| 1310 | Carga | M.G. | 75 | " |
| 1320 | | Conten. | 65 | " |
| 1330 | | Ro-Ro | 40 | " |
| 1340 | | Gr.S. | 60 | " |

| | | | | |
|---|---|---|---|---|
| 1350 | | G.L. | 32 | " |
| 1360 | | Refrig. | 52 | " |
| 1410 | Muellaje | IMG | 60 | " |
| 1420 | | Conten. | 40 | " |
| 1430 | | Ro-Ro | 40 | " |
| 1440 | | Gr.S. | 40 | " |
| 1450 | | G.L. | 30 | " |
| 1460 | | Refrig. | 10 | " |
| 1510 | Muellaje | E.M.G. | 50 | " |
| 1520 | | Conten. | 30 | " |
| 1530 | | Ro-Ro | 30 | " |
| 1540 | | Gr.S. | 30 | " |
| 1550 | | G.L. | 30 | " |
| 1560 | | Refrig. | 10 | " |
| 1610 | Manip. | IMG | 110 | " |
| 1620 | | Conten. | 50 | " |
| 1630 | | Ro-Ro | 60 | " |
| 1640 | | Gr.S. | 60 | " |
| 1650 | | G.L. | 60 | " |
| 1660 | | Refrig. | 50 | " |
| 1710 | Manip. | EMG | 110 | " |
| 1720 | | Conten. | 50 | " |
| 1730 | | Ro-Ro | 50 | " |
| 1740 | | Gr.S. | 50 | " |
| 1750 | | G.L. | 50 | " |
| 1760 | | Refrig. | 50 | " |
| 1810 | Serv. Refrig. | | – | |
| 1820 | Báscula | | | |
| 1830 | Bodega | | | |
| 1840 | Misceláneos | | | |

# CHAPTER 6
# FORECAST ON PORT DEMAND

# CHAPTER 6. FORECAST ON PORT DEMAND

## 6-1 Volume Tendencies of Port Cargoes

### 6-1-1 Costa Rican Ports and Their Characteristics

Costa Rica has three foreign trade ports: the port of Limon on the Atlantic side and the port of Puntarenas and the port of Golfito on the Pacific side. Their characteristics are as follows:

(1) The Port of Limon

The port of Limon consists of Limon and Moin is under the control of the JAPDEVA.

Limon has a general cargo pier and a banana pier but both were constructed more than 50 years ago and are extremely obsolete in structure and function. At present, a new wharf for large cargo ships and container ships is being constructed. Of the approximately 1,100,000 tons/year (1977) of dry cargoes handled at Limon, bananas accounted for 700,000 tons and other cargoes accounted for about 400,000 tons/year. Limon is connected with the central highlands by railway and road transport.

Moin is now used exclusively for petroleum comprising approximately equal quantities of crude oil and refined oil. After being refined, petroleum is transported to a depot near Cartago by pipeline. From the depot, it is distributed by railways and lorries to all parts of the country. A pier exclusively for bananas is under construction. In the future, bananas will be handled at Moin.

(2) The Port of Puntarenas

The port of Puntarenas comprises Puntarenas Jetty, Punta Morales, Jetty facilities for the exclusive use of Fertica, facilities for the exclusive use of the RECOPE (now abolished), a fishing port and a ferry-boat facility. Caldera now being constructed will replace Puntarenas Jetty. Other facilities including Punta Morales and Fertica will continue to be used under their present conditions after the opening of the port of Caldera.

Puntarenas Jetty handles 70,000 ~ 80,000 tons/year of wheat and about 300,000– 400,000 tons/year of general cargoes. The handling of these cargoes will be one of roles played by the port of Caldera when it is opened. The Puntarenas Jetty will then be abolished.

Punta Morales is used exclusively for the shipment of sugar. The export of all sugar was made the charge of Punta Morales in 1976. It has sugar warehouses (about 80,000 tons) and a belt conveyor system.

Fertica, the only fertilizer plant in this country, has a small exclusive wharf on its site and offshore cargo handling is conducted, using barges. It imports raw materials, such as salts and ammonia, and exports some of its products. It will continue to use its own port facility in the future to import raw materials because of restrictions including the type of packing (bulk) of raw materials and the system of storage warehouses. It also uses the facility to export its products by means of barges and offshore loading but the port of Caldera should be used for this purpose when it is opened and containerization of transporting products may be developed.

(3) The Port of Golfito

The port of Golfito is a private facility of a banana company and only handles the export of bananas and some goods of banana-related industries.

From these forms of utilization of the various ports, goods to be handled by the port of Caldera when it is opened and goods most unlikely to be handled by it may be classified as follows:

Goods unlikely to be handled by the port of Caldera

Import: Crude oil and refined oil (Moin)
Raw materials of fertilizers (Fertica's exclusive facility)

Export: Bananas (ports of Limon and Golfito)
Sugar (Punta Morales)

Goods likely to be handled by the port of Caldera only

Import: Wheat

Export: Fertilizer products (according to the development of containerization)

Goods likely to be handled by both ports of Caldera and Limon General cargoes other than the above.

However, improvements in transportation through containerization and other methods is being planned for bananas and, if such improvements becomes effective, bananas may be handled at Caldera.

6-1-2 Volume of General Cargoes in Costa Rica

The 6-1-1 and Fig. 6-1-1 show the volume of cargo handled by the ports of Limon and Puntarenas in 1969 – 1977. The volume of general cargo is obtained by subtracting petroleum fertilizer, raw materials, wheat, bananas and sugar from the total volume of cargo.

According to these data, imported goods have increased by an annual average of 6%, which is nearly equal to 5.9% representing the average increase of GDP mentioned in Chapter 2. Whereas, exports have not increased much during the past 10 years, showing a virtual levelling-off. This shows that, while the demand for iron and steel, automobiles and other industrial products has increased with the nation's economic growth, the export of agricultural products other than bananas and sugar has not increased.

The volume of general cargo handled by the ports of Limon and Puntarenas is nearly equal in both import and export. (In the averages for 1969 – 1977, Puntarenas and Limon represented 46% and 54% respectively in import, and represented 49% and 51% respectively, in export.) Though there are small annual variations in these ratios, one may safely consider that the same tendency will continue in the future.

Table 6-1-1 (1) Cargo Volume at Ports of Limon and Puntarenas 1969–1977 Import

| Year | General Cargo | | | | | Special Cargo | | | | Total | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Limon | | Puntarenas | | Total | Limon | | Puntarenas | | Limon | Puntarenas |
| | $10^3$ tons | (%) | $10^3$ tons | (%) | $10^3$ tons | Oil | Fertilizer Material | Wheat | Oil | $10^3$ tons | $10^3$ tons |
| 1969 | 163.5 | (53.3) | 143.3 | (46.7) | 306.8 | 334.4 | 56.2 | 78.0 | 29.5 | 497.8 | 307.1 |
| 1970 | 207.7 | (51.9) | 192.2 | (48.1) | 399.9 | 351.9 | 53.4 | 68.0 | 76.6 | 559.6 | 390.2 |
| 1971 | 188.5 | (47.8) | 205.5 | (52.5) | 394.0 | 410.9 | 104.9 | 58.6 | 78.0 | 599.4 | 447.0 |
| 1972 | 221.0 | (48.8) | 231.6 | (51.2) | 452.6 | 428.2 | 71.7 | 66.5 | 22.3 | 649.2 | 392.1 |
| 1973 | 243.3 | (56.5) | 187.3 | (43.5) | 430.6 | 445.5 | 78.7 | 74.8 | 37.5 | 688.8 | 378.3 |
| 1974 | 330.4 | (55.0) | 269.9 | (45.0) | 600.3 | 513.9 | 81.6 | 64.6 | 41.9 | 844.3 | 458.0 |
| 1975 | 273.1 | (57.5) | 201.7 | (42 5) | 474.8 | 602.9 | 69.5 | 82.7 | – | 876.0 | 353.9 |
| 1976 | 272.5 | (59 4) | 185.9 | (40.6) | 458.4 | 584.5 | 100.9 | 70.4 | 3.4 | 857.0 | 360.6 |
| 1977 | 294.1 | (52.5) | 265.7 | (47.5) | 559.8 | 787.8 | 153.8 | 76.2 | 22.5 | 1,081.9 | 518.2 |

Source: Cuadros Estadisticos sobre Sector Transportes, DGP/MOPT

Note: *Fertilizer material is calculated by an assumption that 80% of fertilizer is material and 20% is product, according to the information from FERTICA.*

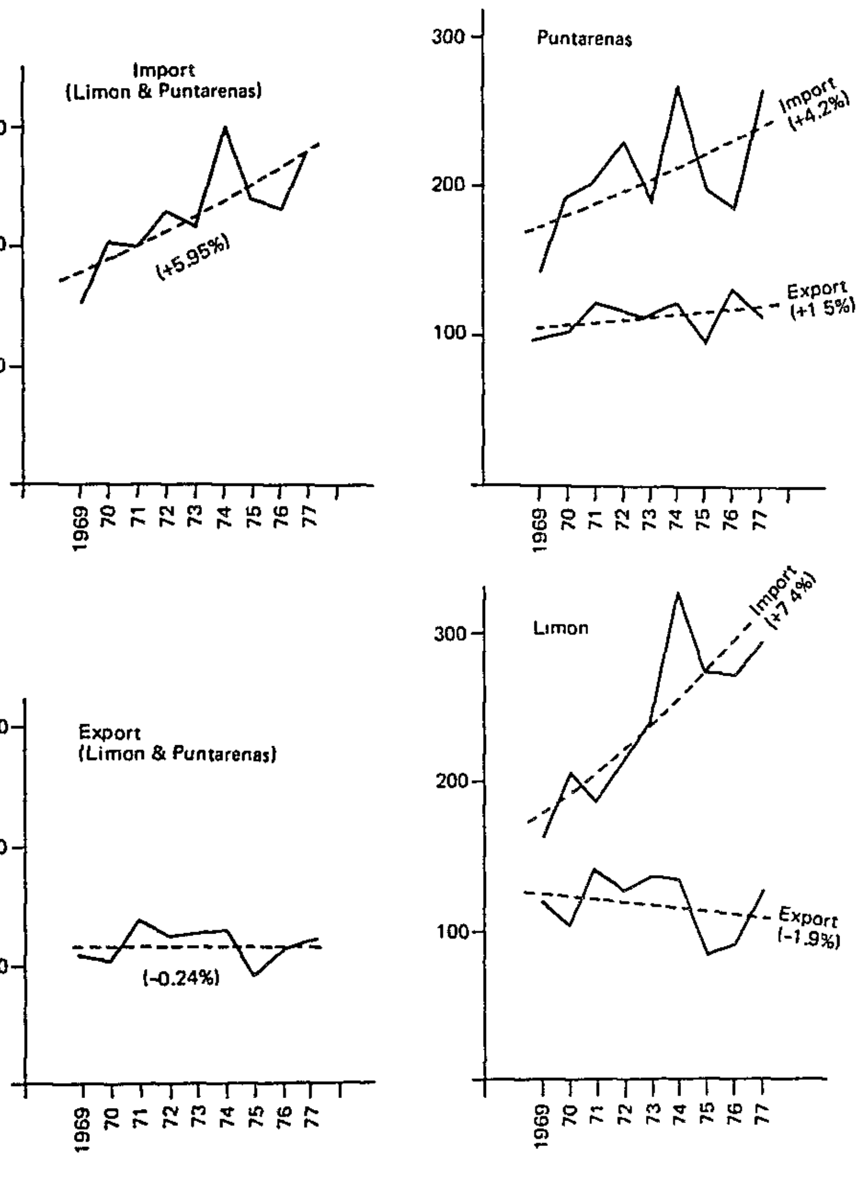
Table 6-1-1 (2) Cargo Volume at Ports of Limon and Puntarenas 1969–1977 Export

| Year | General Cargo | | | | | Special Cargo | | Total | |
|---|---|---|---|---|---|---|---|---|---|
| | Limon | | Puntarenas | | Total | Limon | Puntarenas | Limon | Puntarenas |
| | $10^3$ tons | (%) | $10^3$ tons | (%) | $10^3$ tons | Banana | Sugar | $10^3$ tons | $10^3$ tons |
| 1969 | 118.5 | (54.4) | 99.3 | (45.6) | 217.8 | 372.8 | 28.2 | 491.3 | 127.5 |
| 1970 | 100.1 | (49.6) | 101.9 | (50.4) | 202.0 | 515.7 | 50.6 | 615.8 | 152.5 |
| 1971 | 141.5 | (53.5) | 123.2 | (46.5) | 264.7 | 562.5 | 62.7 | 704.0 | 186.0 |
| 1972 | 127.5 | (52.2) | 116.9 | (47.8) | 244.4 | 698.6 | 42.7 | 826.1 | 159.6 |
| 1973 | 136.6 | (54.9) | 112.1 | (45.1) | 248.7 | 817.2 | 66.2 | 953.8 | 178.2 |
| 1974 | 133.7 | (52.5) | 121.1 | (47.5) | 254.8 | 762.6 | 69.2 | 896.3 | 190.2 |
| 1975 | 84.5 | (46.8) | 96.1 | (53.2) | 180.6 | 845.2 | 70.1 | 929.7 | 166.2 |
| 1976 | 89.7 | (40.5) | 132.0 | (59.5) | 221.7 | 775.1 | 69.0 | 865.8 | 201.0 |
| 1977 | 124.0 | (52.0) | 114.6 | (48.0) | 238.6 | 707.1 | 74.0 | 831.1 | 188.6 |

Source: Cuadros Estadisticos sobre Sector Transportes, DGP/MOPT

## Fig. 6-1-1 General Cargo Volume

Unit 1,000 metric tons



## 6-2 Forecast on Cargo Volumes by Commodity

### 6-2-1 Wheat

Costs Rica, which does not domestically produce any wheat, depends entirely on import for the supply of this grain. At present, imported wheat is unloaded at Puntarenas and transported to Alajuela by railway. Table 6-2-1 shows the imports of wheat and flour in 1965 – 1977 based on DGP/MOPT statistics and the per-capita wheat consumptions calculated through division by the population in each year. According to the table, wheat was annually consumed at 38 kg per capita as the average for 1969 – 1977 and there was no clear tendency of increase in the meantime. It is said that in Costa Rica, people tend to take wheat as a staple in proportion to the rise of their level of income but this cannot be quantitatively confirmed. In forecasting for the future, an increase rate of 1.3% or 1/2 of GDP/capita (Table 2-2-4), in the annual per-capita consumption of wheat may be assumed. The results of estimation of wheat consumption from forecast population values and this increase rate are shown in Table 6-2-2.

### 6-2-2 General Cargoes

The Directorate General of Planning, the Ministry of Public Works and Transport, is forming an overall domestic transportation plan for the period up to 2,000 financed by the World Bank. This plan predicts the future population and income level in each of the 22 areas as well as the domestic movement of goods, by 76 items, and the export and import of goods by computing the demand/supply balance of each item good in each area. This survey is a two-year project undertaken by Systan International Inc., and its results were reported on Sep. 4, 1980.

Table A 6-1-1 and 6-1-2 list consolidated forecast values concerning port cargoes included in the plan. Table A 6-1-3 to 6-1-5 list forecast values consolidated by ports.

These forecast values were established from detailed investigation and their precision is believed to be high. So, they are used here, with only partial modifications, as forecast values on volumes of cargoes.

Iron and steel, paper products, chemical products and machinery are the general goods imported in particularly large quantities. Iron and steel are now imported mostly as finished products but the Government is planning to import ingots and scraps in the future and increase the domestic rolling of steel. Since the GDP/MOPT forecasts (Table 6-2-3) on the import of iron and steel are rather conservative in view of the nation's GDP growth and its per-capita consumption of iron and steel, they are amended as in Fig. 6-2-1. Carton for exporting bananas accounts for about a half of the imported paper products. This is because boxes are needed by 2 lb for every 40 lb of bananas. It is likely that the import of carton will not increase much if, in the future, transporting methods are rationalized or if the domestic production of paper boxes increases.

In the Costa Rica export trade, meanwhile, fertilizer products, coffee and beef are the three important commodities. The export of fertilizers, products manufactured at Fertica from imported raw materials, is unlikely to appreciably increase because, at the moment, there is no plan to extend the existing capacity of the plant of 300,000 tons per year, and because the domestic demand for fertilizers seems likely to increase. The production of coffee, one of the most important exports of Costa Rica, has increased by only a little more than 1% during the past 10 years and its export has increased by a more 0.7% – 0.9% per year and cannot be expected to greatly increase in the future.

### 6-2-3 Cargoes at the Port of Caldera

Table 6-2-4 shows cargo volume at the port of Caldera tabulated by commodity of principal goods after modifying DGP/MOPT forecast values on wheat and iron and steel in accordance with the discussion of the preceding section.

**Table 6-2-1 Wheat Consumption**

Unit: tons

| Year | Wheat Import | Flour Import | | Total | Per Capita (kg/person) | |
|---|---|---|---|---|---|---|
| | | Puntarenas | Limon | | | |
| 1965 | 51 | 24,879 | n.a. | | | |
| 1966 | – | 23,677 | n.a. | | | |
| 1967 | 43,077 | 11,423 | n.a. | | | |
| 1968 | 62,613 | 60 | n.a. | | | |
| 1969 | 77,977 | 220 | 289 | 78,639 | 46.7 | |
| 1970 | 68,006 | 273 | 148 | 68,553 | 39.7 | |
| 1971 | 58,565 | 32 | 146 | 58,796 | 32.7 | |
| 1972 | 66,483 | 56 | 138 | 66,735 | 36.2 | |
| 1973 | 74,753 | 0 | 33 | 74,796 | 39.9 | Average |
| 1974 | 64,566 | 0 | 78 | 64,667 | 33.7 | 38.1 |
| 1975 | 82,717 | 0 | 83 | 82,825 | 42.1 | |
| 1976 | 70,427 | – | – | 70,427 | 34.9 | |
| 1977 | 76,243 | – | – | 76,243 | 36.8 | |

Source: DGP/MOPT
Note: (Total) = (Wheat Import) + 1.3 x (Flour Import)

**Table 6-2-2 Wheat Import Forecast**

| Year | Wheat Import Per Capita (kg/person) | Population | Wheat Import (1000 tons) |
|---|---|---|---|
| 1969–1977 | 38.1 | | |
| 1980 | 39.6 | 2,213,363 | 87.6 |
| 1985 | 42.2 | 2,484,521 | 104.8 |
| 1990 | 45.1 | 2,775,530 | 125.2 |
| 1995 | 48.1 | 3,075,139 | 147.9 |
| 2000 | 51.3 | 3,377,458 | 173.3 |

Fig. 6-2-1 Forecast of Imported Steel

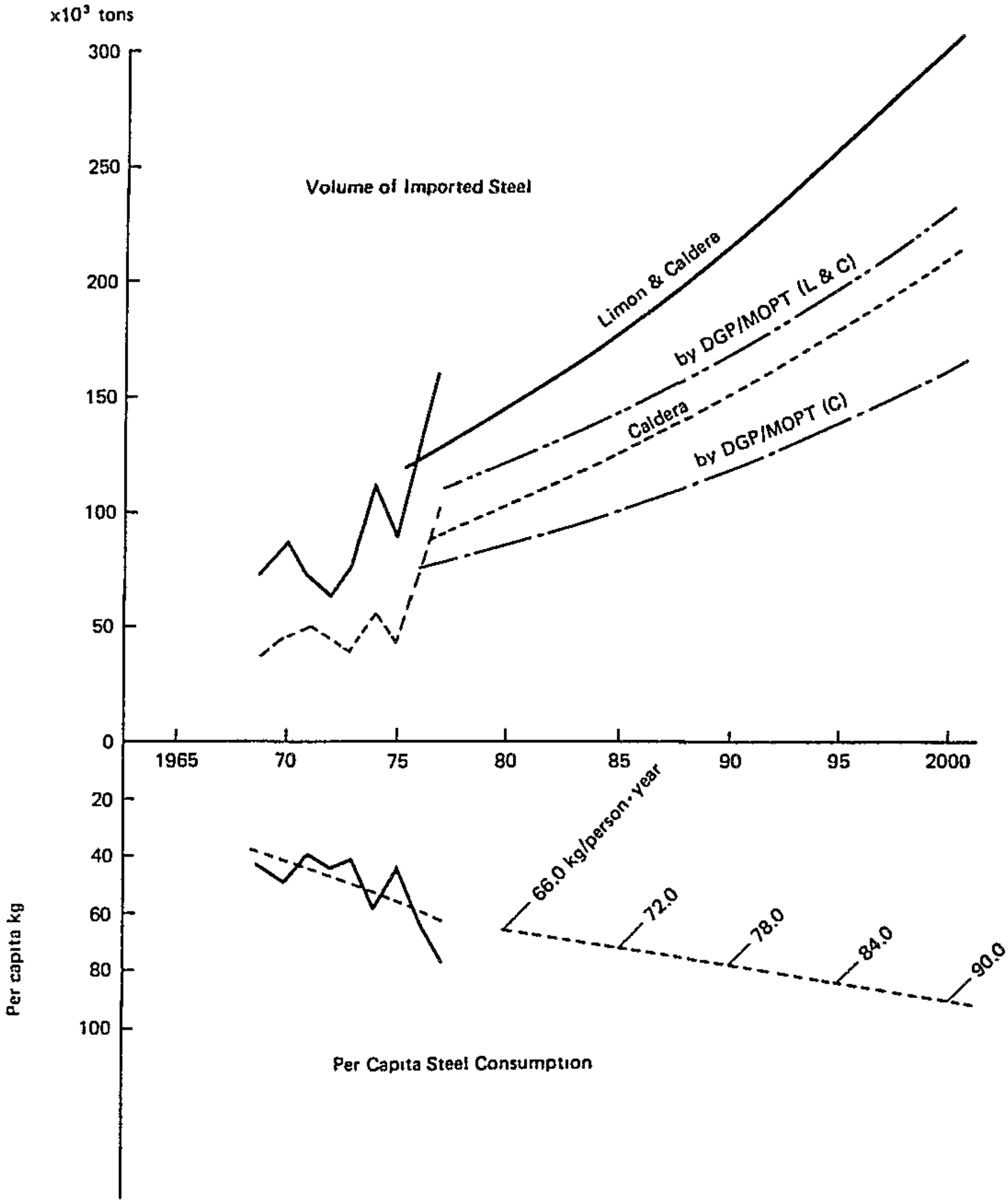


Table 6-2-3 Record and Forecast of Iron & Steel

| Year | Population (1) | Steel Import (2) tons | (2) / (1) kg/person | Import through Puntarenas (Caldera) |
|---|---|---|---|---|
| 1969 | 1,685,170 | 74,435 | 44.2 | |
| 1970 | 1,727,367 | 85,915 | 49.7 | |
| 1972 | 1,797,836 | 71,549 | 39.8 | |
| 1972 | 1,842,831 | 80,875 | 43.9 | |
| 1973 | 1,872,747 | 76,595 | 40.9 | |
| 1974 | 1,921,572 | 111,379 | 58.0 | |
| 1975 | 1,968,438 | 87,182 | 44 3 | |
| 1976 | 2,017,986 | 125,641 | 62.3 | |
| 1977 | 2,070,560 | 157,391 | 76.0 | |
| 1980 | 2,213,363 | 146,100 | 66.0 | 102,300 |
| 1985 | 2,484,521 | 178,900 | 72.0 | 125,200 |
| 1990 | 2,775,530 | 216,500 | 78.0 | 151,600 |
| 1995 | 3,075,139 | 258,300 | 84.0 | 180,800 |
| 2000 | 3,377,458 | 304,000 | 90.0 | 212,800 |

Source: 1969–1977 Cuadros Estadisticos sobre Sector Transportes, DGP/MOPT

Note: The per capita consumption is assumed to increase linearly up to 2000, from 66.0 kg/person at 1980 to 90.0 kg/person at 2000.

## Table 6-2-4 Import and Export of Caldera, 1980–2000

Unit: 1000 M/T

| Import | 1980 | 1985 | 1990 | 1995 | 2000 |
|---|---|---|---|---|---|
| Agricultural products | 8.0 | 15.3 | 19.0 | 23.7 | 29.5 |
| Rubber and its products | 0.9 | 2.5 | 4.2 | 5.5 | 7.0 |
| Paper and its products | 12.5 | 33.3 | 41.8 | 47.6 | 52.6 |
| Fiber, thread and cloth | 4.7 | 7.0 | 7.8 | 9.0 | 10.5 |
| Chemical products | 25.0 | 31.8 | 37.8 | 44.7 | 52.8 |
| Lubricants | 6.9 | 14.2 | 20.3 | 28.5 | 39.6 |
| Fertilizer products | 9.0 | 10.7 | 12.8 | 15.3 | 18.2 |
| Glass and construction materials | 6.8 | 8.2 | 10.5 | 13.9 | 18.5 |
| Machinery | 14.9 | 19.5 | 22.1 | 25.9 | 29.8 |
| Other manufactured products | 9.3 | 12.1 | 16.1 | 23.3 | 33.3 |
| Ingot and scrap | 6.3 | 18.6 | 19.9 | 21.4 | 23.2 |
| Iron and steel | 102.3 | 125.2 | 151.6 | 180.8 | 212.8 |
| Non-ferrous metal products | 2.0 | 3.4 | 4.2 | 5.1 | 6.0 |
| Vehicles | 22.2 | 31.3 | 39.3 | 49.5 | 62.1 |
| Minerals | 4.5 | 5.7 | 7.0 | 8.5 | 10.0 |
| (Total of general cargo) | (235.3) | (338.8) | (414.4) | (502.7) | (605.9) |
| Wheat | 87.6 | 104.8 | 125.2 | 147.9 | 173.3 |
| Beans and corn | 27.0 | 8.0 | 9.0 | 10.0 | 11.0 |
| (Total of grain) | (114.6) | (112.8) | (134.2) | (157.9) | (184.3) |
| Total of Import | 349.9 | 451.6 | 548.6 | 660.6 | 790.2 |

| Export | 1980 | 1985 | 1990 | 1995 | 2000 |
|---|---|---|---|---|---|
| Beef | 6.2 | 6.9 | 7.6 | 10.2 | 13.5 |
| Coffee and cacao | 22.4 | 31.9 | 35.4 | 39.3 | 43.6 |
| Food and animal feeds | 0.6 | 2.4 | 5.7 | 10.8 | 19.9 |
| Fertilizer products | 87.3 | 96.4 | 106.4 | 117.5 | 129.7 |
| Cotton thread & clothing | 0.1 | 16.8 | 19.3 | 22.0 | 24.9 |
| Non-ferrous metal products | 0 | 9.0 | 9.0 | 9.0 | 9.0 |
| Other manufactured products | 0 | 2.0 | 2.8 | 4.0 | 5.7 |
| Total of Export | 116.6 | 165.4 | 186.2 | 212.8 | 246.3 |
| Total of Import and Export | 466.5 | 617.0 | 734.8 | 873.4 | 1,036.5 |

## 6-3 Containerization

### 6-3-1 Current Situation Concerning Containerization on the Pacific Coast of Central America

There are 4 routes and 18 vessels engaged in regular shipping services to the Pacific Coast of Central America in the early 1980s as shown in Table 6-3-1. The routes are Far East/Central-South America, Pacific Coast of North America/Central-South America, Atlantic North America/ Central-South America, and Europe/Central America/Pacific Coast of North America. Of the 18 vessels, 5 are full-container vessels. Since January 1979, the Euro-Pacific Consortium, which operates full-container services between the North American West Coast and Europe, started – under the name of Central America Service – a full container sea route linking also the West Coast of Central America, with calls at Corinto and Acajutra. The other 13 vessels are semi-container or multi-purpose vessels. There are 3 multi-purpose vessels of the Pacific Coast of North America/Central-South America route and 4 semi-container vessels of the Far East/Central-South America route calling at Puntarenas. All of these 7 vessels are operated by the Flota Mercante Grancolombiana.

The container shipping routes between the Port of Puntarenas and the three major container sources of the world – North America, Europe and the Far East – are as follows·

There are two routes between North America and the port of Puntarenas, one being a route on which containers are shipped by full-container or semi-container vessels between North America and the port of Corinto, and by feeder vessels between the port of Corinto and the port of Puntarenas, while another being directly shipped by multi-purpose vessels between North America and the port of Puntarenas. Between Europe and the port of Puntarenas, containers are shipped by full-container vessels between Europe and the port of Corinto and by feeder vessels between the port of Corinto and the port of Puntarenas. Between the Far East and the port of Puntarenas, containers are directly shipped by semi-container vessels. From the port of Corinto, about 80 containers are feeder-serviced twice a month by a smaller vessel or a feeder vessel called "LA BONITA". Overland transporting by trailer trucks is also performed, carrying approx. 1,300 containers of import cargo and approx. 500 export cargo containers in the one year from July 1979. The overland transporting, however, is decreasing due to increased fuel cost.

### 6-3-2 Forecast of container cargo amount at the port of Caldera

By "container cargo amount" in this chapter is meant the amount of container cargo shipped by full-container vessels, semi-container vessels (including multi-purpose vessels) and feeder vessels.

The container cargo amount at the port of Caldera shall be estimated in the following way:

(1) Each item of imported or exported cargo shall be measured in terms of containerization, according to their suitability for containerization and to the opposite country.

(2) For each breakdown, the containerization ratio shall be estimated by year.

(3) The container cargo amount shall be computed from the cargo amount and the containerization ratio by item. The containerization suitability on Table 6-3-2, 6-3-3 shall be classified as follows:

A: Cargo suited for containerization

B: Item containing both cargo suited for containerization and cargo unsuited to containerization

C: Cargo unsuited for containerization

Containerization advancement shall be classified as follows according to the opposite country of trade:

A: Cargo traded mainly with North America, Europe and the Far East;

B: Cargo unable to be classified into A or C;

C: Cargo traded mainly with Central American countries

Thus, the containerization ratio, which is a combination of the above suitability and advancement of containerization shall be estimated as shown on the Table 6-3-4, 6-3-5.
(* Though manufactured fertilizer is exported to Central American countries, approx. 20% of it is assumed to be containerized in the future, being handled at the port of Caldera.)

The container cargo amount is shown on Table 6-3-6, which is computed through multiplying the cargo under Table A6-1-3(a) and (b) by the containerization ratio. Number of containers is the number computed on the assumption that the average weight per container (TEU) is 15 tons.

6-3-3 Prospects for containerization

It is forecast that the container cargo amount handled at the port of Caldera will roughly double by 1985 and triple by 1990 whereas it is 4,600 containers in 1980. Though these are rapid increases as far as the port of Caldera is concerned, they are too small in quantity to affect the containerization of the Central-South America route. For a few years after the opening of the port of Caldera, the current system mainly relying upon semi-container vessels will presumably continue, and the increased container cargoes are to be coped with by increasing loading amount per vessel and number of calling vessels.

In order for full-container vessels to call at the port of Caldera, the following three conditions should be met:

(1) Operation of full-container vessels on the Pacific Coast of Central American route;

(2) Enough amount of cargo for a full-container vessel to call at the Port:

(3) Provisions for container handling facilities

With respect to (1), full-container vessels of the Central America Service on European route have already been operated, container wharves at Central-South American ports have been progressively provided, and amounts of container cargoes are increasing, and full-container vessels on North American route will be operated in a few years. It will take some time (until around 1990) before full-container vessels will replace the currently operated conventional vessels on the Far East route, because its ratio of iron and steel or other cargoes abroad conventional vessels is large.

With respect to (2), it will be around 1985 on the North American route, 1990 – 1995 on the Far East route, and 1995 or later on the European route when 300 TEU per month per route of containers will be handled. On the European route, however, it will be the same time as on the North American route, if the Europe – Central America and the Central America – North America routes are regarded as a route, of the Europe – Central America – North America route combined with the North American route.

With respect to (3), the-11m berth on which container facilities are planned under the First Stage Project of the port of Caldera will be served by a -10m berth for the time being because of ground conditions. Under these conditions, full container vessels in operation by the Central America Service will not be able to use the facilities because they are 1500-container type vessels of -10m draft. Only full container vessels of 750 container type will be able to make use of the -10m berth. According to our hearings with major shipping companies operating liners on the Pacific Coast of Central America route, shipping companies concerned with North America are very aggressive in that they intend to have their container vessels call at the port of Caldera 18 to 24 months after the completion of its container cranes and other container handling facilities under the First Stage Project. Although shipping companies concerned with Europe also have nearly the same plans, those concerned with the Far East do not intend to operate container vessels and will continue their shipping by conventional vessels for the time being due to economical reasons.

Table 6-3-1 Container Vessels in Operation on Pacific Coast of Central America

| Route | Shipping Company | Country | Port of Call | Vessel | G/T | D/W | Container Capacity | Remarks |
|---|---|---|---|---|---|---|---|---|
| North America | Flota Mercante Grancolombiana | Colombia | San Francisco<br>Los Angeles<br>Columbia River<br>Seattle<br>Vancouver<br>San Jose<br>Acajutla<br>Corinto<br>Puntarenas<br>Buenaventura<br>Guayaquil<br>Manta | Ciudad de Cali | 9,715 | 12,193 | TEU 264 | Multi-Purpose Vessel |
| | | | | Ciudad de Ibague | 9,715 | 12,193 | 264 | " |
| | | | | Ciudad de Manta | 9,715 | 11,888 | 264 | " |
| | Lykes Lines | USA | Houston<br>New Orleans<br>Galveston<br>Cartagena<br>Barranquilla<br>Corinto<br>Acajutla<br>Guayaquil<br>Callao<br>Arica<br>Valparaiso<br>San Antonio<br>Matarani<br>Buenaventura | Gulf Merchant | 8,988 | 11,550 | 146 | Semi-Container Vessel |
| | | | | Gulf Shipper | 8,988 | 11,550 | 146 | " |
| | | | | Gulf Trader | 8,988 | 11,550 | 146 | " |
| | | | | Dolly Truman | 10,723 | 14,897 | 138 | " |
| | | | | Mayo Lykes | 7,607 | 10,943 | 138 | " |
| | | | | Ruth Lykes | 10,954 | 14,897 | 138 | " |
| Europe | Central America Service<br>Hapag-Lloyd<br>CGM<br>Incotrans<br>KNSM<br>Royal Mail Line<br>TMM | West Germany<br>France<br>Netherlands<br>Netherlands<br>United Kingdom<br>Mexico | Rotterdam<br>Antwerp<br>Hamburg<br>Bremerhaven<br>Le Havre<br>Liverpool<br>Corinto<br>Acajutla | America Express | 27,393 | 23,417 | 1,416 | Full-Container Vessel |
| | | | | Cordillera Express | 27,939 | 23,051 | 1,416 | " |
| | | | | Incotrans Speed | 29,411 | 26,469 | 1,481 | " |
| | | | | Incotrans Spirit | 29,411 | 26,469 | 1,481 | " |
| | | | | La Fayette | 27,305 | 23,400 | 1,436 | " |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Ear East | Flota Mercante Grancolombiana | Colombia | Yokohama<br>Nagoya<br>Kobe<br>San Jose<br>Acajutla<br>Corinto<br>Puntarenas<br>Buenaventura | Ciudad de Neiva | 11,699 | 12,880 | 215 | Semi-Container Vessel |
| | | | | Ciudad de Santa Marta | 11,693 | 15,000 | 215 | " |
| | | | | Ciudad de Popayan | 11,699 | 15,000 | 215 | " |
| | | | | Ciudad de Quito | 11,945 | 15,649 | 350 | " |

Table 6-3-2 Degree of Containerization (Import)

| No. | Item | Suitability | Advancement |
|---|---|---|---|
| 4 | Fish | A | B |
| 12 | Beans | A | A |
| 21 | Other food products | A | C |
| 23 | Corn (sorgo) | C | A |
| 25 | Other animal feeds | B | C |
| 26 | Processed animal feeds | B | C |
| 28 | Alcoholic beverages | A | A |
| 31 | Cleaginous seeds and nuts | A | C |
| 32 | Rubber | A | C |
| 35 | Waste paper | A | C |
| 37 | Other natural fibers | A | C |
| 39 | Construction raw materials | C | C |
| 40 | Gypsum and Coal | C | B |
| 41 | Other minerals | C | B |
| 42 | Plant, flower and seed | A | B |
| 43 | Chemical products | A | A |
| 51 | Lubricants | C | C |
| 53 | Edible oil | A | C |
| 55 | Manufactured fertilizer | A | A |
| 56 | Tires | A | C |
| 57 | Other rubber products | A | C |
| 58 | Paper and carton | A | A |
| 59 | Paper products | A | A |
| 60 | Threads | A | A |
| 61 | Cloth | A | A |
| 62 | Clothing and leather | A | A |
| 64 | Construction material | B | B |
| 65 | Returned bottle | B | B |
| 67 | Ingots and scrap | C | A |
| 68 | Iron and steel | C | A |
| 69 | Non-ferrous metal pro. | A | A |
| 70 | Glass | A | C |
| 71 | Other manufac. products | A | A |
| 72 | Manufactured metal | A | A |
| 73 | Machinery | B | A |
| 74 | Railway material | B | A |
| 75 | Vehicles | B | A |

Table 6-3-3 Degree of Containerization (Export)

| No. | Item | Suitability | Advancement |
|---|---|---|---|
| 2 | Beef and pork | A | A |
| 20 | Coffee for export | A | A |
| 21 | Other food products | A | C |
| 22 | Cacao | A | C |
| 26 | Processed animal feeds | B | C |
| 36 | Cotton | A | C |
| 55 | Manufactured fertilizer | A | C |
| 60 | Thread | A | C |
| 62 | Clothing and leather | A | C |
| 69 | Non-ferrous metal pro. | A | C |
| 71 | Other manufac. products | A | C |
| 72 | Manufactured metal | A | C |
| 73 | Machinery | B | C |

Table 6-3-4 Containerization Ratio (Import)

%

| Suitability | Advancement | 1980 | 1985 | 1990 | 1995 | 2000 |
|---|---|---|---|---|---|---|
| A | A | 80 | 90 | 95 | 95 | 95 |
| A | B, C | 10 | 20 | 30 | 40 | 50 |
| B | A, B, C | 5 | 10 | 10 | 10 | 10 |
| C | A, B, C | 0 | 0 | 0 | 0 | 0 |

Table 6-3-5 Containerization Ratio (Export)

%

| Suitability | Advancement | 1980 | 1985 | 1990 | 1995 | 2000 |
|---|---|---|---|---|---|---|
| A | A | 30 | 90 | 95 | 95 | 95 |
| A | C | 5 | 10* | 20* | 20* | 20* |
| B | C | 0 | 5 | 10 | 10 | 10 |
| C | A, C | 0 | 0 | 0 | 0 | 0 |

(* Though manufactured fertilizer is exported to Central-South American countries, approx. 20% of it is assumed to be containerized in future being handled at port of Caldera.)

Table 6-3-6 Amount of Container Cargoes

| | | 1980 | 1985 | 1990 | 1995 | 2000 |
|---|---|---|---|---|---|---|
| Import | Volume (1,000 t) | 56.2 | 102.3 | 134.7 | 165.9 | 204.5 |
| | Number (TEU) | 3750 | 6820 | 8980 | 11060 | 13640 |
| Export | Volume (1,000 t) | 12.7 | 46.2 | 67.8 | 77.6 | 89.6 |
| | Number (TEU) | 850 | 3080 | 4520 | 5180 | 5980 |
| Total | Volume (1,000 t) | 68.9 | 148.5 | 202.5 | 243.5 | 294.1 |
| | Number (TEU) | 4600 | 9900 | 13500 | 16240 | 19620 |

Table A 6-1-1 Forecast of General Cargo Volume Import (Limón, Golfito and Puntarenas)

Unit: 1000 M/T

| No. | Name | 1980 | 1985 | 1990 | 1995 | 2000 |
|---|---|---|---|---|---|---|
| 4 | Fish | 0.6 | 0.6 | 0.8 | 0.8 | 0.8 |
| 11 | Corn (maiz) | 3.2 | 0.0 | 0.0 | 0.0 | 0.0 |
| 12 | Beans | 13.3 | 15.5 | 17.5 | 19.1 | 21.5 |
| 13 | Fruit and vegetable | 1.6 | 1.7 | 1.9 | 2.1 | 2.3 |
| 21 | Other food products | 23.9 | 32.3 | 38.5 | 46.4 | 56.3 |
| 23 | Corn (Sorgo) | 20.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 24 | Oleaginous cake, etc. | 10.1 | 10.0 | 13.1 | 16.9 | 21.7 |
| 25 | Other animal feeds | 1.0 | 1.3 | 1.6 | 1.9 | 2.3 |
| 26 | Processed animal feeds | 0.6 | 0.4 | 0.2 | 0.1 | 0.0 |
| 28 | Alcoholic beverages | 1.8 | 2.2 | 2.6 | 3.0 | 3.6 |
| 31 | Oleag. seeds and nuts | 0.2 | 0.2 | 0.3 | 0.3 | 0.4 |
| 32 | Rubber | 3.7 | 6.4 | 10.8 | 12.7 | 15.3 |
| 35 | Waste paper | 3.4 | 3.5 | 4.0 | 5.9 | 5.9 |
| 37 | Other natural fibers | 4.0 | 4.8 | 5.2 | 5.9 | 6.6 |
| 39 | Construction raw materials | 3.4 | 4.3 | 5.6 | 7.1 | 9.0 |
| 40 | Gypsum and Coal | 0.7 | 1.0 | 1.4 | 1.9 | 2.5 |
| 41 | Other minerals | 19.1 | 35.9 | 46.3 | 56.4 | 67.8 |
| 42 | Plant, flower and seed | 0.9 | 1.1 | 1.2 | 1.4 | 1.5 |
| 43 | Chemical products | 100.4 | 115.0 | 135.7 | 159.9 | 188.3 |
| 50 | Asphalt products | 0.4 | 0.6 | 0.6 | 0.7 | 0.8 |
| 51 | Lubricants | 21.9 | 33.8 | 45.9 | 62.3 | 84.4 |
| 53 | Edible oil | 12.3 | 3.4 | 3.8 | 4.3 | 4.9 |
| 55 | Manufac. fertilizer | 72.5 | 78.6 | 85.7 | 94.3 | 104.4 |
| 56 | Tires | 0.7 | 1.2 | 1.5 | 1.8 | 2.4 |
| 57 | Other rubber product | 1.6 | 1.9 | 2.2 | 2.5 | 2.8 |
| 58 | Paper and carton | 117.7 | 164.6 | 194.0 | 210.9 | 230.7 |
| 59 | Paper products | 2.7 | 5.0 | 6.6 | 6.6 | 6 6 |
| 60 | Threads | 3.3 | 5.0 | 5.7 | 6.6 | 7.7 |
| 61 | Cloths | 3.9 | 4.6 | 5.4 | 6.1 | 7.0 |
| 62 | Clothing and leather | 0.1 | 0.1 | 0.2 | 0.5 | 0.2 |
| 64 | Construction materials | 4.0 | 5.5 | 7.6 | 10.1 | 13.6 |
| 65 | Returned bottle | 1.8 | 0.2 | 0.3 | 0.4 | 0.5 |
| 67 | Ingot and scrap | 52.7 | 71.9 | 82.9 | 95.7 | 110.9 |
| 68 | Iron and steel | 120.5 | 142.9 | 168.2 | 198.0 | 232.2 |
| 69 | Non-ferrous metal | 5.3 | 7.2 | 8.7 | 10.5 | 12.5 |
| 70 | Glass | 8.3 | 9.9 | 11.5 | 15.7 | 21.6 |
| 71 | Other manufac. prod. | 19.7 | 23.9 | 29.1 | 36.8 | 47.8 |
| 72 | Manufactured metal | 15.1 | 18.4 | 24.1 | 35.8 | 52.1 |
| 73 | Machinery | 38.5 | 45.3 | 50.5 | 59.1 | 67.9 |
| 74 | Railway material | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 |
| 75 | Vehicles | 36.3 | 47.0 | 58.9 | 74.2 | 93.1 |
| 76 | Non-metallic furniture | 0.0 | 0.0 | 0.0 | 0.1 | 0.1 |
| | Total | 753.2 | 909.2 | 1082.1 | 1276.8 | 1512.0 |
| 7 | Wheat | 101.3 | 113.7 | 127.0 | 140.7 | 154.6 |
| 38 | Fertilizer material | 182.2 | 208.1 | 237.3 | 271.5 | 311.2 |
| 44 | Crude oil | 490.0 | 684.0 | 969.0 | 969.0 | 969.0 |
| 45 | Diesel oil, etc. | 416.3 | 438.1 | 477.3 | 722.2 | 1035.3 |
| 47 | Bunker | 0.0 | 0.0 | 0.0 | 139.2 | 325 4 |
| 49 | Gasoline for aviation | 7.0 | 8.0 | 9.0 | 9.5 | 10.0 |
| 52 | Liquid gas | 8.2 | 11.8 | 17.4 | 24.5 | 34.0 |

Source: DGP/MOPT

## Table A 6-1-2 Forecast of General Cargo Volume Export (Limón, Golfito and Puntarenas)

Unit 1000 M/T

| No. | Name | 1980 | 1985 | 1990 | 1995 | 2000 |
|---|---|---|---|---|---|---|
| 2 | Beef and pork | 36.2 | 40.2 | 44.7 | 59.9 | 79.2 |
| 4 | Fish | 2.0 | 3.0 | 5.0 | 6.6 | 8.2 |
| 10 | Rice | 20.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 13 | Fruit and vegetable | 14.6 | 16 1 | 17.8 | 19.6 | 21.6 |
| 20 | Coffee | 70.4 | 84.4 | 93.2 | 102.9 | 113.6 |
| 21 | Other food products | 25.0 | 35.1 | 49.4 | 69.2 | 97.9 |
| 22 | Cacao | 4.7 | 6.5 | 7.8 | 9.3 | 11.0 |
| 26 | Processed animal feeds | 0.2 | 0.3 | 0.4 | 0.6 | 0.8 |
| 31 | Oleaginous seeds and nuts | 10.0 | 12.5 | 15.0 | 17.5 | 20.0 |
| 35 | Waste paper | 5.3 | 5.4 | 6 0 | 9 1 | 9.1 |
| 36 | Cotton | 0.0 | 16.6 | 19.0 | 21.6 | 24.5 |
| 37 | Other natural fibers | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 |
| 42 | Plant, flower and seed | 1.1 | 1.4 | 1.9 | 2.3 | 3.1 |
| 43 | Chemical products | 1.1 | 3.1 | 4 8 | 8.1 | 12.1 |
| 55 | Manufac. fertilizer | 87.5 | 96.6 | 106.6 | 117.7 | 129.9 |
| 59 | Paper products | 0.9 | 1.8 | 3.6 | 4.2 | 4.2 |
| 60 | Thread | 0.2 | 0.3 | 0.5 | 0 7 | 0.8 |
| 61 | Cloth | 0.1 | 0.1 | 0 1 | 0.2 | 0.2 |
| 62 | Clothing and leather | 1.5 | 2.3 | 2.3 | 2.6 | 2.5 |
| 64 | Construction material | 0.1 | 0.2 | 0.2 | 0.2 | 0.3 |
| 69 | Non-ferrous metal | 0.0 | 9.0 | 9.0 | 9.0 | 9.0 |
| 71 | Other manufac. prod. | 9.9 | 11.6 | 11.8 | 12.6 | 14.0 |
| 72 | Manufactured metal | 0.5 | 2.4 | 4.9 | 8.5 | 13.4 |
| 73 | Machinery | 1.0 | 1.4 | 1.8 | 2.8 | 4.2 |
| 76 | Non-metallic furniture | 0.1 | 0.3 | 0.5 | 0.7 | 1.2 |
| | Total | 292 5 | 350.7 | 406 4 | 486 0 | 580.9 |
| 14 | Banana | 995 2 | 1310 2 | 1495.6 | 1583.6 | 1670.0 |
| 16 | Sugar | 66.4 | 73.9 | 82 5 | 91.9 | 104.7 |
| 63 | Cement | 100.0 | 126.0 | 223.0 | 74.0 | 0.0 |

Table A 6-1-3(a) Forecast of General Cargo Volume

Puntarenas/Caldera Import

Unit: 1000 M/T

| No. | Name | 1980 | 1985 | 1990 | 1995 | 2000 |
|---|---|---|---|---|---|---|
| 4 | Fish | 0.3 | 0.3 | 0.4 | 0.4 | 0.4 |
| 12 | Beans | 7.0 | 8.0 | 9.0 | 10.0 | 11.0 |
| 21 | Other food products | 5.4 | 11.5 | 14.7 | 18.8 | 23.9 |
| 23 | Corn (sorgo) | 20.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 25 | Other animal feeds | 0.4 | 0.5 | 0.6 | 0.7 | 0.8 |
| 26 | Processed animal feeds | 0.1 | 0.0 | 0.0 | 0.0 | 0.0 |
| 28 | Alcoholic beverages | 0.9 | 1.1 | 1.3 | 1.5 | 1.8 |
| 31 | Oleaginous seeds and nuts | 0.1 | 0.1 | 0.1 | 0.1 | 0.2 |
| 32 | Rubber | 0.3 | 1.5 | 3.0 | 4.0 | 5.0 |
| 35 | Waste paper | 2.3 | 2.4 | 2.7 | 4.0 | 4.0 |
| 37 | Other natural fibers | 2.0 | 2.7 | 2.9 | 3.3 | 3.7 |
| 39 | Construction raw materials | 2.1 | 2.6 | 3.4 | 4.3 | 5.4 |
| 40 | Gysum and coal | 0.5 | 0.7 | 1.0 | 1.5 | 2.0 |
| 41 | Other minerals | 4.0 | 5.0 | 6.0 | 7.0 | 8.0 |
| 42 | Plant, flower and seed | 0.3 | 0.4 | 0.4 | 0.5 | 0.5 |
| 43 | Chemical products | 25.0 | 31.8 | 37.8 | 44.7 | 52.8 |
| 51 | Lubricants | 6.9 | 14.2 | 20.3 | 28.5 | 39.6 |
| 53 | Edible oil | 0.5 | 1.4 | 1.5 | 1.7 | 1.9 |
| 55 | Manufactured fertilizer | 9.0 | 10.7 | 12.8 | 15.3 | 18.2 |
| 56 | Tires | 0.4 | 0.7 | 0.9 | 1.1 | 1.5 |
| 57 | Other rubber products | 0.2 | 0.3 | 0.3 | 0.4 | 0.5 |
| 58 | Paper and carton | 9.6 | 28.6 | 36.1 | 40.6 | 45.6 |
| 59 | Paper products | 0.6 | 2.3 | 3.0 | 3.0 | 3.0 |
| 60 | Threads | 1.9 | 3.4 | 3.8 | 4.4 | 5.2 |
| 61 | Cloth | 0.8 | 0.9 | 1.1 | 1.2 | 1.5 |
| 62 | Clothing and leather | 0.0 | 0.0 | 0.0 | 0.1 | 0.1 |
| 64 | Construction material | 1.0 | 1.4 | 2.1 | 2.8 | 3.8 |
| 65 | Returned bottle | 0.2 | 0.0 | 0.1 | 0.1 | 0.1 |
| 67 | Ingots and scrap | 6.3 | 18.6 | 19.9 | 21.4 | 23.2 |
| 68 | Iron and steel | 101.1 | 120.1 | 141.4 | 166.4 | 195.2 |
| 69 | Non-ferrous metal pro | 2.0 | 3.4 | 4.2 | 5.1 | 6.0 |
| 70 | Glass | 3.5 | 4.2 | 4.9 | 6.7 | 9.2 |
| 71 | Other manufac. products | 3.8 | 5.5 | 7.5 | 10.6 | 14.9 |
| 72 | Manufactured metal | 5.3 | 6.4 | 8.4 | 12.5 | 18.2 |
| 73 | Machinery | 14.9 | 19.5 | 22.1 | 25.9 | 29.8 |
| 74 | Railway material | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 |
| 75 | Vehicles | 22.2 | 31.3 | 39.3 | 49.5 | 62.1 |
| | Total | 261.1 | 341.7 | 413.2 | 498.3 | 599.3 |

Table A 6-1-3(b) Forecast of General Cargo Volume

Puntarenas/Caldera Export

Unit: 1000 M/T

| No. | Name | 1980 | 1985 | 1990 | 1995 | 2000 |
|---|---|---|---|---|---|---|
| 2 | Beef and pork | 6.2 | 6.9 | 7.6 | 10.2 | 13.5 |
| 20 | Coffee for export | 21.2 | 30.2 | 33.3 | 36.8 | 40.6 |
| 21 | Other food products | 0.5 | 2.3 | 5.6 | 10.6 | 19.6 |
| 22 | Cacao | 1.2 | 1.7 | 2.1 | 2.5 | 3.0 |
| 26 | Processed animal feeds | 0.1 | 0.1 | 0.1 | 0.2 | 0.3 |
| 36 | Cotton | 0.0 | 16.6 | 19.0 | 21.6 | 24.5 |
| 55 | Manufactured fertilizer | 87.3 | 96.4 | 106.4 | 117.5 | 129.7 |
| 60 | Thread | 0.0 | 0.1 | 0.2 | 0.3 | 0.3 |
| 62 | Clothing and leather | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 |
| 69 | Non-ferrous metal pro. | 0.0 | 9.0 | 9.0 | 9.0 | 9.0 |
| 71 | Other manufac. products | 0.0 | 1.3 | 1.4 | 1.5 | 1.8 |
| 72 | Manufactured metal | 0.0 | 0.5 | 1.0 | 1.7 | 2.7 |
| 73 | Machinery | 0.0 | 0.2 | 0.4 | 0.8 | 1.2 |
| | Total | 116.6 | 165.4 | 186.2 | 212.8 | 246.3 |

Table A 6-1-4(a) Forecast of General Cargo Volume

**Limón** Import

| No. | Name | 1980 | 1985 | 1990 | 1995 | 2000 |
|---|---|---|---|---|---|---|
| 4 | Fish | 0.3 | 0.3 | 0.4 | 0.4 | 0.4 |
| 11 | Corn | 3.2 | 0.0 | 0.0 | 0.0 | 0.0 |
| 12 | Beans | 6.3 | 7.5 | 8.5 | 9.1 | 10.5 |
| 13 | Fruit and Vegetable | 1.6 | 1.7 | 1.9 | 2.1 | 2.3 |
| 21 | Other food products | 18.5 | 20.8 | 23.8 | 27.6 | 32.0 |
| 24 | Oleagi. cake and flour | 10.1 | 10.0 | 13.1 | 16.9 | 21.7 |
| 25 | Other animal feeds | 0.6 | 0.8 | 1.0 | 1.2 | 1.5 |
| 26 | Processed animal feeds | 0.5 | 0 4 | 0.2 | 0.1 | 0 0 |
| 28 | Alcoholic beverages | 0.9 | 1.1 | 1.3 | 1.5 | 1.8 |
| 31 | Oleaginous seeds and nuts | 0.1 | 0.1 | 0.2 | 0.2 | 0.2 |
| 32 | Rubber | 3.4 | 4.9 | 7.8 | 8.7 | 10.3 |
| 35 | Waste paper | 1.1 | 1.1 | 1.3 | 1.9 | 1.9 |
| 37 | Other natural fibers | 2.0 | 2.1 | 2.3 | 2.6 | 2.9 |
| 39 | Construction raw materials | 1.3 | 1.7 | 2.2 | 2.8 | 3.6 |
| 40 | Gypsum and Coal | 0.2 | 0.3 | 0.4 | 0.4 | 0.5 |
| 41 | Other minerals | 15.1 | 30.9 | 40.3 | 49.4 | 59.8 |
| 42 | Plant, flower and seed | 0.6 | 0.7 | 0.8 | 0 9 | 1.0 |
| 43 | Chemical products | 74.7 | 82.4 | 96.9 | 113.7 | 133.0 |
| 50 | Asphalt products | 0.4 | 0.6 | 0.6 | 0.7 | 0.8 |
| 51 | Lubricants | 13.2 | 17.7 | 23.6 | 31.5 | 42.3 |
| 53 | Edible oil | 11.8 | 2 0 | 2.3 | 2.6 | 3.0 |
| 55 | Manufactured fertilizer | 53.2 | 57.6 | 62.6 | 68 7 | 75.9 |
| 56 | Tires | 0.3 | 0 5 | 0.6 | 0.7 | 0.9 |
| 57 | Other rubber products | 1.4 | 1.6 | 1.9 | 2 1 | 2.3 |
| 58 | Paper and carton | 85.0 | 112.9 | 134.8 | 147.2 | 162.0 |
| 59 | Paper products | 2.1 | 2.7 | 3.6 | 3.6 | 3.6 |
| 60 | Threads | 1.4 | 1.6 | 1.9 | 2.2 | 2.5 |
| 61 | Cloth | 3.1 | 3.7 | 4.3 | 4 9 | 5.5 |
| 62 | Clothing and leather | 0.1 | 0.1 | 0.2 | 0.4 | 0.1 |
| 64 | Construction materials | 3.0 | 4.1 | 5.5 | 7.3 | 9.8 |
| 65 | Returned bottle | 1.6 | 0.2 | 0.2 | 0.3 | 0.4 |
| 67 | Ingots and scrap | 46 4 | 53.3 | 63.0 | 74.3 | 87.0 |
| 68 | Iron and steel | 19.1 | 22.4 | 26.4 | 31.1 | 36.5 |
| 69 | Non-ferrous metal products | 3.3 | 3.8 | 4.5 | 5.4 | 6.5 |
| 70 | Glass | 4.8 | 5.7 | 6.6 | 9.0 | 12.4 |
| 71 | Other manufactured products | 15.7 | 18.2 | 21.3 | 25.8 | 32.4 |
| 72 | Manufactured metal | 9.8 | 12 0 | 15.7 | 23.3 | 33.9 |
| 73 | Machinery | 23.4 | 25.6 | 28.1 | 32.9 | 37.7 |
| 74 | Material | 1.8 | 1.8 | 1.8 | 1.8 | 1.8 |
| 75 | Vehicles | 14 1 | 15 7 | 19.6 | 24.7 | 31.0 |
| 76 | Non-metalic furniture | 0.0 | 0.0 | 0.0 | 0.1 | 0.1 |
| | Total | 455.5 | 530.6 | 631.5 | 740 1 | 873.4 |

## Table A 6-1-4(b) Forecast of General Cargo Volume

**Limón** **Export**

Unit: 1000 M/T

| No. | Name | 1980 | 1985 | 1990 | 1995 | 2000 |
|---|---|---|---|---|---|---|
| 2 | Beef and pork | 30.0 | 33.3 | 37.1 | 49.7 | 65.7 |
| 4 | Fish | 2.0 | 3.0 | 5.0 | 6.6 | 8.2 |
| 10 | Rice | 20.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 13 | Fruit and vegetable | 14.6 | 16.1 | 17.8 | 19.6 | 21.6 |
| 20 | Coffee | 48.9 | 53.9 | 59.6 | 65.8 | 72.6 |
| 21 | Other food products | 24.5 | 32.8 | 43.8 | 58.6 | 78.3 |
| 22 | Cacao | 3.5 | 4.8 | 5.7 | 6.8 | 8.0 |
| 26 | Processed animal feeds | 0.1 | 0.2 | 0.3 | 0.4 | 0.5 |
| 35 | Waste paper | 4.5 | 4.6 | 5.2 | 8.3 | 8.3 |
| 37 | Other natural fibers | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 |
| 42 | Plant, flower and seed | 1.1 | 1.4 | 1.9 | 2.3 | 3.1 |
| 43 | Chemical products | 1.1 | 3.1 | 4.8 | 8.1 | 12.1 |
| 55 | Manufactured fertilizer | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 |
| 59 | Paper products | 0.3 | 0.6 | 1.2 | 1.4 | 1.4 |
| 60 | Threads | 0.2 | 0.2 | 0.3 | 0.4 | 0.5 |
| 61 | Cloth | 0.1 | 0.1 | 0.1 | 0.2 | 0.2 |
| 62 | Clothing and leather | 1.4 | 2.2 | 2.2 | 2.5 | 2.4 |
| 64 | Construction material | 0.1 | 0.2 | 0.2 | 0.2 | 0.3 |
| 71 | Other manufactured products | 9.9 | 10.3 | 10.4 | 11.1 | 12.2 |
| 72 | Manufactured metal | 0.5 | 1.9 | 3.9 | 6.8 | 10.7 |
| 73 | Machinery | 1.0 | 1.2 | 1.4 | 2.0 | 3.0 |
| 76 | Non-metalic furniture | 0.1 | 0.3 | 0.5 | 0.7 | 1.2 |
| | Total | 164.2 | 170.5 | 201.7 | 251.8 | 310.6 |

## Table A 6-1-5 Forecast of General Cargo Volume

**Golfito** **Import**

Unit: 1000 M/T

| No. | Name | 1980 | 1985 | 1990 | 1995 | 2000 |
|---|---|---|---|---|---|---|
| 43 | Chemical products | 0.7 | 0.8 | 1.0 | 1.5 | 2.0 |
| 51 | Lubricants | 1 8 | 1.9 | 2.0 | 2.2 | 2.5 |
| 55 | Manufactured fertilizer | 10.3 | 10.3 | 10.3 | 10.3 | 10.3 |
| 58 | Paper and carton | 23.1 | 23.1 | 23.1 | 23.1 | 23.1 |
| 68 | Iron and steel | 0.3 | 0.4 | 0.4 | 0.5 | 0.5 |
| 71 | Other manufac. prod. | 0.2 | 0.2 | 0.3 | 0.4 | 0.5 |
| 73 | Machinery | 0.2 | 0.2 | 0.3 | 0.3 | 0.4 |
| | Total | 36.6 | 36.9 | 37.4 | 38.3 | 39.3 |

**Export**

| No. | Name | 1980 | 1985 | 1990 | 1995 | 2000 |
|---|---|---|---|---|---|---|
| 20 | Coffee | 0.3 | 0.3 | 0.3 | 0.3 | 0.4 |
| 31 | Oleag. seeds and nuts | 10.0 | 12.5 | 15.0 | 17.5 | 20.0 |
| 35 | Waste paper | 0.8 | 0.8 | 0 8 | 0.8 | 0.8 |
| 59 | Paper products | 0.6 | 1.2 | 2.4 | 2.8 | 2.8 |
| | Total | 11.7 | 14.8 | 18.5 | 21.4 | 24.0 |

# CHAPTER 7
# SIMULATION STUDY ON THE NUMBER AND THE CONSTRUCTION TIMING OF REQUIRED BERTHS

# CHAPTER 7 SIMULATION STUDY ON THE NUMBER AND THE CONSTRUCTION TIMING OF REQUIRED BERTHS

## 7-1 Application of Queuing Theory to Ports

Ships having entered a port, berth in their designated berths according to the order to arrival for cargo handling. But if these berths are occupied, ships have to wait until ships having arrived earlier leave their berths. This phenomenon of ships arriving and leaving a port can be applied to queuing theory, as can similarly the situation at problem similar to that a bank, where variables include the number of windows and the time each customer takes at the windows. Using this example of a bank, if the arrival of customers, the number of windows and the service time for customers at the windows are compared respectively to the arrival of ships, the number of berths and the berthing time by ships, the model of ship arrivals and departures at a port is, basically, the same as the model used for the phenomenon of window service at a bank, etc. Yet, in spite of this similarity between ships waiting at a port and the above phenomenon at a bank, etc., a queuing theory unique to ports must be developed for two reasons: the difference between the arrival of customers and the arrival of ships, and the difference between the service time for customers by clerks and the berthing time by ships. To this end, the pattern of ship entries and the pattern of the berthing time must be found out. Great efforts are being exerted to clarify these patterns at ports. As to the pattern of ship entries, normally it is random for other than container ships and ferry boats for which regular service is available; Poisson arrivals, namely, entry time intervals are often of exponential distribution in Japan as in other countries.

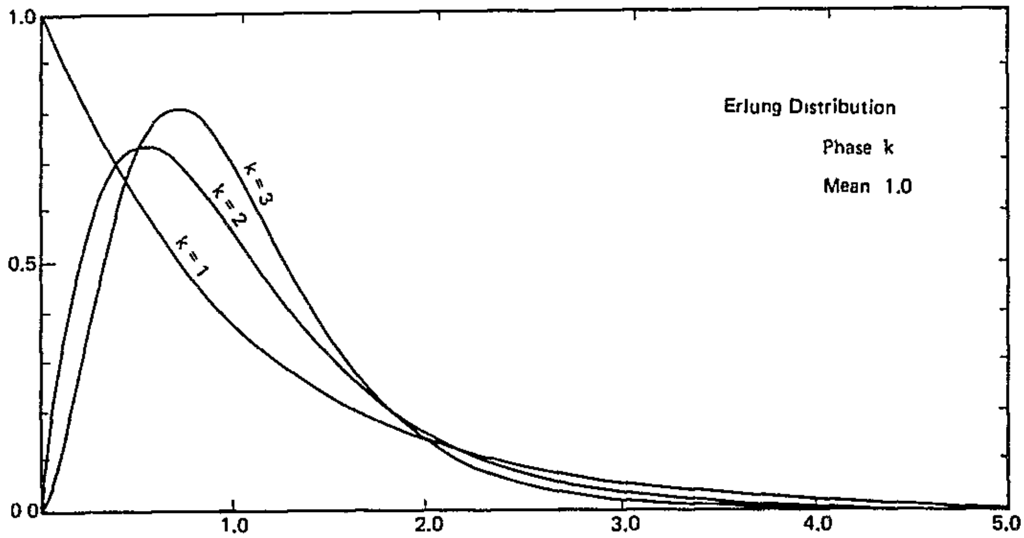
In the pattern of the berthing time by ships, normally there is one peak expressed by a histogram that is rather on the left side and it often conforms to the Erlung distribution in Phase 2 or Phase 3. (See Fig. 7-1-1)

As is known, already the following four factors are indispensable to the determination of the queuing phenomenon:

1 Distribution of arrivals of customers to be served
2 Distribution of service times
3 Number of service windows
4 Methods of service

Factor 4 concerns such matters as service in the order of arrival or preferential service. Normally, service in the order of arrival predominates but, in the case of a port, preferential service is considered for full-container ships.

Fig. 7-1-1 The Erlung Distribution




## 7-2 Analysis of Present Condition

In this chapter, a study of the number of required berths and construction time for the second project at the Port of Caldera has been carried out by means of simulation tests. Preceding this, an analysis of the current conditions at the Port of Puntarenas is presented.

### 7-2-1 Ships Analyzed in the Study

Ships analyzed in the study are those having used the Port of Puntarenas from January, 1979 to May, 1980. The number of ships which entered the prot during this period (517 days) was a total of 323 which 82.9% were general cargo vessels, 11.6%, semi-container vessels, and 5.5% bulk carriers. Analysis of these kind of ships were made by identifying ships' name from the Lloyd's Register of Shipping (1979 – 1980).

### 7-2-2 Waiting Time

The average waiting time for ships entering the Port of Puntarenas was 47.2 hours, this being divided into 47.3 hours for general cargo vessels, 123.7 hours for bulk carriers and 34.1 hours for semi-container vessels. The maximum waiting time was 320 hours for all vessels and 310 hours for general cargo vessels. From these figures, it is clear that the Port of Puntarenas has been used to full capacity.

### 7-2-3 Arrival Distribution

Fig. 7-2-1 and Fig. 7-2-2 show the distribution of vessels which entered the Port of Puntarenas during this period, respectively for all vessels and general cargo vessels.

In the figure, the full line shows the distribution of actual arrivals and the dotted line shows the theoretical Poisson's distribution. As seen from the figure, the actual line and the theoretical line are very closely matched. Arrival of ships at a port is supposed to be in accordance with the

Fig. 7-2-1 Distribution of Ship Arrival (all ships)

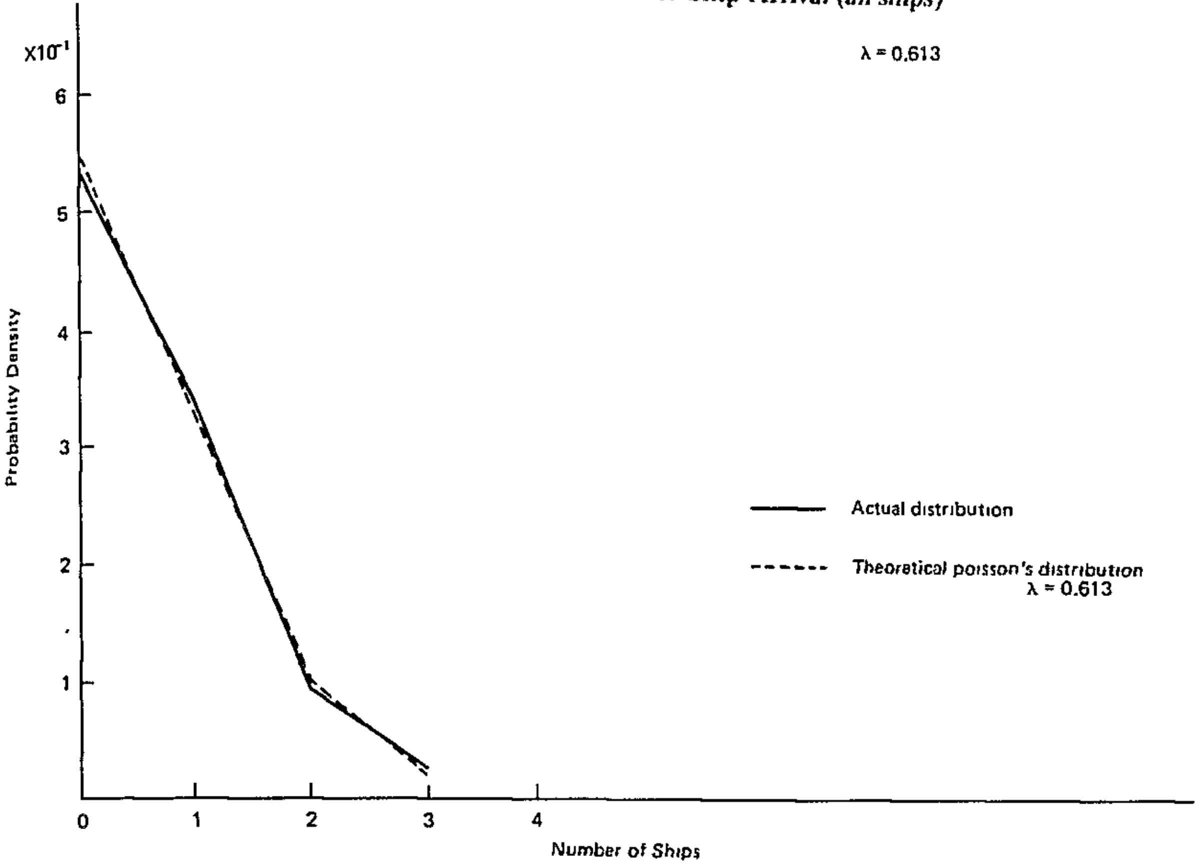
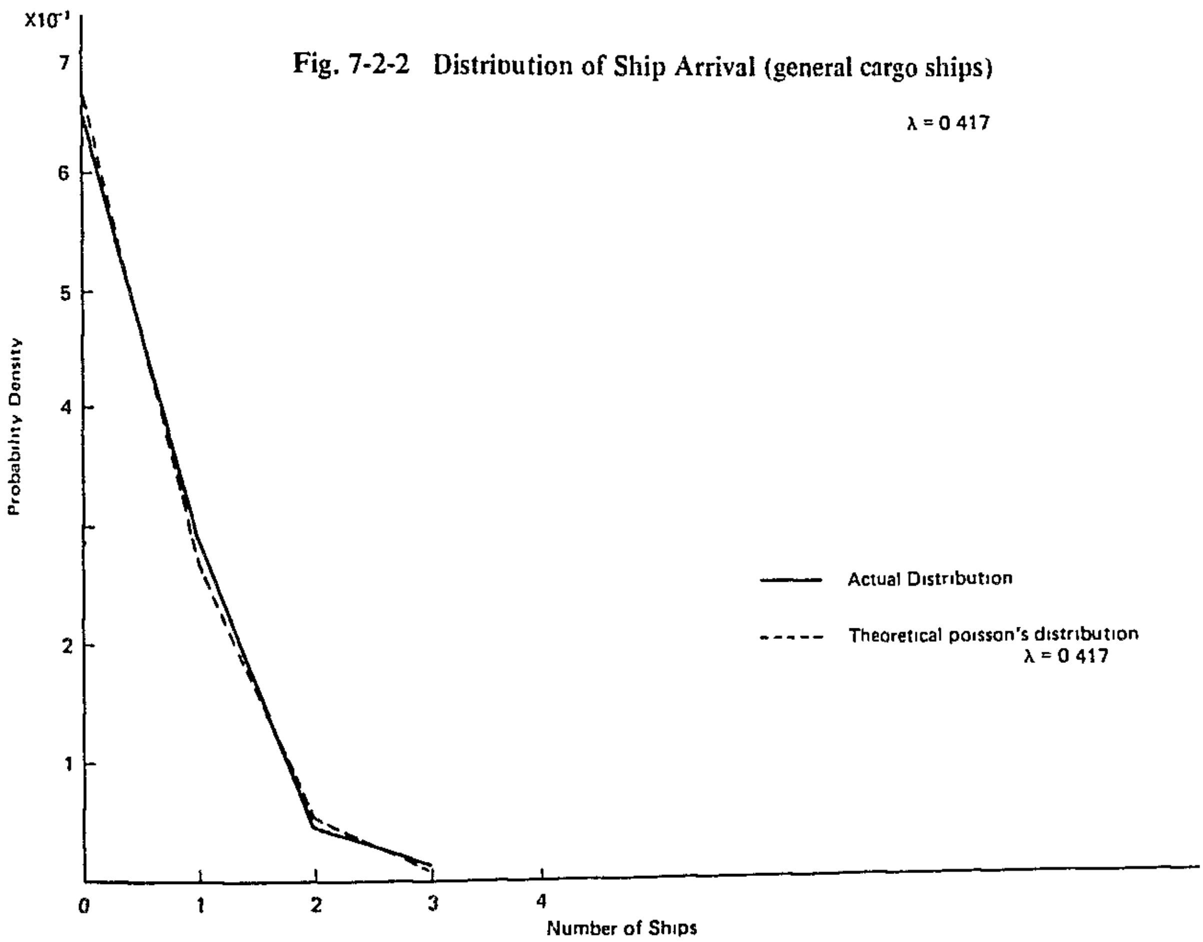



Fig. 7-2-2 Distribution of Ship Arrival (general cargo ships)



Poisson's distribution and this clearly applies to the case of the Port of Puntarenas.

Therefore, in simulation testing, Poisson's distribution can be used to approximate the actual arrival distribution for the Port of Caldera.

### 7-2-4 Record of Berthing Hours

There are three types of ships (general cargo vessels, semi-container vessels and bulk carriers) presently entering the Port of Puntarenas. The berthing hours by type and site of ships are as follows.

| | mean | min. | max. |
|---|---|---|---|
| (1) General cargo vessels | | | |
| ~ 5,000 DWT | 48.9 h | 5 h | 120 h |
| 5,000 ~ 10,000 DWT | 55.5 h | 15 h | 185 h |
| 10,000 ~ 15,000 DWT | 66.9 h | 15 h | 185 h |
| 15,000 DWT ~ | 177.1 h | 30 h | 325 h |
| ② Semi-container vessels | | | |
| 5,000 ~ 10,000 DWT | 43.3 h | 35 h | 60 h |
| 10,000 ~ 15,000 DWT | 49.3 h | 40 h | 65 h |
| (3) Bulk carriers | | | |
| 10,000 ~ 15,000 DWT | 385.5 h | 350 h | 425 h |
| 15,000 DWT ~ | 352 h | 20 h | 600 h |

From the above can be seen that the larger the ship is, the longer the berthing hours will be, showing tha the cargo loaded or unloaded per ship is estimated to be larger.

### 7-2-5 Distribution of Berthing Hours

Fig. 7-2-3 shows the distribution of berthing hours for general cargo vessels.

As can be seen from the figure, the peak is close to the left (30 h) and it almost resembles the so called Erlung distribution. Therefore, in the simulation test, the berthing time distribution for general cargo vessels at the Port of Caldera may appropriately use the Erlung distribution as well.

Figs. 7-2-4 ~ 7-2-7 show berthing time distributions of bulk carriers and semi-container vessels. As can be seen from the figures, there is no peak, but only a sporadic regular distribution is shown, which is different from that of general cargo vessels.

Therefore, in the simulation test, the berthing time distribution for bulk carriers and semi-container vessels at the Port of Caldera may use a regular distribution as well.

### 7-2-6 Others

Figs. A 7-2-1 ~ 7-2-16 show, besides the above, cargo handling time distribution, waiting time distribution, port staying time distribution, offshore cargo handling time distribution, unloading tonnage distribution, loading tonnage distribution, total tonnage distribution and ship size (DWT) distribution.

Fig. 7-2-3 Distribution of Berthing Time (general cargo ships)

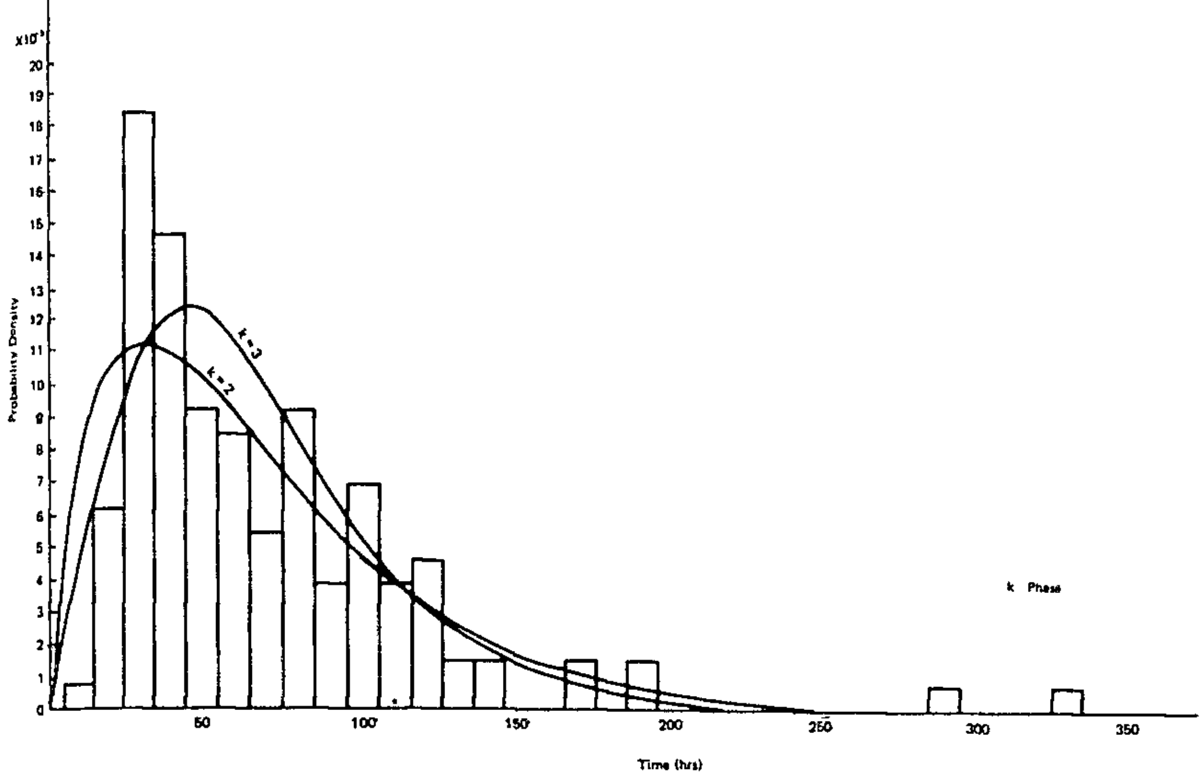



Fig. 7-2-4 Distribution of Berthing Time
(Bulk Carrier 10,000~15,000 DWT)

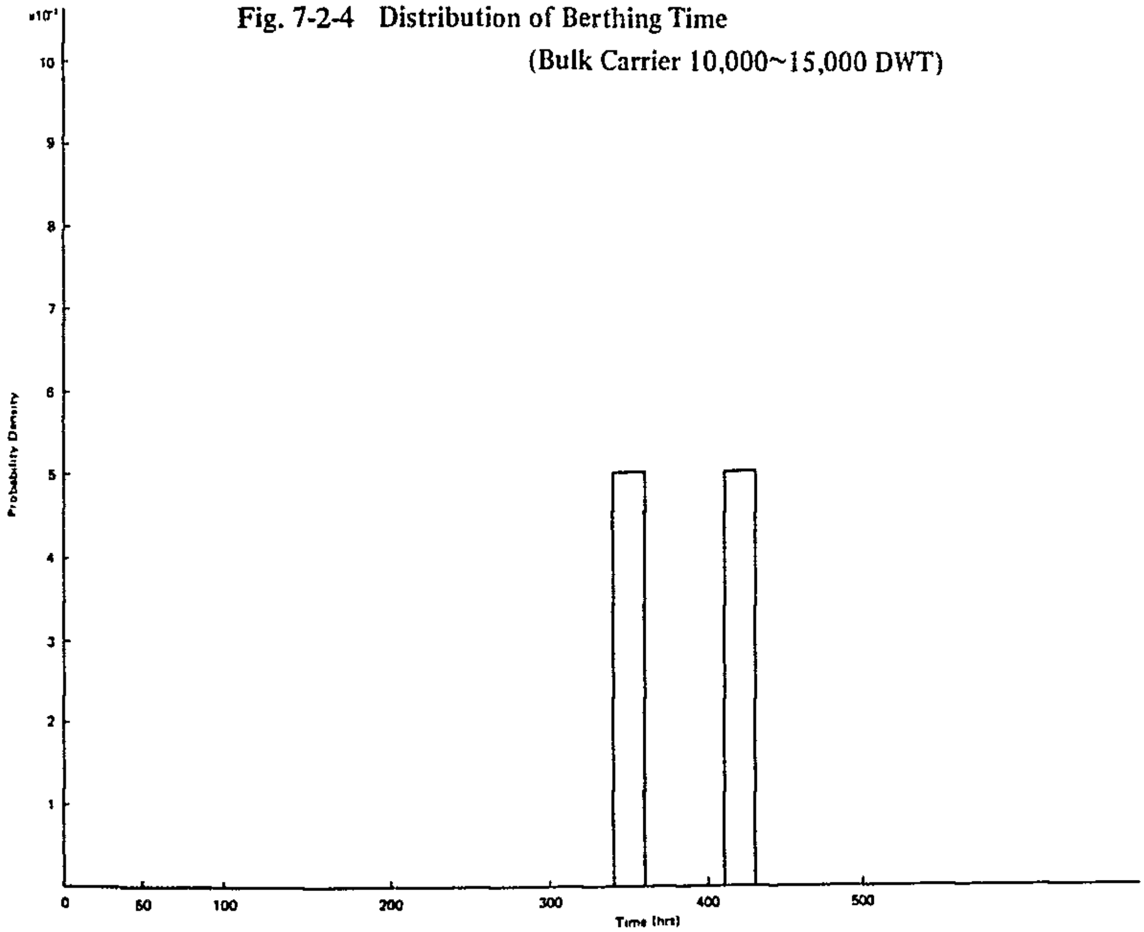


Fig. 7-2-5 Distribution of Berthing Time
(Bulk Carrier 15,000 DWT ~)

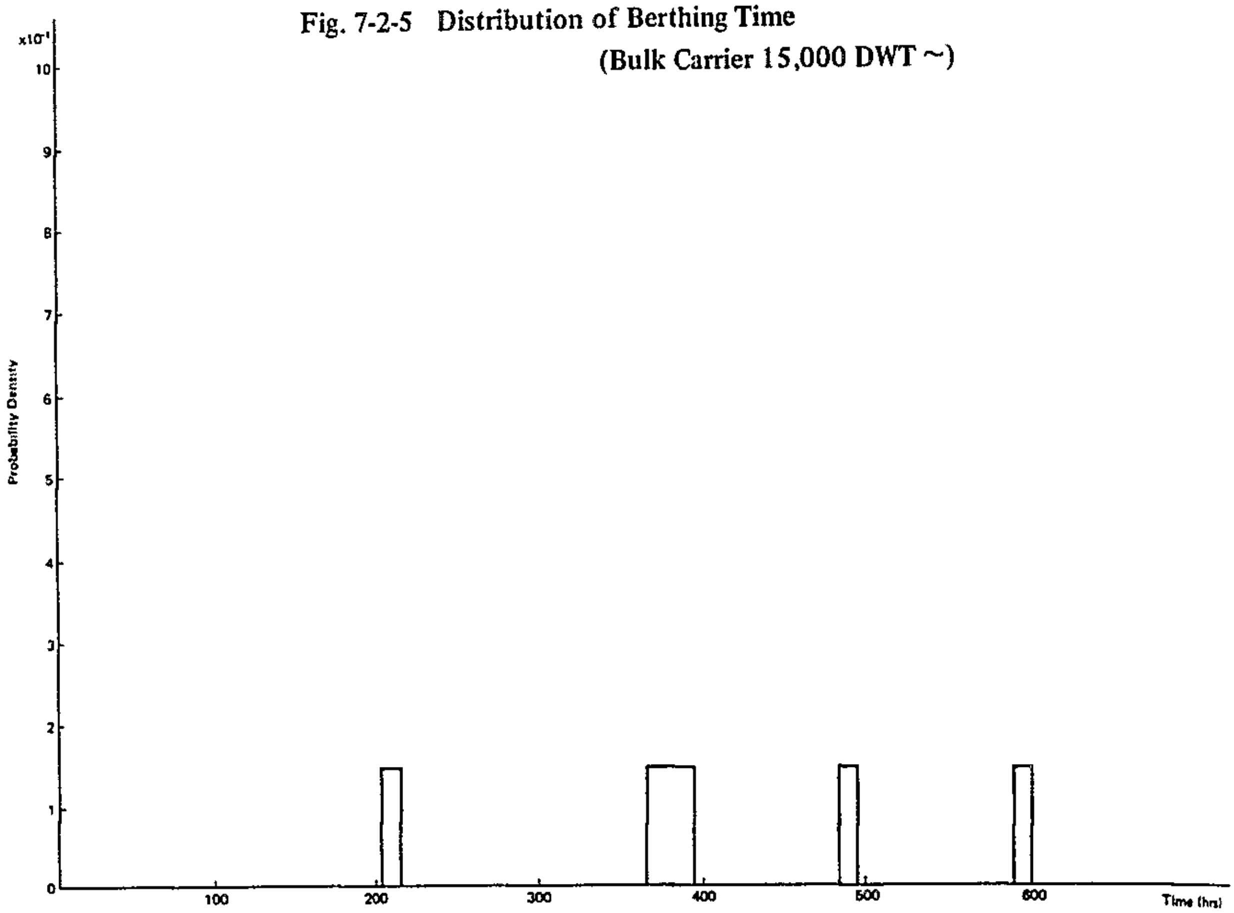



Fig. 7-2-6 Distribution of Berthing Time
(Semi-Container Vessel 5,000~10,000 DWT)

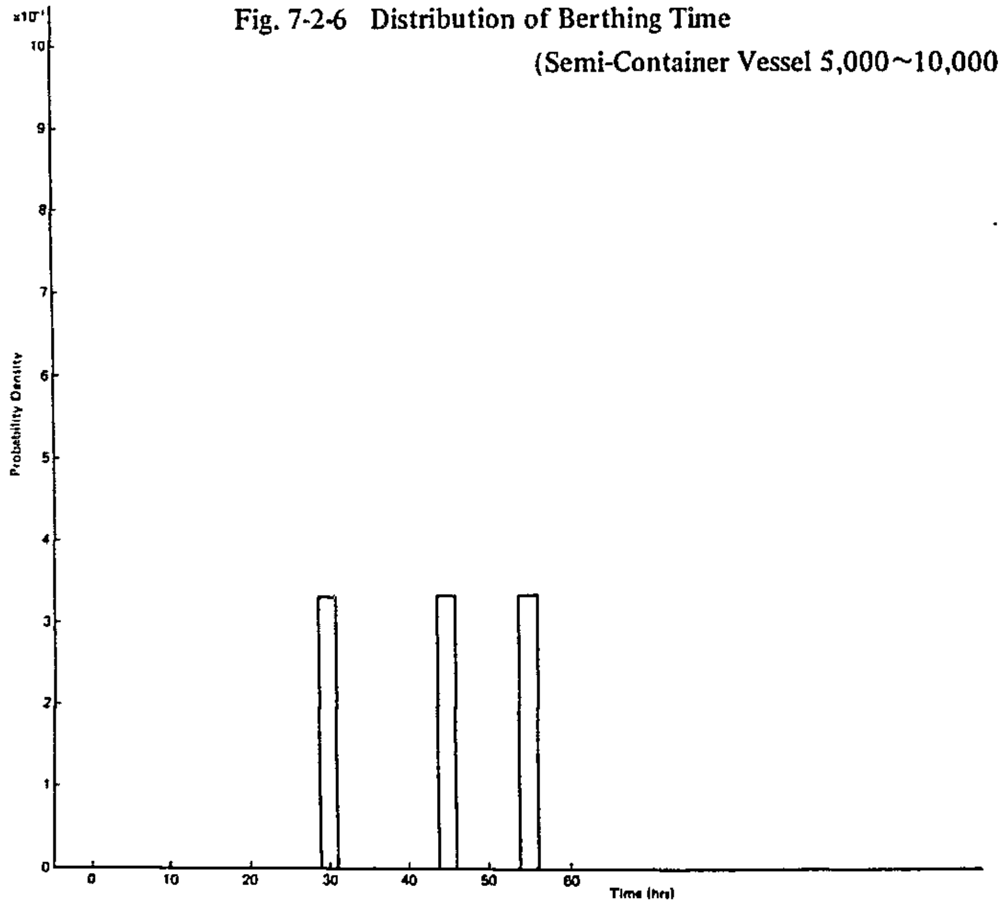
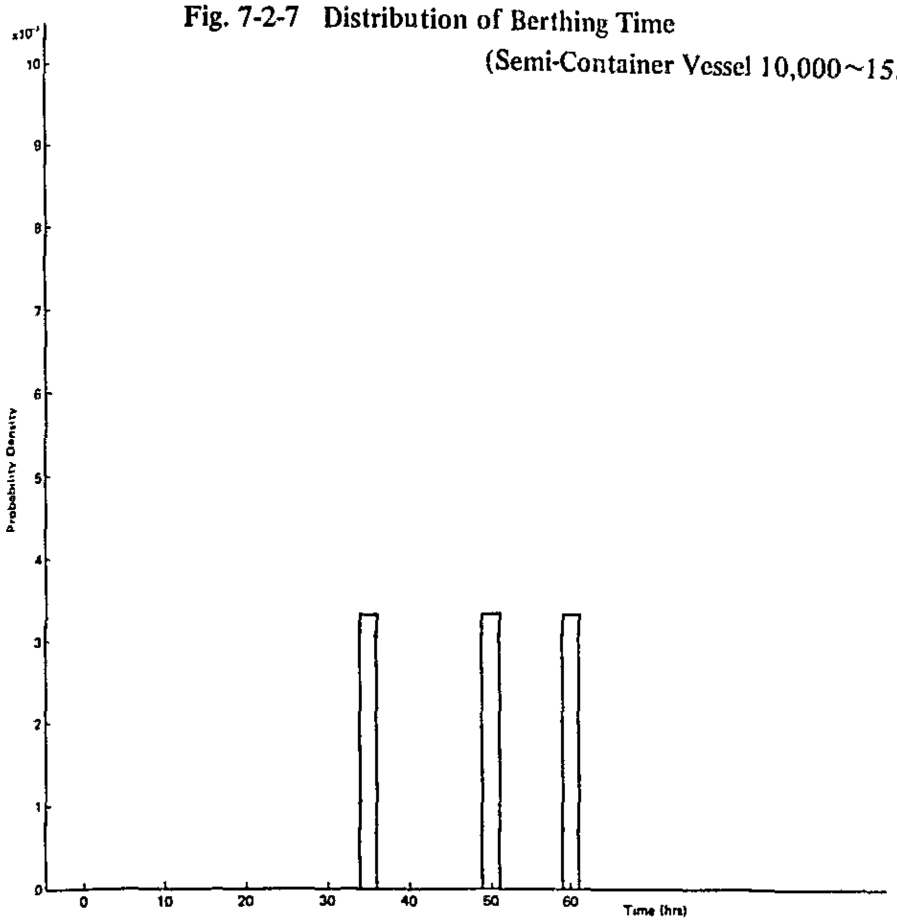


Fig. 7-2-7 Distribution of Berthing Time
(Semi-Container Vessel 10,000~15,000 DWT)




*Cargo handling hours show a peak at the left and the maximum cargo handling hours are 340* hours for all ships and 290 hours for general cargo vessels. An accumulation of less than 50 hours of cargo handling time accounts for about 50% of total hours. Average time is 76.7 hours for all vessels and 67.3 hours for general cargo vessels.

The distribution of port staying time is similar to an Erlung distribution with a peak on the left side, and maximum port staying time is 350 hours for all vessels and general cargo vessels. An accumulation of less than 100 hours of port staying time accounts for 50% of total hours. Average time is 124.5 hours for all vessels and 116.8 hours for general cargo vessels.

The distribution of cargo handling time resembles an Erlung distribution with a peak on the left side, and the maximum cargo handling time is 240 hours for all vessels and 210 hours for general cargo vessels. Average time is 52 hours for all vessels and 50.5 hours for general cargo vessels. *Unloading tonnage shows an exponential distribution and the maximum unloading* tonnage is 13,000 tons for all vessels and 11,500 tons for general cargo vessels. Average unloading tonnage is 1,560 tons for all vessels and 1,300 tons for general cargo vessels.

The distribution of loading tonnage shows an exponential distribution as with the unloading tonnage, and the maximum loading tonnage is 2,300 tons for all vessels and 2,300 tons for general cargo vessels.

## 7-3 Methodology of the Simulation Test

### 7-3-1 Purpose of the Test

Ships entering the port take a berth according to their order of arrival and then start loading/ unloading work. If the berths are occupied, the ships wait until preceding ships disembark. Queing theory has been used to make a projection concerning the situation of ships calling at or leaving the port. However, theoretical analysis alon cannot cope with the complicated reality of port activities. For this reason, a computer is used to follow the movement of ships chosen at ramdom as they arrive at the port and while they are entering – berthing, – loading/unloading and leaving. The computer thus examines waiting and berthing conditions at the Port of Caldera as it now stands after the completion of the First Stage Project and simulates a test of the scale and actual timing for the Second Stage Project.

### 7-3-2 Flow and Structure of the Simulation Model

Figs. 7-3-1 ~ 7-3-3 shows the flow and structure of the simulation model executed for the current study. In the above flow, the number of ships entering the port and their berthing hours are given, and the number of waiting ships and their waiting time and berthing hours are calculated as well as the berth occupancy rate and the cost for ships' waiting, etc.

Fig. 7-3-1 Structure of Simulation Model

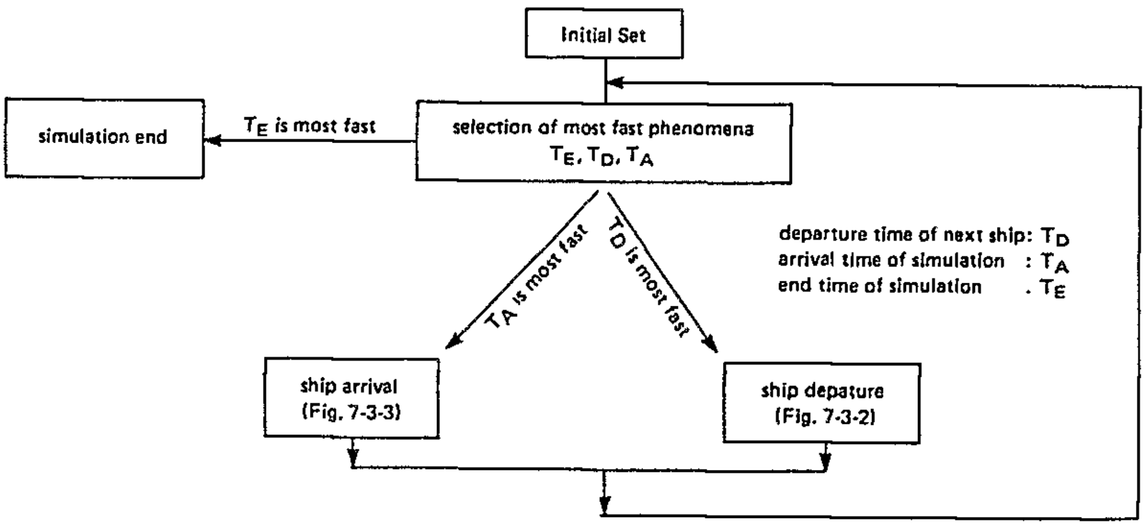
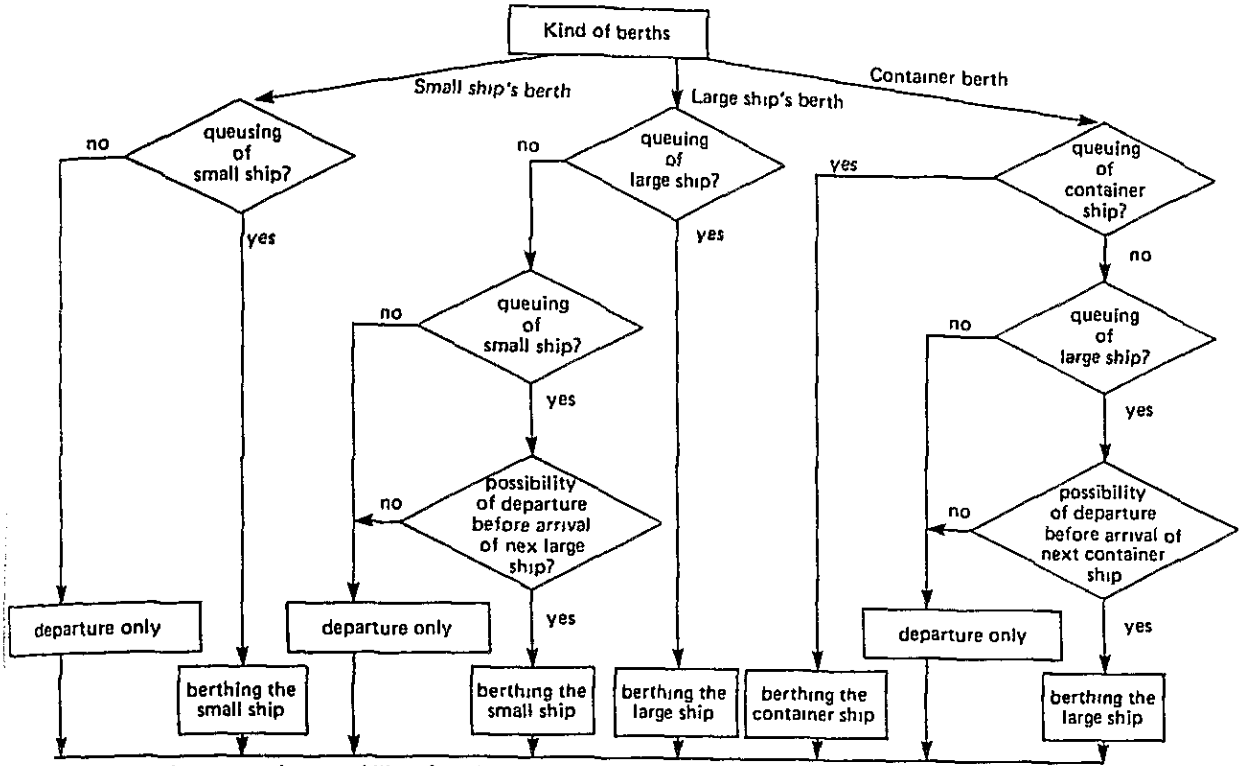


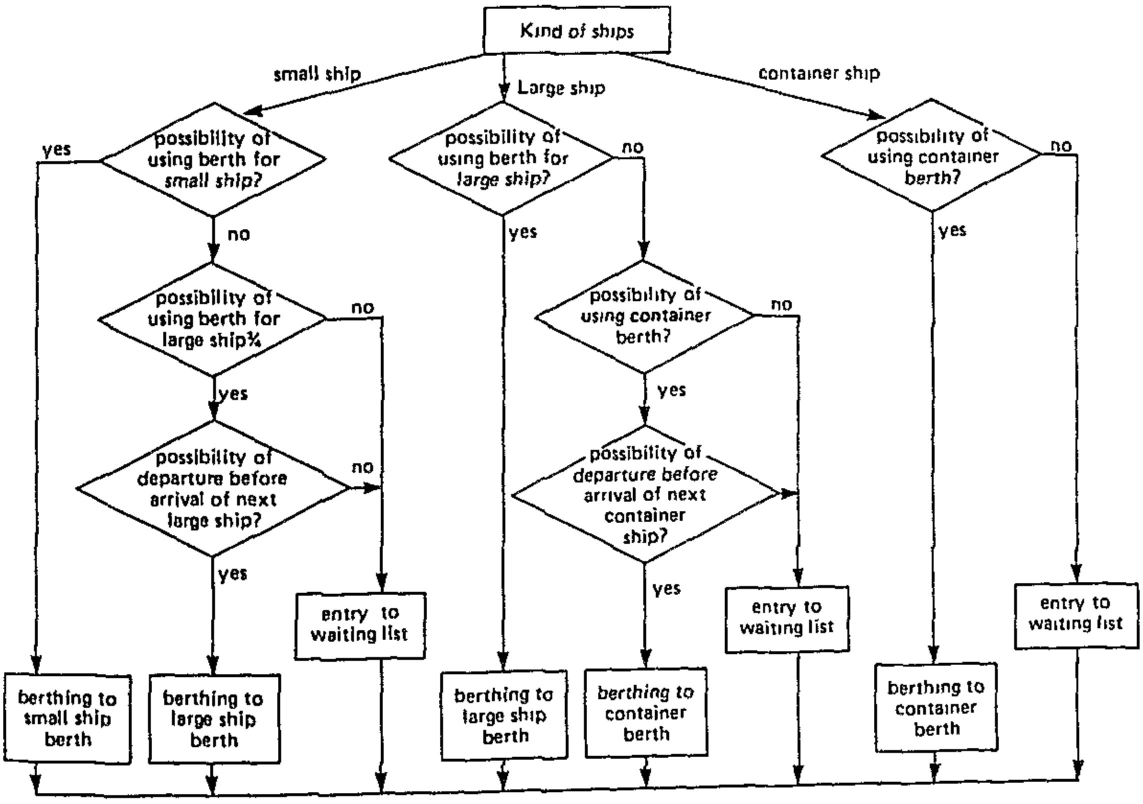
Fig. 7-3-2 Ship departure




departure only: possibility of one berth

berthing: berthing next ship simultaneously with ship departure moving up waiting order one by one

Fig. 7-3-3 ship arrival




entry to waiting list. list up the last in waiting order

## 7-4 Simulation Test

7-4-1 Simulation was made every year from 1985 to 2000 for the following cases:

(1) after the completion of the First Stage Project

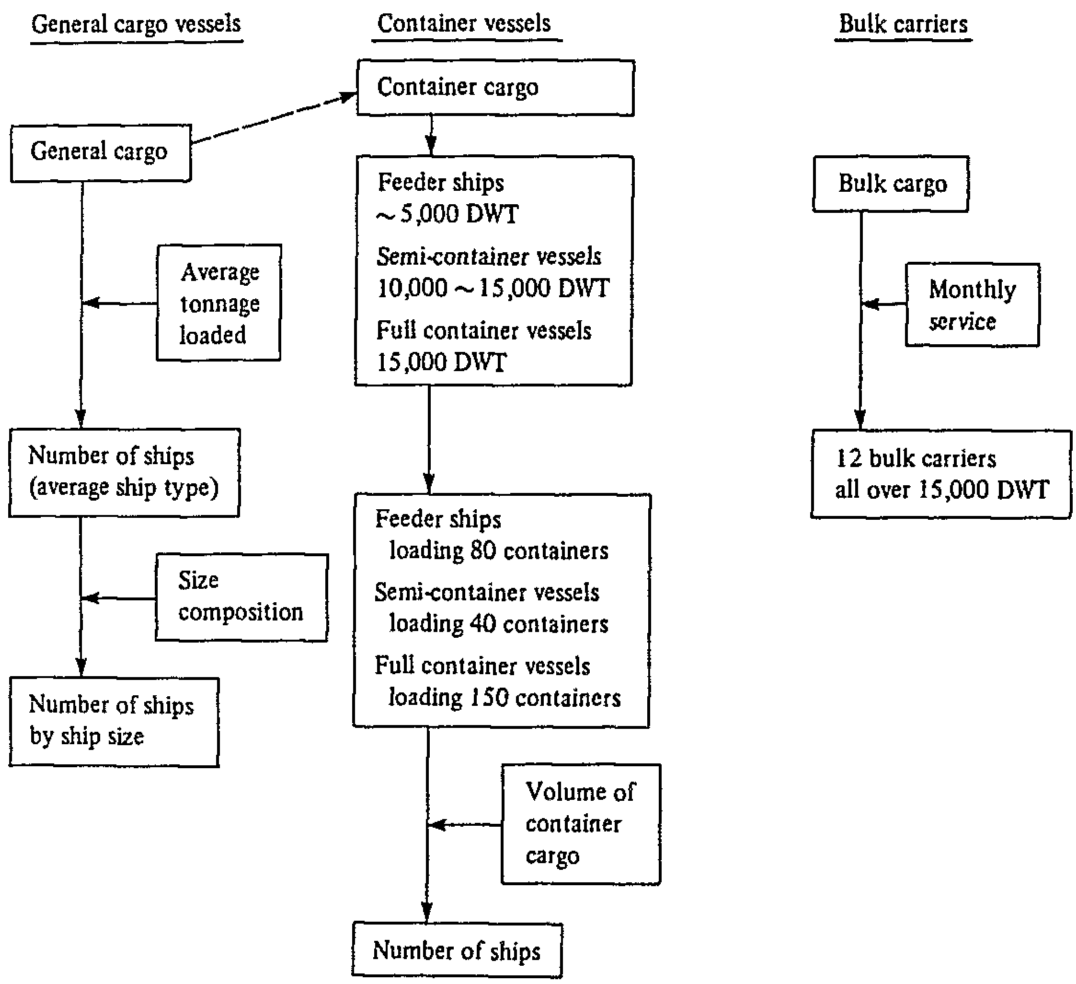
(2) for the case of an additional berth to (1).

### 7-4-2 Input Data

For simulation it is necessary to estimate the number of ships entering the port and berthing hours for every year. The number of ships entering the port and berthing hours are estimated for general cargo vessels, bulk carriers and semi-container vessels.

(1) Projection of the number of ships entering the port

The projection flow of number of ships entering the port is shown as follows;



(1)-A General Cargo Vessels

Total tonnage loaded in 1979 was 257,362 tons of both imports and exports according to the data of the Port of Puntarenas (Chapter 6), and the number of ships entering the port was 215.6/year including general cargo vessels and semi-container vessels.

The average tonnage loaded is calculated from the above as 1,194 tons/ships.

The average tonnage loaded is estimated for 2000 as 30% up from 1979 as follows.

| | | |
|---|---|---|
| 80 | 1200 | tons/ship |
| 85 | 1300 | " |
| 90 | 1400 | " |
| 95 | 1500 | " |
| 2000 | 1600 | " |

The number of general cargo vessels for each year is calculated from the volume of general cargo each year and the above average tonnage loaded. The number is allocated to each size of ship in 2000 based on the actual number in 1979, considering a 20% increase of ship size.

The arrival distribution is in accordance with the Poisson's distribution.

(1)-B Bulk Carrier

Bulk carriers are estimated for monthly service in consideration of past experience, and the number of ships entering the port each year is estimated at 12 ships. The number is estimated at 12 for the future in consideration of the use of larger ships for the increase of cargo volume in the future.

A regular distribution is employed for the arrival distribution.

(1)-C Container Vessels

Here, container vessels include full container vessels, semi-container ships and feeder ships. The number of containers loaded per ship is estimated as follows.

| | |
|---|---|
| Full container vessels | 150 containers |
| Semi-container vessels | 40 containers |
| Feeder ships | 80 containers |

The number of ships for each year is estimated from the volume of container cargo given in Chapter 6 and the number of containers per ship as follows.

| | 1980 | 1985 | 1990 | 1995 | 2000 |
|---|---|---|---|---|---|
| Full container vessels | 0 | 24(0) | 60(0) | 74(0) | 91(0) |
| Semi-container vessels | 47 | 48(85) | 24(112) | 31(138) | 31(170) |
| Feeder ships | 24 | 18(43) | 12(56) | 12(69) | 15(85) |

Figures in brakets show the case where full container vessels will not be in service. A regular distribution is employed for each arrival distribution.

(2) Examination of Cargo Handling Capacity

The method of cargo handling and its capacity is discussed here to estimate berthing hours in the following paragraph. As cargo handling equipment included in the First Stage Project of the

Port of Caldera has been already decided (see Chapter 5), a study of cargo handling capacity at the Port of Caldera is made on the equipment given above.

(2)-A Cargo Handling Equipment for General Cargo

The following equipment has already been decided for use in the Project.

| | Capacity | Number | Handling Capacity/hour |
|---|---|---|---|
| Forklift (1) | 3 tons | 10 | 350 t |
| 〃 (2) | 5 tons | 5 | 250 t |
| 〃 (3) | 6 tons | 3 | 180 t |
| 〃 (4) | 15 tons | 1 | 80 t |
| | | 19 | 860 t |

The above mentioned cargo handling capacity per hour is estimated for the cycle time for travelling from the berth to the transit shed and for the actual load as 70% – 50% of the nominal load.

The cargo handling capacity of the ships' crane is estimated from the handling capacity per ship at the Port of Puntarenas.

| | (1) Handling capacity during operation | (2) Actual handling capacity |
|---|---|---|
| Jan. '79 | 18.7 t/h | 10.0 t/h |
| Feb. | 22.2 | 13.5 |
| Mar. | 17.9 | 10.0 |
| Apr. | 18.2 | 10.0 |
| June | 16.6 | 8.3 |
| July | 17.6 | 8.3 |
| Aug. | 17.0 | 7.1 |
| Sep. | 24.6 | 10.7 |
| Nov. | 16.5 | 7.4 |
| Dec. | 20.8 | 11.3 |
| Total | 190.1 | 96.6 |
| Average | 19.0 | 9.7 |

From the foregoing relations (1) and (2), the following formula is introduced for the actual capacity.

$$C = 0.55991 \times E - 0.9840 \qquad (7.1)$$

where, C: Actual capacity

E: Capacity during operation

The actual capacity is set at 27.0 tons/hour in 1980 and 32.6 tons/hour after 1985, assuming E = 50 t/h initially and E = 60 t/h later assuming improved skill with equipment in the latter.

The foregoing handling capacity is estimated based on experience at the Port of Puntarenas and is substantially lower than the normal 20 tons/hour per gang (depending on the number of gangs used), so there is room for improvement in the future.

From the foregoing, the capacity of the said forklifts will be sufficient for the transit sheds and on the apron and for ships berthed at 3 berths.

(2)-B Cargo Handling Equipment for Bulk Cargo

In the First Stage Project, four portable type pneumatic unloaders with a 60t/h capacity are to be introduced.

The following handling capacity is estimated allowing for the skill required to handle the equipment.

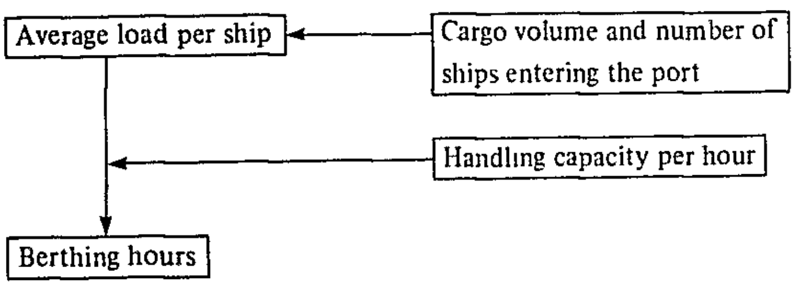
| | | | |
|---|---|---|---|
| 1980 | 60 t/h × 24 h × 4 ca × 0.8[1)] × | 0.45[2)] | ≒ 2,000 t/day |
| 85 | | 0.5 | ≒ 2,300 |
| 90 | | 0.55 | ≒ 2,600 |
| 95 | | 0.65 | ≒ 3,000 |
| 2000 | | 0.65 | ≒ 3,000 |

1): Handling efficiency

2): Operating coefficient

With the capacity given above, handling work will be completed within 5 days and 4 unloaders are considered to be sufficient.

(3) Projection of Berthing Time




(3)-A General cargo vessels

Ships' cranes are used for handling general cargo.

As loading/unloading work at the Port of Caldera, unlike the Port of Puntarenas, is carried out in the order ships' crane – apron (forklift) – transit shed, the ships' crane can be fully utilized. From the relations between the net capacity of ships' gear and actual capacity presently carried out at the Port of Puntarenas, the actual capacity and barthing time at the Port of Caldera is estimated as follows.

| | Average load volume | Average handling capacity | Average berthing hour |
|---|---|---|---|
| 1980 | 1,200 | 27 t/h | 44.4 h |
| 85 | 1,300 | 32.6 | 39.9 |
| 90 | 1,400 | 32.6 | 42.9 |
| 95 | 1,500 | 32.6 | 46.0 |
| 2000 | 1,600 | 32.6 | 49.1 |

Berthing time by size of ships is allocated according to the ratio of berthing time by size of ships for the year 1979. The berthing time distribution is, as shown in Table 7-1-1 ~ Table 7-4-2, the Erlung distribution up to 5000 DWT (3) and Erlung distribution (2) for over 5000 DWT.

Berthing time by size of ship in 1979 is as follows.

| | DWT ~ 5,000 | ~ 10,000 | ~ 15,000 | 15,000 ~ | Average |
|---|---|---|---|---|---|
| Number of ships entering the port | 44.2 | 39.8 | 91.0 | 14.1 | |
| Berthing hour | 48.9 h | 55.5 | 66.9 | 177.1 | 68.5 |

(3)-B Bulk carrier

4 pneumatic unloaders (nominal capacity 60 t/h) have been considered for introduction during the First Stage Project for handling bulk cargo. There is a low estimation for the capacity for each year in the early years in consideration of the skill required to handle the equipment. Thus the berthing time is estimated as follows.

| | Cargo volume ($10^3$ tons) | Load volume/ship (t/ship) | Handling capacity (t/day) | Berthing hour (h) |
|---|---|---|---|---|
| 1980 | 114.6 | 9,550 | 2,000 | 120.6 |
| 85 | 112.8 | 9,400 | 2,300 | 98.1 |
| 90 | 134.2 | 11,180 | 2,600 | 103.2 |
| 95 | 157.9 | 13,160 | 3,000 | 105.3 |
| 2000 | 184.3 | 15,360 | 3,000 | 122.9 |

A regular distribution is employed as the berthing time distribution.

(3)-C Container vessels

(1) Feeder ship

Assuming the number of containers loaded per ship as 80, then the containers handled are 80 x 2 = 160; and assuming a handling time of one container with mobile cranes as 10 minutes, berthing hours per ship will be

160 x 10 min/container = 1600 min. = 26.7 h

(2) Semi-container ship

(a) Container

The number of containers loaded per ship is 40 and containers handled are 40 x 2 = 80 and assuming a handling time of one container as 5 minutes, 80 x 5 min/container = 6.7 h

(b) General cargo

Load volume per ship is 1500 tons.

Handling capacity is:

| | |
|---|---|
| 1980 | 27.0 t/h |
| 85 | 32.6 " |
| ≀ | ≀ |
| 2000 | 32.6 " |

Berthing hours will be:

| | | |
|---|---|---|
| 1980 | 6.7 h + 1500/27 | = 62.3 h |
| 85 | 6.7 h + 1500/32.6 | = 52.7 h |
| 90 | " | = 52.7 h |
| 95 | " | = 52.7 h |
| 2000 | " | = 52.7 h |

(c) Full container vessel

The number of containers loaded per ship is 150 and the number of containers handled is 150 x 2 = 300 and the ratio of 20′ and 40′ containers is 2 : 1. Containers handled are 150 + 75 = 225, with handling time per containe being estimated at 5 min. The berthing time per ship is

225 x 5 min./container = 1125 min. = 18.8 h

Five minutes per container was used as container handling time because berths proposed by the First Stage Project are not exclusively used for containers. Containers will be put together with general cargoes and forklifts will be used to move them. A wharf constructed under the Second Stage Project will be exclusively used for containers and the control and management of containers will be smoothly carried out. Then containers will them be moved by straddle carriers; thus 2.5 min./container will be the handling time.

The berthing time distribution for each container ship employs the regular distribution.

Table 7-4-1 ~ 7-4-2 show input data for the number of ships entering the port each year and berthing hours as described above as well as the actual performance o the Port of Puntarenas in 1979.

## Table 7-4-1 Number of Calling Ships

### – At the Port of Caldera –

| Year | General Cargo Ships | | | | Bulk Carriers | | | | Semi-Container Ships | | | | Full Container Ships | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | -5,000 DWT | 5,000–10,000 DWT | 10,000–15,000 DWT | 15,000 DWT– | | | | 15,000 DWT– | -5,000 DWT | 5,000–10,000 DWT | 10,000–15,000 DWT | -15,000 DWT | | | | -15,000 DWT |
| 1980 | 30.3 | 27.2 | 62.3 | 9.7 | 0.0 | 0.0 | 0.0 | 12.0 | 24.0 | 0.0 | 47.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 1981 | 31.0 | 27.9 | 65.3 | 10.1 | 0.0 | 0.0 | 0.0 | 12.0 | 22.8 | 0.0 | 47.2 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 1982 | 31.7 | 28.7 | 68.3 | 10.5 | 0.0 | 0.0 | 0.0 | 12.0 | 21.6 | 0.0 | 47.4 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 1983 | 32.4 | 29.4 | 71.2 | 11.0 | 0.0 | 0.0 | 0.0 | 12.0 | 20.4 | 0.0 | 47.6 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 1984 | 33.1 | 30.2 | 74.2 | 11.4 | 0.0 | 0.0 | 0.0 | 12.0 | 19.2 | 0.0 | 47.8 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 1985 | 33.8 | 30.9 | 77.2 | 11.8 | 0.0 | 0.0 | 0.0 | 12.0 | 18.0 | 0.0 | 48.0 | 0.0 | 0.0 | 0.0 | 0.0 | 24.0 |
| 1986 | 34.6 | 31.8 | 81.0 | 12.3 | 0.0 | 0.0 | 0.0 | 12.0 | 16.8 | 0.0 | 43.2 | 0.0 | 0.0 | 0.0 | 0.0 | 31.2 |
| 1987 | 35.4 | 32.7 | 84.8 | 12.9 | 0.0 | 0.0 | 0.0 | 12.0 | 15.6 | 0.0 | 38.4 | 0.0 | 0.0 | 0.0 | 0.0 | 38.4 |
| 1988 | 36.3 | 33.6 | 88.7 | 13.4 | 0.0 | 0.0 | 0.0 | 12.0 | 14.4 | 0.0 | 33.6 | 0.0 | 0.0 | 0.0 | 0.0 | 45.6 |
| 1989 | 37.1 | 34.5 | 92.5 | 14.0 | 0.0 | 0.0 | 0.0 | 12.0 | 13.2 | 0.0 | 28.8 | 0.0 | 0.0 | 0.0 | 0.0 | 52.8 |
| 1990 | 37.9 | 35.4 | 96.3 | 14.5 | 0.0 | 0.0 | 0.0 | 12.0 | 12.0 | 0.0 | 24.0 | 0.0 | 0.0 | 0.0 | 0.0 | 60.0 |
| 1991 | 38.7 | 36.3 | 100.8 | 15.1 | 0.0 | 0.0 | 0.0 | 12.0 | 12.0 | 0.0 | 25.4 | 0.0 | 0.0 | 0.0 | 0.0 | 62.8 |
| 1992 | 39.5 | 37.3 | 105.2 | 15.7 | 0.0 | 0.0 | 0.0 | 12.0 | 12.0 | 0.0 | 26.8 | 0.0 | 0.0 | 0.0 | 0.0 | 65.6 |
| 1993 | 40.4 | 38.2 | 109.7 | 16.2 | 0.0 | 0.0 | 0.0 | 12.0 | 12.0 | 0.0 | 28.2 | 0.0 | 0.0 | 0.0 | 0.0 | 68.4 |
| 1994 | 41.2 | 39.2 | 114.1 | 16.8 | 0.0 | 0.0 | 0.0 | 12.0 | 12.0 | 0.0 | 29.6 | 0.0 | 0.0 | 0.0 | 0.0 | 71.2 |
| 1995 | 42.0 | 40.1 | 18.6 | 17.4 | 0.0 | 0.0 | 0.0 | 12.0 | 12.0 | 0.0 | 31.0 | 0.0 | 0.0 | 0.0 | 0.0 | 74.0 |
| 1996 | 42.6 | 40.9 | 123.3 | 17.9 | 0.0 | 0.0 | 0.0 | 12.0 | 12.6 | 0.0 | 31.0 | 0.0 | 0.0 | 0.0 | 0.0 | 77.4 |
| 1997 | 43.1 | 41.6 | 128.0 | 18.5 | 0.0 | 0.0 | 0.0 | 12.0 | 13.2 | 0.0 | 31.0 | 0.0 | 0.0 | 0.0 | 0.0 | 80.8 |
| 1998 | 43.7 | 42.4 | 132.6 | 19.0 | 0.0 | 0.0 | 0.0 | 12.0 | 13.8 | 0.0 | 31.0 | 0.0 | 0.0 | 0.0 | 0.0 | 84.2 |
| 1999 | 44.2 | 43.1 | 137.3 | 19.6 | 0.0 | 0.0 | 0.0 | 12.0 | 14.4 | 0.0 | 31.0 | 0.0 | 0.0 | 0.0 | 0.0 | 87.6 |
| 2000 | 44.8 | 43.9 | 142.0 | 20.1 | 0.0 | 0.0 | 0.0 | 12.0 | 15.0 | 0.0 | 31.0 | 0.0 | 0.0 | 0.0 | 0.0 | 91.0 |

Table 7-4-2 Berthing Time of Calling Ships

– At the Port of Caldera –

| Year | General Cargo Ships | | | | Bulk Carriers | | | | Semi-Container Ships | | | | Full Container Ships | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | –5,000 DWT | 5,000–10,000 DWT | 10,000–15,000 DWT | –15,000 DWT– | | | | 15,000 DWT– | –5,000 DWT | 5,000–10,000 DWT | 10,000–15,000 DWT | 15,000 DWT– | | | | 15,000 DWT– |
| 1980 | 31.7 | 36.0 | 43.4 | 114.8 | 0.0 | 0.0 | 0.0 | 120.6 | 13.3 | 0.0 | 62.3 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 1981 | 31.1 | 35.3 | 42.5 | 112.5 | 0.0 | 0.0 | 0.0 | 116.1 | 13.3 | 0.0 | 60.4 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 1982 | 30.4 | 34.5 | 41.6 | 110.1 | 0.0 | 0.0 | 0.0 | 111.6 | 13.3 | 0.0 | 58.5 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 1983 | 29.8 | 33.8 | 40.8 | 107.8 | 0.0 | 0.0 | 0.0 | 107.1 | 13.3 | 0.0 | 56.5 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 1984 | 29.1 | 33.0 | 39.9 | 105.4 | 0.0 | 0.0 | 0.0 | 102.6 | 13.3 | 0.0 | 54.6 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 1985 | 28.5 | 32.3 | 39.0 | 103.1 | 0.0 | 0.0 | 0.0 | 98.1 | 13.3 | 0.0 | 52.7 | 0.0 | 0.0 | 0.0 | 0.0 | 9.4 |
| 1986 | 28.9 | 32.8 | 39.6 | 104.7 | 0.0 | 0.0 | 0.0 | 99.1 | 13.3 | 0.0 | 52.7 | 0.0 | 0.0 | 0.0 | 0.0 | 9.4 |
| 1987 | 29.3 | 33.3 | 40.2 | 106.2 | 0.0 | 0.0 | 0.0 | 100.1 | 13.3 | 0.0 | 52.7 | 0.0 | 0.0 | 0.0 | 0.0 | 9.4 |
| 1988 | 29.8 | 33.7 | 40.7 | 107.8 | 0.0 | 0.0 | 0.0 | 101.2 | 13.3 | 0.0 | 52.7 | 0.0 | 0.0 | 0.0 | 0.0 | 9.4 |
| 1989 | 30.2 | 34.2 | 41.3 | 109.3 | 0.0 | 0.0 | 0.0 | 102.2 | 13.3 | 0.0 | 52.7 | 0.0 | 0.0 | 0.0 | 0.0 | 9.4 |
| 1990 | 30.6 | 34.7 | 41.9 | 110.9 | 0.0 | 0.0 | 0.0 | 103.2 | 13.3 | 0.0 | 52.7 | 0.0 | 0.0 | 0.0 | 0.0 | 9.4 |
| 1991 | 31.0 | 35.2 | 42.5 | 112.5 | 0.0 | 0.0 | 0.0 | 103.6 | 13.3 | 0.0 | 52.7 | 0.0 | 0.0 | 0.0 | 0.0 | 9.4 |
| 1992 | 31.5 | 35.7 | 43.1 | 114.1 | 0.0 | 0.0 | 0.0 | 104.0 | 13.3 | 0.0 | 52.7 | 0.0 | 0.0 | 0.0 | 0.0 | 9.4 |
| 1993 | 31.9 | 36.3 | 43.7 | 115.7 | 0.0 | 0.0 | 0.0 | 104.5 | 13.3 | 0.0 | 52.7 | 0.0 | 0.0 | 0.0 | 0.0 | 9.4 |
| 1994 | 32.4 | 36.8 | 44.3 | 117.3 | 0.0 | 0.0 | 0.0 | 104.9 | 13.3 | 0.0 | 52.7 | 0.0 | 0.0 | 0.0 | 0.0 | 9.4 |
| 1995 | 32.8 | 37.3 | 44.9 | 118.9 | 0.0 | 0.0 | 0.0 | 105.3 | 13.3 | 0.0 | 52.7 | 0.0 | 0.0 | 0.0 | 0.0 | 9.4 |
| 1996 | 33.3 | 37.8 | 45.5 | 120.5 | 0.0 | 0.0 | 0.0 | 108.8 | 13.3 | 0.0 | 52.7 | 0.0 | 0.0 | 0.0 | 0.0 | 9.4 |
| 1997 | 33.7 | 38.3 | 46.1 | 122.1 | 0.0 | 0.0 | 0.0 | 112.3 | 13.3 | 0.0 | 52.7 | 0.0 | 0.0 | 0.0 | 0.0 | 9.4 |
| 1998 | 34.2 | 38.8 | 46.8 | 123.7 | 0.0 | 0.0 | 0.0 | 115.9 | 13.3 | 0.0 | 52.7 | 0.0 | 0.0 | 0.0 | 0.0 | 9.4 |
| 1999 | 34.6 | 39.3 | 47.4 | 125.3 | 0.0 | 0.0 | 0.0 | 119.4 | 13.3 | 0.0 | 52.7 | 0.0 | 0.0 | 0.0 | 0.0 | 9.4 |
| 2000 | 35.1 | 39.8 | 48.0 | 126.9 | 0.0 | 0.0 | 0.0 | 122.9 | 13.3 | 0.0 | 52.7 | 0.0 | 0.0 | 0.0 | 0.0 | 9.4 |

7-4-3 Results of the Simulation Test

(1) Situation after the Completion of the First Stage Project

The following are simultation results showing how the berth will be used after the completion of the First Stage Project.

The simulation was conducted for the following cases.

Case 1. From 1985 on North American Route and from 1990 on European and Far East Routes, full container vessels will stop at the Port of Caldera and have priority in the use of berths.

Case 2. Unless a container berth is constructed, full container vessels will not stop at the Port of Caldera, but semi-container vessels and feeder ships will stop instead, for handling containers. In this case, no priority will be given to any type of ships in the use of berths.

(1)-A Situation of waiting ships

In Case 1, as priority is given to full container vessels for the use of berths at the Port of Caldera, any other vessels than full container vessels must wait for berthing longer than in Case 2 Accordingly, conditions for waiting ships are more severe than in Case 2.

Case 1

In 1985, ships' waiting time will exceed 24 hours on average and in 1987, it will reach about 50 hours, roughly the same level as at the Port of Puntarenas. After 1988, waiting time will sharply increase and chronic waiting conditions will result. (See Fig. 7-4-1 and Table 7-4-3)

From 1985, about 35% of all ships entering the port will wait for berthing and this will exceed 40% in 1988, and as waiting time will reach astronomical figures in 1990, calculations have not been made past 1994. (See Fig. 7-4-2)

The waiting situation for large ships (ships over 5,000 DWT including full container vessels) show a trend similar to the average for all ships, but the average waiting time per ship is greater than for all ships. Average waiting time per large ship will exceed 24 hours in 1983 and 48 hours in 1987. (See Fig. 7-4-3)

As there are few small ships entering the port, waiting time for these ships is negligible.

Case 2

Compared with Case 1, the average waiting time per ship will start to increase from 1990 and the waiting time per ship will exceed 24 hours in 1995 and 48 hours in 1998, about 10 years later than for Case 1.

About 35% of all ships entering the port will wait for berthing in 1989, 40% in 1991 and 50% in 1996, and as compared with Case 1, the emergence of waiting ships will be delayed a few years. (See Table 7-4-4)

Fig. 7-4-1 Waiting Time

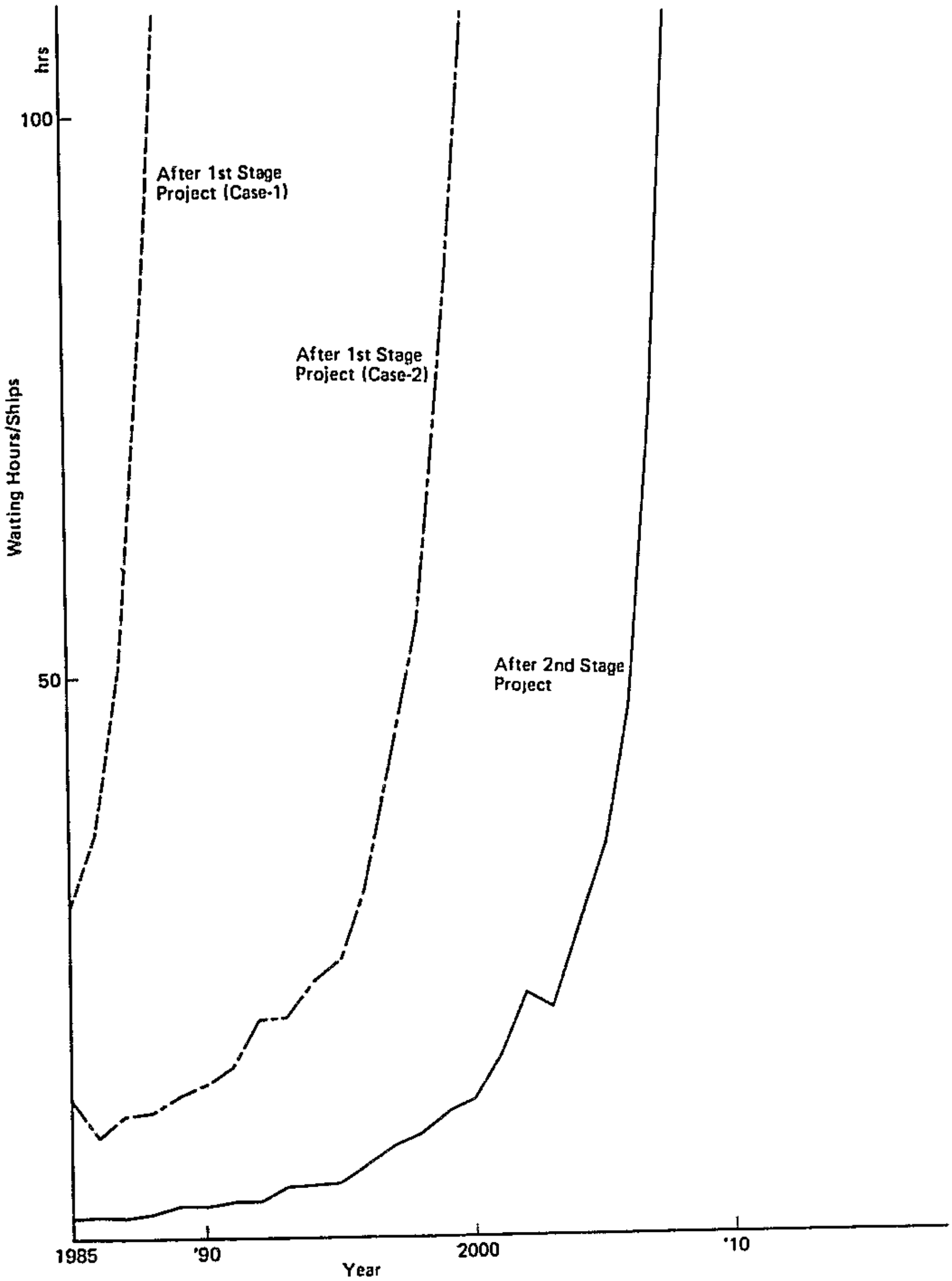


Fig. 7-4-2 Share of Waiting Ships

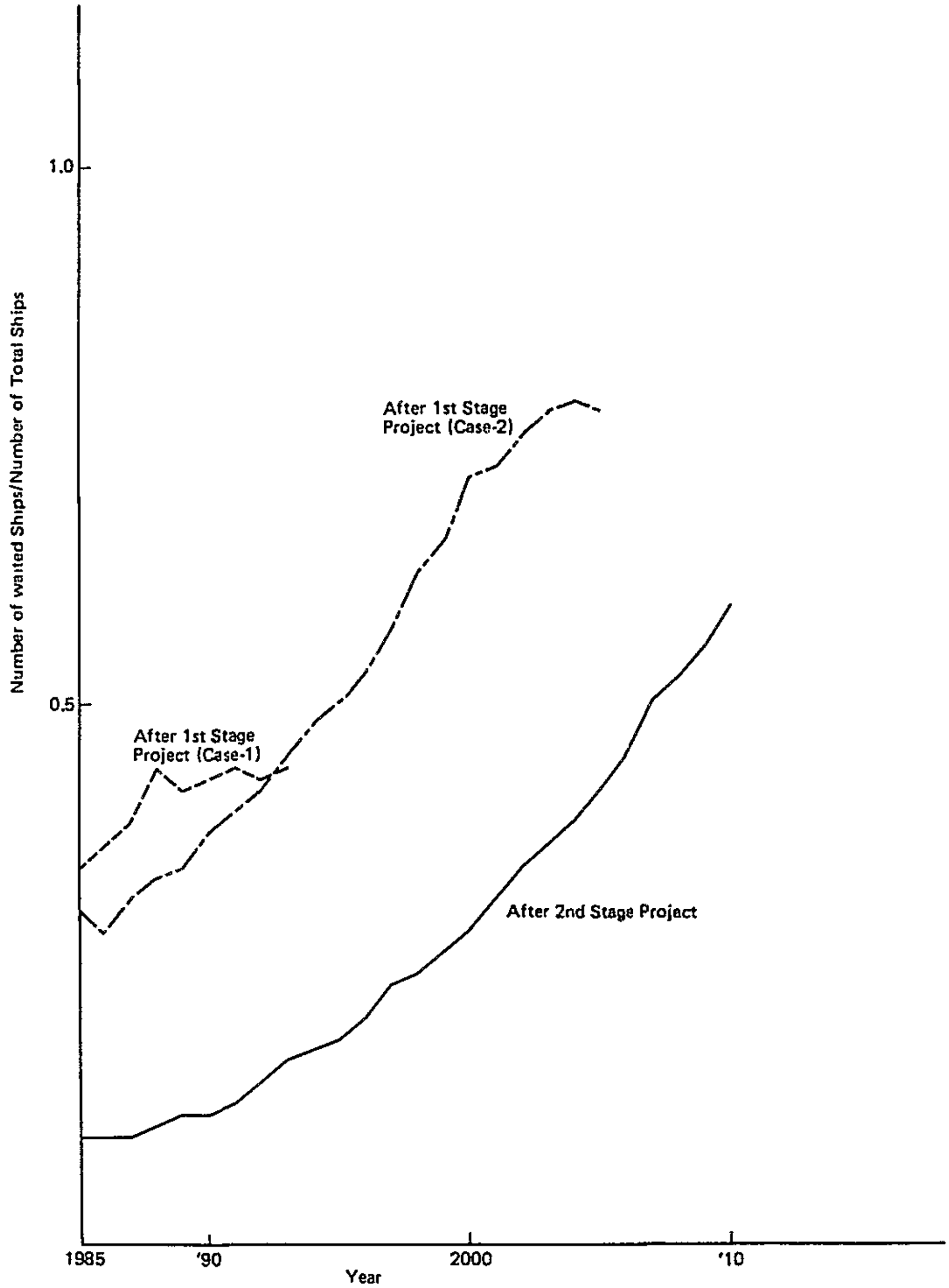


Fig. 7-4-3 Waiting Time of Large Vessels

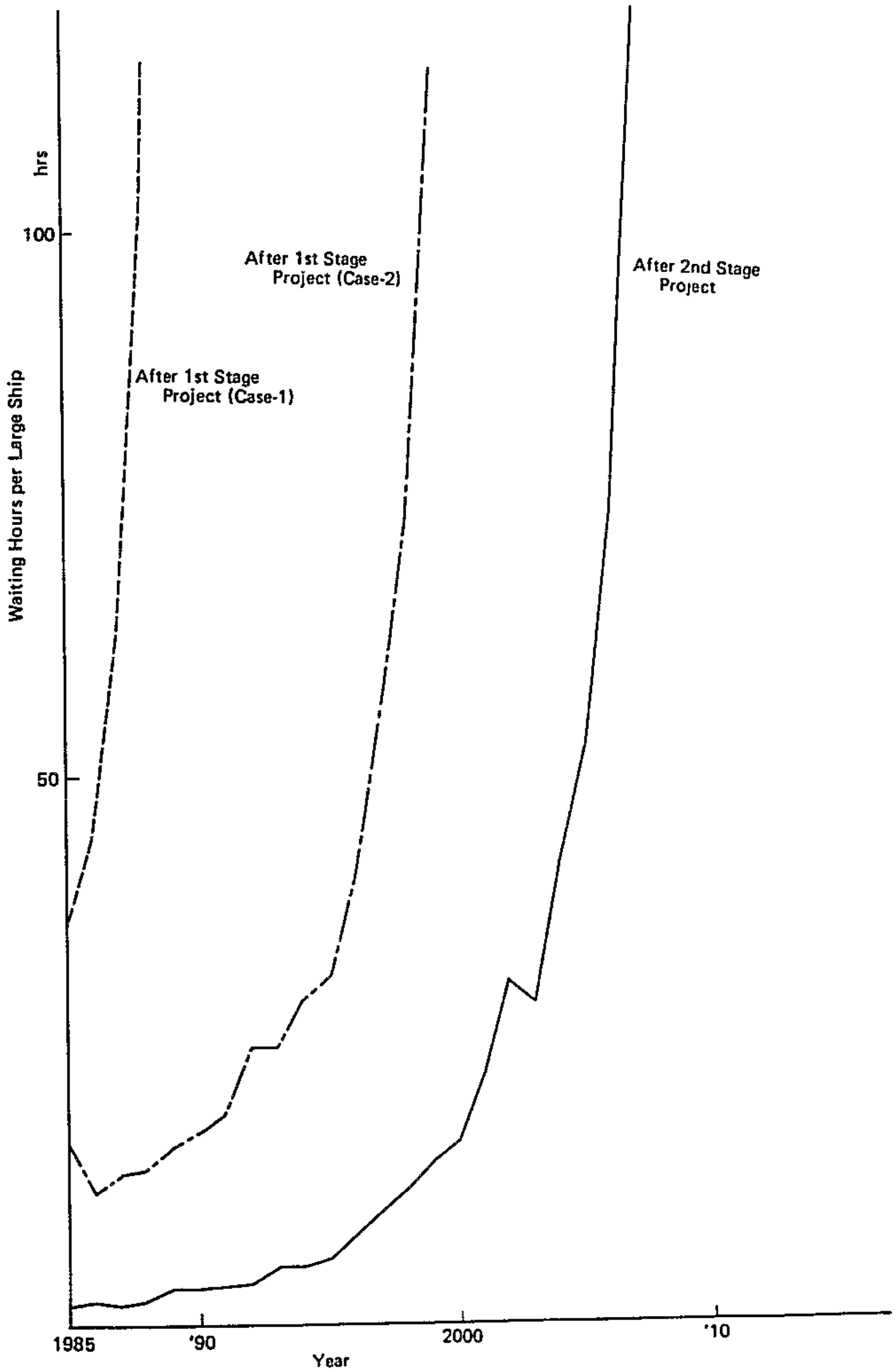


Table 7-4-3 Situation of Waiting Ships After 1st Stage Project (Case 1)

| Year | Ship Waiting | | | Berth Occupancy Rate | |
|---|---|---|---|---|---|
| | No. of Ships Waited/No of Calling Ships | Waiting Hours/Calling Ships | Waiting Hours/Ships Waited | Small Berth | Large Berth |
| 1985 | 0.35 | 29.18hrs | 82.91hrs | 0.175 | 0.543 |
| 86 | 0.37 | 35.94 | 97.72 | 0.175 | 0.555 |
| 87 | 0.39 | 51.36 | 130.40 | 0.175 | 0.566 |
| 88 | 0.44 | 85.85 | 197.05 | 0.179 | 0.584 |
| 89 | 0.42 | 267.77 | 631.90 | 0.179 | 0.593 |
| 90 | 0.43 | 858.83 | 2,000.55 | 0.180 | 0.589 |
| 91 | 0.44 | 1,142.56 | 2,583.92 | 0.184 | 0.611 |
| 92 | 0.43 | 1,585.65 | 3,655.00 | 0.189 | 0.610 |
| 93 | 0.44 | 1,819.99 | 4,101.39 | 0.150 | 0.473 |

Table 7-4-4 Situation of Waiting Ships After 2nd Stage Project (Case 2)

| Year | Ship Waiting | | | Berth Occupancy Rate | |
|---|---|---|---|---|---|
| | No. of Ships Waited/No of Calling Ships | Waiting Hours/Calling Ships | Waiting Hours/Ships Waited | Small Berth | Large Berth |
| 1985 | 0.31 | 12.77hrs | 41.40hrs | 0.205 | 0.550 |
| 86 | 0.29 | 9.48 | 32.24 | 0.214 | 0.566 |
| 87 | 0.32 | 10.84 | 34.26 | 0.226 | 0.581 |
| 88 | 0.34 | 11.19 | 32.68 | 0.229 | 0.599 |
| 89 | 0.35 | 12.54 | 36.09 | 0.236 | 0.615 |
| 90 | 0.38 | 13.77 | 36.46 | 0.243 | 0.627 |
| 91 | 0.40 | 15.27 | 38.54 | 0.250 | 0.653 |
| 92 | 0.42 | 19.53 | 46.30 | 0.261 | 0.677 |
| 93 | 0.45 | 19.65 | 43.53 | 0.271 | 0.701 |
| 94 | 0.48 | 22.86 | 47.86 | 0.282 | 0.724 |
| 94 | 0.50 | 24.65 | 49.08 | 0.289 | 0.752 |
| 96 | 0.53 | 30.89 | 58.00 | 0.303 | 0.782 |
| 97 | 0.57 | 42.75 | 75.28 | 0.315 | 0.813 |
| 98 | 0.62 | 54.26 | 88.16 | 0.330 | 0.846 |
| 99 | 0.65 | 81.15 | 124.25 | 0.336 | 0.878 |
| 2000 | 0.71 | 110.70 | 156.72 | 0.351 | 0.906 |
| 01 | 0.72 | 167.67 | 230.75 | 0.342 | 0.936 |
| 02 | 0.75 | 290.94 | 387.62 | 0.327 | 0.963 |
| 03 | 0.77 | 494.30 | 635.03 | 0.313 | 0.991 |
| 04 | 0.78 | 1,248.48 | 1,593.30 | 0.293 | 0.163 |
| 05 | 0.77 | 1,794.50 | 2,318.16 | 0.211 | 0.802 |

(1)-B Berth occupancy

In Case 1 where full container vessels enter the port, berth occupancy conditions are lower than in Case 2 in spite of greater waiting times.

In other words, as a full container vessel will decrease port staying time by shortening cargo handling time, the berth occupancy rate of Case 1 will be consequently lowered.

Case 1

Concerning container vessels entering the port from 1985, the berth occupancy rate for large ships will be 54% in 1985, exceed 55% in 1986 and 60% in 1991.

This cannot be called high level use, as a 55 – 65% occupancy rate is considered normal in the case of two berths. In the system of using berths by order of arrival, when the occupancy rate exceeds 60%, the berths start to congest. But in a system where priority is given to container vessels, this criterion does not seem to apply. Judging from the increase in waiting time, around 55% from 1985 – '86 may be considered as the marginal occupancy rate for Case 1, so the necessity of constructing a new wharf is clear.

The occupancy rate for small ships is low so no expansion is required for the immediate future concerning these small ships.

Case 2

In Case 2, where no full container vessels enter the port and berths are used according to order of arrival, the berth occupancy rate for large ship berths reaches 55% in 1985, 60% in 1988 and 65% in 1991, giving a higher berth occupancy rate compared to Case 1. Judging only from the occupancy rate, the necessity for constructing large ship berths is apparent from 1988 to '91 when the level of berth occupancy rate will be 60% – 65%. (See Fig. 7-4-4)

The occupancy rate of berths by small ships is higher than in Case 1, but an additional small ship berth will not be required in the near future.

(2) Situation After the Completion of the Second Stage Project

In the case of Second Stage Project, assuming that a container pier is to be constructed and that full container vessels are to enter the port, simulation was carried out only for the case where full container vessels have priority in the use of the container pier. Only one container berth is expected to be constructed. In this case, full container vessels use only the container pier. When this pier is not being used by full container vessels, it will be used by general cargo vessels (except small ships) or semi-container vessels.

(2)-A Situation of waiting ships

After one container berth is added, the waiting time will largely be reduced compared to the situation after the completion of the First Stage Project. Until 1995, average waiting time for all ships will be less than 5 hours and then will start to increase though even in 2000, waiting time will only be about 12 hours as a result of the construction of another berth. (See Table 7-4-5)

Waiting time per ship exceeds 10 hours for large ships only in 1997, and 24 hours in 2002. Until 1997, the waiting ships are less than 10% of all ships entering the port and it will be after 2000 when they comprise 30%.

Fig. 7-4-4 Berth Occupancy Rate

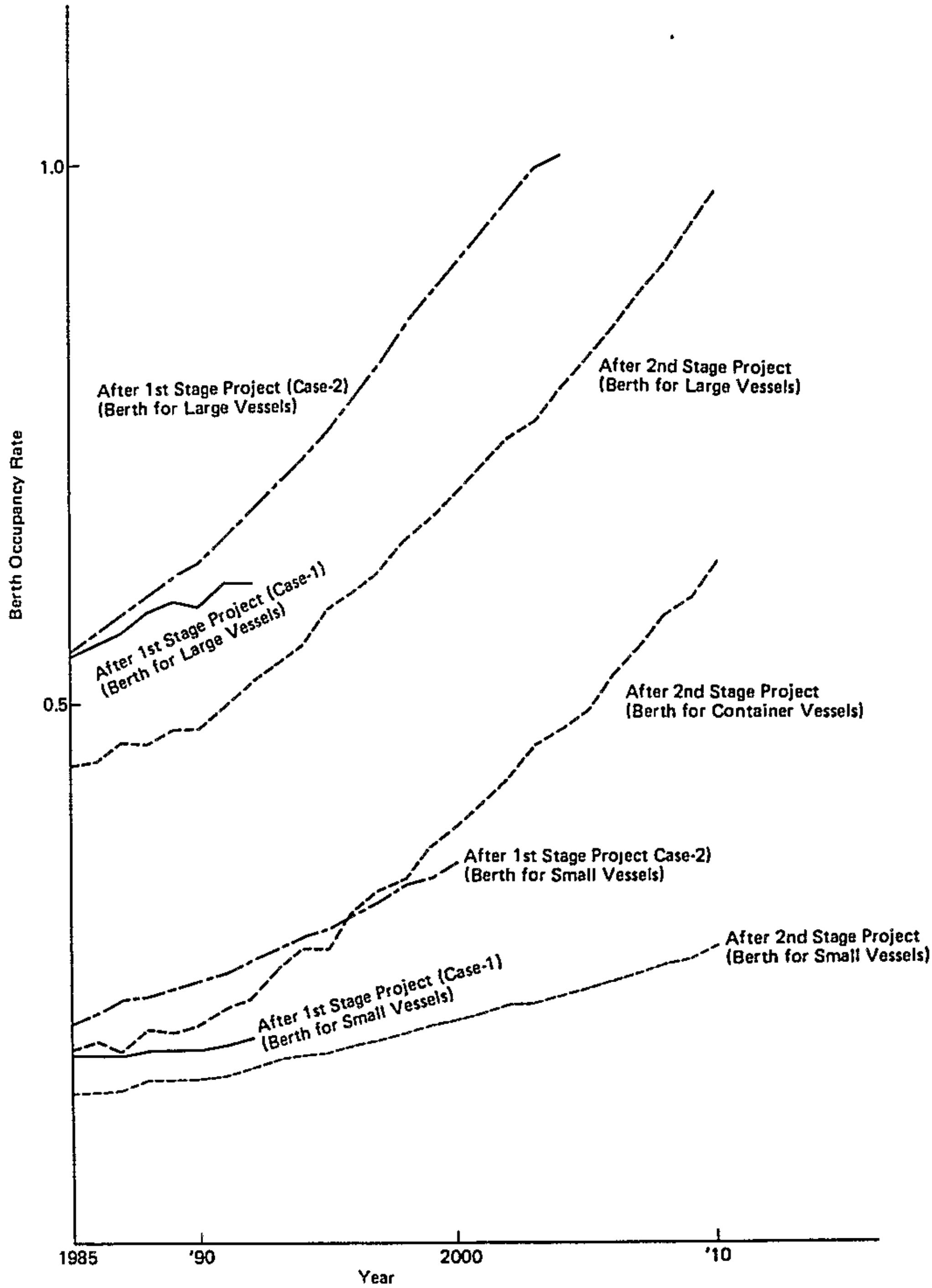


Table 7-4-5 Situation of Waiting Ships
After Second Stage Project

| Year | Ship Waiting | | | Berth Occupancy Rate | | |
|---|---|---|---|---|---|---|
| | No of Ships Waited/No of Calling Ships | Waiting Hours/Calling Ships | Waiting Hours/Ships Waited | Samll Berth | Large Berth | Container Berth |
| 1985 | 0.10 | 1.81 hrs | 18.55 hrs | 0.140 | 0.443 | 0.180 |
| 86 | 0.10 | 1.90 | 18.29 | 0.141 | 0.448 | 0.187 |
| 87 | 0.10 | 1.79 | 17.58 | 0.144 | 0.464 | 0.179 |
| 88 | 0.11 | 2.04 | 17.79 | 0.151 | 0.462 | 0.199 |
| 89 | 0.12 | 2.79 | 23.04 | 0.151 | 0.475 | 0.196 |
| 90 | 0.12 | 2.72 | 21.81 | 0.153 | 0.476 | 0.204 |
| 91 | 0.13 | 3.03 | 23.94 | 0.156 | 0.497 | 0.218 |
| 92 | 0.15 | 3.11 | 21.32 | 0.163 | 0.517 | 0.229 |
| 93 | 0.17 | 4.41 | 25.59 | 0.170 | 0.535 | 0.255 |
| 94 | 0.18 | 4.61 | 26.22 | 0.173 | 0.553 | 0.273 |
| 95 | 0.19 | 4.94 | 25.72 | 0.176 | 0.585 | 0.273 |
| 96 | 0.21 | 6.43 | 30.81 | 0.183 | 0.600 | 0.306 |
| 97 | 0.24 | 8.01 | 34.10 | 0.187 | 0.619 | 0.326 |
| 98 | 0.25 | 9.25 | 36.51 | 0.195 | 0.651 | 0.335 |
| 99 | 0.27 | 11.11 | 40.65 | 0.201 | 0.668 | 0.365 |
| 2000 | 0.29 | 12.36 | 42.64 | 0.206 | 0.692 | 0.384 |
| 01 | 0.32 | 16.19 | 51.12 | 0.213 | 0.718 | 0.406 |
| 02 | 0.35 | 21.73 | 61.34 | 0.220 | 0.742 | 0.429 |
| 03 | 0.37 | 20.60 | 56.45 | 0.223 | 0.759 | 0.458 |
| 04 | 0.39 | 28.18 | 71.73 | 0.228 | 0.791 | 0.472 |
| 05 | 0.42 | 34.55 | 81.67 | 0.235 | 0.818 | 0.490 |
| 06 | 0.45 | 47.41 | 105.26 | 0.241 | 0.844 | 0.523 |
| 07 | 0.50 | 73.69 | 146.11 | 0.249 | 0.876 | 0.548 |
| 08 | 0.52 | 124.06 | 238.82 | 0.257 | 0.902 | 0.578 |
| 09 | 0.55 | 200.29 | 366.72 | 0.262 | 0.937 | 0.593 |
| 10 | 0.59 | 305.63 | 514.42 | 0.273 | 0.970 | 0.628 |

(2)-B Berth occupancy

By adding one container berth, the occupancy rates of two large ship berths will be more than 10% lower than is the case during the First Stage Project. As a result, the occupancy rate will exceed 50% in 1992, reach a level of 55% in 1994 and exceed 60% in 1996. After adding one container berth, there will be no need for another berth for general cargo vessels until about 1995.

Also, the construction of an additional container berth will not be required until after 2000 unless container cargo increases beyond expectations.

As for small ship berths, there will be no need for an addition to the one berth currently used.