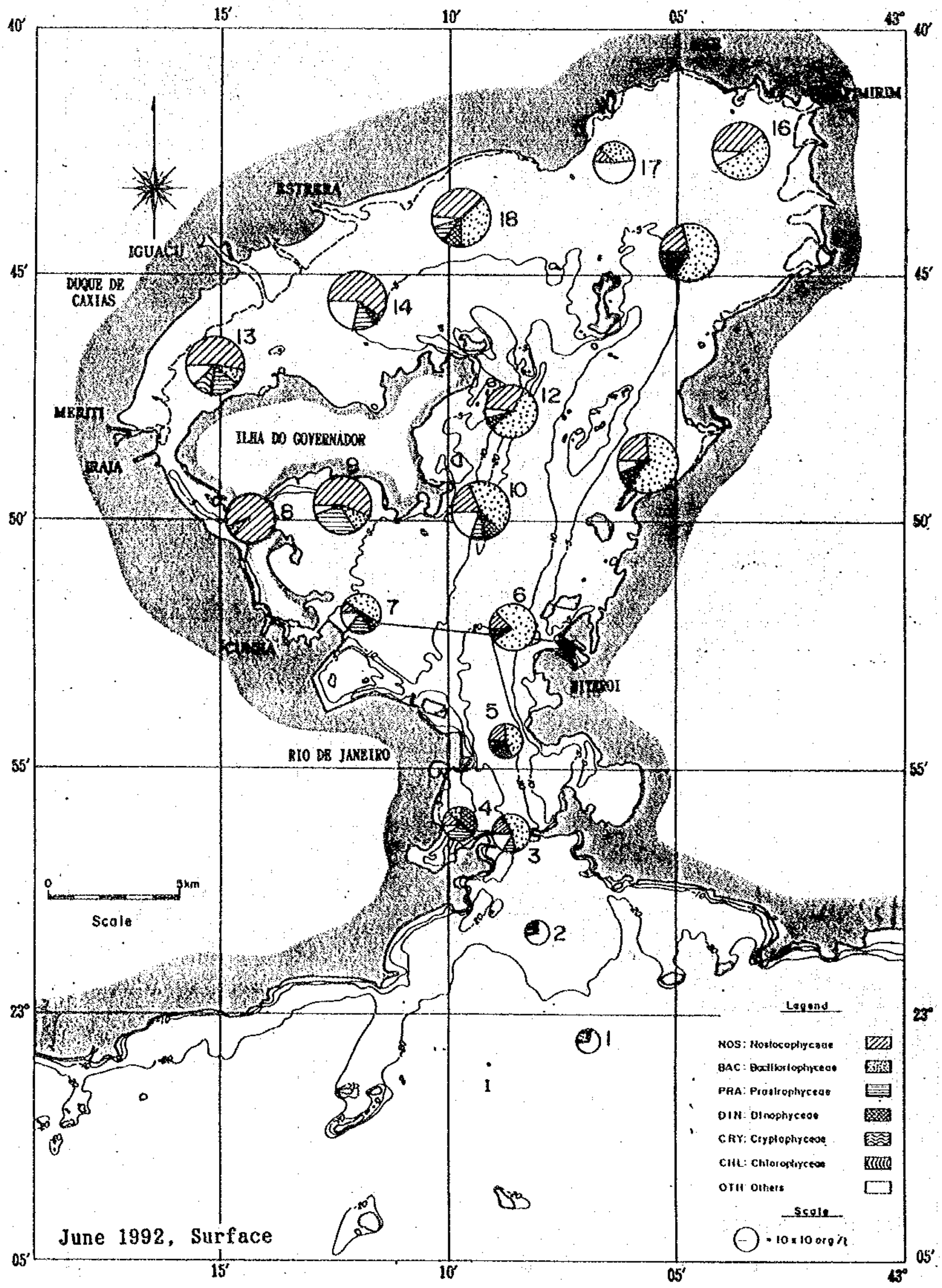

Fig. 6.1- 2(3) Distribution of Phytoplankton Population

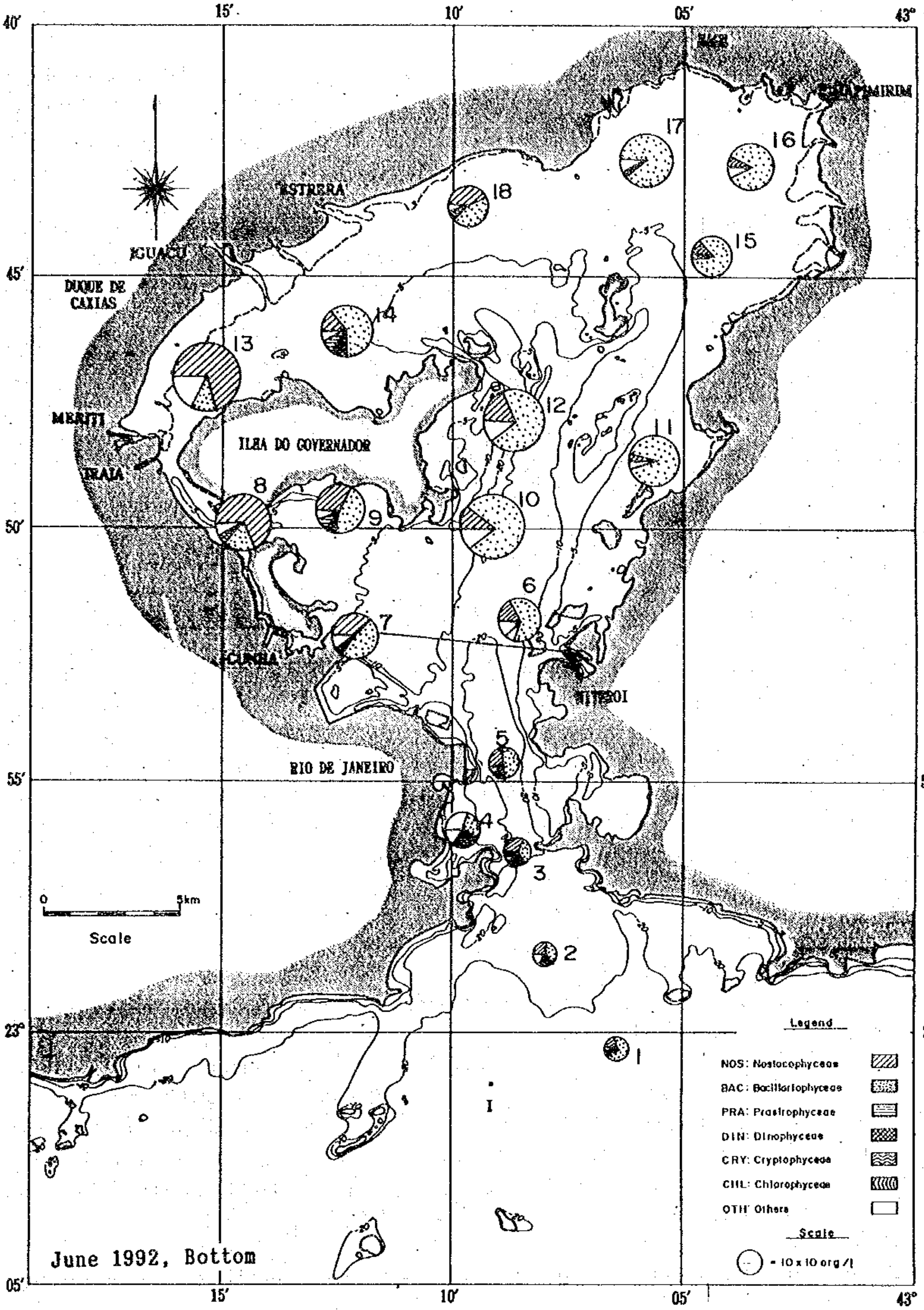

Fig. 6.1- 2(4) Distribution of Phytoplankton Population

6.1.3 Limiting Factor for Phytoplankton Production and Trophic Level

In ecosystems located in tropical regions where there is abundant solar radiation and high temperatures, as is the case with Guanabara Bay, nutrients will constitute a critical factor in the control of eutrophication.

The relationship between nutrient and algae in an aquatic system from the viewpoint of physiological characteristics is very complex with many different algae species and forms of nutrients interfering in this relationship.

However, a number of recent studies have proved that N and P are scarce in the natural environment, and these parameters have been introduced into aquatic system management and controls planning, associated with the biomass expressed by Chl-a.

To verify this, an elaborate correlation between N and P ratio in water and in algae biomass, in Guanabara Bay, was formed.

It was assumed in this correlation that the N and P ratio in algae is the same as that of the seston because algae makes up the greater part of suspended matter in water. **Fig. 6.1-3** was prepared, using all data for N, P and Chl-a collected from the water surface layer for 3 sampling surveys (2 samples collected in each survey) at 18 stations performed during 1992. The correlation coeficient values computed in water and algae were, 0.77 and 0.89 respectively. The N and P ratio in water varies considerably, according to the nutrient concentrations while the same phenomenon does not occur in alage, indicating that the chemical composition of aquatic organisms is relatively stable even if environmental conditions change.

Fig.6.1-3 shows N/P ratios were obtained in the range of 6 to 15 in water and 5 to 7.5 in algae which suggests a lack of P for algae growth, particulary, in areas of the Bay with lower concentration of nutrients, which corresponds to the mouth region of the Bay. The sediments in this region are composed predominantly of sand with a small portion of organic matter that can not constitute significant source of nutrient, these facts coincide with the nutrient balance observed in the Bay.

Based on the explanation presented, it is possible to conclude that P is the most probable limiting factor for eutrophication in Guanabara Bay.

The trophic level currently in all areas of the Bay, except the mouth region, should be classified as a very high eutrophic eco-system zone, based on 20 μg/l of chl-a, the maximum admissible limit for trophic level criteria usually adopted.

In such an environment, algae reproduction is rapid. Adopting a value of 1 for maximum growth rate for predominant algae, estimated through primary production obtained during surveys and 0.3 for half saturation constant, a specific growth rate can be computed 0.25/d that means approximately 4 days for turnover time of algae in the bay.

	Seston	Water
N	0.132 + 4.92 x P	0.562 + 4.42P
R	0.89	0.77
Sample Number	48	49

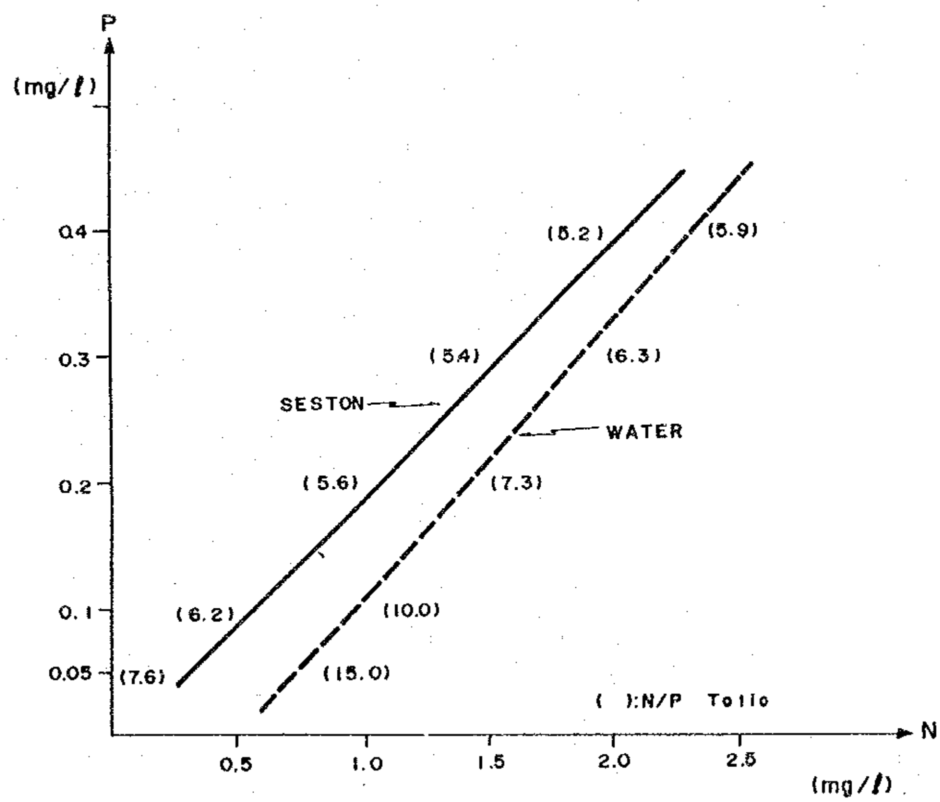

Fig. 6.1- 3 N and P Ratio in Water and in Seston

6.2 Zooplankton Community

6.2.1 Species Variation

Zooplankton sampling was performed at 17 stations in June 1992 and at 12 stations in October 1992 using a water pump with 2 types of plankton net and a conical net equipped with a flowmeter.

The classification and quantification of collected samples was carried out by the Department of Biology at UFRJ.

The phase 1 survey showed very low zooplankton density at all sampling stations as compared to the data obtained from earlier research due to insufficient pump capacity. Even though, the data indicated that the Copepoda group predominated numerically and had a higher density at the mouth of the Bay. In the area highly polluted adjacent to Ilha do Governador lower zooplankton density was observed.

In phase 2, 23 species of microzooplankton and 70 species of macrozooplankton were identified. Classification results are registered in the Supporting Report.

The predominant species identified were Acartia lilljeborji, Paracalunus quasimodo, Paracalanus crassirostis, etc., all of which belong to the Copepoda group and are typical of ocean coastal regions. P. quasimodo is, for example, neritic, termofil and epiplanktonic, being considered an opportunistic hervivorous, consuming, principally, phytoplankton, protozoa, etc. In the absence of plant food, they introduce detritus Copepoda naupli which is absolutely predominant in the microzooplankton community over the entire area.

6.2.2 Distribution Pattern

Fig. 6.2.1 shows the distribution pattern of microzooplankton. It shows higher values at the mouth region and lower values in the central and the inner part of the Bay, particularly in the area adjacent to Ilha do Governador. Macrozooplankton showed the same distribution pattern and their distribution characteristics particularly stand out on the water surface. The population on the western side of the Bay is extremely restricted but larger at the entrance of the Bay. The central area of the Bay presents intermediate values.

The density at the bottom layer commonly showed higher values than those at the surface, following however, the same regional variation pattern observed in the surface layer.

This type of zooplankton distribution could be explained, partially, by complex pollution effects represented by high ammonia concentration, grease and oil contamination, heavy metals, organic toxic substances and sulfide compounds etc., and partially by meso and oligohalino conditions which occur in the rainy season in the west side and inner part of the Bay when a great amount of river water inflows from the basin. The influence of pollution effects, however, was more moderate in the central area of the Bay.

The mouth region of the Bay can be considered to be almost free from the harmful effects of pollution and the euhalino condition offers favorable conditions to the predominant group of zooplankton originating from the coastal area of the ocean. Population density obtained by use of the surface plankton net resulted in higher values than those in the pumped samples, showing, nevertheless, the same tendencies in zooplankton composition and distribution characristics as observed in other samples.

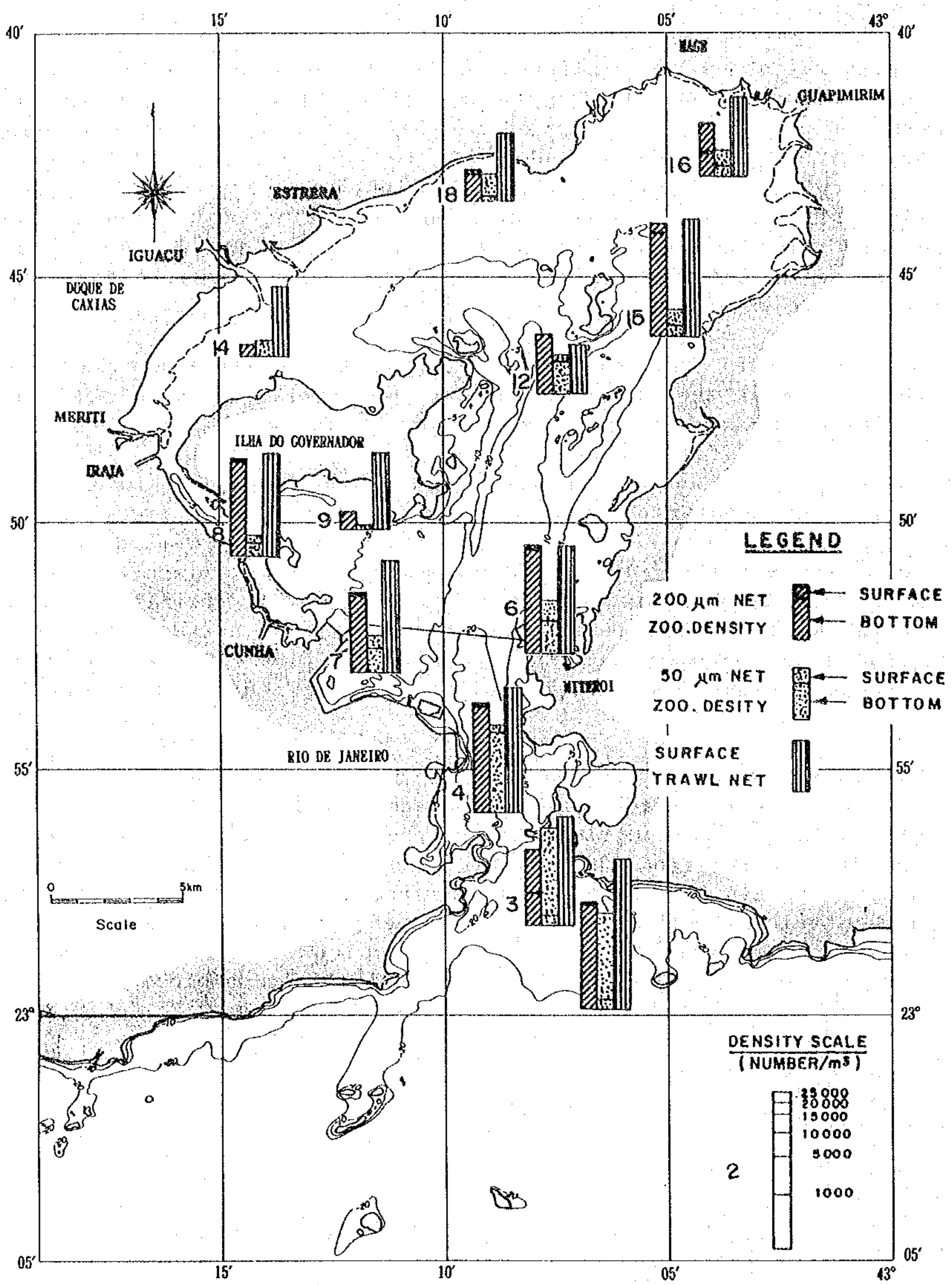

Fig. 6.2- 1   Zooplankton Community Distribution

6.2.3 Zooplankton Density

Table 6.2-1 gives an idea of the size of the zooplankton biomass in Guanabara Bay.

Table 6.2-1 Ratios of Algae and Zooplankton Biomass

Biomass	STATION											
	1	2	3	4	5	6	7	8	9	10	11	12
Algae biomass	0,87	2,23	3,00	6,78	8,31	8,51	8,10	7,98	10,09	7,07	3,20	4,92
Zoo biomass	0,033	0,022	0,021	0,011	0,010	0,040	0,004	0,001	0,003	0,006	0,005	0,026
A/Z ratio (%)	4	1	0,7	0,2	0,1	0,5	0,05	--	0,03	0,2	0,2	0,5

The biomass value of phytoplankton in this table was evaluated based on Chl-a and the biomass of zooplankton was determined in the laboratory in the Department of Zoology, at UFRJ. The percentage of zooplankton biomass in relation to phytoplankton obtained by this evaluation is very low, except for stations 1 and 2 located at the mouth of the Bay, if compared to the biomass ratio usually found in an eutrophic environment, where it varies normally between 1 and 10 %.

This low density of zooplankton in the bay seems to enable zooplankton survive almost independently from phytoplankton proliferation that usually serve as food for them.

Fig. 6.2-2 indicates a negative correlation between the zoo and phytoplankton population. Therefore, an increase in zooplankton density results in Chl-a decrease. Generally speaking, zooplankton population must increase, with algae proliferation according to the food web relation between them. This relationship, however, tends to be lower in eutrophic systems because of large amount of bacteria and suspended organic matter that offer zooplankton other food options, besides phytoplankton.

On the other hand, phytoplankton produced predominantly in eutrophicated ecosystems is mostly of the Cianophyceae group, usually, form large colonies that can not be eaten as food by zooplankton.

The zooplankton and Chl-a relation (**Fig. 6.2-2**) could be explained, satisfactory, by the behavior mentioned above, suggesting that zooplankton production in Guanabara Bay develops almost having nothing to do with phytoplankton proliferation.

The explanation presented leads to the conclusion that Guanabara Bay is not offering, presently, favorable conditions for zooplankton production.

On the other hand the lower correlation suggests that secondary production, represented by zooplankton does not constitute an important factor for the application of an eutrophication simulation model.

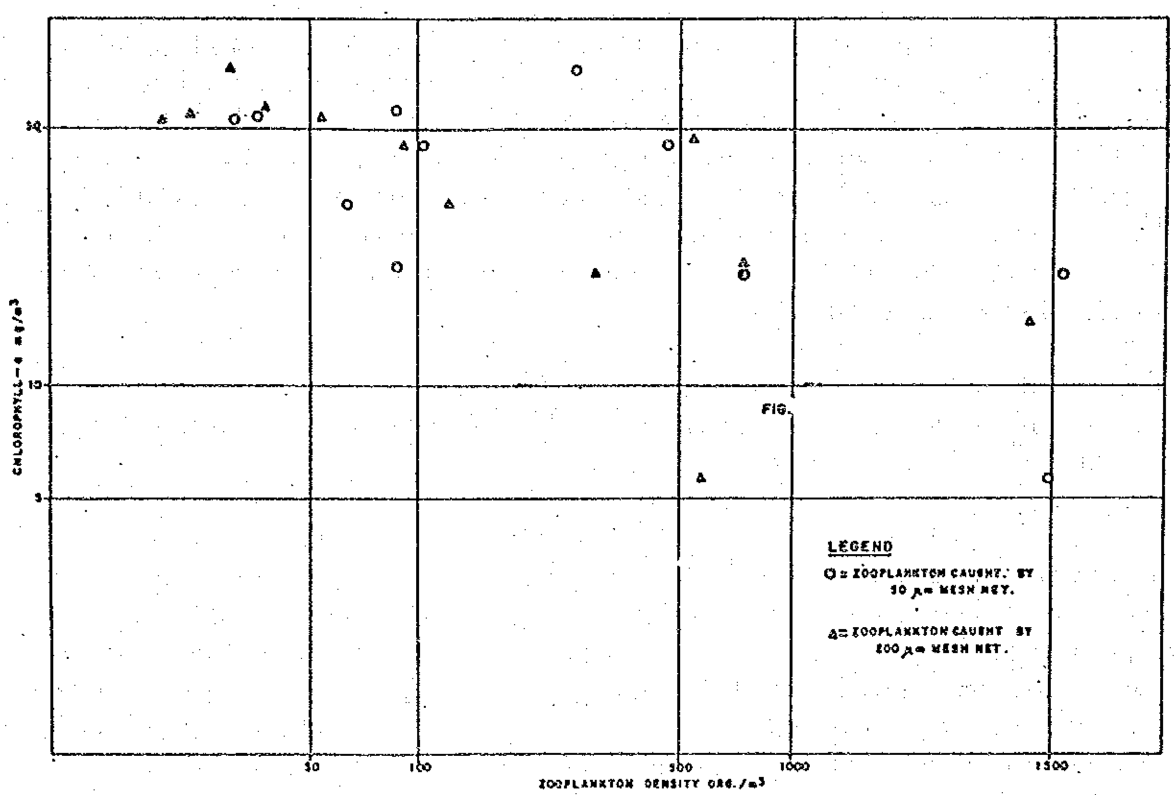

Fig. 6.2- 2 Relationship between Chl-a and Zooplankton Density

6.3 Benthic Community

Data on benthos were collected at 16 stations in June 1992 and 13 stations in October 1992 using a Peterson dredge sampler. Classification and quantification were carried in the FEEMA laboratory.

The distribution results shown in **Fig. 6.3-1** are divided into three distinct areas. At the inner part of the Bay, northern side of Ilha do Governador and Ilha de Paqueta, very few or a total absence of benthic organisms was observed. Such a low population occurred due largely to reduced oxygen concentrations in the bottom layer and, at the same time, the sediment composed of silt with organic concentration maintained in anaerobic condition, together with reduced sulfide compounds which have a toxic effect on benthic animals.

In the central Bay area bounded by the southern side of Ilha do Governador and Fundao, a large amount of Gastropoda, Littoridina australis was collected. In this region a relatively high level of pollution is observed with only 1 to 2 mg/l of DO in the bottom layer at the sampling station located near Galeao Bridge (St. 8).

The large difference in the biological distribution found between the two areas, mentioned above, could be attributed to the difference of the sediment characterisctics. The predominant characteristics of the sediments in the latter area are sand with silt without H_2S production. An environment in such a degradated condition allows for the development of only a few kinds of opportunistic organisms. Of the total population of 33,000 org./m^2 found in the phase 1 and of 44,000 org./m^2 in the phase 2 at St. 8, only 2 species were found in the phase 1 and 4 species in the phase 2, resulting consequently in a very low diversity index, suggesting that the environment is extremely selective.

On the stretch which extends between the entrance and the Rio-Niteroi Bridge, water quality is much better compared to the areas already mentioned, and the sediments constitute fine sand with very small proportion organic matter. In this condition, the benthos community appeared more diversified, with the Polychaeta errantia population predominating.

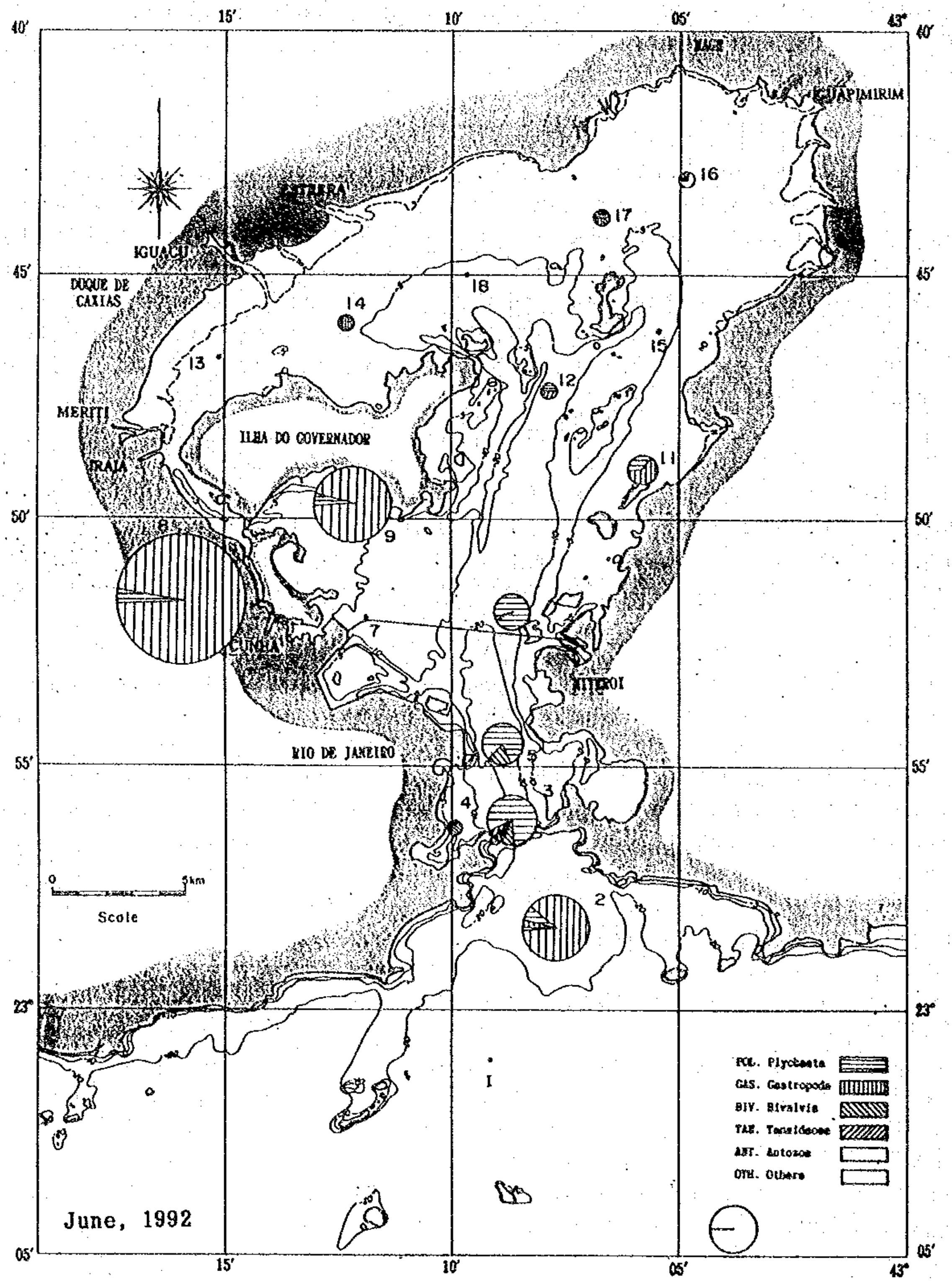

Fig. 6.3- 1(1) Benthic Community Distribution

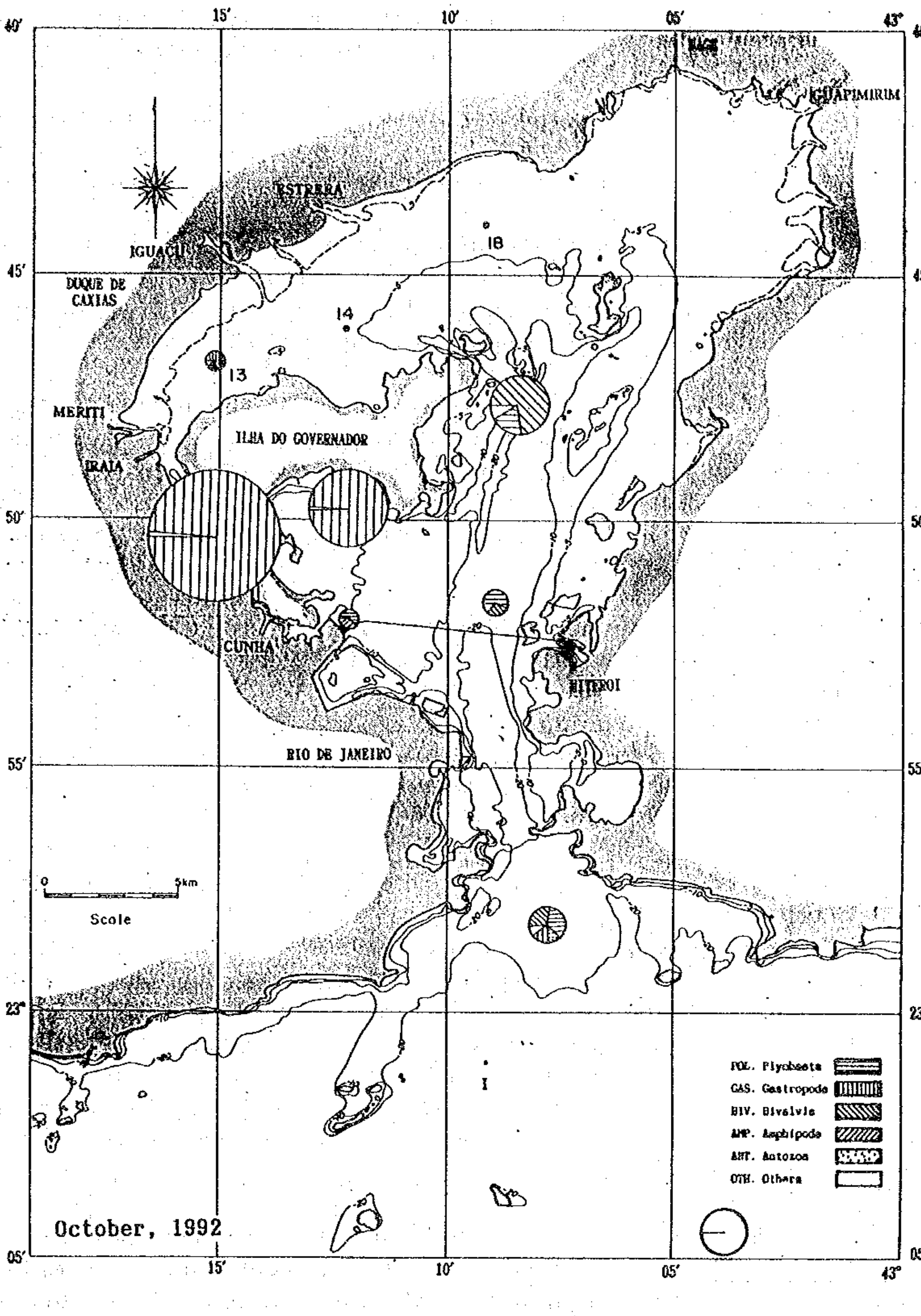

Fig. 6.3- 1 (2) Benthic Community Distribution

6.4 Fouling Community

In Guanabara Bay, rocky coast suitable for the production of fouling organisms occupies a relatively small area found mainly near the entrance of the Bay and around Ilha de Paqueta.

The coast consists of stone and concrete, even though its area is more extensive than the rocky coast, anthrophic activity is limited to the southern and central parts of the coastline.

Fouling fauna sampling was performed at 8 stations in the 1st phase and 5 stations in the 2nd. Classification and quantification of these samples was carried out by the Dept. of Oceanography at UERJ with the cooperation of National Museum at UFRJ.

The results of the two surveys performed showed the presence of 41 species of zoobenthos and 5 species of macroalgae, thus there is a relatively rich population of organisms at most sampling stations. Generally speaking, the middle littoral superior zone had a higher fauna population than the infra littoral superior zone (See Supporting Report).

Fig. 6.4-1 shows the surface distribution ratio of macrofaunas estimated visually at all sampling stations. This figure presents the predominance on rocky surfaces of macroalgae (Enter-mopha sp. Ulva graciraria and Hypnea sp.) that are relatively sensitive to pollution and salinity changes at the stations at Ilha de Paqueta, Santos Dummond Domestic airport, Ponta de Gragoata and Enseada de Botafogo.

Mussels Perna perna belonging to the Cirripedia group is of commercial importance and was abundantly observed at the entrance of the Bay. Approximately 95 of the pillars of the Rio-Niteroi Bridge extending 8.5 km are known as important production sources for these mussels. However, very few mussels were caught in the two phases of the sampling survey because the frequent scrapping of fishermen has caused a decrease in this fauna. Instead of these mussel zoobenthos, Bugula nentina and Styiella plicata, covering the surfaces of the bridge pillares situated at Niteroi side were observed.

The general distribution pattern of the main zoobenthos can be seen in **Fig. 6.4-2**. The Polychaeta group, found at 11 sampling stations, constitutes organisms with the largest distribution area among the fouling fauna.

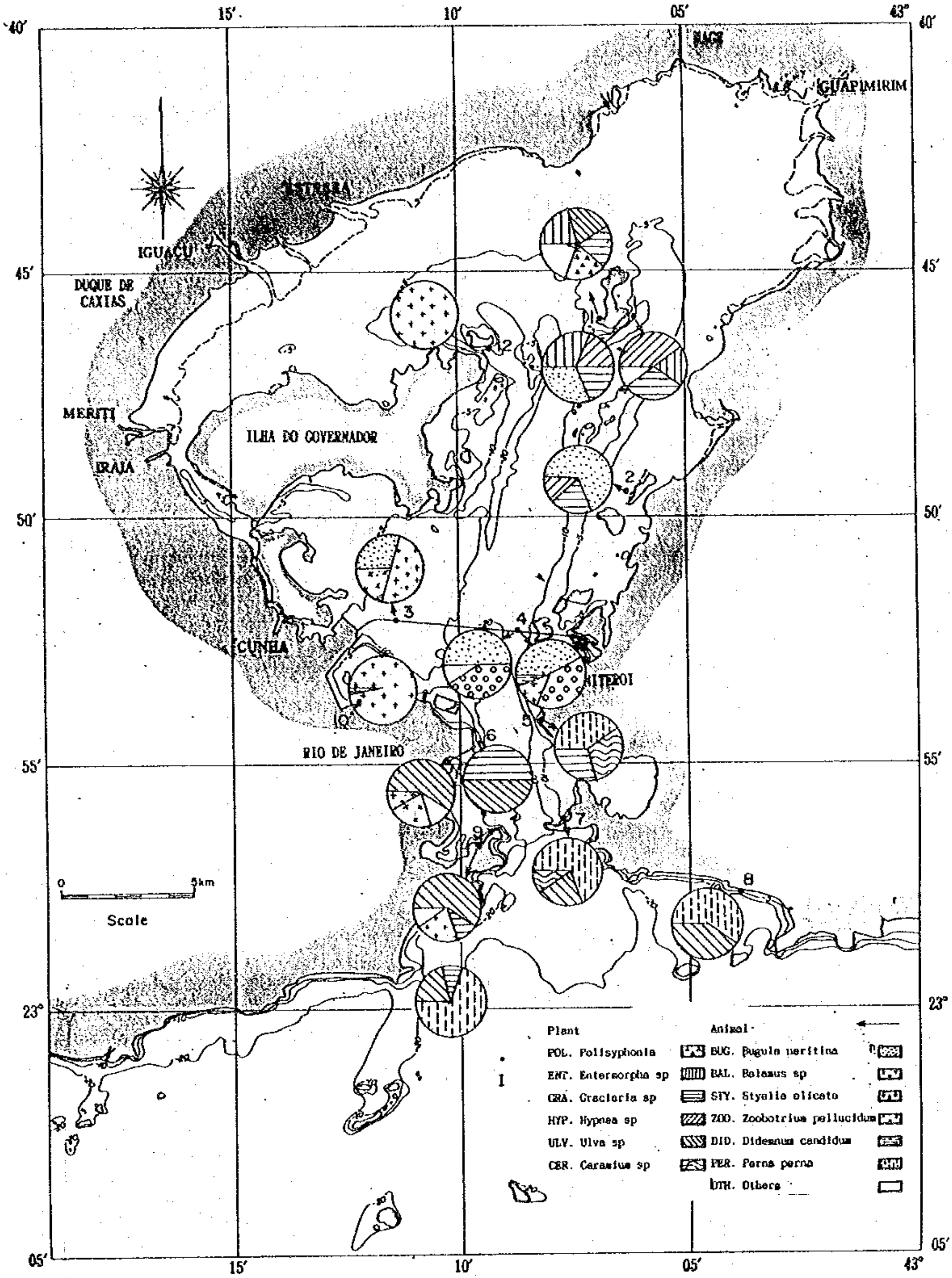

Fig. 6.4- 1 Distribution Ratio of Macrofauna in Fouling Community

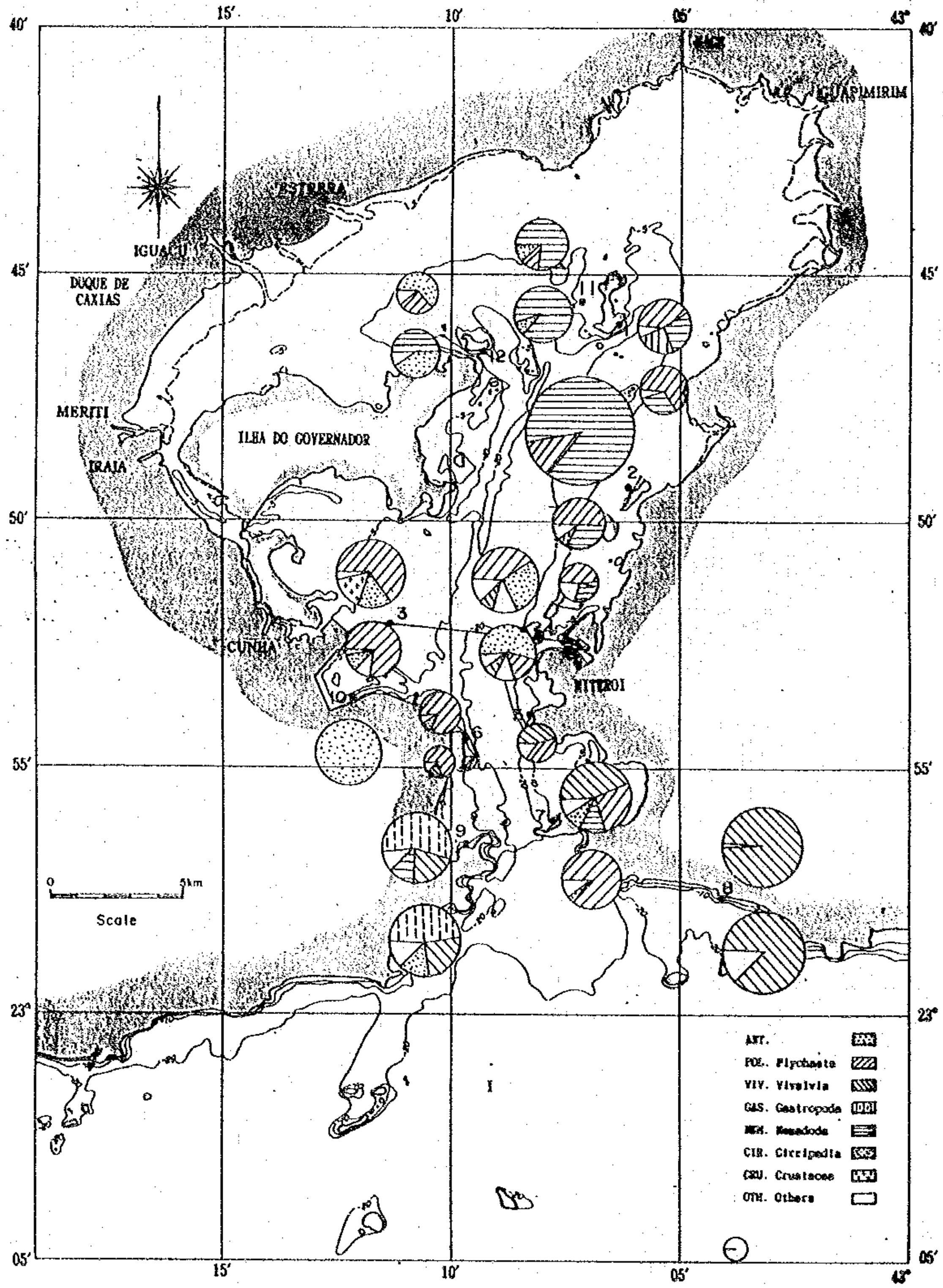

Fig. 6.4- 2 Distribution Ratio of Zoobenthos in Fouling Community

Balanaus sp. from the Cirripedia group, in particular B. amphirite and amphirite, which are considered biological pollution indicators, were observed to be predominant in Rio de Janeiro Harbor, where pollution levels are high.

The Nematoda and Gastropoda groups as well as Perna perna, as explained, were observed; each of them in the limited areas.

Data presented above indicated the proliferation tendencies of each fouling fauna group in a restricted area without any general trends in their distribution pattern. Those facts were confirmed by the statistical analysis.

6.5 Fishes

According to IBAMA statistical data at Maua and Ramos fishermen colonies, and from inventory data obtained at the Niteroi market in this study, about 6 tons/day of commercial fish production was estimated as the maximum production within the Bay, in addition to about 1 ton per day of mussels Perna perna. About 80 % of the catch is composed by Corvina, Bagre, Tainha, Sardinha de boca torta, Parati, Espada and Enchova.

According to Prof. Gustavo W. A. Nenon of the National Museum at the Universidade Federal do Rio de Janeiro, Guanabara Bay plays a very important role as a fish nursery ground. Some types of fish, for instance, Tainha, Parati, Sardinha and some species of Manjuba, that are most popular in this region, etc. enter the bay to mature and then return to the ocean.

On the other hand, Enchova, some species of Linguado, Corvina and Pescadinhas go into the Bay for reproduction. This fish's behavior signifies the close relationship between the Bay and the ocean in view of fish production, as can be seen in many other situations in the estuary system. So, if such predatory fishing activities and water quality degradation continue, it would cause the rupture of relationship in the near future, severely affecting fish production not only in the Guanabara Bay, but also in the adjacent ocean coastal areas.

6.6 Managrove Swamps and Salt Marsh

6.6.1 General Situtation of Mangroves in Guanabara Bay

The profile of the main area of salt marsh and mangrove swamps and the distribution of mangrove forests in the Guanabara Bay basin is shown in **Fig. 6.6-1**.

Although the Guapimirim and Cacerebu basins are preserved by the Federal Legister, significant interference due human activities, principally on the south-east side of this area is noticeable.

The mangrove forests extending along the Rio Estrela and Rio Iguacu are seriously damaged, mainly on the right side of the Rio Estrela and the left side of the Rio Iguacu. Furtheremore in an appreciable area located at the lower side of a garbage landfill, Jardim Gramacho, a mangrove forest is almost non-existent. The ground of this area has completely dried, water only at approximately 30 cm below the surface.

The general distribution of mangrove forests observed in the study area shows Laguncuraria sp., normally near the river, Avicennia sp. at the inner parts and, in some cases, Rhizophora sp. near the river. The mangrove forest existing in the Guapimirim basin is generally higher in elevation than in other areas at approximately 3 - 5 meters for Laguncuraria sp., and 10 - 12 meters for Avicennia sp.. It is important to mention Spartina sp., Hisbiscus sp., and Typha sp. cover an appreciable area of the mangrove forests.

6.6.2 Sediment Quality

As for the characteristics of the sediments in the researched basis that consist fundamental substracts to support all the biological and forestal evolution, as well as casual sewage disposal. The physico chemical analysis performed in the 12 stations generally, showed light acid and high concentrations of organic matters (8 to 49 % of volatile matter lost) (See Supporting Report). The concentrations of N and P were also relatively high compared to normal soil composition, ranging from 1.3 to 2.0 % and 0.71 to 0.26 %, respectively. This fertility could be derived, mainly, from the contribution of litter originating from mangrove forests and pollution sources. On the other hand, the sediments are black in color due to the reduction process and are composed mostly of clay and silt (94 - 99 %), indicating a very low permeability.

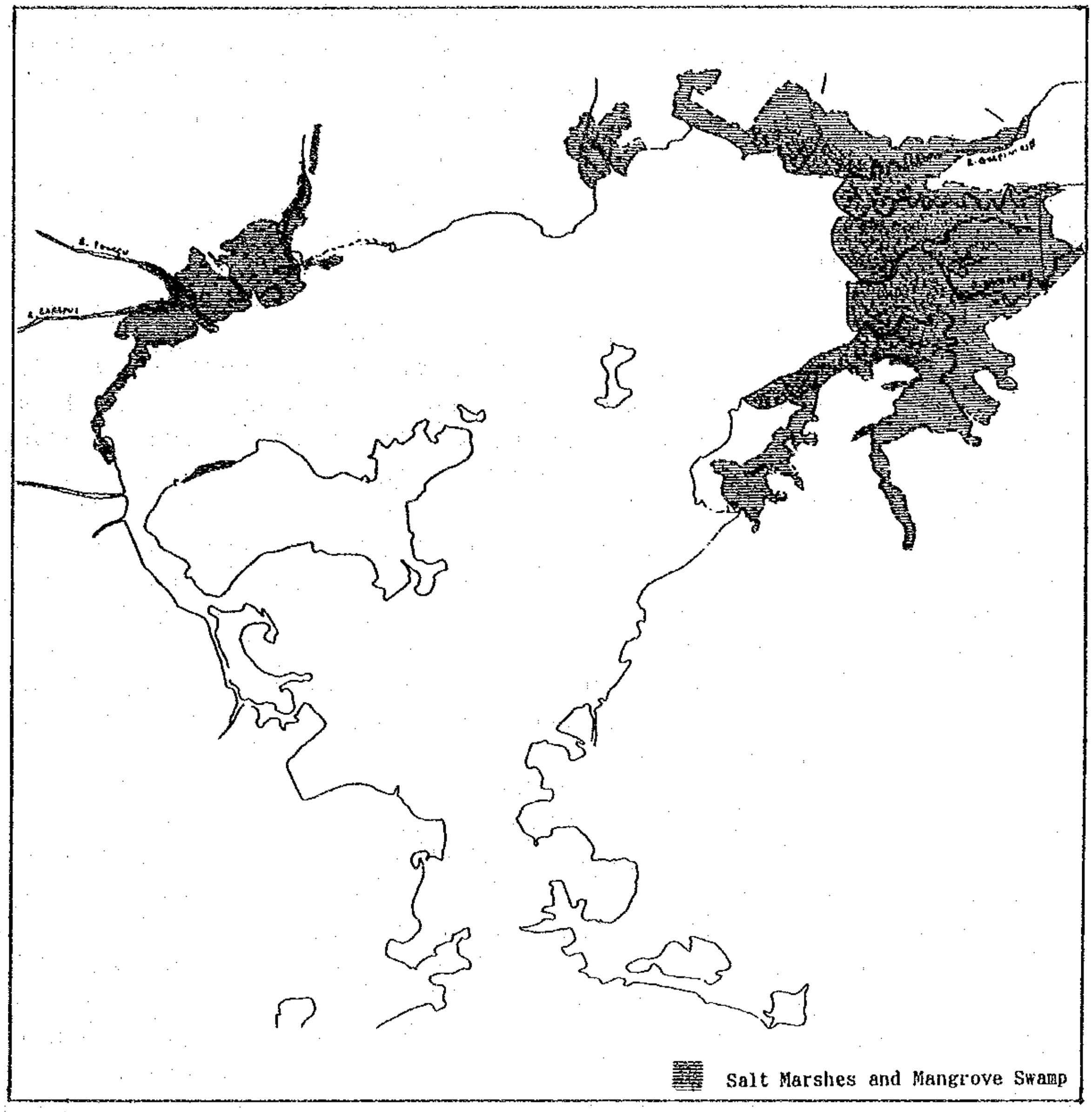

Fig. 6.6- 1 Distribution of Salt Marshes and Mangrove Swamp

It was verified that the concentration of organic matter and phosphorous in the Iguacu and Estrela basins, affected by pollution flow, tended to be higher concentrations than the Guapimirim and Cacerebu basins. In particular, the station located at the middle part of Estrela basin showed an extremely high organic matter content (48 %) where high population of crabs is found.

As for heavy metals, all parameters analyzed showed lower values than the maximum limit established by the criteria for practical agricultural use proposed by EPA/USA, however, higher Hg concentrations were found in the Iguacu and Estrela basins located near a pollution source compared to the Gaupimirim basin.

6.6.3 Crab Community

Based on the investigation on the community of crabs performed in 12 areas a predominance of the Uca group was detected followed by Ucides sp. and Chasmagnathus sp. The crab population ranges from 20 to 80 org./m^2, and the population in Estrela and Iguacu basins was observed to be higher (See Supporting Report).

Based on the data obtained, it seems that the destruction and the pollution level in the mangrove forests, in the researched areas, has not yet reached the level where it adversely affects the crab population. On the contrary some crab groups such as Uca sp. have yield a higher population growth rate in the Estrela and Iguacu basins where more intensive environmental changes can be observed, than in the APA-Guapmirim.

Crabs seem to be the most important consumers of organic matter in mangrove swamps, representing almost 75 % of all animal biomass in this environment. On the other hand, they essentially contribute to the oxidation of organic matter and reduce compound contents in sediments through the excavation of their burrows.

As for the benthos community the results showed a predominant presence of the Polychaeta Errantia group at major sampling stations. The total population of organisms at each station ranged from 22 to 4,653 org./m^2, generally showing a high population at stations situated near the sea-shore. The significant features of benthic distribution in the basins were not observed.

In the case of Guanabara Bay, the biomass balance estimated through the collected data indicated that the crab production rate is slightly lower than the litter accumulation rate in the sediment in the mangrove swamps.

The mangrove swamp and estuary system is important from the view point of water purification process of the Bay. Collected information during the survey suggests that mangrove swamps and marshes located, mainly, in the inner part of the Bay contribute in the retention of substances acting as a natural filter and, therefore, improving the water quality in the Bay.

An important aspect to be pointed out is that a mangrove forest is a very vulnerable ecosystem, where constant accumulation of sediments occurs as well as the invasion of grasses that succeed mangrove trees in time. So it is essential to adopt aggressive measures for the comprehensive and permanent preservation of mangrove swamps and it is not sufficient to leave them untouched.

CHAPTER 7

HISTORICAL CHANGE IN ENVIRONMENT AND CURRENT USE OF THE BAY

CHAPTER 7

HISTORICAL CHANGE IN THE ENVIRONMENT AND CURRENT USE OF THE BAY

Kowledge on past environmental changes in Guanabara Bay and its basin is important to understand the bay's original biofacies and environmental assimilating capacity.

In this chapter, the environmental changes in Guanabara Bay and its basin were deduced from the statistical data showing the change in population and industry, old oceanographic chart, the analytical results on core samples of bottom sediments, and other evidences.

Further, the current use of the water area and the coast in Guanbara Bay was also reviewed to calculate the potential benefits that can be gained from the improvement of water quality.

7.1 Historical Change in the Environment around the Bay

7.1.1 Changes in Land Use

Brazil was discovered in 1500 and Rio de Janeiro was built on the coast of Guanabara Bay during the period 1557 to 1567. Through the development of sugar cane plantations from the 16th Century to the 18th Century and the development of coffee plantations carried out in the early half of the 19th Century, the majority of the primeval forests which once widely covered the coastal areas of Guanabara Bay disappeared.

The population of the City of Rio de Janeiro already exceeded a million by early in the 20th Century, before industrialization got under way. In the 1950's, as a result of the active promotion of industrialization by the federal government, industrial production in Rio de Janeiro increased rapidly and its population jumped to exceed 5 million by the 1960's.

Meanwhile, the GNP of the nation of Brazil kept increasing during the period of 1956 to 1962 at an average annual rate of 7.8% and although there was a pause after that, it exhibited remarkable growth during the 1968 to 1973 period which was later to be called "the Brazilian Miracle".

The natural environment of the coastal areas of Guanabara Bay altered drastically due to development which has continued for almost five centuries. Amador (1992) assumed that 70 to 80% of the forests, mangroves, marshlands, tidelands and sand dunes in the coastal area of Guanabara Bay disappeared during this period due to development.

By comparing the areas of the land use categories shown on the LANDSAT images of the Guanabara Bay basin, taken in 1984 and 1991, we can see that the urban districts and grassland (including farmland) expanded their total area by about $240km^2$, while forests and marshlands decreased by about $220km^2$ (refer to Chapter 2). Although the change of land use during the 7 years was only about 5% of the overall area of the coastal areas, the decreasing trend of the forests and marshlands still continues.

7.1.2 Changes in the Shoreline and Water Depth

Reclamation works have been carried out in many places along the shoreline, accompanied by the discharge of soil and refuse from developed districts in the coastal areas, the shoreline of Guanabara Bay is slowly moving out and the depth of water in the Bay is getting shallower.

DHN published marine charts of Guanabara Bay (scale 1/50,000) in 1962 and 1992. The marine chart published in 1962 was composed from survey results collected from 1922 to 1938, and the one issued in 1992 was based on survey results obtained from 1961 to 1962.

Fig. 7.1-1 shows the comparison between these two marine charts proving the occurrence of a substantial change in the shoreline near the Fundao Channel. Also, the difference in the depth of water in the inner part of the Bay, from the two marine charts, is 1.5m to 2m showing that, during a period starting between 1922 and 1988 and ending in the 1960's, the depth of water became shallower at the surprising rate of 2.6 - 4.9cm/year (**Fig. 7.1-2**).

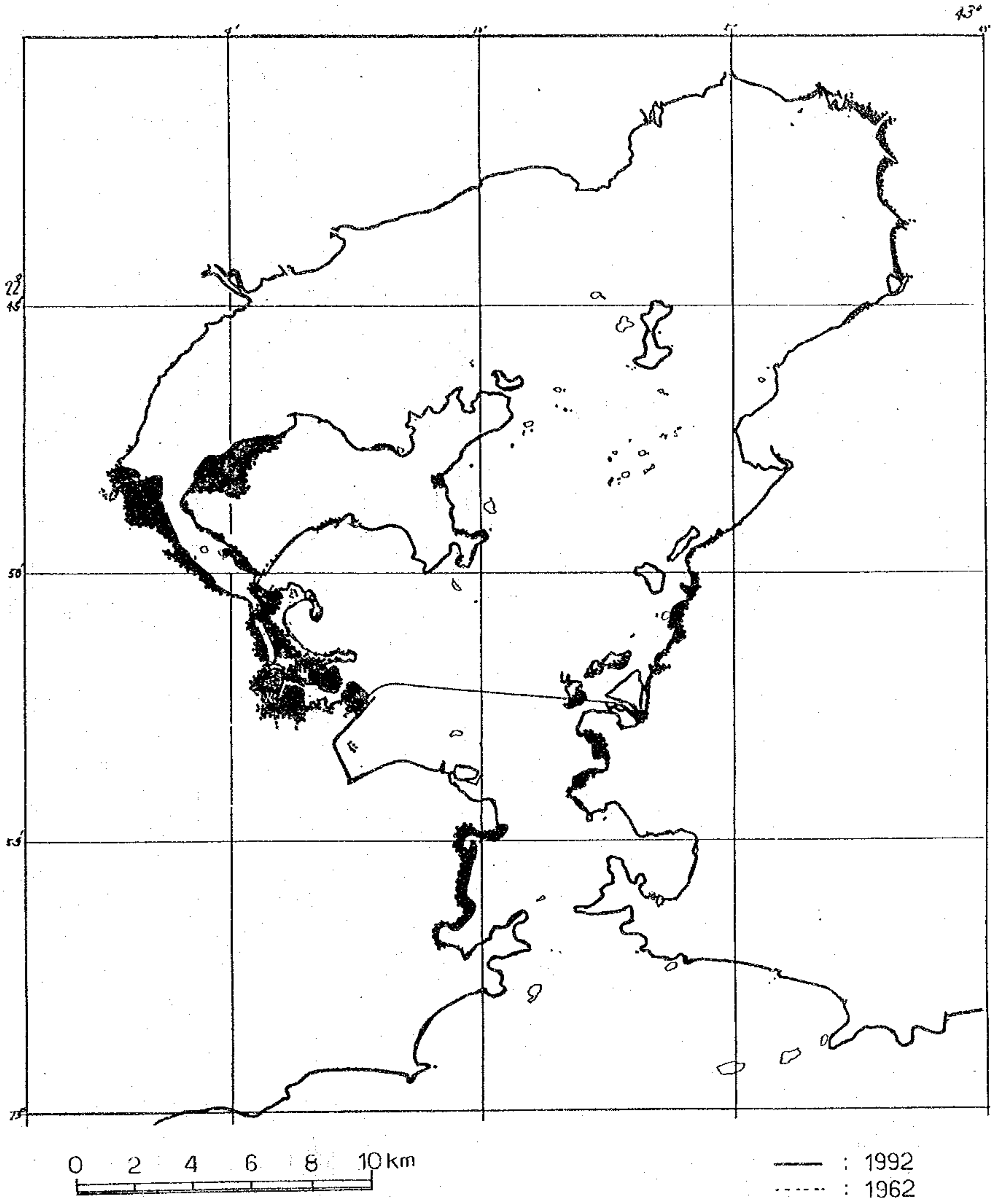

Fig. 7.1- 1 Migration of the Shoreline of Guanabara Bay

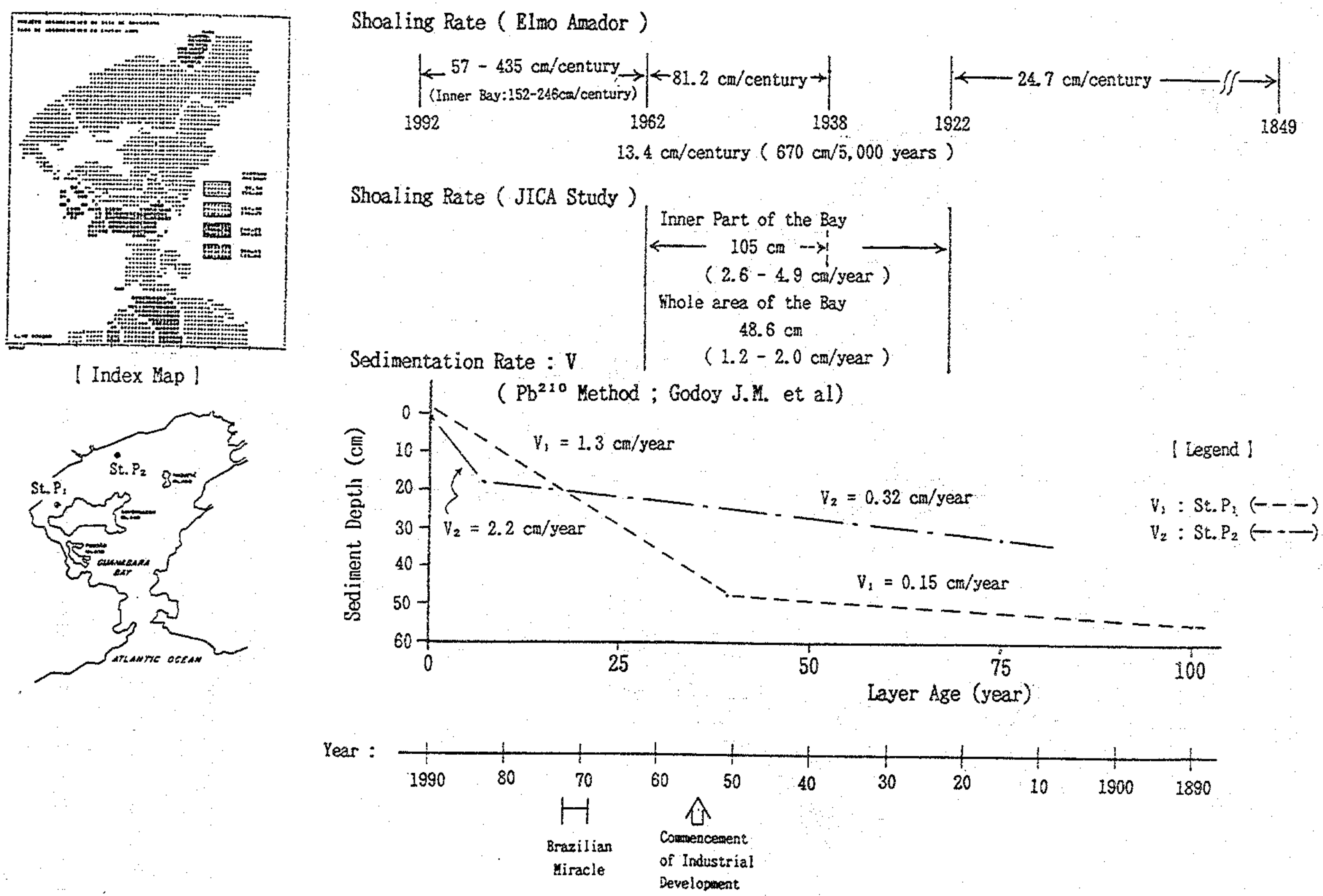

Fig. 7.1- 2 Change in Water Depth of Guanabara Bay

Godoy J.M. et al (1991) calculated the sedimentation rate in the Bay using the Pb^{210} test. According to the results for the water area to the north of Ilha de Governador, the sedimentation rate was 0.15 - 0.32cm/year, at layers deeper than 20 - 50cm into the seabed; however, the sedimentation rate at layers shallower than 20 - 50cm the rate was 1.3 - 2.2cm/year, almost 10 times faster.

Such an abnormally high sedimentation rate cannot be assumed to be caused by natural sedimentation from the basin. Accumulations of refuse were found in many places in the urban districts in the coastal areas, especially along the roads and rivers passing through favelas.

According to COMLURB, collection of daily garbage in the favelas is at the highest 40 % of the total volume, so therefore the uncollected garbage eventually flows into rivers.

Moreover, according to SERLA, the majority of material being dredged from downstream sections of the rivers flowing into the Bay is this refuse.

A lot of refuse can be seen floating in the Bay after rain and columnar samples of sediments contained pieces of garbage. Consequently, the abnormally high sedimentation rate inside the Bay is largely due to the enormous volume of refuse coming from the urban districts.

7.1.3 Changes in Sediment Quality

Along with the changes in the shoreline and water depth, water quality and sediment quality inside the Bay have rapidly deteriorated. This is because the construction of wastewater treatment and garbage treatment facilities have fallen behind the increase in population and the progress of production activities in the coastal areas, thus a lot of wastewater and garbage is discharging into the Bay.

According to the analysis of columnar samples of sediment taken at 4 points in the inner part of the Bay, concentrations of COD, KN and TP sharply increase at depths 30 - 45cm below the seabed. Chronological assessment of the columnar samples of sediment using Pb^{210} concluded that this depth corresponds to the 1950's (see Chapter 5). As mentioned this is the period when industrialization in Brazil began its progress.

7.1.4 Changes in the Biomass

Oliveira L.P.H. (1957) compared the results of biological surveys in Guanabara Bay carried out during periods of 1920 - 30 and 1950 - 55 and pointed out that sea life such as oysters, seahorses, seaurchins, starfish and shrimps in non-polluted areas of the ocean had already started to decrease in 1950 - 55.

It was 1968 when FEEMA first performed water quality analysis, at that time the BOD concentration was already 5 - 8mg/l in the western part and 3 - 4mg/l in the eastern part. According to a questionnaire conducted during the present survey many inhabitants replied that they used to swim frequently in the Bay up until 35 years ago and they used to catch crabs and shrimps up until 20 years ago (see Chapter 14).

From the results of investigations, deterioration of water quality in Guanabara Bay started sometime in the early half of the 1950's and got progressively worse in the 1960's. And according to the results of observations made during the last 15 years, by FEEMA, pollution became even worse during the 1980's and at present the Bay is like a huge oxidation pond.

7.2 Current Use of the Bay

7.2.1 Use as a Field for Marine Transportation

Fig. 7.2-1 shows the current utilization of the surface and coast of Guanabara Bay.

The central fairway extends from the mouth through to the center of the Bay for about 10km (20 - 30m deep) with anchorages (1 - 10) provided on both sides of the fairway.

An Average of 6 vessels enter or leave the Bay per day and 30 to 100 vessels, when congested, stay in the anchorages. Cruise control of these boats is carried out by the Naval Port Control Bureau.

The Rio de Janeiro Port (P) is the third largest port in Brazil handling 2.5 million tons of cargo per year. Downtown Rio faces the port and railways and trunk roads originate from here. However, harbor facilities have become rundown and their functions have been deteriorating.

Although it is necessary to dredge the port frequently since it is being buried by soil and refuse, there has not been any dredging done for four years when an area to 40m from the wharf line was dredged to a depth of 5 - 8m. The works were restricted owing to a shortage of funds. The port and the wharf are under the control of the Rio Dock Company (CDRJ) which is employed by the federal government. Dredged earth and sand are dumped into the area (S) at a depth of about 30m.

Key transportation facilities presently existing inside the Bay include the Rio de Janeiro - Niteroi Bridge (H), the ferry routes, the international airport (on Ilha do Governador) and the domestic airport.

Current Use of Coast and Water Area of the Guanabara Bay
Uso Atual da Costeira e da Espelho da Água da Baia de Guanabara

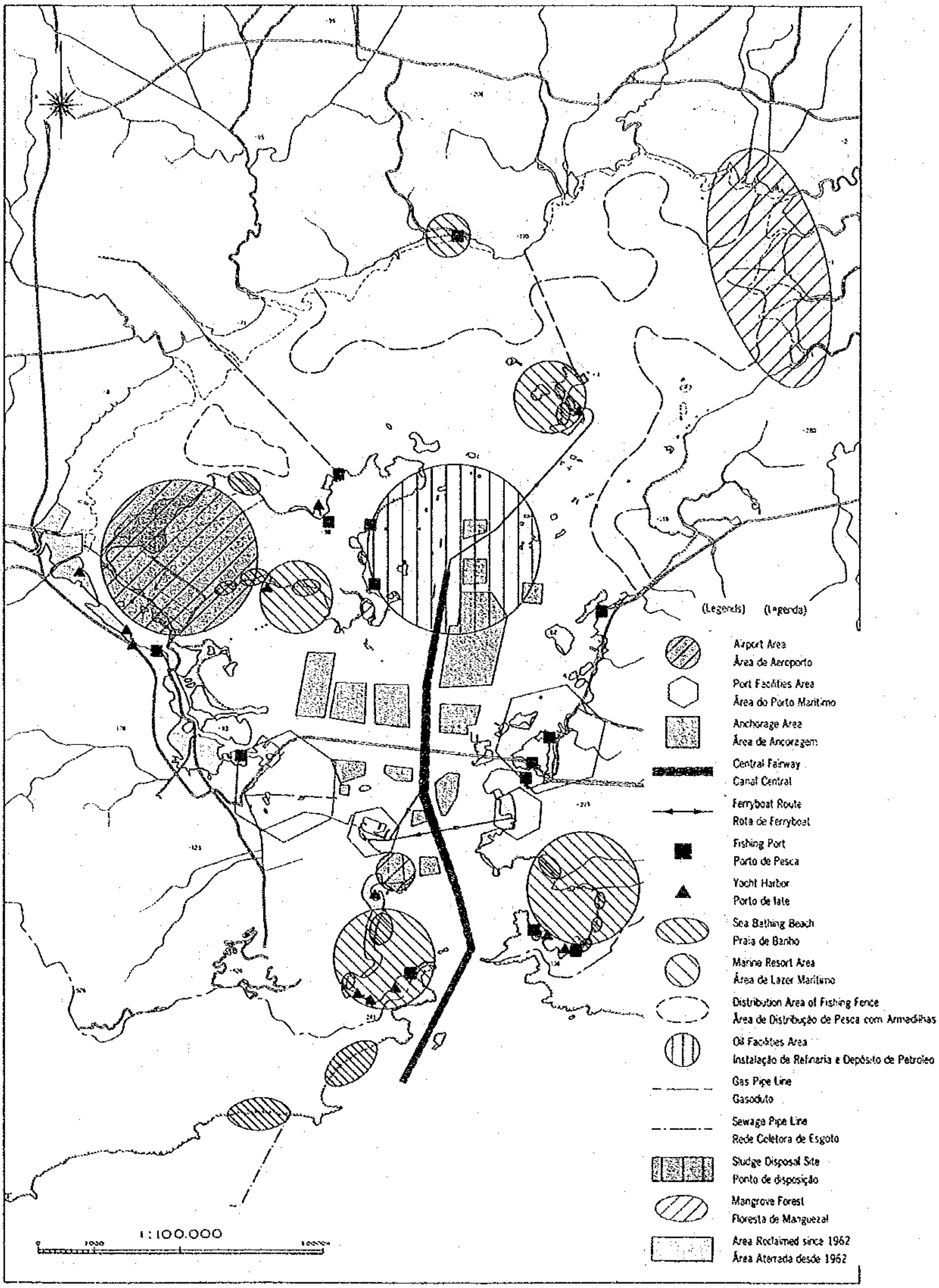

Fig. 7.2- 1 Utilization of Guanabara.Bay

7.2.2 Use as an Energy Station

There are two oil refineries and more than ten oil storage facilities some of which are connected by submarine pipelines (B). Also, the Bay is dotted with exclusive tanker piers.

From these oil refineries, warm wastewater containing a substantial volume of oil and refractory organic substances is constantly discharged into the Bay in large quantities. In addition, there is always the possibility of accidents involving tankers causing oil spills. In fact, in 1975, an Iraqi flag tanker had a serious accident spilling some 6,000 tons of crude oil into the Bay, and many accidents occur on coastal roads involving tank lorries where oil spills out over the ground.

7.2.3 Use as a Fishing Field

Guanabara Bay was once a rich fishing field with shrimps and sardines and a place where many fishermen made living. However, over fishing and water pollution caused sharply reduced fishery production in the Bay from the later half of 1960's. The current haul is estimated to be 6 tons/day at the most and the fishing population to be about five thousand.

There still exists many fishing fences in the Bay in the inner part where the water is shallower than 10m but many of them are not being used. **Fig. 7.3-1** shows 15 fishing harbors but some of them are not in use now.

7.2.4 Use as a Area for Coastal Resorts

There are many sight-seeing and recreational spots around the coast of Guanabara Bay. In particular, areas closer to the mouth of the Bay are scattered with smaller inlets with white-sand beaches coupled with sheer cliffs behind them they offer spectacular sights.

Many bathing beaches and yacht harbors taking advantage of these inlets are scattered from Botafogo Bay to Gloria Bay on the west side, Jurujuba Bay area on the east coast and on the shores of Ilha do Governador and Ilha de Paqueta in the central part of the Bay.

Also, the beaches of Copacabana, Ipanema and Lebron are world famous. However, regretfully, the majority of these bathing beaches prohibit actual bathing due to hygienic reasons. The green brown water surface mars the beauty of these beaches.

7.2.5 Use as a Place of Living

Along the eastern and western side near the mouth of the Bay, the urban areas of Rio de Janeiro and of Niteroi lie with many office buildings and residential apartment buildings. The shore of the Bay is thus an important place for living and working but there are many residents who complain of the offensive odors generated by sludge accumulating at the mouth of the rivers and at the outlets of water channels, and from malodors coming from the factories and the solid waste treatment plants.

7.2.6 As a Field for the Preservation of the Ecosystem

Vast mangrove forests and marshlands with thick growths of aquatic plants lie around the mouth of the Guapimirim River at the northeastern end of the Bay. Mangrove forests are important grounds for the breeding of shrimps and young fish and marshlands are important for the purification of the water and as habitats for water birds.

Although this district has been designated as a permanently protected area, it is gradually being destroyed due to development, discarded refuse, lumbering, etc.

7.2.7 Use as a Disposal Site for Garbage

The Gramacho Landfill where 5,500tons/day of daily refuse from the City of Rio de Janeiro is dumped, is located between the mouth of the Iguacu River and the mouth of the Sarapui River at the northwestern end of the Bay. However, owing to the lack of water proofing, leachate seeps directly into the Bay and during storms, garbage is carried out into the Bay.

As mentioned previously, at present, the surface and the coastal areas of Guanabara Bay are being utilized for many different purposes and their values as environmental resources are being greatly hindered.

7.3 Public Demand and Governmental Plan for the Recuperation of the Bay and its Surroundings

7.3.1 Resident Awareness

Improvement of the environment as a public assets is usually carried out with public undertaking by the federal government or local governments. However, in order that the objectives in such regard may only be achieved when residents of the subject area eagerly want environmental improvement and the project planning by the authorities is backed up by the residents.

According to the responses of a questionnaire by residents (rate of recovery: 53%) conducted on 1,700 ordinary residents, fishermen, members of environmental organizations and yacht clubs, regarding the future prospects of Guanabara Bay, about 45% of the respondents hoped for the revival of the marine sporting ground or recreational ground, and about 30% of them were anxious for reviving the fishery grounds for crabs and shrimps.

As for the mangrove forests, about 80% of the respondents realize its importance as the ground for fostering fry crabs and shrimps or as a field to protect birds. They, therefore, would like the discharge of wastewater from plants and the discarding of garbage to be strictly restricted by competent laws. (Refer to Chapter 14)

The "Baia Viva", a non-governmental environmental organization established in the 1970's for the purpose of preservating the mangrove forests in the coastal areas of Guanabara Bay presently has a membership of about 100,000 people including 6,000 fishermen actively helping to preserve the environment of Guanabara Bay and its adjacent areas.

7.3.2 Federal and State Government Programs

The 1990's is at long last seeing the full implementation of many Federal and State environmental improvement projects for Guanabara Bay.

The Federal Government of Brazil, being concerned about deterioration of the urban environment of the city of Rio de Janeiro, announced "Projeto Ambiente Rio" in January 1991. In order to realize the concept the Rio de Janeiro state government enacted

"Programa de Saneamento Basico da Bacia da Baia de Guanabara" in November 1992, and established GEDEG under the direct jurisdiction of the state governor as the working organization of the program in December of the same year (Decree No. 17138). The project is to be financed by IDB and OECF and a loan agreement was exchanged in 1993.

This project consists of construction and improvement plans for sewer systems, solid waste disposal facilities, drinking water supply, human resettlements, etc. to be implemented by local self-governing bodies in the coastal areas of Guanabara Bay. In regard to the sewer system, IDB is expected to finance the construction of 4 sewage treatment plants and to lay sewer pipe in area on the eastern coast of Guanabara Bay and OECF is to provide a loan to build 3 sewage treatment plants and to lay sewer pipe in areas on the western coast of the Bay(**Table 7.3-1, Fig. 7.3-1**). The first phase is scheduled to begin in 1994, and the year 2000 is the completion date.

While, the State of Rio de Janeiro designated the Bay as a permanently protected area (State Constitution Article 265 & 266) in 1989 because pollution of the coastal areas in the municipal districts of Rio de Janeiro was causing serious damage to the ecosystem and state economy, and the state established specific measures for the preservation of the areas in 1990 (Law No. 1,700).

Subsequently, in July 1991, the State of Rio de Janeiro requested technical assistance to establish a master plan aiming at ecological recovery in Guanabara Bay from the Government of Japan through the mediation of the Federal Government of Brazil.

"The Study on Recuperation of the Guanabara Bay Ecosystem" is thence based on said request.

Separate from the said two projects, the State of Rio de Janeiro implemented the "Rio-Reconstruction Project" (World Bank financed) with prevention of flood damage as its main objective after the devastating flood of February 28, 1988. The working organization of this project, GEROE, carried out dredging, reforestation and the construction of solid-waste disposal facilities and sewer systems, mainly in the Baixa da Fluminense district where damage from the flood was serious. The target year of this project is 1994.

As aforementioned, three major projects related to the environmental improvement of Guanabara Bay and its coastal areas are currently being carried out but the contents of these projects have not yet been adjusted appropriately. Also, due to the economic recession in Brazil, it is feared that the State of Rio de Janeiro may be unable to continue sharing the local portion of these projects.

Table 7.3-1 Outline of Sewage Treatment Plants planned by the IDB/OECF Program

PROGRAMA CEDAE - 1ª ETAPA - 1998

Sistema	Contribuição per capita l/hab/dia	Vazão total (m^3/s)	Vazão tratada (m^3/s) ETE existente	Vazão tratada (m^3/s) ETE Programada	
Lado Oeste					
Alegria	240	4,6	0	4,0	Alegria
Penha	240	1,7	1,6	-	-
Pavuna/Meriti/Acari	200	3,3	0,3	1,0	Pavuna
Sarapuí	200	2,1	0,2	1,0	Sarapuí
Bangu	200	0,8	-	-	-
Bota/Iguaçu	200	2,3	-	-	-
Ilha do Gov.	240	0,57	0,25	-	-
Lado Norte					
Estrela	200	0,5	-	-	-
Magé	200	0,17	-	-	-
Guapi/Macacu	200	0,7	-	-	-
Lado Leste					
São Gonçalo	200	1,75	-	0,62	S II
Niterói Centro/Norte	240	0,48	-	0,5	Toque-Toque
Niterói Sul	300	0,85	0,6	0,22	Icaraí
TOTAL	-	19,82	2,95	7,34	-

PROGRAMA CEDAE - 2ª ETAPA - 2005

Sistema	Contribuição per capita l/hab/dia	Vazão total (m^3/s)	Vazão tratada (m^3/s) ETE existente	Vazão tratada (m^3/s) ETE Programada	
Lado Oeste					
Alegria	240	4,9	4,0	1,0	Alegria
Penha	240	1,1 (a)	1,6	-	-
Pavuna/Meriti/Acari	200	4,4 (a)	1,3	2,7	(b)
Sarapuí	200	2,4	1,2	1,25	(c)
Bangu	200	0,9	-	-	-
Bota/Iguaçu	200	2,6	-	2,0	Bota
Ilha do Gov.	240	0,6	0,25	0,4	ETIG
Lado Norte					
Estrela	200	0,54	-	-	-
Magé	200	0,19	-	0,2	Magé
Guapi/Macacu	200	0,76	-	-	-
Lado Leste					
São Gonçalo	200	2,0	0,62	0,78	(d)
Niterói Centro/Norte	240	0,51	0,5	-	-
Niterói Sul	300	0,9	0,82	-	-
TOTAL	-	21,8	10,29	8,33	-

Notas: (a) Contribuição da sub-bacia de Irajá (0,76 m^3/s) desviada da ETE Penha para ETE Vigário Geral, do Sistema Pavuna/Meriti/Acari.
(b) ETE's previstas: Pavuna (ampliação), Acari, Vigário Geral
(c) ETE's previstas: Sarapuí (ampliação), Edson Passos, Santo Antônio
(d) ETE's previstas: S I, S II, S IV e S V.

Source : Program de Saneamento Basico da Bacia de Baia de Guanabara (Rio, Dezenbro de 1992)

Source : Program de Saneamento Basico
da Bacia de Baia de Guanabara
(Rio, Dezenbro de 1992)

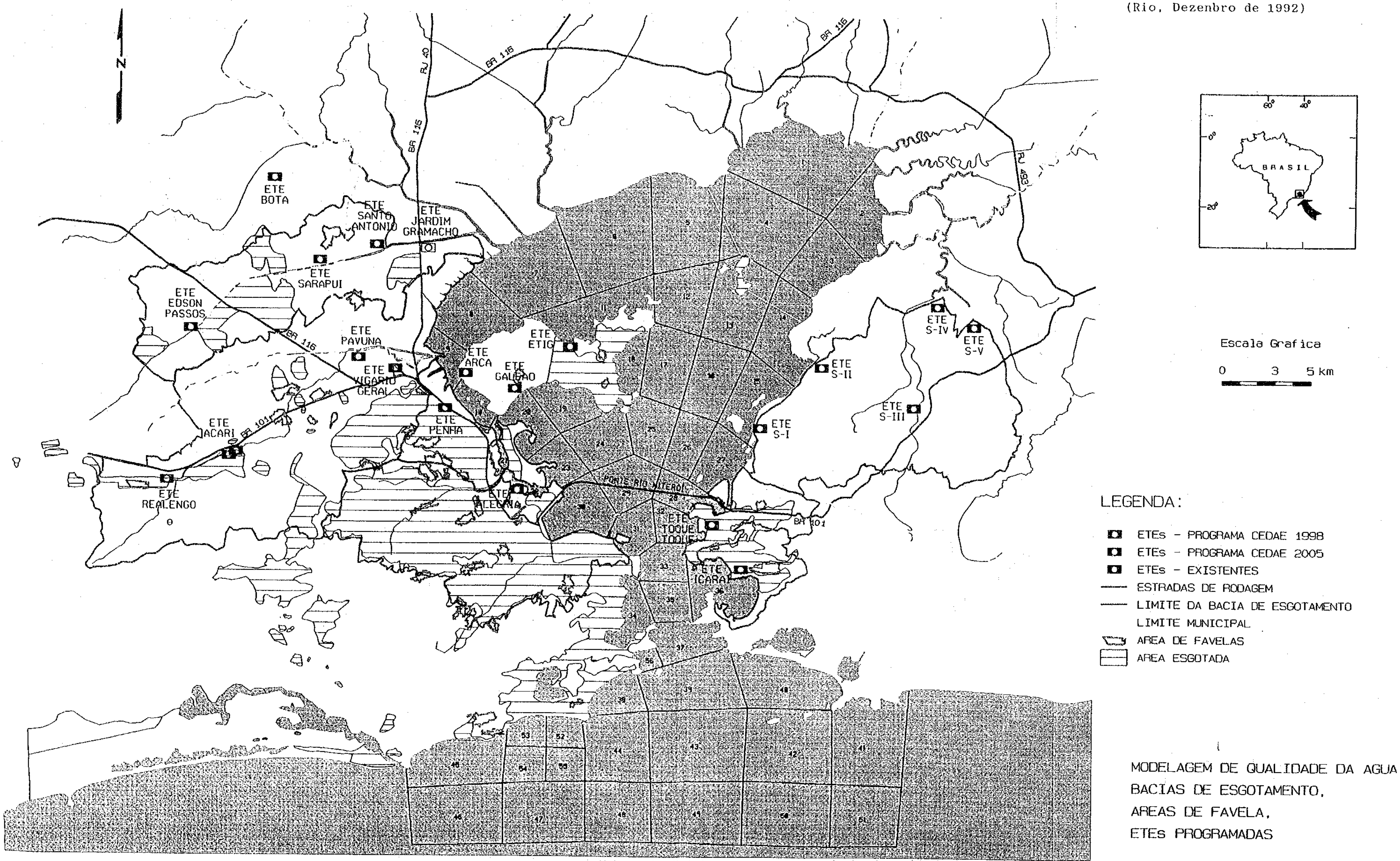

Fig. 7.3-1 Location Map of Sewage Treat Plants planned by the IDB. ·ogram

PART IV

POLLUTION SOURCES

AND

RUNOFF LOADS

CHAPTER 8

POLLUTION SOURCES

AND

EFFLUENT LOADS

CHAPTER 8

POLLUTION SOURCES AND EFFLUENT LOAD

The analysis of river and bay pollution mechanisms requires data on the type and volume of pollutants discharged from the basin. Pollution sources are divided into point sources and non-point sources, and this chapter classifies the former into domestic, industrial, commercial and public sources. This chapter also clarifies the distribution of these pollution sources and estimate the effluent or generation load in each category.

The kind and volume of pollutants from non-point sources are primarily determined by the current land use conditions in the basin and reflected in the river runoff load described in Chapter 9.

8.1 Categorization of Pollution Sources

Generation source is divided into point pollution sources of which the discharge point is easily defined and nonpoint pollution sources of which the discharge point is difficult to define.

As for the study area, point pollution sources are subdivided into domestic pollution sources (houses), industrial pollution sources (factories), commercial pollution sources (stores and offices) and public pollution sources (sewage treatment plants, solid waste disposal sites etc.) considering the completion degree of existing statistical data.

Non-point pollution sources are generally divided into forest, farmland, urban area etc. according to the land use category, however, subdivisions were not covered by this study because of the lack of data on the pollution load generated by this land category and neither was a survey on subdivisions carried out in this study.

8.2 Domestic Pollution Sources and their Effluent Loads

8.2.1 Water Supply for Domestic Use

According to CEDAE (Table 8.2-1), the total volume of water used in the Guanabara Bay Basin, for November 1992, was 5.2×10^7 m^3/month(or 1.53×10^6 m^3/day), about 80% of this was for domestic use.

CEDAE estimates the per capita volume of water consumption for domestic use is 250 l/day for middle class citizens and 100 - 150 l/day for lower class citizens on average although hard data is lacking.

Table 8.2-1 Water Consumption in the Guanabara Bay Basin

unit: m^3/month

District	Domestic	Commercial	Industrial	Public	Total
Rio de Janeiro	33,484,916	4,760,972	2,093,940	2,328,666	42,666,603
Nova Iguacu	2,296,505	250,663	70,263	40,644	2,658,076
D. de Caxias	1,901,233	206,022	24,523	43,244	2,175,023
Nilopolis	808,968	56,858	2,146	30,039	898,013
Sao Goncalo	3,070,183	247,685	102,107	41,107	3,461,078
Niteroi	---	---	---	---	---
Mage	---	---	---	---	---
Itaborai	---	---	---	---	---
C. de Macacu	43,195	2,800	21	3,300	49,318
Rio Bonito	---	---	---	---	---
Total	41,605,000	5,525,000	2,293,000	2,487,000	51,908,131
(%)	(80.1)	(10.6)	(4.4)	(4.8)	(100)

Source: CEDAE (1992)

8.2.2 Estimation of Generation Load from Domestic Sources

The generated load of domestic origin is usually estimated by population and pollutant load factor. CEDAE uses 54 grams of BOD/day/head presented by Imhoff (1956) as the pollutant load factor for domestic wastewater because it had been proved adequate by the IES, predecessor of FEEMA.

As the total population in the Guanabara Bay Basin is about 7.6 million, the total generated load of domestic origin amounts to 38 tons/day of BOD.

The per capita pollutant load factor was assumed at 54 grams of BOD/day for middle class citizens and 27 grams of BOD/day for lower class citizens (in the Favelas and rural areas).

The value for each sub-basin is shown in **Table 8.2-2.**

Table 8.2-2 Domestic Generation Load by Sub-Basin in BOD

Basin No.	Population Urban	Favela	Rural	Total	Generated Load of BOD (ton/day) Urban	Favela	Rural	Total	(%)
1	45,335	7,975	0	53,310	2.45	0.22	0.00	2.67	
2	35,485	6,260	0	41,745	1.92	0.17	0.00	2.09	
3	31,843	5,615	0	37,458	1.72	0.15	0.00	1.87	
4	43,607	0	0	43,607	2.35	0.00	0.00	2.35	
5	178,106	4,993	0	183,099	9.62	0.13	0.00	9.75	
6	138,636	0	0	138,636	7.49	0.00	0.00	7.49	
Eastern basin				497,855				26.22	6.9
7	31,925	0	0	31,925	1.72	0.00	0.00	1.72	
8	470,420	0	0	470,420	25.40	0.00	0.00	25.40	6.6
9	323,386	0	12,807	336,193	17.46	0.00	0.35	17.81	4.7
9-1	73,265	0	1,198	74,463	3.96	0.00	0.03	3.99	
9-2	148,819	0	2,537	151,356	8.04	0.00	0.07	8.11	
9-3	101,302	0	9,072	110,374	5.47	0.00	0.24	5.71	
10	53,839	0	16,014	69,853	2.91	0.00	0.43	3.34	
10-1	0	0	1,595	1,595	0.00	0.00	0.04	0.04	
10-2	10,115	0	2,360	12,475	0.55	0.00	0.06	0.61	
10-3	16,864	0	1,713	18,577	0.91	0.00	0.05	0.96	
10-4	6,018	0	4,294	10,312	0.32	0.00	0.12	0.44	
10-5	6,061	0	2,922	8,983	0.33	0.00	0.08	0.41	
10-6	14,781	0	3,130	17,911	0.80	0.00	0.08	0.88	
11	8,247	0	211	8,458	0.45	0.00	0.01	0.46	
12	35,128	0	1,242	36,370	1.90	0.00	0.03	1.93	
13	9,843	0	841	10,684	0.53	0.00	0.02	0.55	
14	8,968	0	3,942	12,910	0.48	0.00	0.11	0.59	
North-eastern basin				976,813				51.8	13.5
15	8,321	0	220	8,541	0.45	0.00	0.01	0.46	
16	244,160	27,853	30,482	302,495	13.18	0.75	0.82	14.75	3.9
16-1	24,146	0	52	24,216	1.30	0.00	0.00	1.30	
16-2	74,610	8,968	528	84,106	4.03	0.24	0.01	4.28	
16-3	145,386	18,885	29,902	194,173	7.85	0.51	0.81	9.17	
17	1,645,577	117,633	7,075	1,770,285	88.86	3.18	0.19	92.23	24.1
17-1	190,958	12,897	406	204,261	10.31	0.35	0.01	10.67	
17-2	18,472	0	916	19,388	0.99	0.00	0.02	1.01	
17-3	10,421	0	1,822	12,243	0.56	0.00	0.05	0.61	
17-4	94,504	0	348	94,852	5.10	0.00	0.01	5.11	
17-5	394,155	29,528	3,583	427,266	21.28	0.80	0.10	22.18	
17-6	937,067	75,208	0	1,102,275	50.60	2.03	0.00	52.63	
North-western basin				2,213,412			114.57	29.9	
18	132,091	0	0	132,091	7.13	0.00	0.00	7.13	
19	1,303,013	189,445	0	1,492,458	70.36	5.12	0.00	75.48	19.7
19-1	892,406	161,976	0	1,054,382	48.19	4.37	0.00	52.56	
19-2	410,607	27,469	0	438,076	22.17	0.74	0.00	22.91	
20	336,160	164,116	0	500,276	18.15	4.43	0.00	22.58	5.9
21	609,525	205,864	0	815,389	32.91	5.56	0.00	38.26	10.0

Basin No.	Population Urban	Favela	Rural	Total	Generated Load of BOD (ton/day) Urban	Favela	Rural	Total	(%)
22	40,444	19,567	0	60,011	2.18	0.53	0.00	2.71	
23	387,783	113,093	0	500,876	20.94	3.05	0.00	23.99	6.3
24	331,030	27,592	0	358,622	17.88	0.74	0.00	18.62	4.9
Western basin				3,727,632				181.64	47.5
25	102,599	51,304	0	153,903	5.54	1.39	0.00	6.93	
26	5,277	0	0	5,277	0.28	0.00	0.00	0.28	
27	3,254	0	0	3,254	0.18	0.00	0.00	0.18	
28	11,034	0	0	11,034	0.60	0.00	0.00	0.60	
29	4,851	0	0	4,851	0.26	0.00	0.00	0.26	
Islands				173,319				8.25	2.2
	6,579,887	941,310	72,834	7,594,031	355.31	25.42	1.97	382.70	100.00
				COD(Mn)	142.12	10.17	0.08	153.08	

1) Urban population is the population in an urban area without the Favelas.
2) Favela population was determined for each sub-basin based on Table 3.2-4 and 3.2-5.
3) Per capita factor of domestic alley generated load is 54 g/day for urban people and 27 g/day for favela people.
4) Measured BOD/COD(Mn) ratio for domestic waste water was 2.5 at Penha WWTP.

8.2.3 Estimation of Effluent Load of Domestic Origin

For all urban areas without sewage works, the installation of septic tanks with an approved removal ratio has been required since 1967. But, the actual popularization rate of septic tanks is unknown. Further, the septic tank cannot maintain its primary efficiency without periodic sludge removal and general maintenance. Consequently, the effluent load of domestic origin is considered almost equal to the generation load.

8.3 Public Pollution Sources and their Effluent Loads

8.3.1 Effluent Load from Sewage Treatment Plants

A sewage treatment plant is an important facility for water quality improvement, and at the same time, it is also an influential pollution source for the receiving body of the treated wastewater.

Table 8.3-1 shows the existing sewage treatment plants in the Guanabara Bay Basin, four(4) of which are located in Ilha do Governador and two(2) of which are controlled by INFRAERO instead of CEDAE. Details of these existing sewage treatment plants are shown in **Fig. 8.3-1**.

Sewage treatment plants controlled by CEDAE receive not only domestic wastewater but also industrial and commercial wastewater. Consequently, the population served by each plant cannot be estimated exactly. The served population shown in **Table 8.3-1** was estimated from the inflow volume on the assumption that all the inflow to the plant was of domestic origin.

Total flow treated in CEDAE's sewage treatment plants amounts to 224,398 ton/day that is 13 % of the total water supply of the Guanabara Bay Basin.

8.3.2 Effluent Load from Solid Waste Disposal Sites

Solid waste disposal sites carrying out no preventive measures for leachate are also influential public pollution sources. **Table 8.3-2** details the disposal sites distributed in the Guanabara Bay Basin.

FEEMA estimated that leachate from the Gramacho landfill amounted to 800 m^3/day and calculated the effluent load based on the concentrations of pollutants in the leachate is determined in the FEEMA laboratory. The results are shown in **Table 8.3-3.**

8.3.3 Effluent Load from other Public Facilities

Hospitals, stations, parks, schools and other facilities are also included as public pollution sources, but not enough information is available to estimate the effluent load.

Table 8.3-1 Existing Sewage Treatment Plants in the Guanabara Bay Basin

No. Name	STP-1 PENHA	STP-2 ETIG	STP-3 ETEG	STP-4 ETAR-AIRJ	STP-5 ETAR-TECA	STP-6 ICARAI	STP-7 REALENGO	STP-8 ACARI
Sub-Basin No.	20	25	25	25	25	2,3	19-2	19-2
Superintendence	CEDAE	CEDAE	CEDAE	INFRAERO	INFRAERO	CEDAE	CEDAE	CEDAE
Treatment Mehtod	ASM+TF	ASM	TF	ASM	OD	ASM	TF	ASM
Av. Flow (ton/day)	122,746	22,977	3,959	2,401	1,002	60,408	2,968	11,340
Water Quality(BOD)								
Inflowed (mg/l)	217	243	345	334	219	291	179	161
Treated (mg/l)	20	26	78	84	50	27	9	7
Removal Ratio (%)	91	89	77	77	77	91	95	96
Effl. Load (kg/day)	2,494	699	305	202	50	1,633	27	80
Beneficial Pop.	493,370	103,419	25,389	14,844	4,047	325,920	9,745	33,750
Receiving Body	Guanabara B.	Guanabara B.	Guanabara B.	Guanabara B.	Guanabara B.	Guanabara B.	R. Acari	R. Acari
Sludge Volume								
Sludge Treatment	Gramacho							
Inflow of Industrial Waste Water	Nothing	Nothing	Nothing	Nothing	Nothing	?	?	Nothing

Water quality, removal ratio and effluent load are described in BOD.

Treatment Method
ASM : Activated Sludge Method
OD : Oxidation Ditch
TF : Trickling Filter

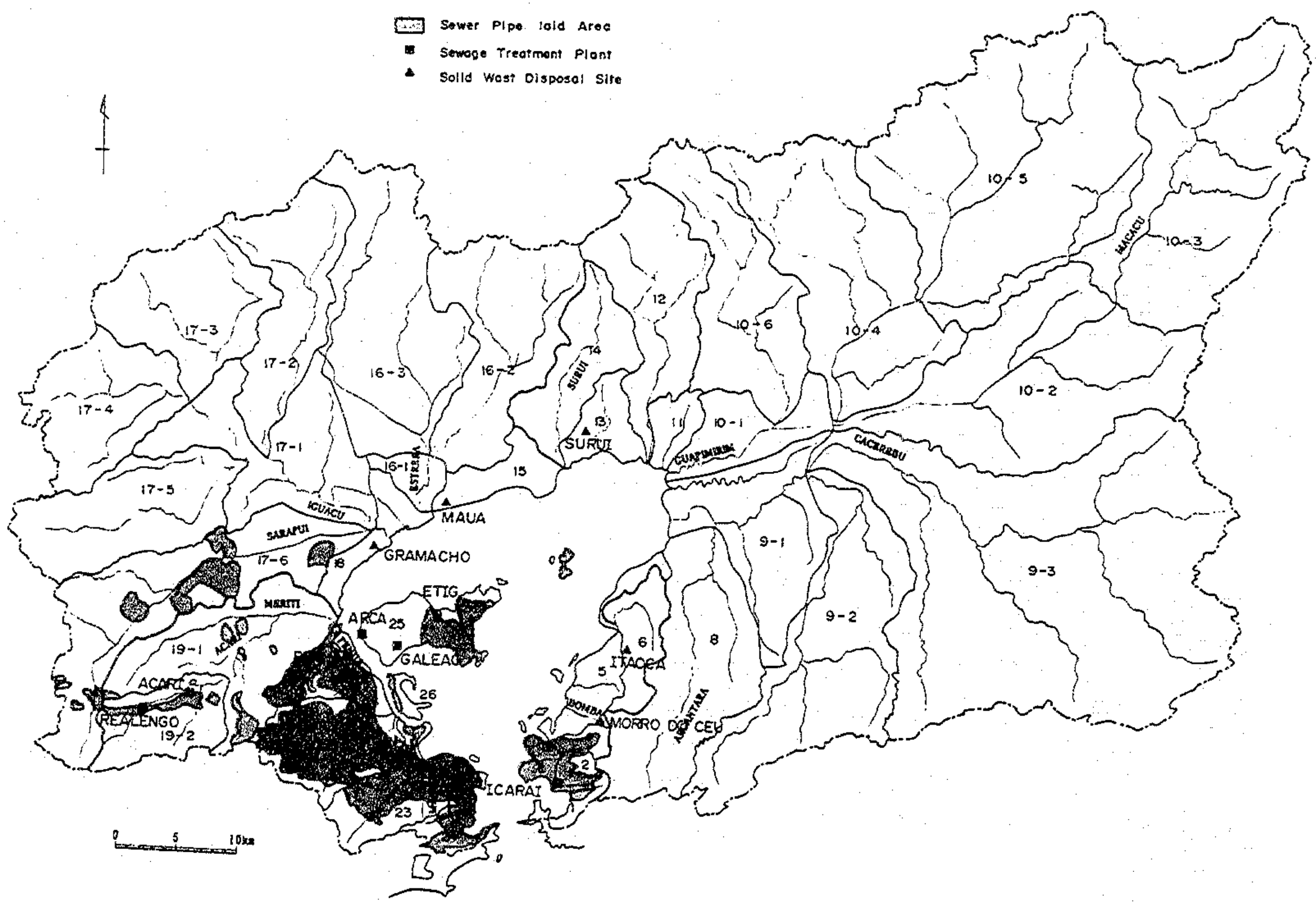

Fig. 8.3- 1 Existing Sewage Treatment Plants and Solid Waste Disposal Sites

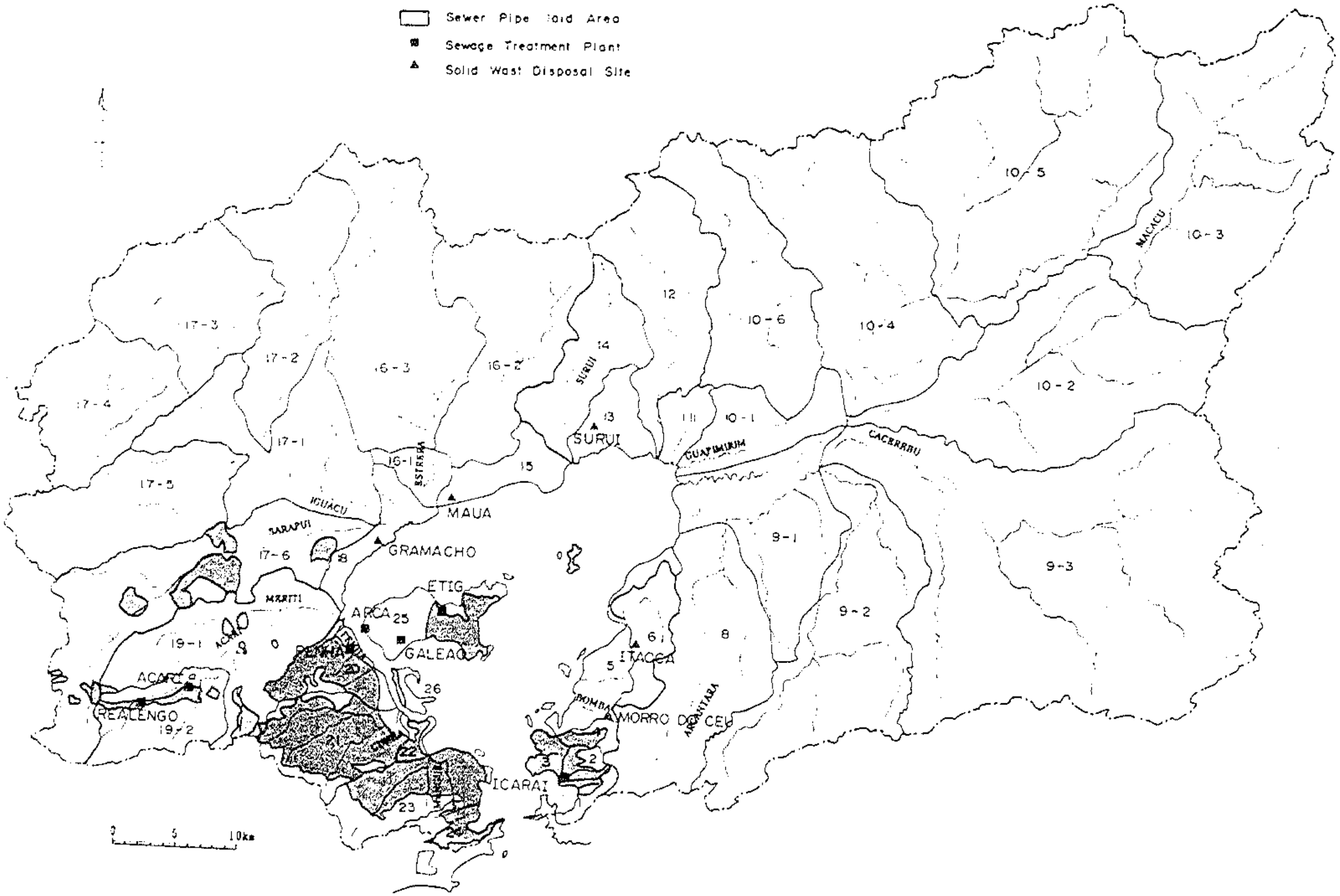

Fig. 8.3-1 Existing Sewage Treatment Plants and Solid Waste Disposal Sites

Table 8.3-2 Existing Solid Waste Disposal Sites in the Guanabara Bay Basin

Municipality	Site Name	Basin No.	Area (km^2)	Disposal (ton/day)	Receiving Body of Leachate
Rio de Janeiro	Gramacho	18	112.0	5000	Guanabara B.
	Gericino	19-1	0.01	314	R. Meriti
	Caju	22	30.0	---	Guanabara B.
Nova Iguacu	Tingua	17-4	4.0	56	R. Iguacu
Sao Goncalo	Itaoca	7	8.0	285	Guanabara B.
Niteroi	Morro do Ceu	8	6.0	71	Guanabara B.
Mage	Surui/Maua	12	1.0	39	R. Roncador
Itaborai	Ferman	9-2	3.0	20	R. Cacerebu
C. de Macacu	Japuiba	10-3	0.5	6	R. Macacu

after FEEMA (1992)

Table 8.3-3 Leachate from Gramacho Landfill

Item	Av. Concentration (mg/l)	Load (kg/day)
pH	8.2	
BOD	580	4,000
COD(Cr)	7,000	5,600
T-N	1,990	1,592
TOC	1,290	1,032
Nickel	0.74	592
Cadmium	0.09	0.072
Copper	0.25	0.200
Manganese	0.25	0.200
Zinc	0.50	0.400
Chromium	1.60	1.280

after COMLURB (1992)

Discharge of leachate is estimated at 1,234m^3/day by COPPE (1992)

8.4 Industrial Pollution Sources and their Effluent Loads

8.4.1 Major Industries and their Distribution

The total number of factories in the eleven(11) municipalities within the Guanabara Bay Basin is 12,492, according to 1985 Census figures. Further, in the state of Rio de Janeiro 60 % of factories employ ten (10) or less employees. The number and gross production of these factories is shown in Chapter 3 by industrial category.

FEEMA recently listed 455 factories which contributed about 90 % of all organic substances discharged into Guanabara Bay. **Table 8.4-1** shows the name, location and estimated pollution loads of the 117 heaviest contributors of pollution loads into the Guanabara Bay Basin selected from the FEEMA/DCON list arranged in 1993. Unfortunately, the COD and oil in the effluent load had not been calculated..

Table 8.4-2 shows the contribution ratio of BOD load of each industrial category. Food and chemical industries occupy 45 % and 22 % respectively of the total effluent load of industrial origin in terms of BOD.

Fig. 8.4-1 shows the distribution of these industries. As it can be seen, most of the industries are located in the western and north-western sub-basins. It should be noted that the chemical factories are centered in sub-basin 17-1 and the food factories are centered in sub-basin 5, while many different kinds of factories are located in sub-basin 21.

Table 8.4-1 Major Industrial Pollution Sources

Sub-Basin	Factory No.	Industry Category	Effl. Load (kg/day) BOD	COD	OIL	Receiving Body
1	007	1	2131	3493	32	Guanabara B.
5	001	1	6700	10287	42	Guanabara B.
	004	1	2400	3050	58	"
	008	1	2095	6000	167	"
	009	1	1940			"
	027	1	800	1967	14	"
	034	1	660	3000	90	"
	044	1	510	1350	468	"
	047	1	480			"
	062	1	380			"
	113	7	220			"
	050	2	450			"
8	057	1	405	1090		Alcantara R.
	066	8	376			"
	107	4	240			"
9-3	049	1	480			Cacerebu R.
10-6	005	3	2304	3292		Soberbo R.
12	071	8	346			Roncador R.
16-2	021	8	921	3168		Piabeta R.
16-3	002	4	4400			Saracuruna R.
	130	4	170			"
	078	4	320			"
	017	8	1200			Estrela R.
17-1	015	4	1320	3247	396	Iguacu R.
	026	1	820			"
	031	1	720			"
	061	4	380			"
	065	1	378			"
	072	1	340			"
	074	4	330	3247	396	"
	082	7	316			"
	087	4	300			"
	088	4	300			"
	090	4	300			"
	098	4	270			"
	102	4	260			"
	114	4	220			"
	122	4	190			"
	138	4	160			"
	018	4	1200			Tomada C.
	075	4	330			"

(continued)

Sub-Basin	Factory No.	Industry Category	Effl. Load (kg/day) BOD	COD	OIL	Receiving Body
17-5	076	1	322	1000	140	Iguacu R.
17-6	013	8	1500			Tinas R.
	016	1	1290			Sarapui R.
	083	1	312			"
	121	4	195			"
	036	1	600			Caboclo R.
	119	1	200			Queimado R.
18	029	4	792			Tomada C.
	086	4	308			"
	137	14	160			Guanabara B.
19-1	010	1	1800			Meriti R.
	115	4	210			"
	067	14	375			"
	120	7	195			"
	020	1	1120			Acari R.
	045	1	500			"
	081	8	318			"
	089	4	300			"
	099	4	269	1277		"
	100	8	260			"
19-2	144	4	145			Acari R.
20	030	1	720			Guanabara B.
	042	8	520			
	035	1	643			Jraja R.
	038	14	530			"
	040	1	530			"
	056	3	420			"
	085	8	310			"
	043	8	515			Penha C.
	092	8	290			"
	143	4	145			"
	104	4	250			"
	111	4	230			"
21	006	2	2300			Timbo R.
	019	3	1122			"
	033	4	688			"
	041	1	520			"
	048	1	480			"
	058	8	382			"
	073		330			Timbo R.
	123	7	190			"
	124	7	190			"
	125	8	180			"

(continued)

Sub-Basin	Factory No.	Industry Category	Effl. Load (kg/day) BOD	COD	OIL	Receiving Body
	011	1	1760			Jacare R.
	059	4	380			"
	080	4	320			"
	105	4	240			"
	132	14	170			"
	037	1	589			Cunha C.
	060	4	380			"
	068	14	360			"
	093	4	288			"
	052	3	430			Faria R.
	053	2	420			"
	108	4	240			"
	012	1	1700			RSS-05(?)
21	126	4	180			"
	101	4	260			RSS-05
	103	4	260			"
22	064	14	380			RSS-05
	069	4	360			"
	077	1	320			"
	079	14	320			"
23	046	7	500			Maracana R.
	054	8	420			"
	116	14	210			"
	133	14	170			"
	134	7	160			"
	136	14	160			"
	096	14	280			RSS-03
	097	14	270			"
	117	7	210			"
24	003	2	4000	4800	25	RSS-01
	032	1	700			RSS-02
	051	14	448			Guanabara B.
25	094	8	284			STP-3 (ETEG)

Ind. No. : Industry No. registered in FEEMA/DECON Inventory
Category : Industrial Category
1 : Food   2 : Beverage   3 : Paper
4 : Chemicals   7 : Pharmaceutical
8 : Textile   14 : Others (Plastics, Mechanicals, Landry, Printing etc.)
The columns of COD and Oil will be filled up by FEEMA/DCON

Table 8.4- 2 Industrial Effluent Load by Industrial Category

unit: kg/day of BOD

Basin No.	Industrial Category 1	2	3	4	7	8	14	Total 1-14	Total %
1	2,131	---	---	---	---	---	---	2,131	2.7
5	15,965	450	---	---	220	---	---	16,635	21.4
E Basin	(18,096)	(450)			(220)			(18,766)	(24.2)
8	405	---	---	240	---	376	---	1,021	1.3
9-3	480	---	---	---	---	---	---	480	0.6
10	---	---	---	---	---	---	---	2,304	3.0
12	---	---	---	---	---	346	---	346	0.4
NE Basin	(885)	(2,304)	(240)			(722)		(4,151)	(5.4)
16-2	---	---	---	---	---	921	---	921	1.2
16-3	---	---	---	4,890	---	1,200	---	6,090	7.9
17-1	2,258	---	---	5,560	316	---	---	8,134	10.5
17-5	322	---	---	---	---	---	---	322	0.4
17-6	2,402	---	---	195	---	1,500	---	4,097	5.3
18	---	---	---	1,100	---	---	160	1,260	1.6
NW Basin	(4,982)			(11,745)	(316)	(3,621)	(160)	(20,824)	(26.8)
19-1	3,420	---	---	779	195	578	375	5,347	6.9
19-2	---	---	---	145	---	---	---	145	0.2
20	1,893	---	420	625	---	1,635	530	5,103	6.6
21	5,049	2,720	1,552	3,236	380	562	530	14,029	18.1
22	320	---	---	360	---	---	700	1,380	1.8
23	---	---	---	---	870	420	1,090	2,380	3.1
24	700	4,000	---	---	---	---	448	5,148	6.6
W Basin	(11,382)	(6,720)	(1,972)	(5,145)	(1,445)	(3,195)	(3,083)	(33,532)	(43.2)
25	---	---	---	---	---	284	---	284	0.4
	35,345	7,170	4,276	17,130	1,981	7,822	3,833	77,557	
	(45.6)	(9.2)	(5.5)	(22.1)	(2.6)	(10.1)	(4.9)		(100.0)%

Industrial category
1: Food 2: Beverage 3: Paper 4: Chemicals
7: Pharmaceutical 8: Textile
14: Others (Plastics, Mechanicals, Landry, Printing etc.)

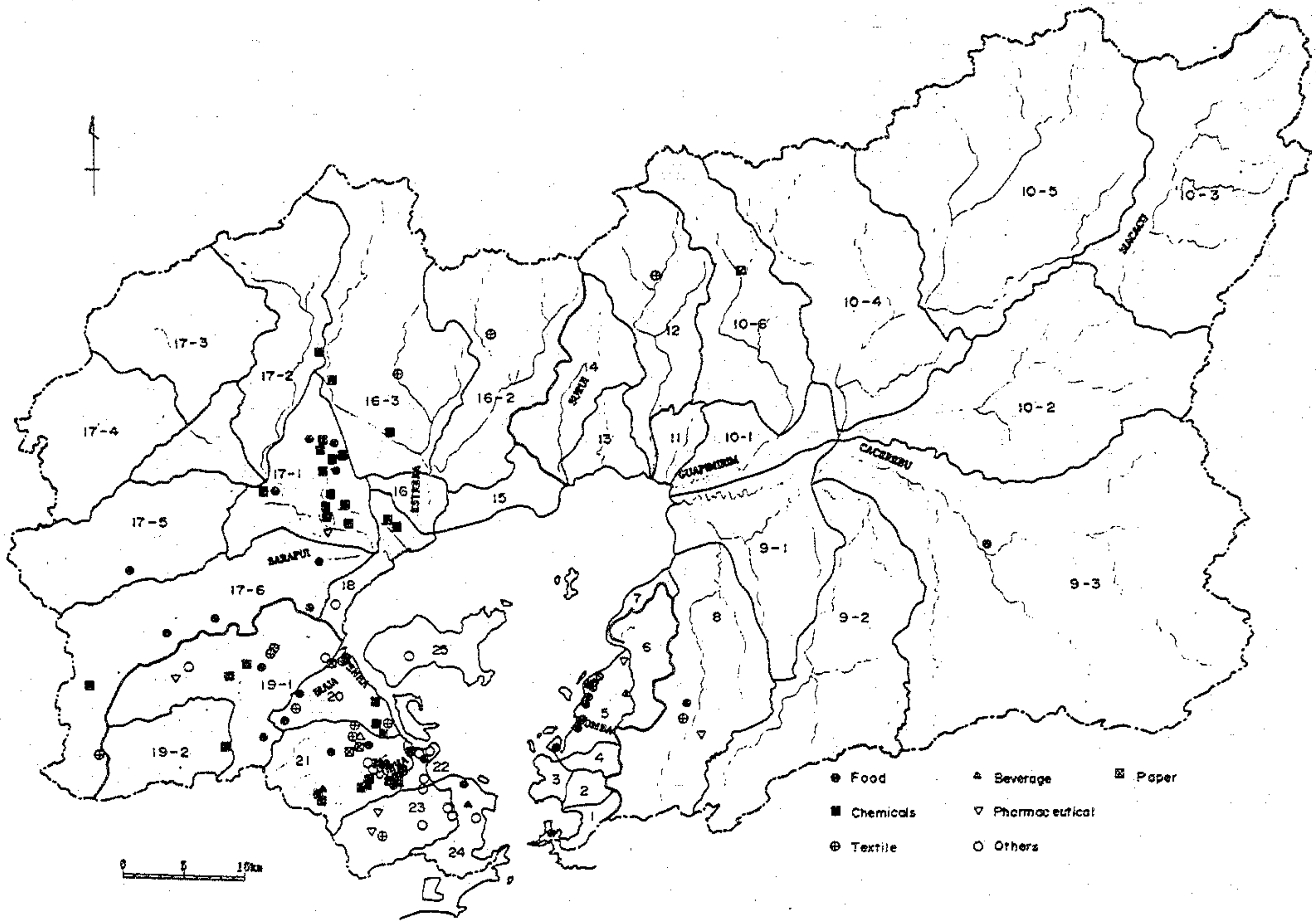

Fig. 8.4- 1 Distribution of Industrial Pollution Sources monitored by FEEMA

8.4.2 Measurement of Effluent Load from Several Factories

(1) Selection of Factories

The effluent load of eight (8) factories selected from the four (4) principal categories was measured in this study with the cooperation of FEEMA/DECOM.

In terms of organic substances, the food industry is the greatest contributor to pollutant loads. Three factories among the eight chosen was because of this reason. On the other hand, although REDUC and BAYER have their own treatment facilities, they were selected considering their petrochemical and chemical processes.

Besides the factories mentioned above, one factory from the metallurgy, textile and paper industry were picked as they also represent important position in terms of pollution contribution into the Guanabara Bay Basin.

(2) Collection of Samples

At all factories, sampling were performed over two days. The collection time was programmed according to the working regime of each industry.

The flow of effluent was measured every thirty minutes, and a sample for water quality analysis was taken at the same time.

(3) Survey Results

The mean concentrations and loads of all parameters analyzed from the 8 factories are summarized in **Table 8.4-3** and **Table 8.4-4**.

QUAKER PRODUTOS ALIMENTICIOS S/A is considered the heaviest organic matter contributor in the Guanabara Bay Basin. Pressure flotation is the only treatment in operation presently in this factory, which, however, obtains a very low treatment rate. It was recommend to introduce pH controls and the addition of a chemical coagulant to improve its operation.

Table 8.4- 3 Measured Effluent Load from Several Factories

Name	QUAKER	SADIA	SPAN (Leite Mimo)	REDUC (REFINARIA DE CAXIAS)		BAYER DO BRASIL	GULHERME TELL	CIBRAPEL S/A	ELETROMAR
Factory No.	001	---	076	015		---	---	005	
Basin No.	5		17-5	17-1		17-6		10-6	
Ind. Category	1	1	1	4		4	8	3	11
Raw Material	Fish(80ton/day)	Meat(130-150ton/day)	Milk	Petroleum(16,000m^3/day)		?			
Products	Cans of fish Fish meal (18ton/day)	Sausage, Hum (130-150 ton/day)	Milk (240 kl/day) Yoghurt (2.5 kl/day) Butter (14 ton/day)	Gasoline Lubricant		Insecticide Veterinary	Dyed textile (120 ton/day)	Package paper (132 ton/day)	Parts (900,000/day)
Number of Employees	650	1,100	240	5,400		1,320	250	270	1,100
Treatment Facility									
Type	Pressure flotation	Pressure flotation Oxidation ditch Filter press	Aeration lagoon Settling tank	Oil separater Equalization tank		Aeration lagoon	Neutralization tank Sedimentation tank Activated sludege		pH adjustment Primary sed. tank Coagulation tank Settling tank
Efficiency	very low	56% in BOD 34% in COD(Cr)	96% in BOD 97% in COD(Cr)			61% in BOD 35% in COD		16% in BOD 43% in COD	97% in COD(Cr)
Effluent water				Fresh water	Salt water				
Discharge(m^3/day)	1,237	312	222	19,128	528,000	140.2	2,539.3	2,156.5	140
Quality (mg/l)									
pH	6.3	---	7.5	---	---	7.2	12.5	5.1	---
BOD	3,650	490	15	10	17	320	83	510	7.0
COD(Cr)	6,550	1,090	35	159	375	1,850	609	285	18
COD(Mn)	510	55	8	14.4	7.3	50	28	34.4	3.5
TP	53	34.5	0.43	2.6	0.4	125	3.9	0.75	---
TN	243	37	6	11.0	2.6	114	18.3	2.0	---
SS	1,540	660	10	22.8	21.5	140	19.3	75.0	---
H. extract	2,025	---	---	64	54	---	---	---	---
COD(Cr)/BOD	1.79	2.22	2.36	15.9	22.06	5.78	7.34	1.54	2.57
COD(Mn)/BOD	0.14	0.11	0.235	1.44	0.43	0.16	0.34	0.07	0.50
Load (kg/day)									
BOD	4,515(6,700)*	153	3.3(322)*	191	8,976(1,320)*	45.0	211	1,100(2,304)*	1.0
COD(Cr)	8,102	340	7.8	3,041	198,000	259.0	1,546	1,693	2.5
COD(Mn)	631	17	1.8	275	3,854	7.0	71	74	0.5
TP	66	10.8	0.1	50	211	17.5	9.9	1.6	---
TN	301	11.5	1.3	210	1,373	0.6	465	4.3	---
SS	1,905	205.9	2.2	436	11,352	19.6	49.0	162.0	---
H. extract	2,505	---	---	1,224	28,512	---	---	---	---

* Figures in parentheses are BOD load estimated by FEEMA (DECON).

** REDUC uses salt water from the Guanabara Bay as cooling water. Consequently, the net load generated in the factory is the difference between the effluent load and the load contained in salt water.

Table 8.4-4 Toxic Substances Discharged by Several Factories

Name	REDUC	BAYER DO BRAZIL	GUILMERME TELL	ELETROMAR
Factory No.	015	---	---	---
Basin No.	17-1	17-6	?	?
Ind. Category	4	4	8	11
Treatment Facility	furnishing	furnishing	nothing	furnishing
Discharge(m^3/day)	547,128	140.2	2,539.3	140.0
Effluent Load (kg/day)				
CN	--	--	0.23	0.05
Phenol	384	nil.	nil.	--
Ni	nil.	0.14	--	0.11
Cu	nil.	0.56	0.69	0.04
Cr	nil.	0.35	0.48	0.02
Hg	nil.	--	--	--
Zn	67	0.14	--	0.01
Cd	--	nil.	--	nil.
Pb	--	0.28	--	nil.
Sulfide	870	--	--	--

The treatment facility at SADIA CONCORDIA S/A consists of a pressure flotation, an oxidation ditch and a sludge dry bed. A filter press was purchased recently to replace the dry bed which breeds a lot of flies. As is the case with QUAKER PRODUTOS ALIMENTICIOS S/A pressure flotation is not giving satisfactory results. The Oxidation ditch, also, has low efficiency because the system was constructed almost ten years ago and is now not big enough to treat all wastewater generated by the factory. It is planned to construct a new oxidation ditch to supplement this deficiency.

At SPAN (Leite Mimo) the sewage is being treated in an aeration lagoon with a high efficiency. The final effluent is excellent with very low concentrations of BOD, COD and SS. All parameters analyzed had removal rates in range 92 to 97 % except TN which was 72 %. The contribution loads into the river is extremely low because of the excellent treatment.

AT REDUC (Refinaria de Caxias), there are two main effluents: one comes from an open cooling tower system that intakes, approximately, 6 m^3/s of water from Guanabara Bay and discharges into the Rio Iguacu through a cooling lagoon. The other is the effluent originated from a closed cooling tower system and the runoff water from all industrial processes areas. This sewage goes into a treatment facility consisting of an oil separator, an equalization tank and two aeration lagoons.

According to the results, the final effluent from the biological treatment system has a low BOD concentration but is high in COD (COD(Mn)/BOD ratio = 16), indicating the presence of a substantial amount of refractory organic matter, some of which could belong to a toxic substance that causes a mutagenic reaction.

The effluent from the open cooling tower contains a large concentration of oil (56 mg/l). 28.5 ton/day of this effluent flows into the Iguacu River, representing a significant amount. A further, more detailed, investigation on this subject is required to final out its full effects.

BAYER DO BRASIL has a liquid waste treatment system neutralization tank, an activated sludge process and an incinerator with a capacity of 300 ton/day and a land fill basin sealed with polyethylene film for solid waste disposal.

Results of analyses shows low efficienty of the biological process. The high COD(Mn)/BOD ratio observed in the final effluent (6/1) indicates the presence of refractory substances as in the case of the REDUC refinery.

CIA. PRODUTOS INDUSTRIAIS DO BRASIL has no treatment facility. The effluent has a high pH and COD due to dye substances.

Industrial sewage from CIBRAPEL flows initially into a settling tank to remove fiber before discharging into the receiving body. The BOD was reduced by only 16 % in this tank, contributing a substantial amount of organic matter into the river (1,100 kg/day).

The treatment facility of ELETROMAR (WETINGHOUSE), consisting of pH adjustment tanks and 4 coagulation and sedimentation tanks, has been well designed and is being maintained in a very good operating condition. Sewage with high concentrations of several heavy metals and/or toxic matters, such as CN, Cd, Cr, Ni and Zn suffer drastic reductions in this treatment system, only very low concentrations were found in the final effluent.

8.4.3 Estimation of Industrial Origin Effluent Load

Fig. 8.4-2 is the cumulative curve for BOD loads discharged from the major factories listed in **Table 8.4-1.** It seems that the total industrial load discharged into the Guanabara Bay Basin does not exceed 90 tons/day of BOD.

The cumulative curves of BOD load for the food and chemical industries are also shown in **Fig. 8.4-2.**

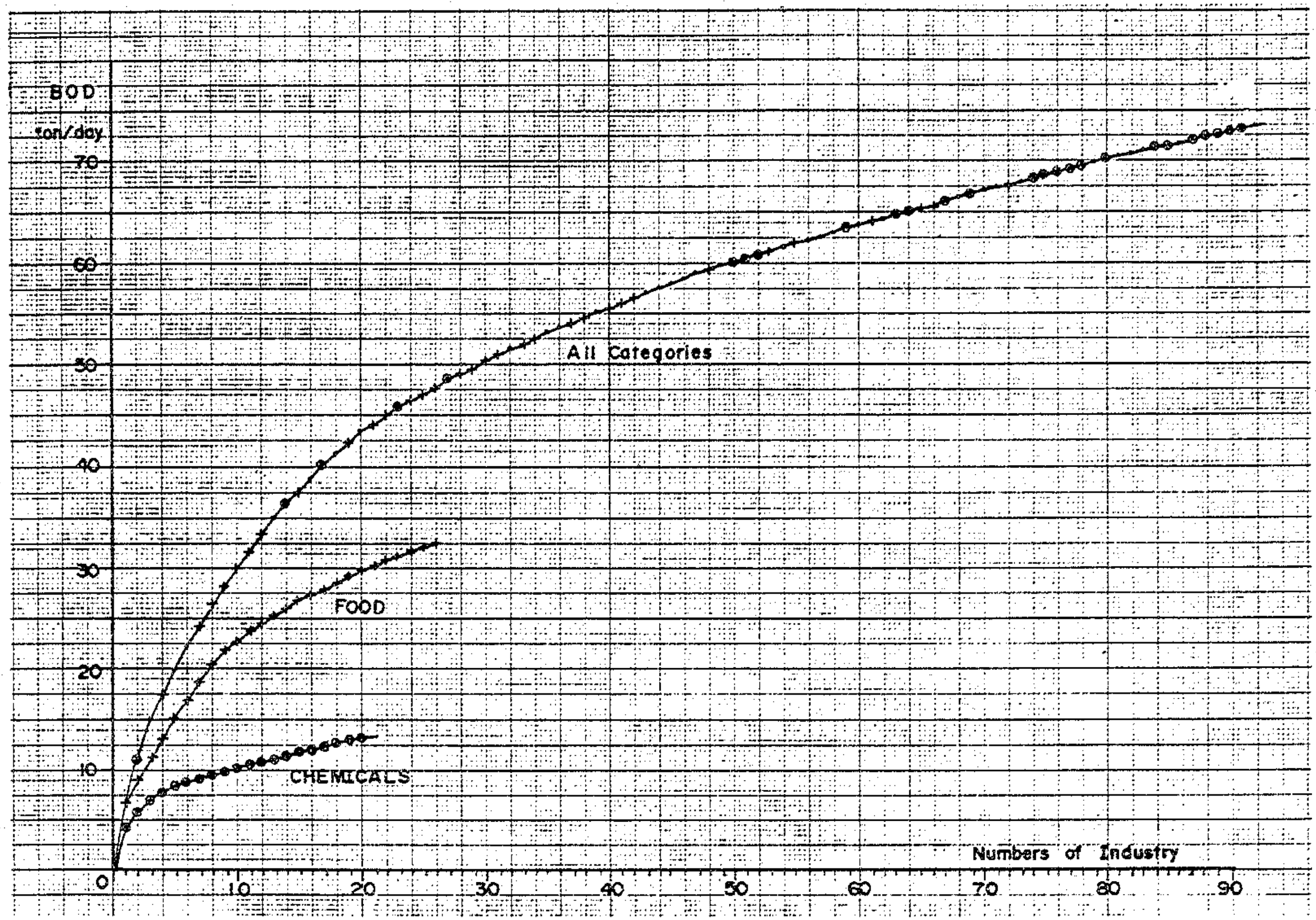

Fig. 8.4- 2 Cumulative Curve of Industrial Effluent Load

8.5 Commercial Pollution Sources and their Effluent Loads

The amount of water consumed for commercial use is about 10% of the total water supply (see **Table 8.2-1**). CEDAE estimates that the average concentration of the commercial wastewater is 240 mg/l (BOD) and discharge is about 80% of water consumed. According to this estimation, the effluent load from commercial sources is calculated at 3.54 tons/day.

8.6 Contribution Ratio of Effluent Load by District

Table 8.6-1 shows the contribution ratio of effluent load by basin when the Guanbara Bay Basin is divided into four basins; that is the Eastern (No.1 - No.6), North-Eastern (No.7 - No.14), North-Western (No.15 - No.18) and Western basin (No.19 - No.24).

The total domestic generated load of BOD was estimated at 383 ton/day of which 48 % comes from the Western basin, 30 % from the North-Western basin, 14 % from the North-Eastern basin up, 7% from the Eastern bain and 2% from the Islands. The domestically generated load changes to effluent load from the sewage treatment plant in areas where sewer and sewage treatment plants have been completed. However, the degree of decreased load through this conversion is unknown because it is difficult to know the served population in each sub-basin.

Industrial effluent load discharged from the factories monitored by FEEMA totalled about 78 ton/day of BOD. 43 % of it comes from by the Western basin, 27 % from the North-Western basin and 24 % is from the Eastern basin. The total industrial effluent load discharged into the Guanabara Bay Basin, however, is assumed to be about 90 ton/day.

As already mentioned, the distribution of industrial pollution sources is different by district. Most factories in the Eastern basin belong to the food industry (mainly fish processing), while most factories in the North-Western basin belong to the chemical industry (mainly petro-chemical). Further, there are many kinds of factories in the Western basin.

When COD(Mn) or COD(Cr) in the effluent load is calculated, the contribution ratio by pollution sources is different from the conclusion mentioned above because COD(Mn)/BOD is 0.4 - 0.5 in domestic wastewater, while it is 0.5 in food industry and 5 - 10 in petro-chemical industry. Consequently, the proportion of industrial effluent load increases and exceeds the domestic effluent load in some sub-basins when COD(Mn) is used as an index.

Table 8.6-2 shows the contribution ratios of the effluent load in COD(Mn) assuming that the ratios of COD(Mn)/BOD for each industrial category are those values shown in the below the table. Industrial origin effluent load occupies more than 40 % of the total effluent load if COD(Mn) is used as a parameter though it was only 16 % for BOD.

Figs. 8.6-1 and **8.6-2** show the domestic and industrial loads in BOD and COD(Mn) respectively in each sub-basin. The industrial effluent load in COD(Mn) exceeds domestic load in sub-basins 5, 16.3, 17-1, 18, 21 and 22.

Table 8.6-1 Contribution Ratio of Effluent Load by Basin in BOD

	Domestic ton/day (%)	Industrial ton/day (%)	Commertial ton/day (%)	Total ton/day (%)
E Basin (1-6)	26.22 (5.3)	18.8 (3.8)	4.7 (1.0)	49.7 (10.1)
NE Basin (7-14)	51.8 (10.5)	4.2 (0.9)	--	56.0 (11.3)
NW Basin (15-18)	114.6 (23.2)	20.8 (4.2)	4.1 (0.8)	139.5 (28.3)
W Basin (19-24)	181.6 (36.8)	33.5 (6.8)	24.1 (14.9)	239.2 (48.5)
Islands (25-29)	8.3 (1.7)	0.3 (0.0)	--	8.6 (1.7)
Total	382.7 (77.5)	77.9 (15.8)	32.9 (6.7)	493.5 (100.0)

Table 8.6-2 Contribution Ratio of Effluent Load by Basin in COD(Mn)

	Domestic ton/day (%)	Industrial ton/day (%)	Commertial ton/day (%)	Total ton/day (%)
E Basin (1-6)	10.5 (3.7)	10.4 (3.6)	1.9 (0.7)	22.8 (8.0)
NE Basin (7-14)	20.7 (7.2)	2.2 (0.8)	--	22.9 (8.0)
NW Basin (15-18)	45.8 (16.0)	63.4 (22.2)	1.6 (0.6)	110.8 (38.8)
W Basin (19-24)	72.7 (25.4)	43.5 (15.2)	9.6 (3.4)	125.8 (44.0)
Islands (25-29)	3.3 (1.2)	0.1 (0.0)	--	3.4 (1.2)
Total	153.0 (53.6)	119.5 (41.8)	13.1 (4.6)	285.7 (100.0)

Assumed : COD(Mn)/BOD

Domestic	0.4
Industrial	
Food	0.5
Beverage	0.8
Paper	1.0
Chemicals	5.0
Pharmaceutical	0.6
Textile	1.0
Others	1.0

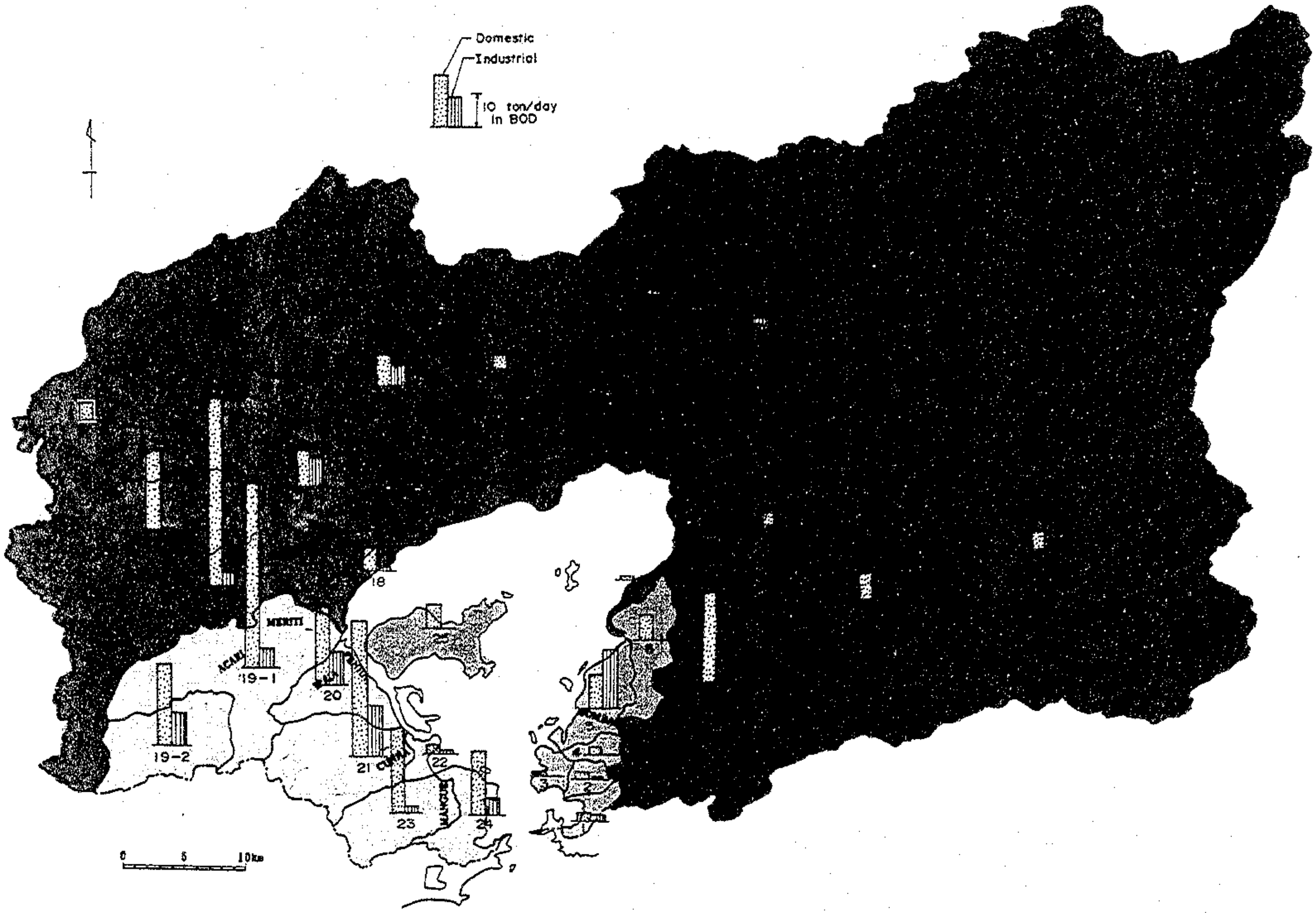

Fig. 8.6- 1 Effluent Load from Domestic and Industrial Pollution Sources by Basin in BOD

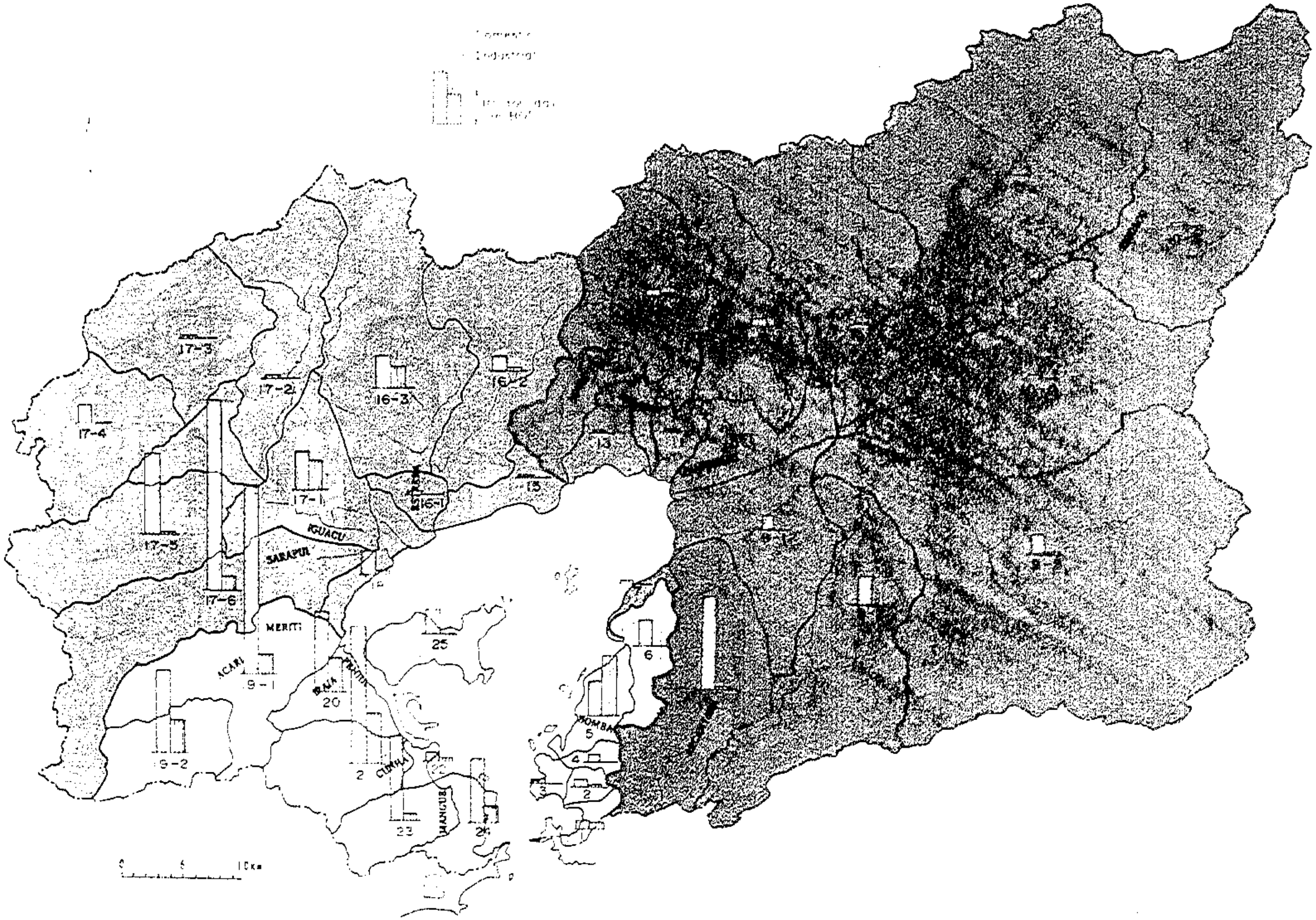

Fig. 8.6-1 Effluent Load from Domestic and Industrial Pollution Sources by Basin in BOD

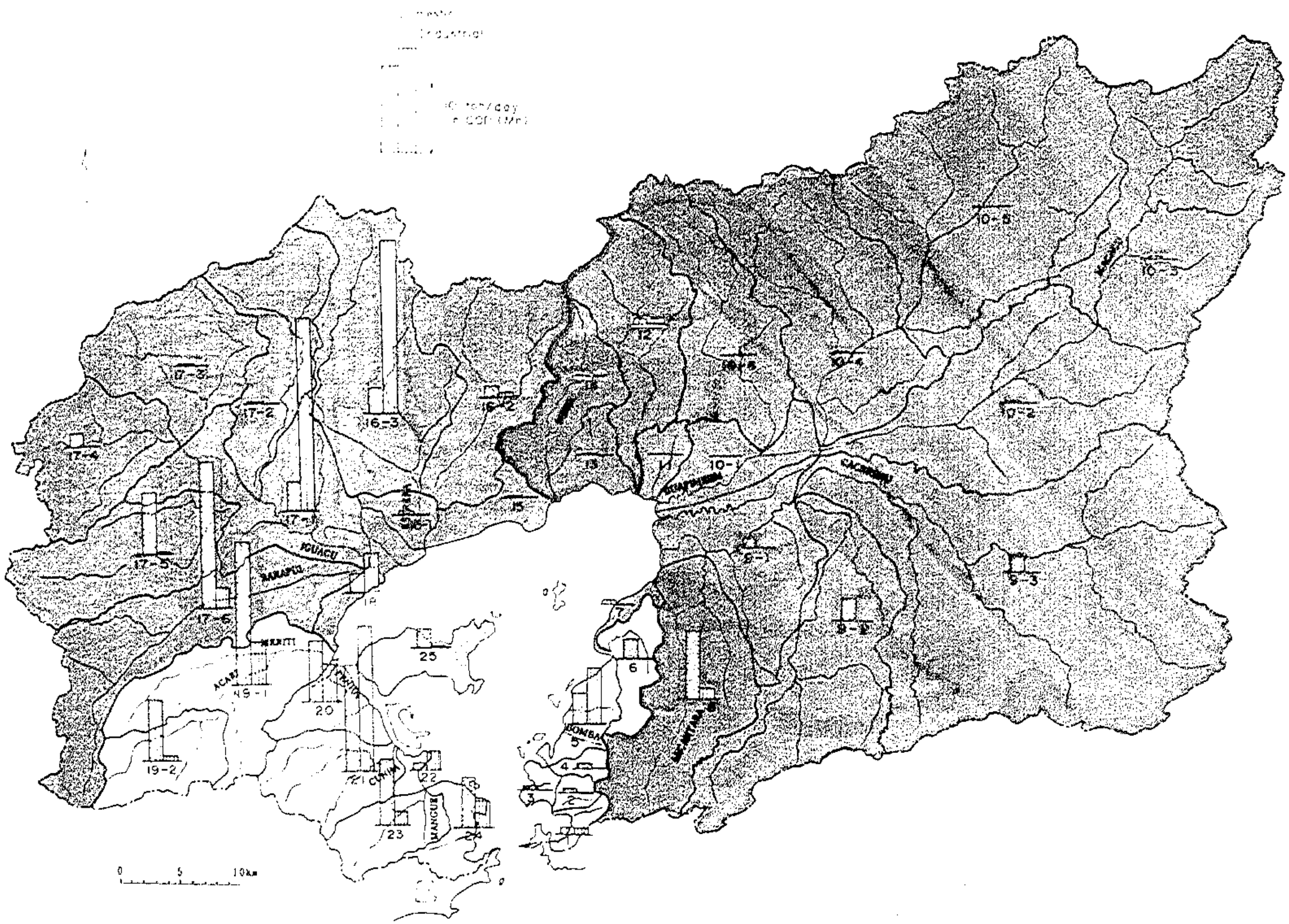

Fig. 8.6-2 Effluent Load from Domestic and Industrial Pollution Sources by Basin in COD (Mn)

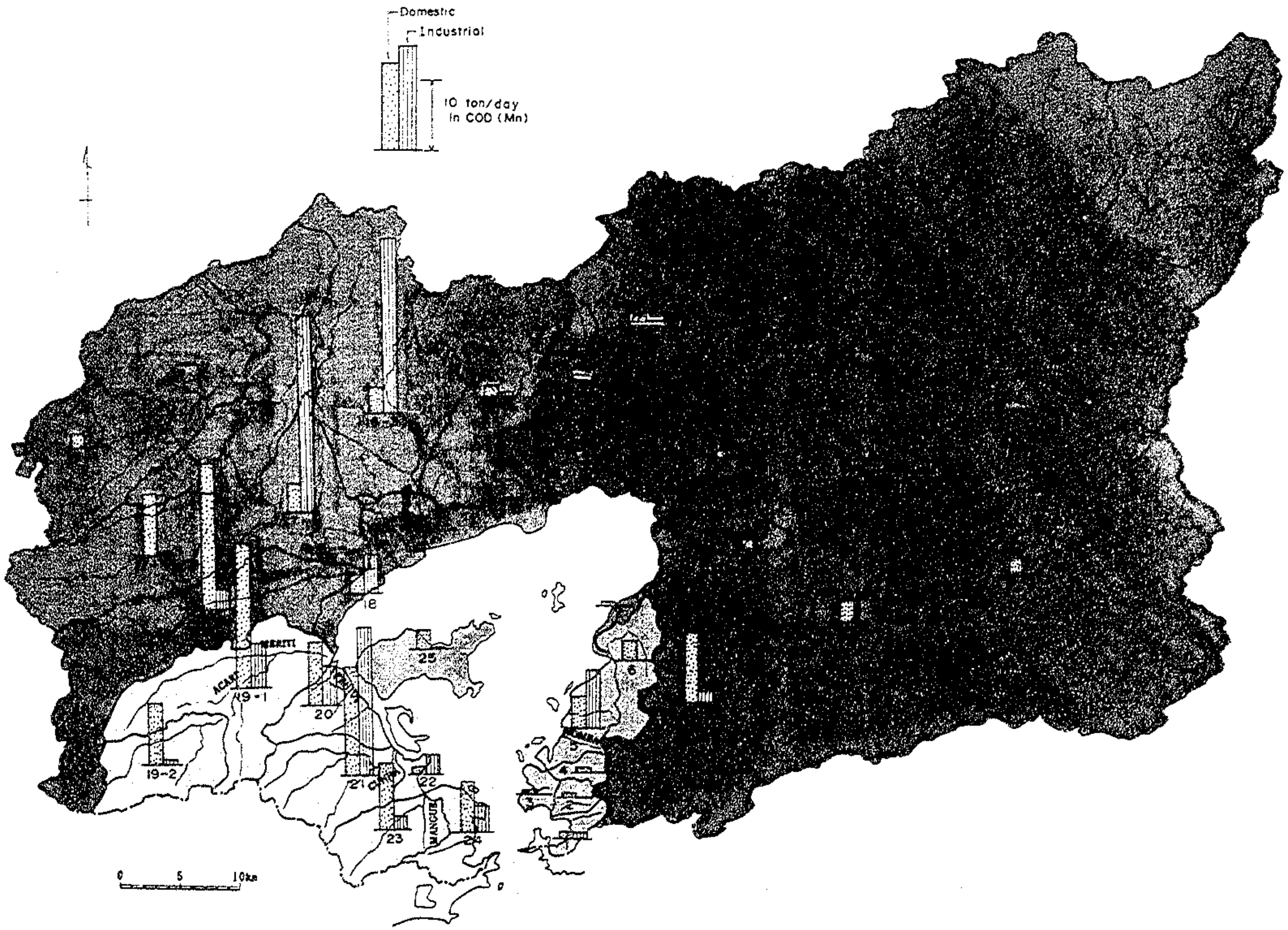

Fig. 8.6- 2 Effluent Load from Domestic and Industrial Pollution Sources by Basin in COD (Mn)