16.6.2 Target Reduction Load for Organic Matters

(1) Contribution Rate of Each Basin

We numerically examined the individual effect of each basin on the water quality in Guanabara Bay.

The Guanabara Bay basin was divided into four (4) smaller basins (western, northwestern northeastern and eastern basin) plus the area of the islands; and the water area in the Bay was also divided into eleven (11) areas, as shown in **Fig. 16.6-2.** This division of the water area closely resembles the water area division for beneficial uses *shown in* **Fig. 16.3-2.**

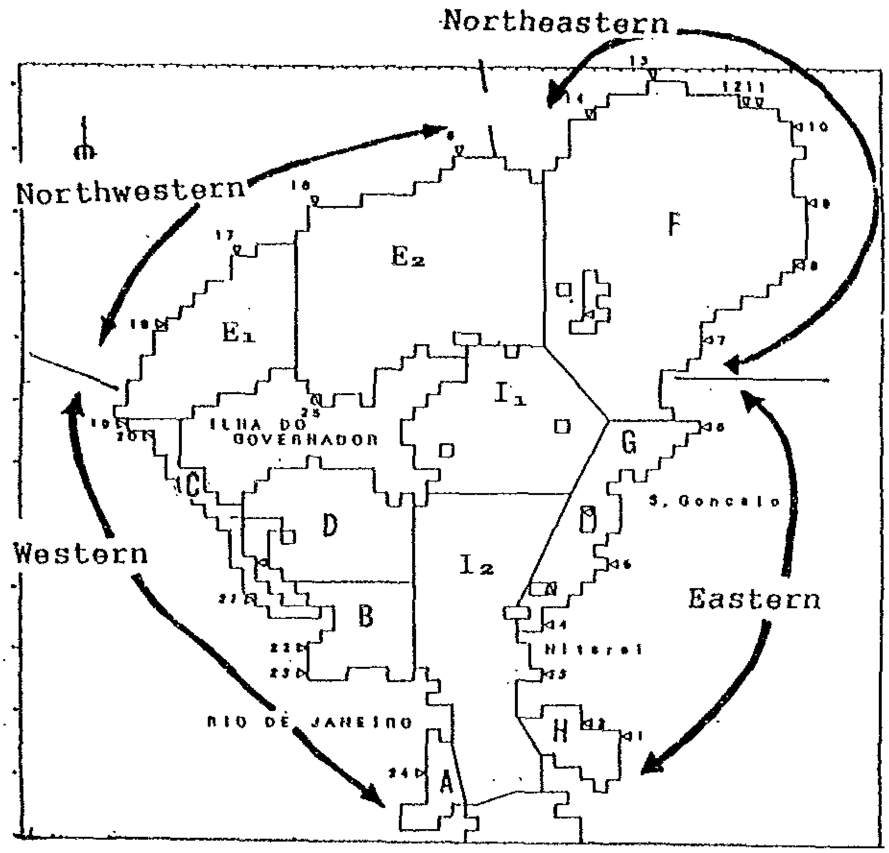


Fig. 16.6- 2 Division of Basin and Water Area

The final results, the contribution rate of present effluent loads of each basin and the island area to the water quality in each water area, is shown in **Fig. 16.6-3**. Here, the contribution rate was calculated by the following procedure;

(1) We calculated the present mean water quality in each water area (Block A to I_2) using present annual mean inflowing loads.

(2) We calculated the mean water quality in each water area on the assumption that the BOD and O-P load from each basin and the release from sediments in each water area were zero.

(3) We calculated the variation rate (decreasing rate) in each water area as the difference between (1) and (2).

(4) We assumed the variation rate (deceasing rate) for all basins to be a contribution rate in each water area.

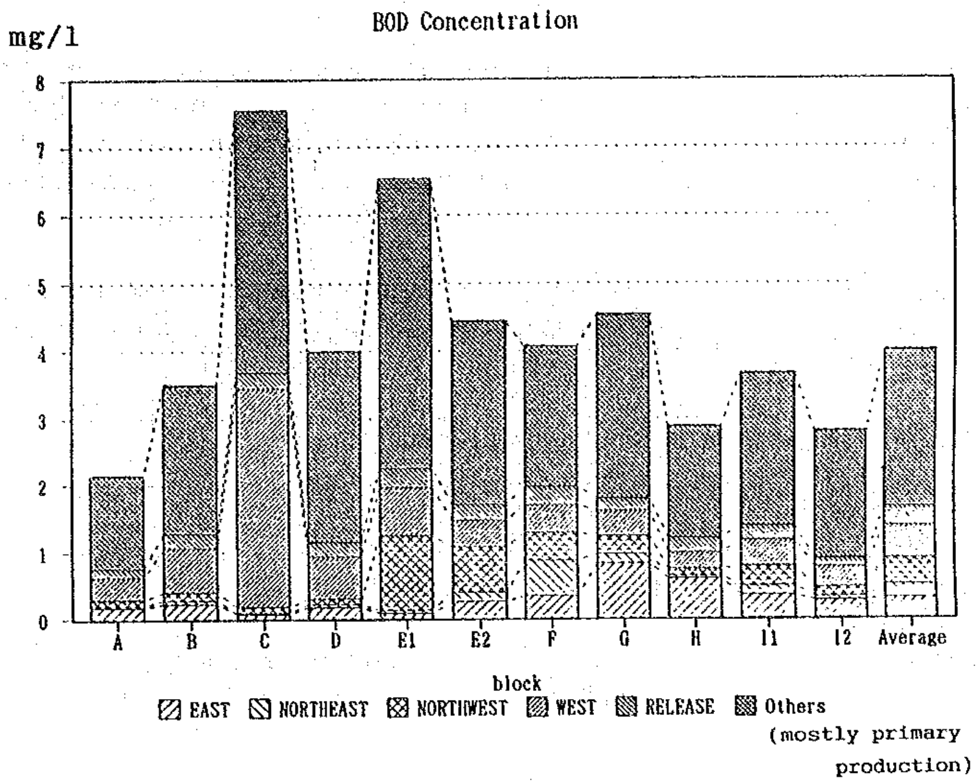
(5) We also calculated the effect of the release from sediments.

The results show that the primary production contribute strongly around 60% in all water areas ("others" in **Fig. 16.6-3** mostly come from primary production).

The contribution rate from the basins and the island area to the whole Bay is the highest from the western basin at 12 %, followed by the northwestern basin at 10%, the eastern basin at 8%. It is notable that the effect of the release from sediments is 7 % for the whole Bay.

Out of the basins and the island area, the western basin has the strongest influence on all the water areas, particularly in the west part and central part of the Bay. The northwestern basin affects the water area adjacent to it, Blocks E_1 and E_2 as the eastern basin affects Blocks G and H.

Block F, containing the Guapimirim mangrove area and Paqueta island, is a fragile water area. This area is affected strongly by the northeastern basin, but also affected by the northwestern basin, western basin, and the eastern basin plus the release from sediment at the comparatively high rate.



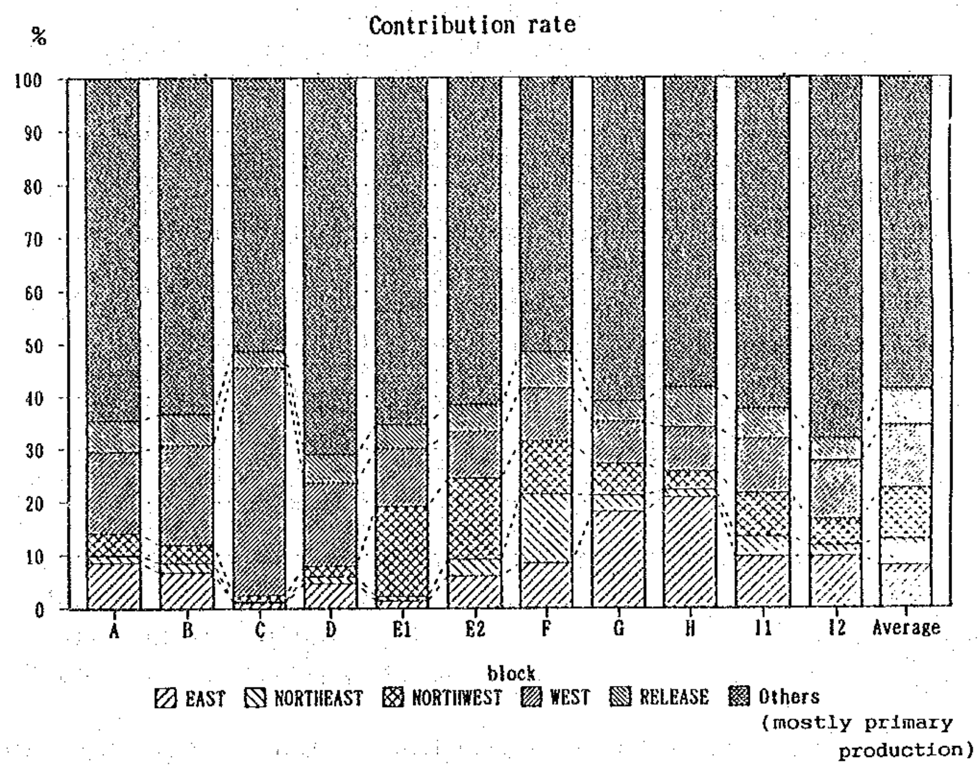


Fig. 16.6- 3 Contribution Rate of Each Basin to the Water Quality of Water Areas

(2) Target Reduction Load by Basin

Judging from the distribution of the present water quality and the future estimated water quality, the water areas expected to have difficulties in meeting the target water quality for the mid to long-term plan (see **Fig. 16.5-2**) are Block C, E_1, F, H and I_1 (see **Fig. 16.6-2**).

Seeing the contribution rate to these blocks from the basins and the island area, the following characteristics are mentioned (**Fig. 16.6-3**);

Block C : Strong influence from the western basin.
Water quality improvement will occur by reducing loads from the western basin.

Block E_1: Strong influence from the northwestern basin and western basin.
Water quality improvement will occur by reducing loads from the northwestern basin and western basin.

Block H : Strong influence from the eastern basin.
Water quality improvement will occur by reducing loads from the eastern basin.

Block F : Comparatively strong influence from the northeastern basin.
Water quality improvement will occur by reducing loads from the northeastern basin together with the reduction of loads from the western, northwestern and eastern basins.

Block I_1: Water quality improvement will occur by reducing loads from all basins.

As can be seen by the above explanation, the water quality improvement in Block F and I_1 will be governed by the reduction of loads taken for other three blocks, namely Block C, E_1 and H. Based on this, examination of effects of reducing loads to the water quality was made taking up three blocks; Block C, E_1 and H.

Fig. 16.6-4 shows the results of calculation made by simulation models and it depicts the relation between the reduction rate of loads and anticipated corresponding water quality (average of the block).

In order to identify the degree of the water quality improvement which ensures that the whole area of the block concerned could meet the target water quality, calculations have been made and the results show;

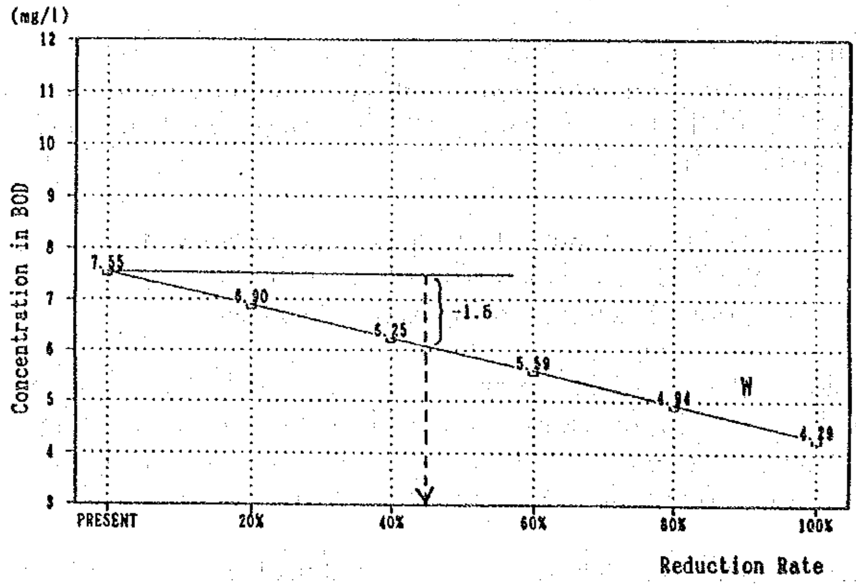
Block C needs 1.5 mg/l improvement
Block E_1 needs 1.0 mg/l improvement
Block H needs 0.25 mg/l improvement

The reduction of loads corresponding to the degree of the water quality improvement above can be read by **Fig. 16.6-4**. For instance, in case of Block C, the improvement of 1.5 mg/l BOD corresponds to about 40 % reduction of loads.

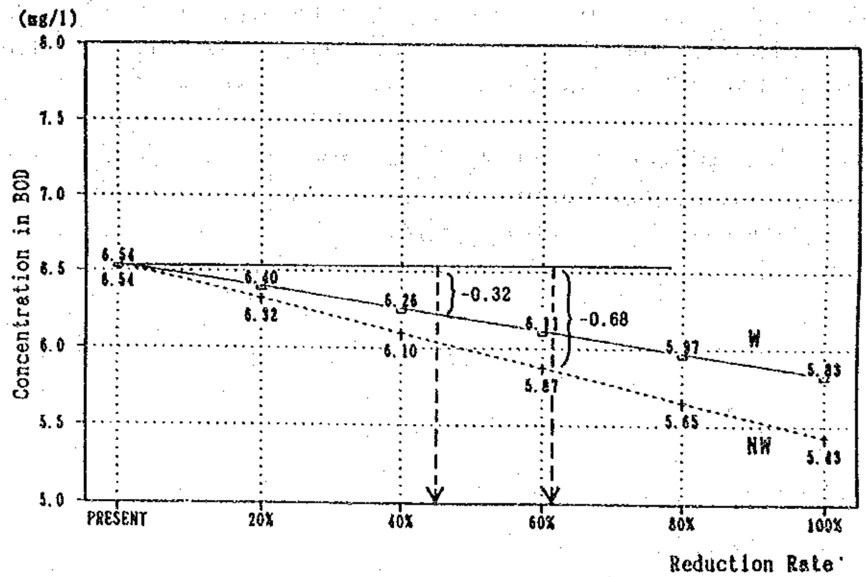
Although more than 40 % of reduction of loads from the northwestern basin is needed for Block E_1, we concluded that 40 % reduction of loads for the western, northwestern and eastern basins could provide the basis for identifying the multiplying effects of the reduction of loads to the entire area of Guanabara Bay.

For the effluent loads from the northeastern basin, we will keep the present for loads because the present water quality near the river-mouth is around 5 mg/l.

(a) Effects of Reduction in Load from the W. Basin to Block C



(b) Effects of Reduction in Load from the W. Basin and the NW. Basin to Block E1



(c) Effects of Reduction in Load from the E. Basin to Block H

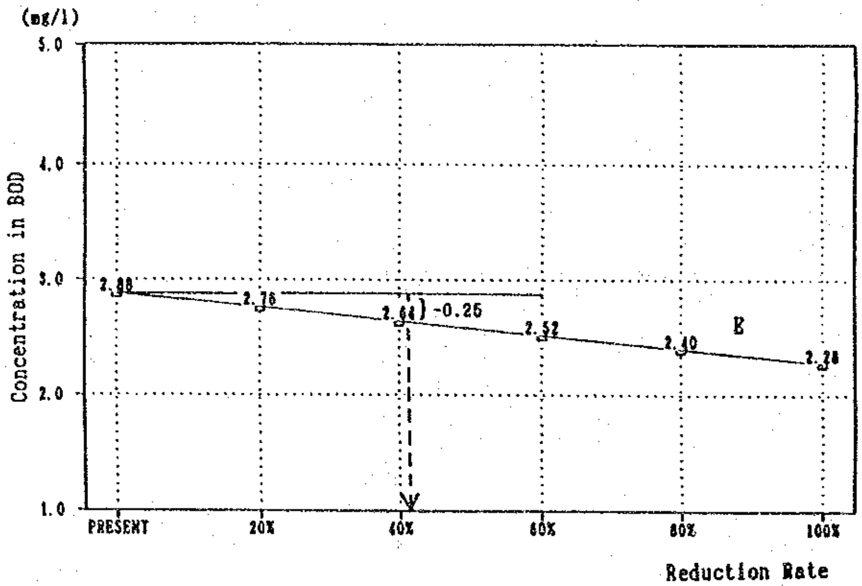


Fig. 16.6- 4 Relationship between Reduction Load and Water Quality

(3) Effects by the Reduction of Load

The result of 40 % reduction in effluent loads (BOD and O-P), from the western, northwestern and eastern basins, from the present loads is shown in **Fig. 16.6-5**. Here, we set the effluent loads from the northeastern basin as the present level of loads.

In this case, the water quality in the Bay almost meets the target water quality for BOD for mid to long-term plan except that in the central part of the Bay, in which the values are around 3.4 mg/l.

This means that there are difficulties in meeting the target water quality in the central part of the Bay if measures taken focus only on the reduction of BOD and do not cover the reduction of nutrient salts because of the high contribution of primary production of around 60 % in the central part of the Bay.

Therefore, it is necessary to take measures to reduce nutrient salts.

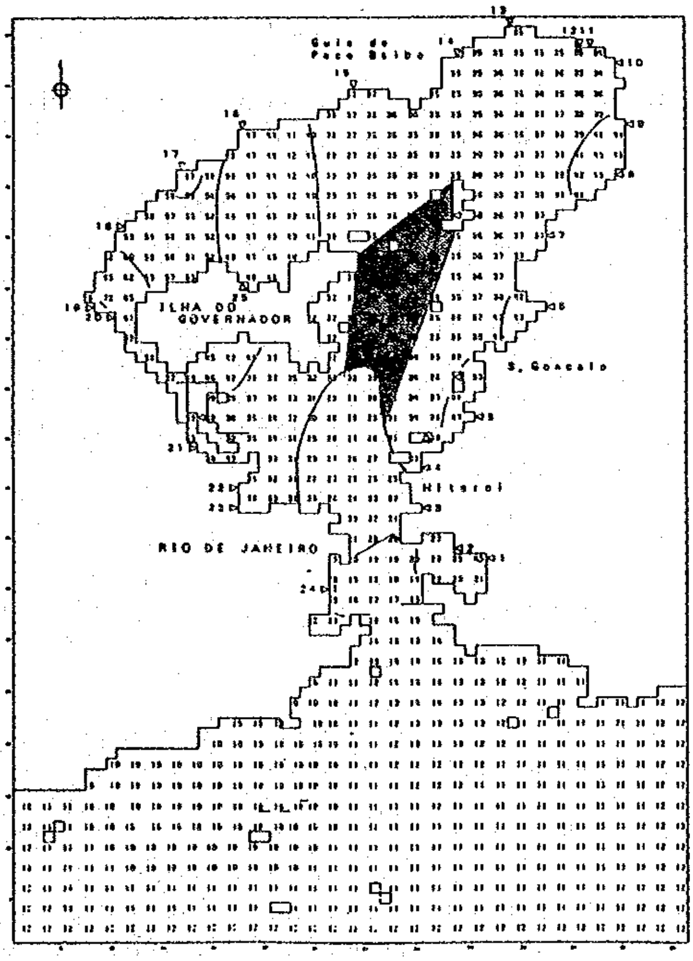


Fig. 16.6- 5 BOD Distribution after Reduction of Effluent Load (Trial Case 1)

16.6.3 Target Load Reduction for Nutrient Salts

Though there are difficulties in deciding how much the nutrient salts should be reduced, we assumed the same percentage of reduction for nutrient salts as was used for organic matter (BOD and O-P) in the previous section.

Namely, we tried to examine the effects by the following effluent load reductions from the basins;

Western Basin	: 40 % reduction in organic matter (BOD and O-P), plus 40 % reduction in nutrient salts (PO_4-P)
Northwestern Basin	: 40 % reduction in organic matter (BOD and O-P), plus 40 % reduction in nutrient salts (PO_4-P)
Eastern Basin	: 40 % reduction in organic matter (BOD and O-P), plus 40 % reduction in nutrient salts (PO_4-P)
Northeastern Basin	: present loads for both organic matter and nutrient salts.

The BOD distribution after the reduction of effluent loads mentioned above by a simulation model is shown in **Fig. 16.6-6**.

Fig. 16.6-6 shows that most of the central part of the Bay, in which the target water quality (less than 3 mg/l in BOD) could not be met by reducing only the organic matter, meets the target water quality by reducing the primary production in the Bay induced by the reduction of nutrient salts.

Comparing **Fig. 16.6-6** with **Fig. 16.6-5**, it can be seen a 40 % reduction in nutrient salts translates into a reduction of around 0.3 mg/l to 0.5 mg/l (about 10 % reduction) of BOD over the whole area in the bay.

Further, it is calculated that still 66 % of the BOD concentration is caused by primary production as an average for the whole Bay area(**Fig. 16.6-7**).

The target reduction loads for both organic matter (BOD) and nutrient salts (T-P) required to meet the target water quality for mid to long-term plan are summarized in **Table 16.6-1**.

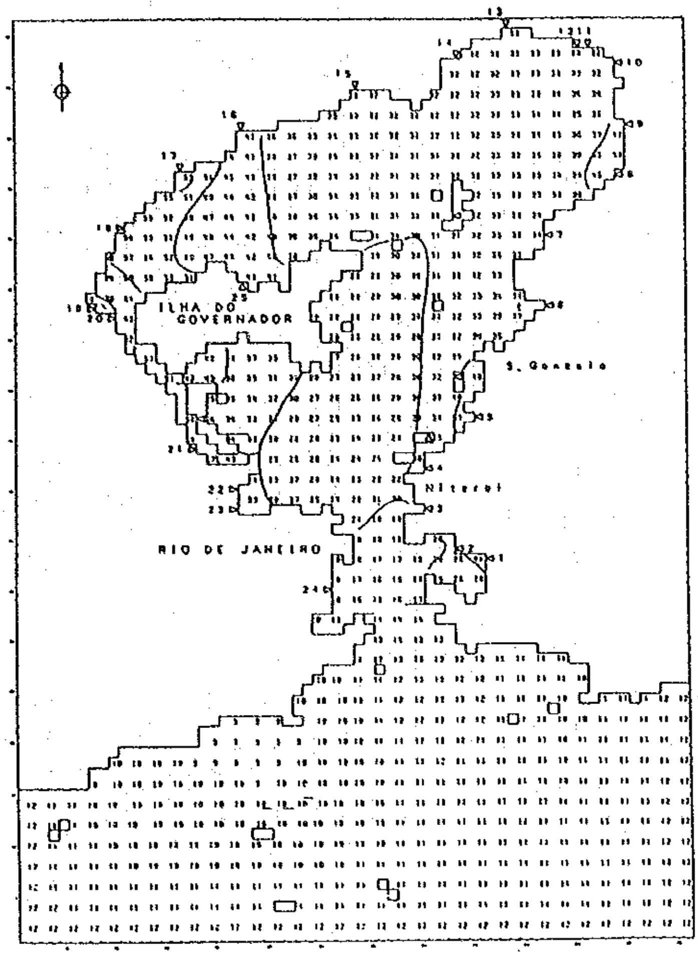


Fig. 16.6- 6 BOD Distribution after Reduction of Effluent Load (Trial Case 2)

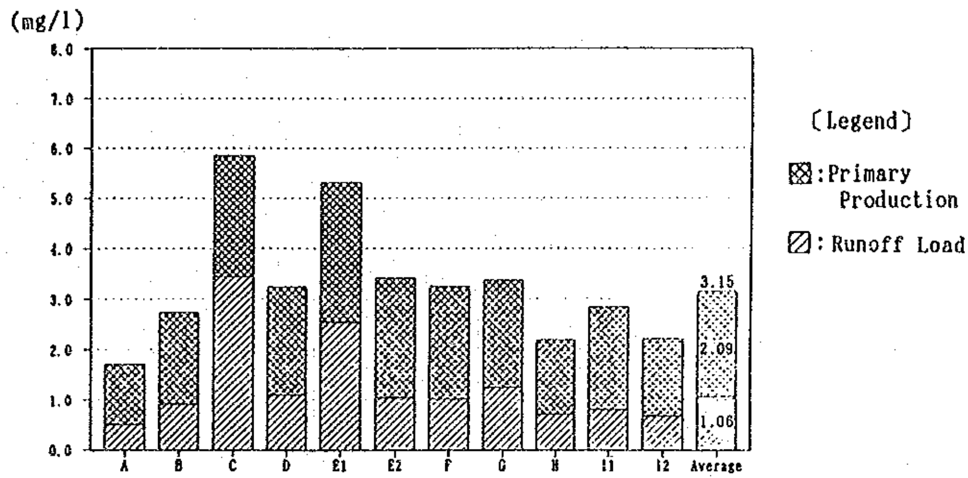


Fig.16.6-7 Origin of BOD Concentration (Trial Case 2)

Table 16.6- 1 Target Reduction Load (Mid to Long-Term Plan)

unit : ton/day

Name of Basin	Organic Matters in BOD			Nutrient Salts in T-P		
	Runoff Load (Present)	Target Reduction Load	Target Runoff Load	Runoff Load (Present)	Target Reduction Load	Target Runoff Load
Eastern Basin	40.1	-16.0 (-40.0%)	24	1.39	-0.56 (-40.0%)	0.8
Northeastern Basin	44.1	0.0 (0.0%)	44	2.53	0.0 (0.0%)	2.5
Northwestern Basin	98.6	-39.4 (-40.0%)	59	5.56	-2.22 (-40.0%)	3.3
Western Basin	164.2	-65.7 (-40.0%)	98	10.39	-4.16 (-40.0%)	6.2
Islands	7.8	-0.0 (0.0%)	7	0.47	-0.00 (0.0%)	0.4
Total	354.8 (100%)	-121.1 (-34.1%)	232 (65%)	20.34 (100%)	-6.94 (-34.1%)	13.2 (65%)

16.6.4 Target Reduction Load for Short-Term Plan

In this section, we examine the target reduction loads required to meet the target water quality for short-term plan in the target year 2000 set in the previous section.

Since the implementation of the IDB/OECF program with a primary treatment system is planned by the year 2000, we suppose that it is completed on 2000.

Fig. 16.6-8 shows the estimated future concentration of BOD (2000). The shaded areas represent areas where the target water quality for the short-term plan set in the previous section (see **Fig.16.5-1 and Table 16.5-3**) is not attained.

In spite of the implementation of the IDB/OECF program in 2000, more than 5 mg/l of BOD is still estimated to be at the offshore area near the mouth of Rio Estrela northwest of the Bay and at the mouth of Rio Guapimirim northeast of the Bay and thus do not meet the target water quality: these water areas belong to Class B.

This means that more effective and urgent measures are necessary in order to meet the target water quality for the short-term plan.

With regard to the offshore area at the mouth of Rio Estrela, as seen in section 16.6.2, the reduction of runoff loads from the northwestern basin is effective. The reduction rate from the northwestern basin in BOD, to meet the target water quality for short-term plan, is estimated to be around 20% from the simulation results shown in **Fig.16.6-8** and **Fig.16.6-5**.

For the area near the mouth of Rio Guapimirim, the target water quality for the short-term plan, in terms of BOD (less than 5 mg/l), will be attained by keeping the present runoff loads from the northeastern basin, because the present water quality near the river-mouth is around 5mg/l.

With all above, **Table 16.6-2** shows the target reduction loads for organic matter, in terms of BOD, required to meet the target water quality for the short-term plan set in the previous section.

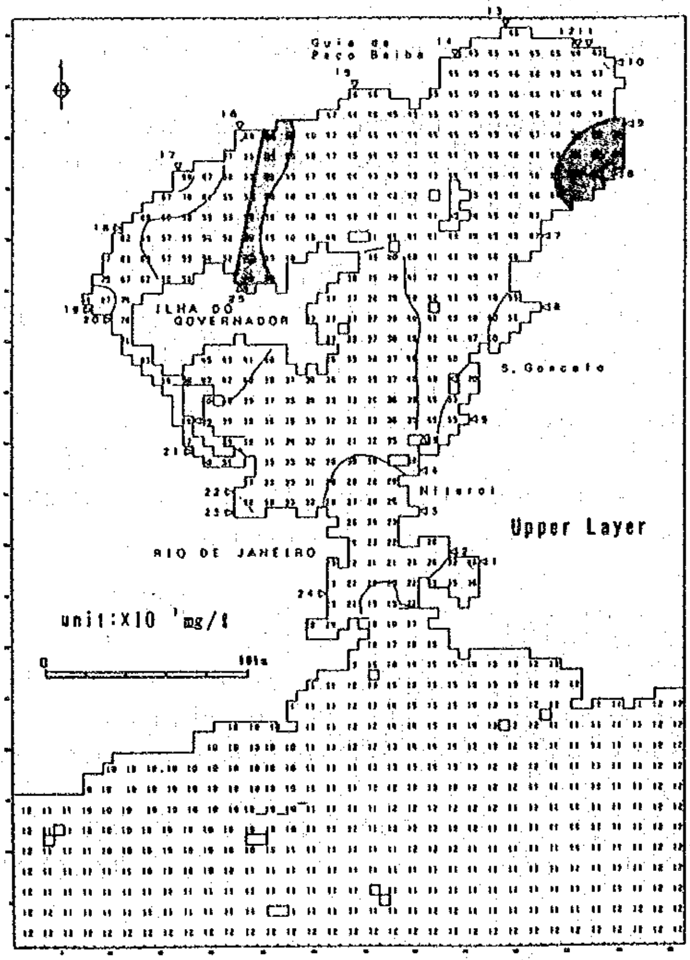


Fig.16.6- 8 Future Water Quality(BOD) by IDB/OECF Program in 2000 (Primary Treatment)

Table 16.6- 2 Target Reduction Load (Short-Term Plan)

unit : ton/day

Name of Basin	Organic Matters in BOD				
	Runoff Load (Present)	Runoff Load in 2000 (No Measure)	IDB/OECF in 2000 (Primary)	Target Reduction Load	Target Runoff Load
Eastern Basin	40.1	44.4	35.6	– 4.5	35.6
Northeastern Basin	44.1	55.6	55.6	± 0.0 (± 0%)	44.1
Northwestern Basin	98.6	114.8	107.0	– 19.7 (– 20%)	78.9
Western Basin	164.2	176.4	135.8	– 28.4	135.8
Islands	7.8	8.3	6.6	– 1.2	6.6
Total	354.8 (100 %)	399.5 (112.6 %)	340.6 (96.0 %)	– 53.8 (–15.2 %)	301.0 (84.8 %)

16.7 Selection of Applicable Measures and Their Effects

16.7.1 Applicable Measures for the Priority Areas

On the study of applicable measures for the priority areas, we suppose that the first stage of the IDB/OECF program is put into practice.

(1) Applicable Measures for Influential Sub-Basins

Applicable measures for the influential sub-basins selected in the foregoing section are summarized in **Table 16.7-1** from the standpoint of reducing domestic and industrial effluent load, lowering effluent loads from non-point sources, and measures applicable to rivers flowing into the Bay.

This table also includes measures proposed in the IDB/OECF program and plans drawn up by COMLURB and SERLA.

As the influential sub-basins are areas discharging large effluent loads and as was shown by a numerical simulation the reduction of them strongly contributes to the improvement of water quality in the Bay, the construction and/or improvement of sewage treatment plants becomes the principal measure for the reduction of domestic effluent loads. Since there are many favela areas in Sub-Basin No. 20, 21 and 23, wastewater treatment in these areas is also important.

An ocean outfall system is worthy of consideration in Sub-Basin No. 20, 21, 23 of Rio de Janeiro and in Sub-Basin No. 4, 5, 6 of Niteroi situated near the bay-mouth.

In Sub-Basin No. 17 and 19, a stabilization pond system is applicable as a measure for domestic wastewater treatment in areas without sewage plans in order to reduce not only organic matter but also nutrient salts.

Regarding the measures for the reduction of industrial effluent loads, a tightening in the monitoring of effluent loads under DZ 205-R5 (1991) "Instruction for Organic Load Control from Industries" is the first priority. In Sub-Basin No. 17 which has chemical and petrochemical factories, and in Sub-Basin No. 21 and 4, 5 which have food and beverage factories, joint treatment plants are recommended.

Table 16.7- 1 Applicable Measures for Influential Sub-Basins

Sub-Basin No. (River Name)	Measure for Reduction of Domestic Effluent Load	Measure for Reduction of Industrial Effluent Load	Measure for Reduction of Effluent Load from Non-Point Sources	Measure to Rivers flowing into the Bay
19 (Meriti)	*Construction of Pavuna STP (Population:410,000) 2000 : primary treatment (2010 : secondary treatment) .Capacity-up of existing Acari & Realengo STP [redacted]	.Tightening of monitoring to effluent load	.Prevention of forests in the Pera Branca State Park	[redacted] ΔDredging
17-6 (Sarapui)	*Construction of Sarapui STP (Population:430,000) 2000 : primary treatment (2010 : secondary treatment) [redacted]	.Tightening of monitoring to effluent load	.Improvement of garbage collection/ treatment system .Control of land use in Nova Iguacu	ΔWidening of river (including removal of Favelas) ΔConstruction of flood-control dam ΔDredging [redacted]
21 (Cunha)	*Construction of Alegria STP (Population:1,530,000) 2000 : primary treatment 2010 : secondary treatment .Ocean outfall with primary treatment (2010) [redacted]	.Construction of joint treatment plant for food & beverage factories (High concentrated organic substances)	OImprovement of garbage collection /treatment system in Favela □Reforest around Favela	ΔRemoval screen of flotage ΔDredging
17-1.5 (Iguacu)	*Construction of Bota STP (2010 : primary treatment) [redacted]	.Construction of joint treatment plant for petrochemical factories (Refractory organic substances)	OImprovement of garbage collection/ treatment system in Nova Iguacu .Control of land use in Nova Iguacu	[redacted]
20 (Iraja)	*Improvement of existing Penha STP (Population:700,000; secondary treatment) .Ocean outfall with primary treatment [redacted]	.Tightening of monitoring to effluent load	OImprovement of garbage collection/ treatment system in Favela □Reforest around Favela	ΔDredging
23 (Mangue)	*Construction of Alegria STP 2000 : primary treatment (2010 : secondary treatment) .Ocean outfall with with primary treatment (2010) [redacted]	.Tightening of monitoring to effluent load	.Prevention of forests in Tijuca OImprovement of garbage collection/ treatment system in Favela	ΔDredging
8 (Alcantara)	*Construction of S-III.IV.V STP (2010 : primary treatment)	.Tightening of monitoring to effluent load	.Control of land use in San Goncalo	[redacted]
4.5.6 (Imboassu)	*Construction of Sao Goncalo STP 2000 : primary treatment (2010 : secondary treatment) .Ocean outfall with primary treatment (2005)	.Construction of joint treatment plant for food factories (processing of sea products) (high concentrated organic substances)		

[Note] * : IDB/OECF Program O : plan by COMLURB Δ : under practice by SERLA with World Bank loan
□ : IEF STP : Sewage Treatment Plant

Table [illegible] Applicable Measures for Influential Sub Basins

[illegible]	Measure for Reduction of Domestic Effluent Load	Measure for Reduction of Industrial Effluent Load	Measure for Reduction of Effluent Load from Non-Point Sources	Measure to Rivers flowing into the Bay
[illegible]	[illegible] .Stabilization Pond	.Tightening of monitoring to effluent load	.Prevention of forests [illegible]	.Retardation ponds or swirl separation tank ΔDredging
[illegible]	[illegible] .Stabilization Pond	.Tightening of monitoring to effluent load	.Improvement of garbage collection/treatment system .Control of land use [illegible]	[illegible] ΔDredging .Retardation pond or swirl separation tank
[illegible]	[illegible] .Ocean outfall with primary treatment (2010) .Waste water treatment in Favela	.Construction of joint treatment plant [illegible]	.Improvement of garbage collection/treatment system in Favela [illegible]	[illegible] ΔDredging
[illegible]	[illegible] .Stabilization Pond	.Construction of joint treatment plant [illegible]	.Improvement of garbage collection treatment system in Nova Iguaçu .Control of land use [illegible]	.Retardation pond or swirl separation tank
[illegible]	[illegible] .Ocean outfall with primary treatment .Waste water treatment in Favela	.Tightening of monitoring to effluent load	.Improvement of garbage collection treatment system in Favela [illegible]	ΔDredging
[illegible]	[illegible] .Ocean outfall with with primary treatment (2010) .Waste Water treatment in Favela	.Tightening of monitoring to effluent load	.Prevention of forests [illegible] .Improvement of garbage collection treatment system in Favela	ΔDredging
[illegible]	[illegible]	.Tightening of monitoring to effluent load	.Control of land use	.Retardation pond or swirl separation tank
[illegible]	[illegible] .Ocean outfall with primary treatment (2025)	.Construction of joint treatment plant [illegible]		

[illegible]

For the reduction of effluent loads from non-point sources, the improvement of the garbage collection and treatment system, the control of land use and the preservation of forests are important measures.

In river areas, dredging and widening works are being carried out forward. Above that, we want to propose retardation ponds to improve water quality by the oxidation method etc. as well as in preventing floods.

(2) Applicable Measures for Important Beaches and Water Areas

Applicable measures for the important beaches and water areas are summarized in **Table 16.7-2** from the standpoint of measures to the sub-basins directly behind the water areas and to the water areas themselves.

For the sub-basins directly behind the water areas, the reduction of flowing loads by the construction of sewage treatment plants, the tightening of monitoring, the construction of joint treatment plants for industries and so forth are in need as stated in the previous section.

Regarding the applicable measures in the water areas, the removal of polluted bottom sediments and flotages is recommended for Water Areas A and H, which are used as coastal resort beaches.

For Water Area C, the channels, widening and deepening of the channels together with the removal of polluted bottom sediments are effective measures for better water circulation in the inner part of the Bay.

For Water Area D, situated in the south part of the Governador island, the deepening of the shallow areas and the removal of polluted bottom sediments, flotages and obstacles are proposed for better water circulation and the improvement in sediment quality.

Finally, the effective measures for Water Area F, which includes mangroves, are mainly to prevent flow of wastewater. However, the removal of existing polluted sediments is also effective from the standpoint of breeding area for larvae and juvenile fish.

Table 16.7- 2 Applicable Measures for Important Beaches and Water Area

Water Area	Applicable Measures to Sub-Basin directly behind Water Area	Applicable Measures to Water Area
A	Sub-Basin 24 • Prevention of flowing wastewater through storm drainages • Tightening of monitoring to industrial effluent load	• Removal of polluted bottom sediments • Removal of flotages
C	Sub-Basin 19, 20 & 21 (see Table 16.7-1)	• Widening & deepening of the channel • Removal of polluted bottom sediments • Removal of flotages
D	Sub-Basin 25 & 26 • Prevention of flowing wastewater through storm drainages • Tightening of the monitoring to industrial effluent load	• Deepening of shallow area by dredging • Removal of polluted bottom sediments • Removal of flotages & obstacles
F	Sub-Basin 7 to 15 • Construction of sewage treatment plants in the upper stream • Tightening of the monitoring to industrial effluent load • Control of land use	• Removal of polluted bottom sediments
H	Sub-Basin 1, 2 & 3 • Prevention of flowing wastewater through storm drainages • Tightening of the monitoring to industrial effluent load • Construction of joint treatment plant for sea-product processing factory	• Removal of polluted bottom Sediments • Removal of flotages

(3) Applicable Measures for Potentially Critical Sub-Basins

We selected four (4) groups as potentially critical sub-basins (see **Table 16.3-4** and **Fig. 16.3-1**). Group II (Sub-Basin No. 9-2, 9-3, 10-2, 10-5) and Group III (Sub-Basin No. 16-2, 16-3) have a low population density at present. However, the recent urbanization of these areas is seen in the increase in population and urban area, and decrease in forest area.

Moreover, the downstream area is a precious water area covering a mangrove forest and fishing field. It was shown by numerical simulation that effluent loads from these groups strongly affect the inner part of the Bay (**Fig. 16.6-3**).

Therefore, it is desirable to plan such measures as the separated treatment by a stabilization pond, an oxidation ditch and so forth. The construction of sewage treatment plants and land use controls by governmental agencies are proposed as effective measures in these areas.

Regarding the applicable measures in Group I (Sub-Basin No. 1, 2, 3) and Group IV (Sub-Basin No. 24) situated in front of the recreational resort beaches have already been mentioned in previous sections.

16.7.2 Effect of the Sewage Treatment System (IDB/OECF Program)

The IDB/OECF program, currently being carried out to restore the ecosystem of Guanabara Bay, schedules the construction of six sewage treatment plants (primary treatment) in the first stage (by the year 2000) and the full conversion to secondary treatment of these plants for the second stage (by the year 2010).

Runoff load reductions for BOD and PO_4-P by this program are summarized in **Table 16.7-3** for each basin.

This program directs its energies to Rio de Janeiro city (western basin) and Niteroi city (eastern basin). The projected reduction in runoff loads for BOD from these areas is 20 % to 30 %.

However, the runoff loads from the northeastern and northwestern basins increase because there are no plans to construct sewage treatment plants around the north part of the Bay.

Consequently, the total reduction load, for BOD, from all basins is only 4.7 % by 2010 under the IDB/OECF program, compared with the present runoff loads.

This comes from the fact that the water quality in the western and eastern parts of the Bay improves, but in the northwestern and northeastern parts it deteriorates (see **Fig. 16.6-1(b)**).

Further, no measures regarding the reduction of nutrient salts are considered under the IDB/OECF program. Therefore, the runoff loads for nutrient salts in the Bay, by 2010, are projected to increase more than 20 % from the present (**Table 16.7-3**).

Table 16.7- 3 Reduction Load by IDB/OECF Program

BOD unit : ton/day

Name of Basin	IDB/OECF Program (1st Stage)	Runoff Load			Reduction Load (2010-1991)
		1991 (Present)	2000 IDB/OECF Program (Primary)	2010 IDB/OECF Program (Secondary)	
Eastern Basin	Icarai Toque Toque S-II	40.1 t/d (100 %)	35.6 t/d (88.8%)	31.9 t/d (79.6%)	- 8.2 t/d (- 20.4%)
Northeastern Basin		44.1 t/d (100 %)	55.6 t/d (126.1%)	64.5 t/d (146.3%)	+ 20.4 t/d (+ 46.3%)
Northwestern Basin	Sarapui	98.6 t/d (100 %)	107.0 t/d (108.5%)	118.5 t/d (120.2%)	+ 19.9 t/d (+ 20.2%)
Western Basin	Alegria Pavuna	164.2 t/d (100 %)	135.8 t/d (82.7%)	117.4 t/d (71.5%)	- 46.8 t/d (- 28.5%)
Islands		7.8 t/d (100 %)	6.6 t/d (84.6%)	5.8 t/d (74.4%)	- 2.0 t/d (- 25.6%)
TOTAL		354.8 t/d (100 %)	340.6 t/d (96.0%)	338.1 t/d (95.3%)	- 16.6 t/d (- 4.7%)

PO_4-P unit : ton/day

Name of Basin	IDB/OECF Program (1st Stage)	Runoff Load			Reduction Load (2010-1991)
		1991 (Present)	2000 IDB/OECF Program (Primary)	2010 IDB/OECF Program (Secondary)	
Eastern Basin	Icarai Toque Toque S-II	0.56 t/d (100 %)	0.65 t/d (116.1%)	0.71 t/d (126.8%)	+ 0.15 t/d (+ 26.8%)
Northeastern Basin		1.01 t/d (100 %)	1.28 t/d (126.7%)	1.49 t/d (147.5%)	+ 0.48 t/d (+ 47.5%)
Northwestern Basin	Sarapui	2.22 t/d (100 %)	2.60 t/d (117.1%)	3.03 t/d (136.5%)	+ 0.81 t/d (+ 36.5%)
Western Basin	Alegria Pavuna	4.16 t/d (100 %)	4.38 t/d (105.3%)	4.54 t/d (109.1%)	+ 0.38 t/d (+ 9.1%)
Islands		0.19 t/d (100 %)	0.20 t/d (105.3%)	0.22 t/d (115.8%)	+ 0.03 t/d (+ 15.8%)
TOTAL		8.14 t/d (100 %)	9.11 t/d (111.9%)	9.99 t/d (122.7%)	+ 1.85 t/d (+ 22.7%)

16.7.3 Effect of the Ocean Outfall System

On the study of the effects of the ocean outfall system, we suppose that the system is put into practice after the completion of the first stage of the IDB/OECF program, by 2000, and the following three cases were investigated (**Fig. 16.7-1**);

Case 1 : application to the sanitary districts south of the Pavuna's sanitary district and south of the Toque-Toque's sanitary district.

Case 2 : application to the sanitary districts south of the Penha's sanitary district and south of the Toque-Toque's sanitary district.

Case 3 : application to the sanitary districts south of the Alegria's sanitary district and Icarai's sanitary district

The runoff load reductions for BOD and PO_4-P by 2010 by the ocean outfall system are summarized as shown in **Table 16.7-4** for each case by basin.

As this system is easiest to apply to the areas near the ocean, the eastern and western basins are targeted.

The potential reduction load for BOD for each sanitary district by this system comparing with the present runoff loads can be calculated from **Table 16.7-4**. The result is as follows;

ETE Pavuna	:	- 6.8 ton/day
ETE Penha	:	- 7.7
ETE Alegria	:	- 45.0
sub Total	:	- 59.5 ton/day
ETE Toque-Toque	:	- 1.8 ton/day
ETE Icarai	:	- 4.5
sub Total	:	- 6.3 ton/day
Total	:	- 66.8 ton/day

The ocean outfall system is also likely to reduce the runoff loads of nutrient salts. For example, 1.42 ton/day of PO_4-P (3.55 ton/day of T-P) will be reduced in Case 1.

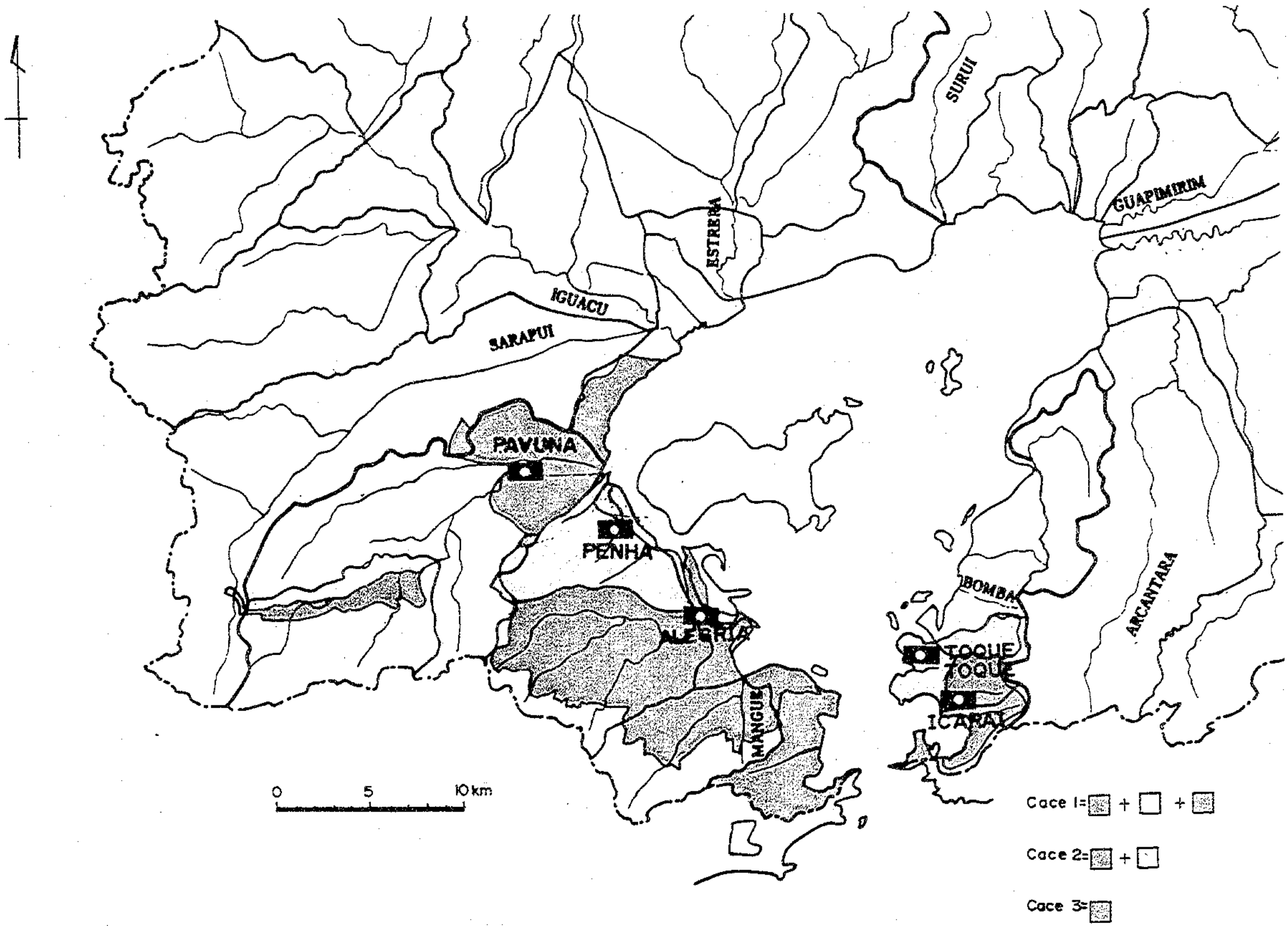


Fig. 16-7- 1 Supposed Sanitary District for Ocean Outfall System

Table 16.7- 4 Reduction Load by Ocean Outfall System

BOD unit : ton/day

Name of Basin	Runoff Load				Reduction Load		
	1991	2010			1991 - Case 1	1991 - Case 2	1991 - Case 3
	(Present)	Case 1	Case 2	Case 3			
Eastern Basin	40.1 (100%)	33.8 (84.3)	33.8 (84.3)	35.6 (88.8)	- 6.3 (-15.5)	- 6.3 (-15.5)	- 4.5 (-11.2)
Northeastern Basin	44.1 (100%)	64.5 (146.3)	64.5 (146.3)	64.5 (146.3)	+ 20.4 (+46.3)	+ 20.4 (+46.3)	+ 20.4 (+46.3)
Northwestern Basin	98.6 (100%)	123.9 (125.7)	123.9 (125.7)	123.9 (125.7)	+ 25.3 (+25.7)	+ 25.3 (+25.7)	+ 25.3 (+25.7)
Western Basin	164.2 (100%)	104.7 (63.8)	111.5 (67.9)	119.2 (72.6)	- 59.5 (-36.2)	- 52.7 (-32.1)	- 45.0 (-27.4)
Islands	7.8 (100%)	6.8 (87.2)	6.8 (87.2)	6.8 (87.2)	- 1.0 (-12.8)	- 1.0 (-12.8)	- 1.0 (-12.8)
TOTAL	354.8 (100%)	333.7 (94.1)	340.5 (96.0)	350.0 (98.6)	- 21.1 (- 5.9)	- 14.3 (- 4.0)	- 4.8 (- 1.4)

PO_4-P unit : ton/day

Name of Basin	Runoff Load				Reduction Load		
	1991	2010			1991 - Case 1	1991 - Case 2	1991 - Case 3
	(Present)	Case 1	Case 2	Case 3			
Eastern Basin	0.56 (100%)	0.53 (94.6)	0.53 (84.6)	0.61 (108.9)	- 0.03 (- 5.4)	- 0.03 (- 5.4)	+ 0.05 (+ 8.9)
Northeastern Basin	1.01 (100%)	1.49 (147.5)	1.49 (147.5)	1.49 (147.5)	+ 0.48 (+47.5)	+ 0.48 (+47.5)	+ 0.48 (+47.5)
Northwestern Basin	2.22 (100%)	3.04 (136.9)	3.04 (136.9)	3.04 (136.9)	+ 0.82 (+36.9)	+ 0.82 (+36.9)	+ 0.82 (+36.9)
Western Basin	4.16 (100%)	2.77 (66.6)	3.09 (74.3)	3.42 (82.2)	- 1.39 (-33.4)	- 1.07 (-25.7)	- 0.74 (-17.8)
Islands	0.19 (100%)	0.22 (115.8)	0.22 (115.8)	0.22 (115.8)	+ 0.03 (+15.8)	+ 0.03 (+15.8)	+ 0.03 (+15.8)
TOTAL	8.14 (100%)	8.05 (98.9)	8.37 (102.8)	8.78 (107.9)	- 0.09 (- 1.1)	+ 0.23 (+ 2.8)	+ 0.64 (+ 7.9)

16.7.4 Effect of the Stabilization Pond

A high speed treatment such as the standard activated sludge method is appealing in urban areas where the acquisition of sufficient land is difficult; however when land is available, it is more advantageous to adopt some other method based on the self purification capacities of nature and the simplicity in construction and maintenance. We would in such a case suggest the application of a multicellular stabilization pond system because the reduction rate of organic matter and nutrient salts is higher than that of ordinary secondary treatment systems plus construction and maintenance costs are lower.

We therefore would like to examine the case of constructing large-scaled stabilization treatment ponds in the undeveloped low and swamp area widely remaining in the basins of the Sarapui river, the Iguacu river and so forth, in order to carry out centralized treatments of household wastewater corresponding to the yet unserviced part of the population of Sub-basin No. 17-1,5 (Rio Iguau basin) and No. 17-6 (Rio Sarapui basin) by 2010(See **Fig. 16.7-2**).

Table 16.7-5 shows the design conditions of the two stabilization pond systems shown in **Fig. 16.7-2**. Although the proposed systems are based on large-scale central treatments, they may also be effective in decentralized treatment using medium to small scale ponds dividing the originally planned treatment zone into smaller zones; if the necessary sites can be secured.

System 1 is to be constructed on the lower reaches of the Rio Sarapui to cope with the yet unserviced part of the population of Sub-basin No. 17-6 and system 2 is to be constructed on the lower reaches of the Rio Iguacu to deal with the yet unserviced part of the population of Sub-basin No. 17-1,5. The stabilization ponds are to be 2 to 4 meter deep over 6 stages (6 cells) and the retention time should be about 30 days. Previous studies have proved that this arrangement of stabilization ponds can remove 90 to 95% of BOD and 50 to 60% of N and P while coliform group can be reduced to 1,000MPN/100ml or less, thus removing pollutants at a higher efficiency than the wastewater treatment plants (secondary treatment) planned in the IDB/OECF program.

Approximations of the effluent BOD loads from the beneficial population by the stabilization pond system 1 in the Sarapui river basin and system 2 in the Iguacu river basin are 40.1 ton/day and 47.4 ton/day, respectively.

If we suppose that the stabilization system can remove 90% of BOD, the potential reduction load can be calculated as 36.1 ton/day in the Sarapui river basin and 42.7 ton/day in the Iguacu river basin.

Table 16.7- 5 Design Factors of the Stabilization Pond systems

	System 1	System 2
1. District	Duque de Caxias	Nova Iguacu
2. Sub-Basin No.	17-6 (Rio Sarapui)	17-1,5(Rio Iguacu)
3. Population in 2010	1,306,000	976,133
4. Beneficial Population	1,175,400	878,520
5. Beneficial Population by Activated Sludge Treatment	432,000	0
6. Beneficial Population by Stabilization Pond System	743,400	878,520
7. Inflow Wastewater	1.71×10^5 m^3/day (1.98 m^3/s)	2.02×10^5 m^3/day (2.34 m^3/s)
8. Retention Time	30 days	30 days
9. Area of Pond	205 ha	243 ha

4. Calculated on the assumption that it corresponds to 80 % of the population in the year 2010.

5. The part of the population which the CEDAE Program is planning to service with the activated sludge treatment by 2007.

6. 4 minus 5

7. Calculated on the assumption that the volume of wastewater expected to be drained is 230 l/head.

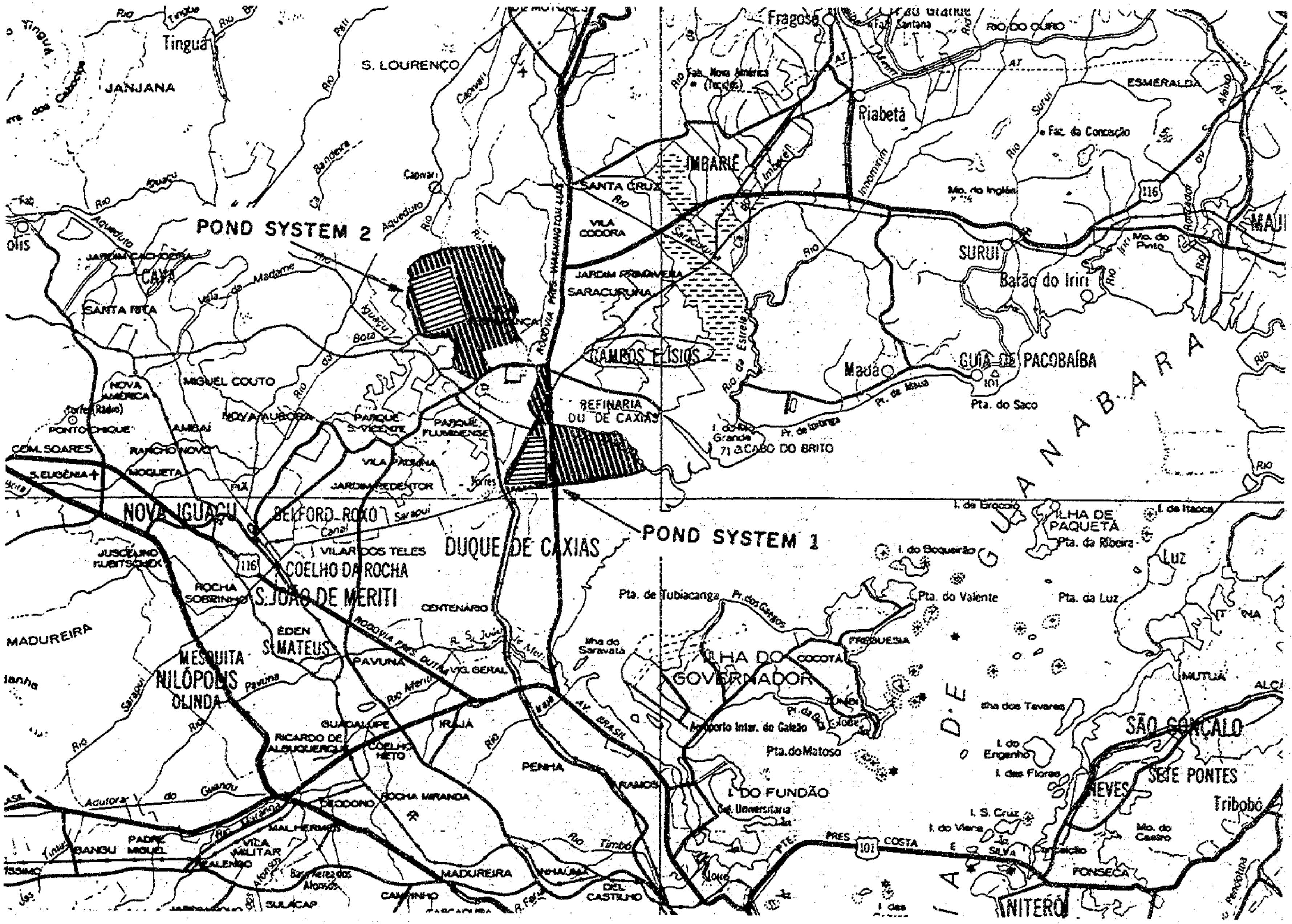


Fig. 16.7- 2 Supposed Location of Stabilization Pond System

16.7.5 Effect of Industrial Wastewater Control

As stated in Chapter 8, most of the industrial pollution sources are located in the western and eastern basins. Their effluent loads for BOD are summarized in **Table 16.7-6** for each basin.

According to DZ205-R5 (1991) "Instruction for Organic Load Control from Industries", Rio de Janeiro set up a target of 70 % reduction at minimum of effluent loads in BOD from industries.

Therefore, we assume that 70 % of the present industrial effluent load, 77.6 ton/day, will be reduced by the efforts of the state government and industry.

Then, the potential reduction load can be calculated as 54.3 ton/day in the whole basin as shown in **Table 16.7-6**.

Table 16.7- 6 Reduction of Industrial Effluent Load (BOD)

Name of Basin	Industrial Effluent Load (present)	Reduction Load
Eastern Basin	18.8 t/day	- 13.2 t/day
Northeastern Basin	4.2	- 2.9
Northwestern Basin	20.8	- 14.6
Western Basin	33.5	- 23.4
Islands	0.3	- 0.2
TOTAL	77.6 t/day	- 54.3 t/day

16.7.6 Effect of Retardation Ponds

As stated in Chapter 9, the specific runoff load in the rainy days is dozens of times larger than that in the clear days, indicating that the load in rainy days occupies a large part in the total runoff load.

Therefore, we would like to examine the case of constructing retardation ponds in the undeveloped area in order to reduce the runoff load in the rainy days.

Some study in Japan has proved that the retardation pond can remove 24% of COD (BOD) and 8 to 16% of N and P.

Here, we suppose that river waters from each basin overflow into a retardation pond when the precipitation excesses 10 mm and are stored until 20 mm.

Then, the area for the retardation ponds roughly needs 9.4 km^2 in the whole basin when we suppose the depth is 2 meters (see the Supporting Report III in detail).

On the other hand, the number of rainy days more than 10 mm is estimated to be around 55 times per year. The retardation ponds supposed in this study can be effective for one third of them, about 20 times per year.

Under the above assumption, approximations of the runoff BOD loads by the retardation pond system can remove about 10 ton per year in the whole basin.

This means that the retardation pond system is not so effective from the viewpoint of reduction of the BOD load.

16.7.7 Effect of Widening the Channel

Numerical simulation was used to evaluate the measures applicable to the Bay area. The improvement of water circulation by deepening and widening the channels were examined by this method.

The study cases are as follows (**Fig. 16.7-3**);

1) Deepening the channels (water depth : 5 m)
2) Deepening and widening the channels
   (water depth : 5 m,
   width : +500 m)

The results for the supposed measures for the Bay are shown in **Fig. 16.7-4** for each water area. The results show that the effect of deepening and widening the channels is significant in the west and inner part of the Bay, because, of better water circulation in the channels and inner part of the Bay. Because of this, we can expect an improvement in the water quality of 28 % in the maximum (BOD) in the channels, and of 7 % to 9 % in Blocks B and D.

Consequently, the improvement of water circulation by deepening and widening the channels is seen as the most effective measure for the western part of the Bay.

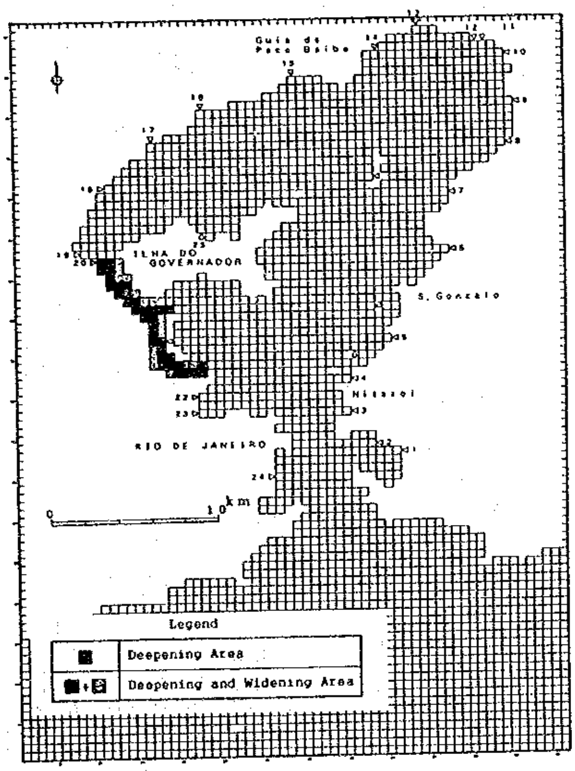


Fig. 16.7- 3 Supposed Measures for the Improvement of Water Circulation in the Bay

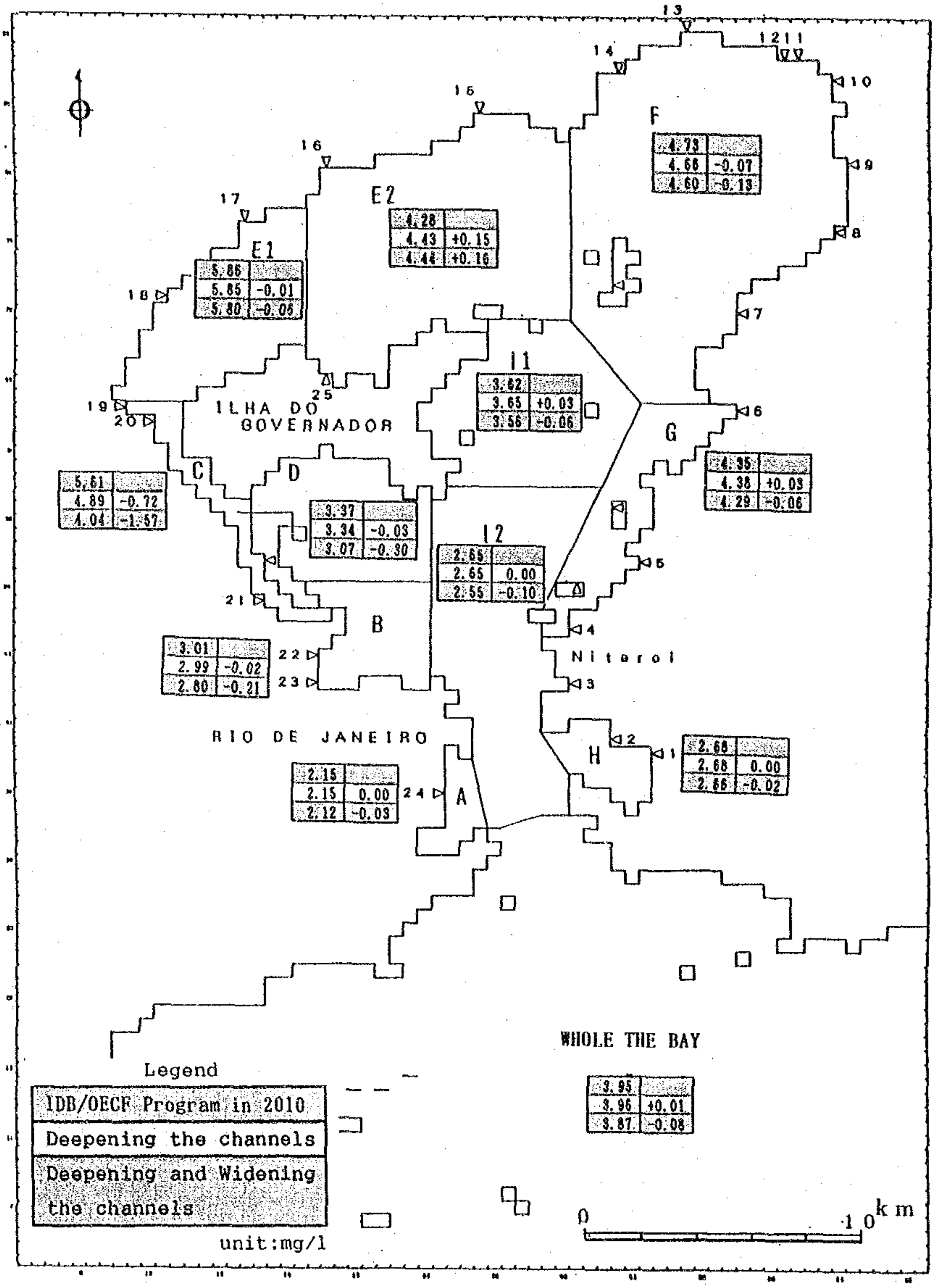


Fig. 16.7- 4 Effect of Supposed Measures in the Bay
(BOD Concentration and Variation)

16.7.8 Effect of Dredging

An evaluation of the effect of the dredging of accumulated sediments to reduce the release load from the polluted sediments on the sea bed; was also examined by numerical simulation.

The study was performed for the case when the release load is assumed to be zero; due to the dredging of the polluted sediments in the west part of the Bay (Blocks C, D, E1 and E2).

The results shown in **Fig. 16.7-5** show that dredging the polluted sediments does not contribute much to the improvement of water quality under the present condition of high flowing loads.

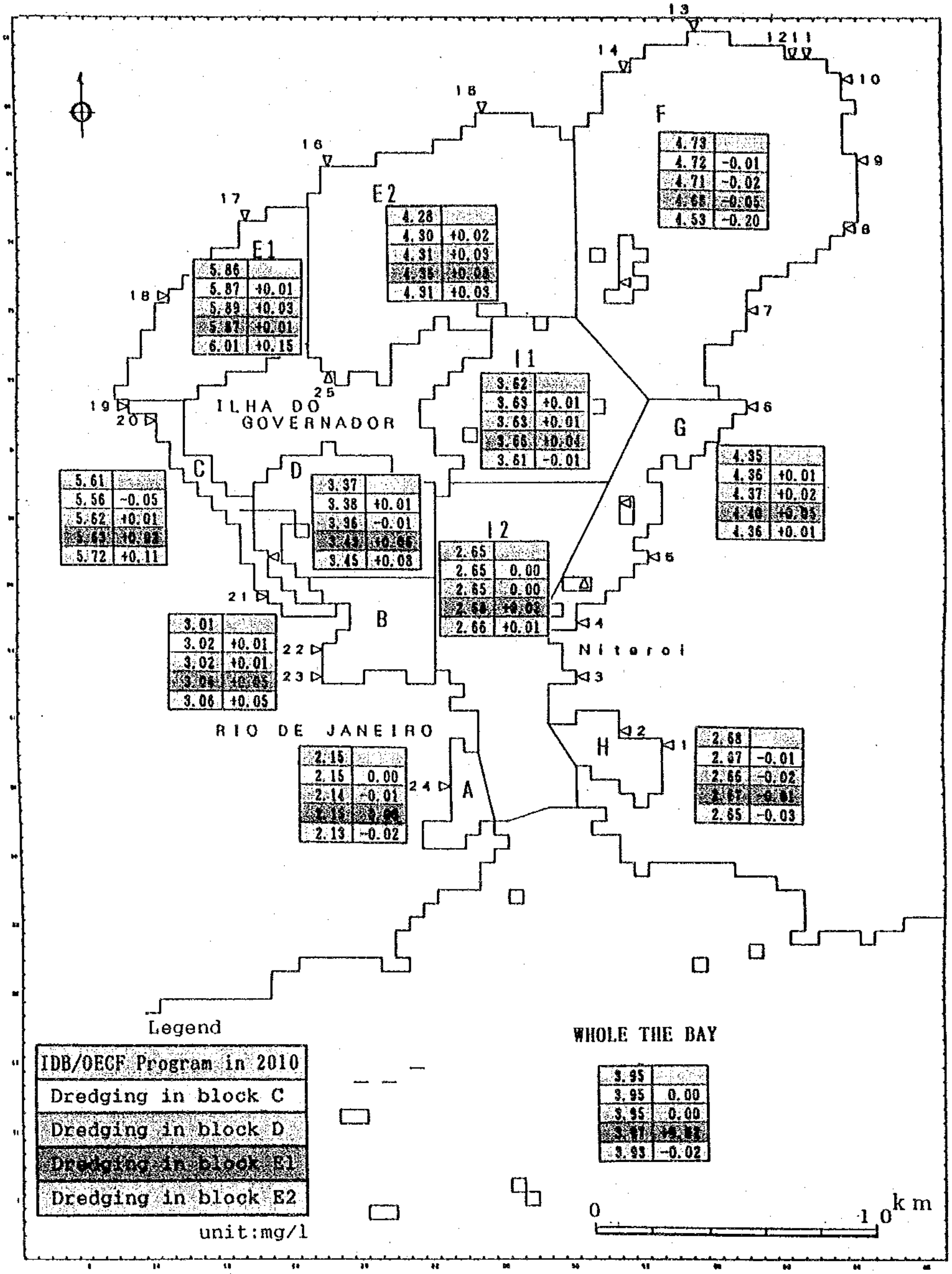


Fig. 16.7- 5 Effect of Supposed Measures in the Bay (Dredging)
(BOD Concentration and Variation)

16.7.9 Effect of High-Grade Sewage Treatment

Finally, we evaluated the effect of high-grade sewage treatments for the reduction of flowing nutrient salts for 20 %, 40 % and 80 % reduction for T-P in the runoff loads from the secondary treatment plants of the IDB/OECF program.

The results shown in **Fig. 16.7-6** show that the 20 %, 40 % and 80 % reductions in T-P, which correspond to 15.7 %, 31.4 % and 62.8 % reductions in T-P from the total amount flowing into the Bay, improve water quality in the whole Bay by 16.7 %, 29.2 % and 50.0 % for T-P, respectively.

Moreover, water quality, in terms of BOD, is also improved. An 80 % reduction in T-P results in a 11.9 % fall in BOD, throughout the whole Bay **(Fig. 16.7-7)**.

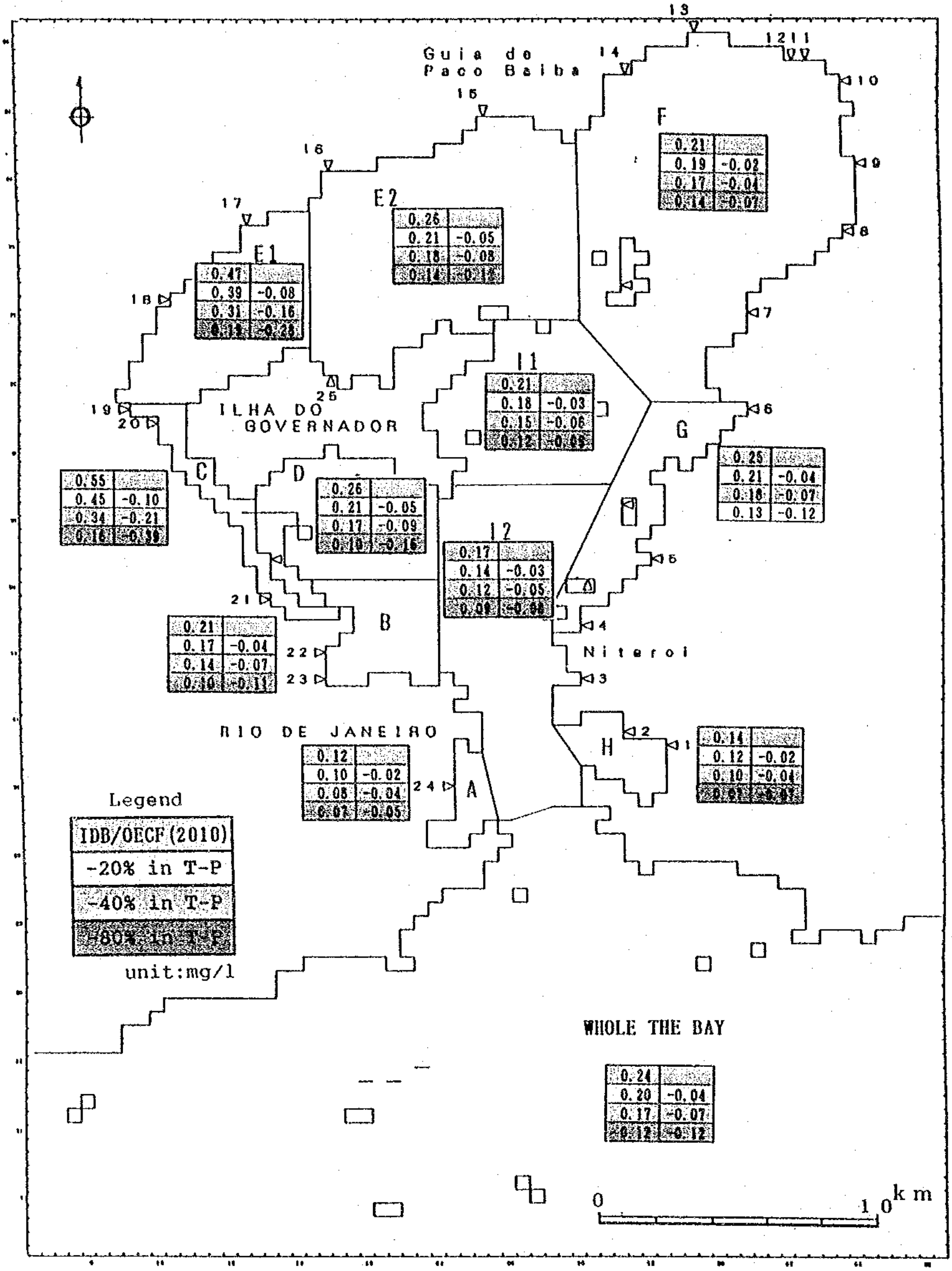


Fig. 16.7- 6 T-P Concentration in Each Block by the Reduction of Inflowing T-P

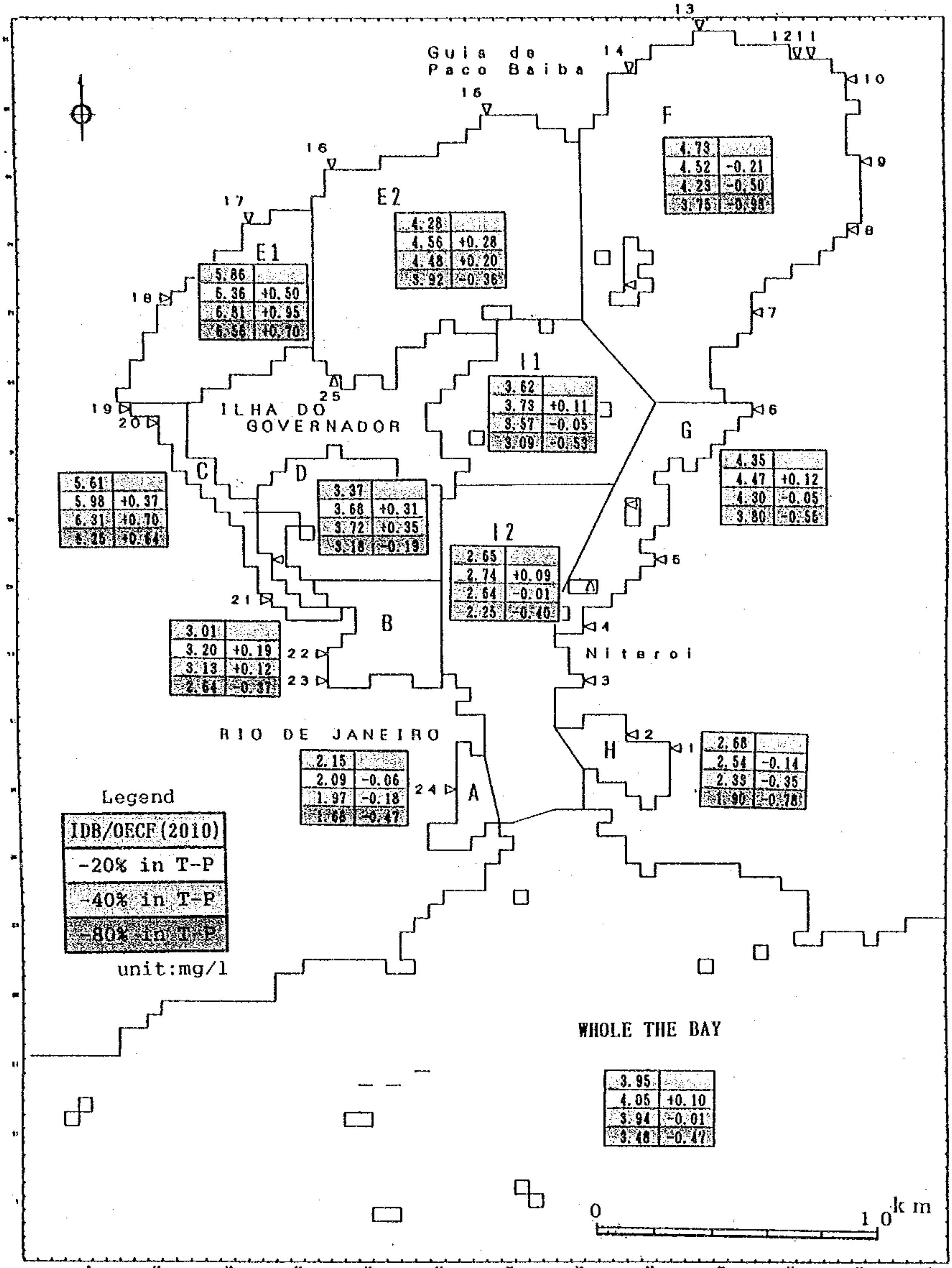


Fig. 16.7- 7 BOD Concentration in Each Block by the Reduction of Inflowing T-P

16.8 Cost of Alternative Measures to Reduce Inflow Load

16.8.1 Cost of the Sewage Treatment System

(1) Conditions of Cost Estimation

The construction cost of the sewage treatment system was estimated for three cases by assuming the some conditions shown in **Table 16.8-1.**

Table 16.8- 1 Assumption for Cost Estimation of Sewage Treatment System

Item		Case 1	Case 2	Case 3
Area	(ha)	4,000	2,000	1,000
Population	(hab)	500,000	250,000	100,000
Volume of Wastewater	(l/hab·day)	200	200	250
	(m^3/sec)	1.2	0.6	0.3
	(m^3/day)	100,000	50,000	25,000
Trunk Sewer	(km)	30	20	10
Diameter: 2.0 m	(km)	10	5	0
1.5 m	(km)	10	5	5
1.0 m	(km)	10	10	5
Collecting Sewer Network	(km)	600	300	150
Pumping Station		5	3	2
Facility Size	(ha)	50	30	15

(2) Unit Cost of Construction

The following unit cost prepared by CEDAE and SABESP in Brazil was used for the cost estimation of the sewage treatment system.

Sewage Treatment Plant	:	**Fig. 16.8-1**
Trunk Sewer	:	**Fig. 16.8-2**
Collecting Sewer Network	:	US$ 80./m (SABESP)
Pumping Station	:	**Fig. 16.8-3**

As no data were found for the cost of a tertiary treatment system in Brazil, we referred to some data in Japan shown in **Fig. 16.8-4**.

The tertiary treatment system adopted here is a circulating denitrification system accelerated by coagulants. By this system, we can expect an 80 - 90% reduction of T-P (65-70% of T-N) and 94-96% reduction of BOD.

(3) Cost of Land Acquisition

We supposed the land acquisition cost as US$ 50,000./ha.

(4) Indirect Cost

Referring to CEDAE's data, we supposed the indirect cost as follows;

<1>	Engineering and Administration	:	10 % of direct cost
	Engineering of project	:	5.0 %
	Management	:	4.5 %
	Administration	:	0.5 %

<2> Additional Cost : 5 % of direct cost
- Control of industrial factories
- Cadastral works
- Rearrangement of resident
- Training
- Others

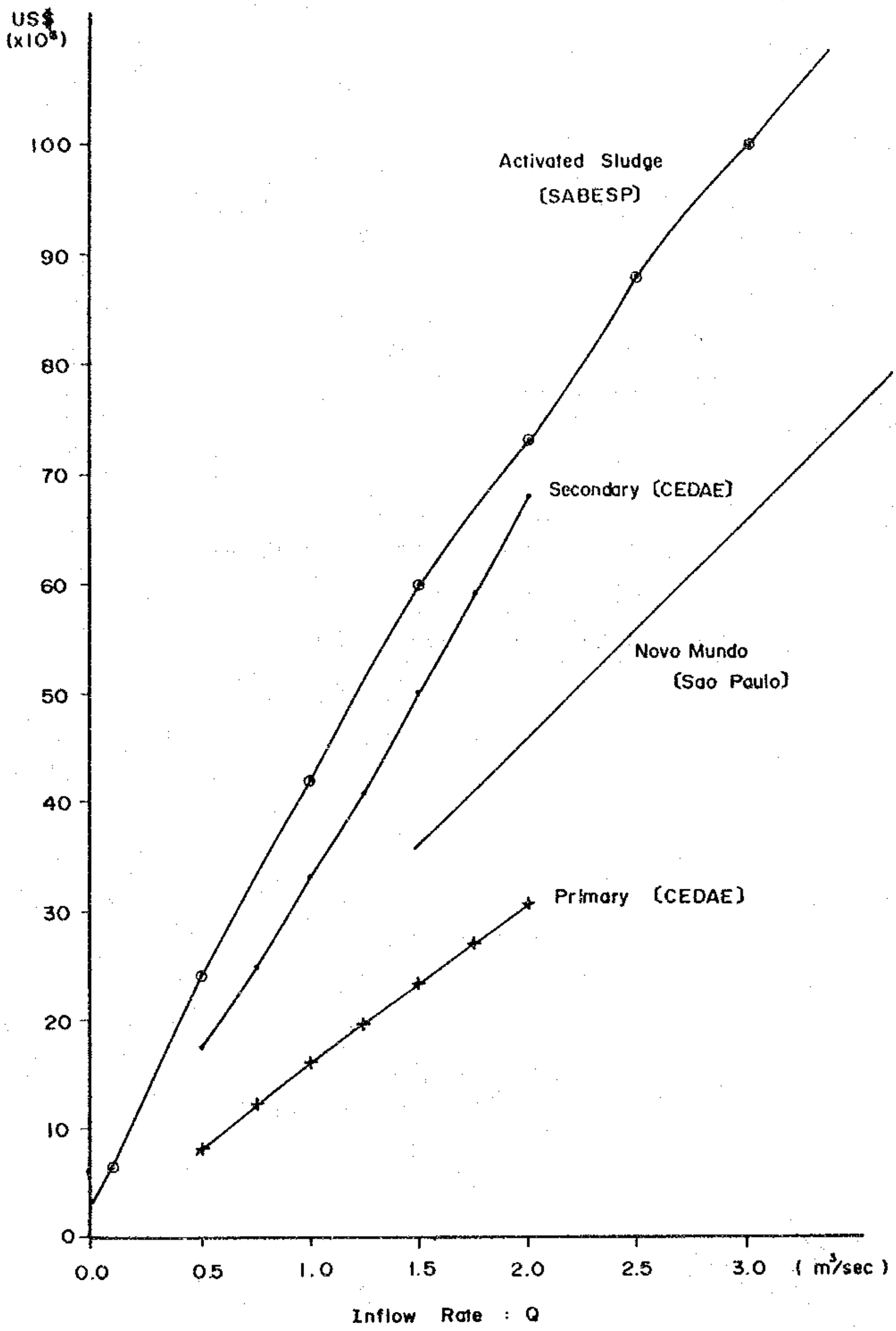


Fig. 16.8- 1 Cost of Sewage Treatment Plant

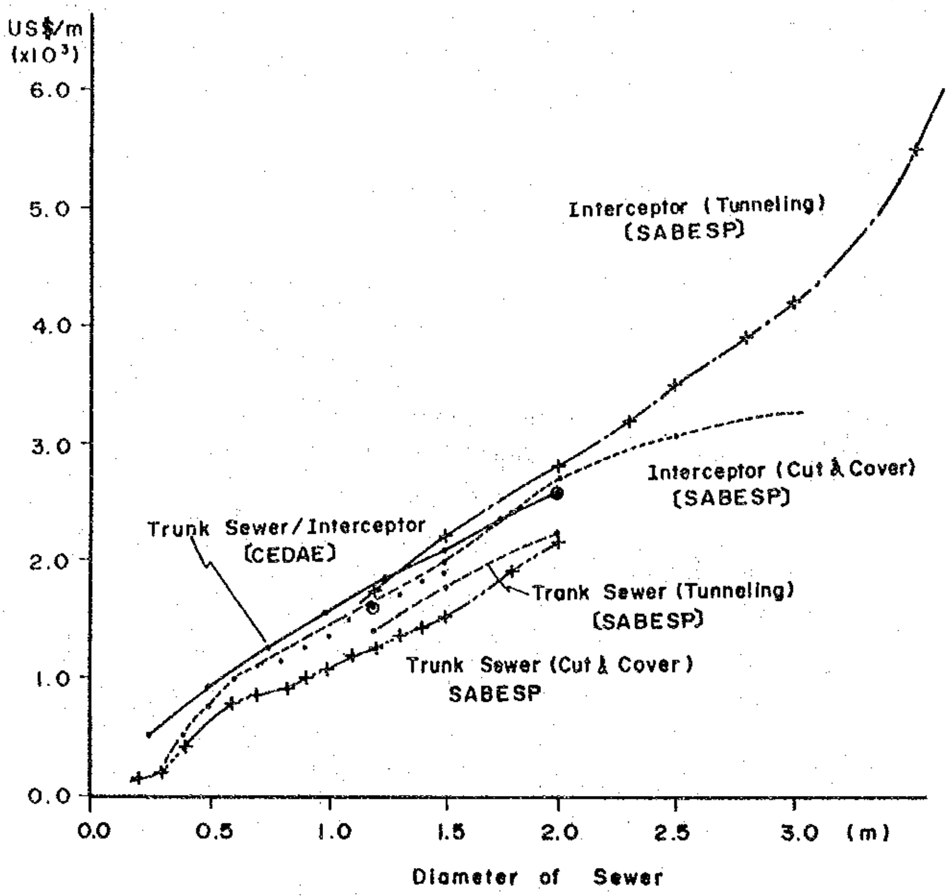


Fig. 16.8- 2 Unit Cost of Sewer Laying

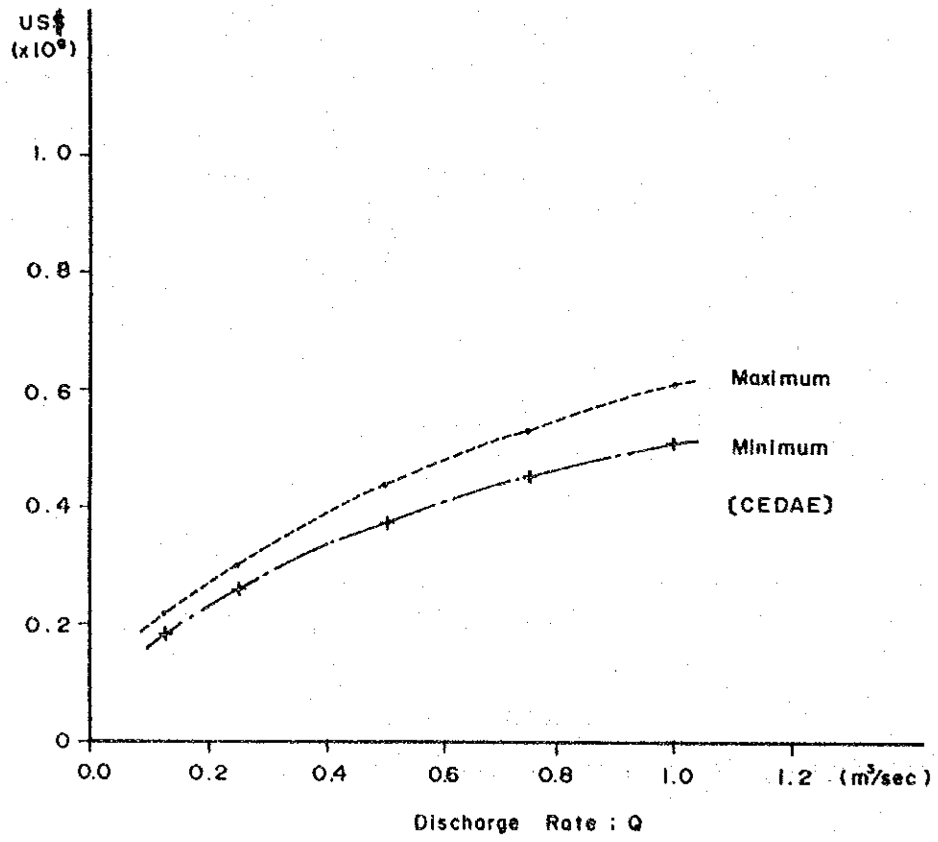


Fig. 16.8- 3 Cost of Pumping Station

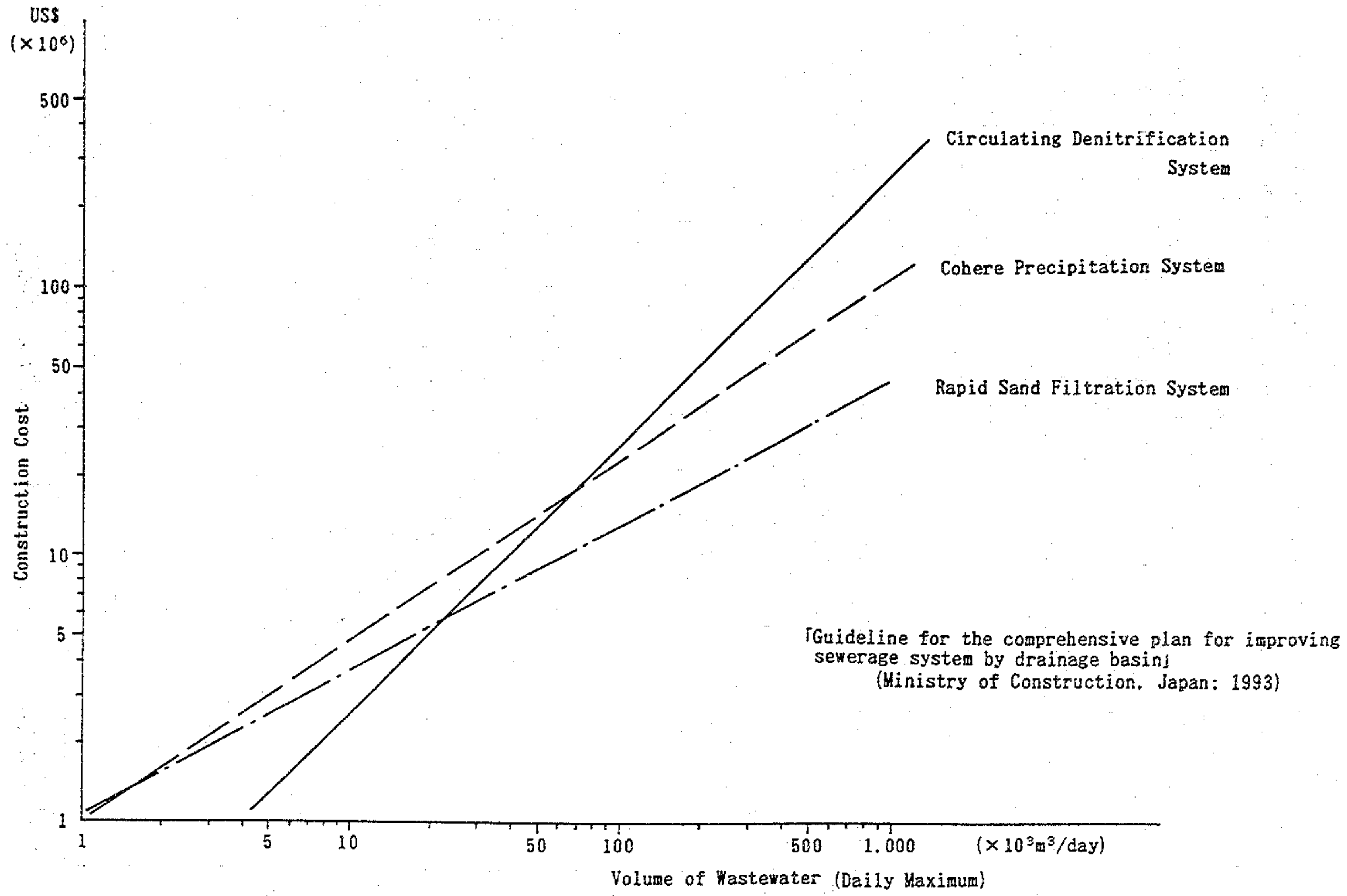


Fig.16.8-4 Cost of Sewage Treatment Plant (Tertiary)

(5) Estimation of Construction Cost

Under the assumptions mentioned above, the initial cost for the construction of sewage treatment system was estimated as shown in **Table 16.8-2** and **Fig. 16.8-5**.

Table 16.8-2 shows that the large-scale plant (Case-1) is effective comparing with the medium to small-scale ones (Case 2 & 3) from viewpoint of the construction cost per habitant.

Saying from viewpoint of the construction cost per unit wastewater volume, however, there is not a wide difference among the scale of US$ 1,700 to 1,930, US$ 2,050 to 2,350 and US$ 2,200 to 2,600 for the primary, secondary and tertiary treatment plants, respectively.

Regarding the primary and secondary treatment, the cost of the secondary treatment plant takes 2.5 times to 3 times of the primary one for the plant itself, though the total cost including sewer laying is not so big difference.

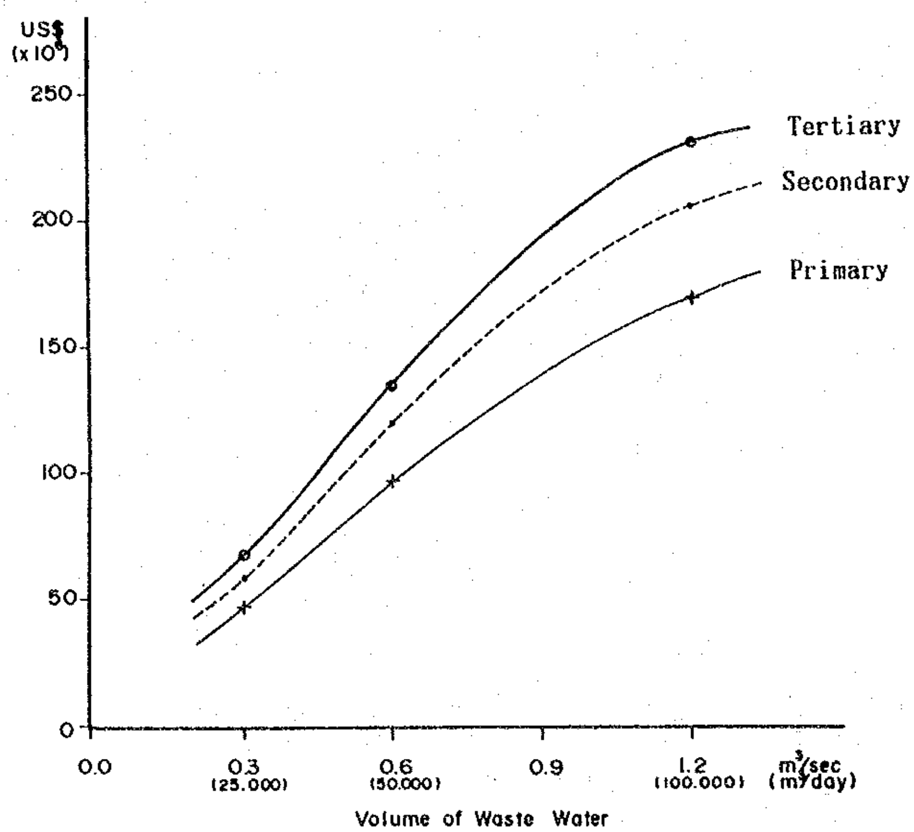


Fig. 16.8-5 Construction Cost of Sewage Treatment System

Table 16.8- 2 Construction Cost of Sewage Treatment System

Item	Cost (US$ x 10^6)								
	Case 1			Case 2			Case 3		
	1-1	1-2	1-3	2-1	2-2	2-3	3-1	3-2	3-3
1. Direct Cost	148.0	178.0	193.0	84.0	99.0	109.0	40.8	50.8	55.8
1.1 Sewage Treatment Plant	20.0	50.0 (+30)	65.0 (+45)	10.0	25.0 (+15)	35.0 (+25)	5.0	15.0 (+10)	20.0 (+15)
1.2 Trunk Sewer / Interceptor	75.0	75.0	75.0	47.5	47.5	47.5	22.5	22.5	22.5
1.3 Construction of Collecting Sewer Network	48.0	48.0	48.0	24.0	24.0	24.0	12.0	12.0	12.0
1.4 Pumping Station	2.5	2.5	2.5	1.0	1.0	1.0	0.5	0.5	0.5
1.5 Land Acquisition	2.5	2.5	2.5	1.5	1.5	1.5	0.8	0.8	0.8
2. Indirect Cost	22.2	26.7	29.0	12.6	14.9	16.4	6.1	7.6	8.4
2.1 Engineering and Administration	14.8	17.8	19.3	8.4	9.9	10.9	4.1	5.1	5.6
2.2 Additional Cost	7.4	8.9	9.7	4.2	5.0	5.5	2.0	2.5	2.8
Total (US$ x 10^6)	170.2	204.7	222.0	96.6	113.9	125.4	46.9	58.4	64.2
(US$ per habitant)	340.	409.	444.	386.	456.	502.	469.	584.	642.
(US$ per m^3/day)	1,702.	2,047.	2,220.	1,932.	2,278.	2,508.	1,876.	2,336.	2,568.

[Note] Case 1-1, Case 2-1, Case 3-1 : primary treatment plant
Case 1-2, Case 2-2, Case 3-2 : secondary treatment plant
Case 1-3, Case 2-3, Case 3-3 : tertiary treatment plant

16.8.2 Cost of the Ocean Outfall System

(1) Conditions of Cost Estimation

The construction cost of the ocean outfall system was estimated for three routes shown in **Fig. 16.8-5** under conditions in **Table 16.8-3**.

Table 16.8-3 Assumption for Cost Estimation of Ocean Outfall System

Dimension	Route 1	Route 2	Route 3
Length on Land	23 Km	16 km	1 km
Length in Sea	10 km	10 km	24 km
Diameter of Sewer	2.0 m	1.5 m	1.5 m

It should be emphasized that the length and routes of the sewer used in the above table are assumed values for cost estimation. To determine the exact length and route, a feasibility study should be carried out hereafter.

(2) Unit Cost of Construction

The following unit cost prepared by CEDAE and SABESP in Brazil was used for the cost estimation of the ocean outfall system.

Sewer or Land : **Fig. 16.8-2**
Submarine Sewer: **Fig. 16.8-7 & Fig. 16.8-8**
Puming Station : **Fig. 16.8-3**

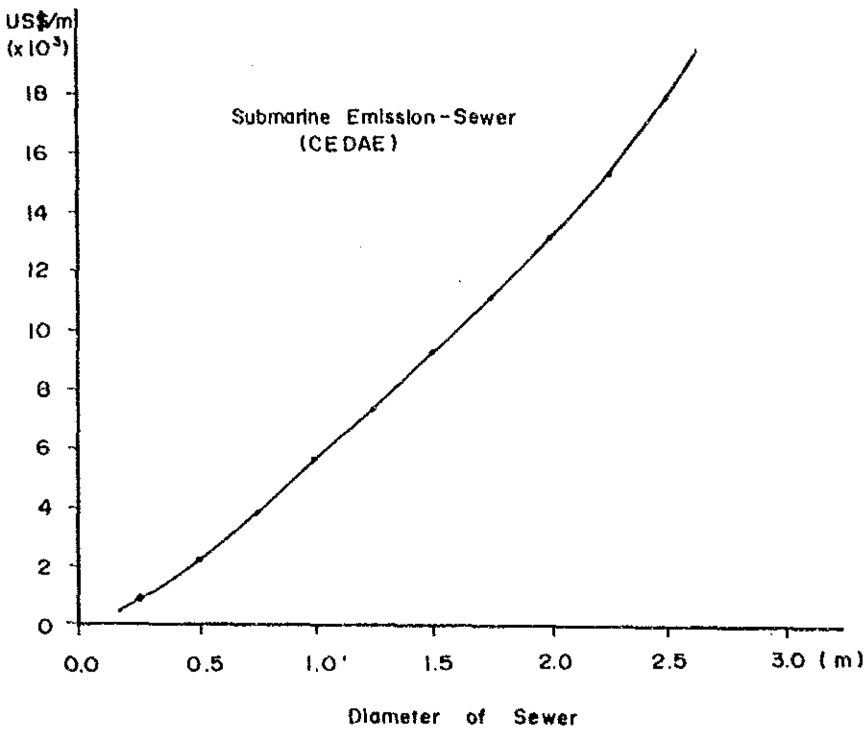


Fig.16.8-7 Unit Cost of Submarine Emission-Sewer Laying

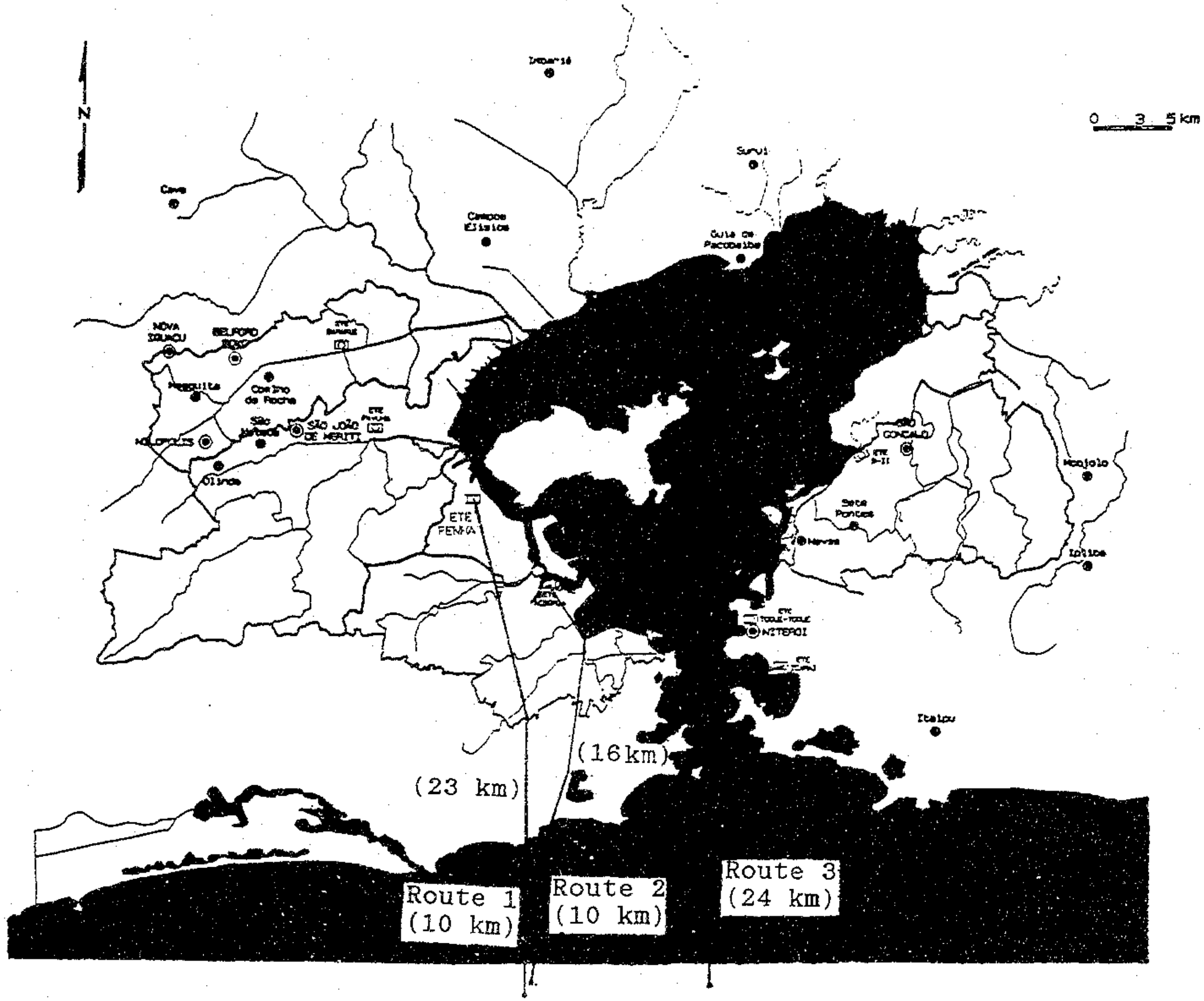


Fig.16.8-6 Supposed Submarine Emission-Sewer Route

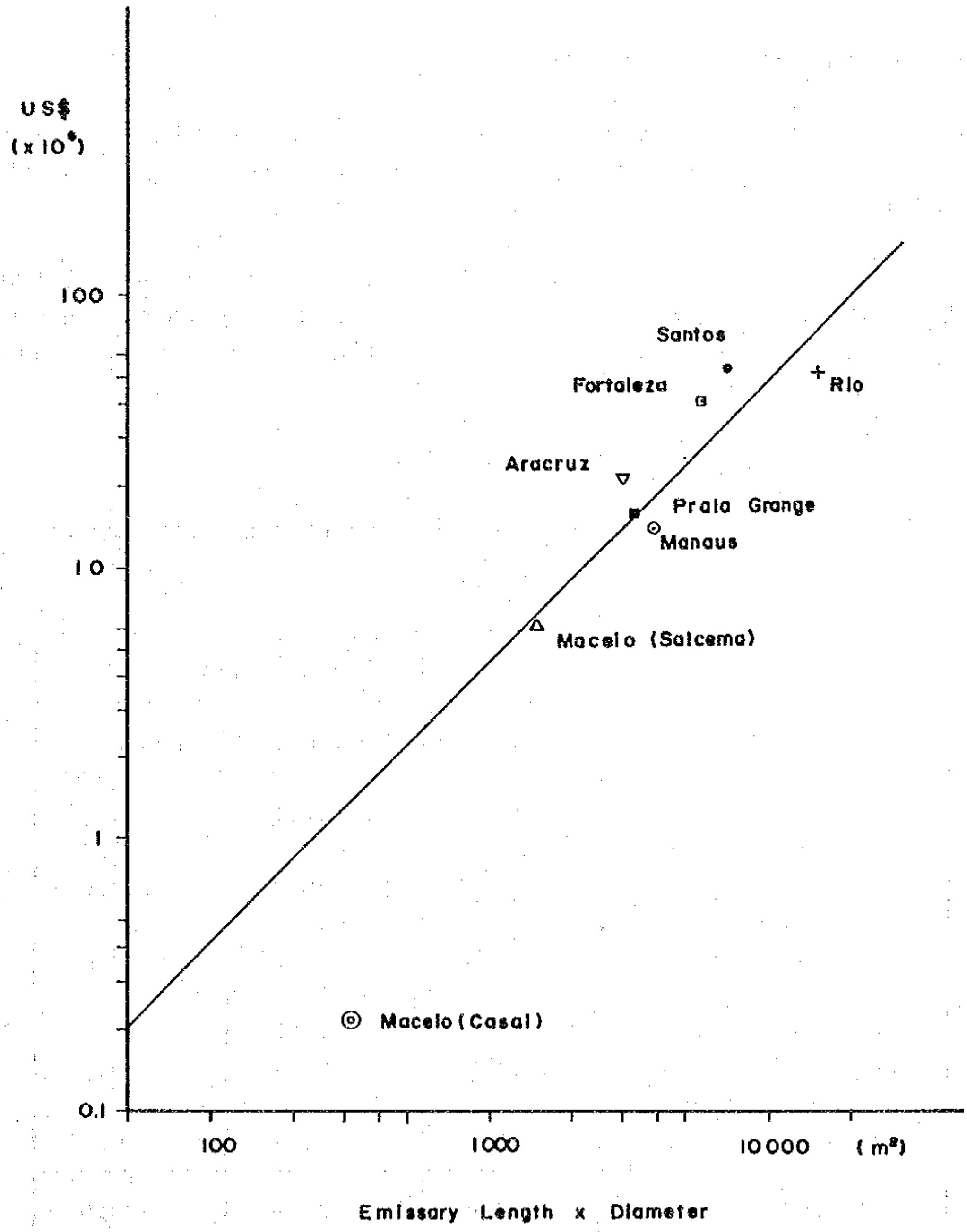


Fig. 16.8-8 Construction Cost of Submarine Emission-Sewer

(3) Indirect Cost

Referring to CEDAE's data, we assumed the indirect cost as follows;

Engineering and Administration : 10 % of direct cost
Additional Cost : 5 % of direct cost

(4) Estimation of Construction Cost

Under the assumptions mentioned above, the initial cost for the construction of ocean outfall system was estimated as shown in **Table 16.8-4**.

Table 16.8-4 shows that the case of Route 3 takes the highest cost in spite of the shortest length of laying sewer, because its length in sea is more than twice comparing with other routes.

Table 16.8- 4 Construction Cost of Submarine Emission-Sewer

Item	Cost (US$ x 10^6)		
	Route 1	Route 2	Route 3
1. Direct Cost	172.0	121.4	203.0
1.1 Sewer on Land	69.0	40.0	2.5
1.2 Submarine Emission-Sewer	100.0	80.0	200.0
1.3 Pumping Station	3.0	1.4	0.5
2. Indirect Cost	25.8	18.2	30.5
2.1 Egineering and Administration	17.2	12.1	20.3
2.2 Additional cost	8.6	6.1	10.2
Total (US$ x10^6)	197.8	139.6	233.5
(US$ per meter)	5,994.	5,369.	9,340.

16.8.3 Cost of the Stabilization Pond

(1) Conditions of Cost Estimation

The construction cost of the multicellular stabilization pond was estimated for three cases shown in **Table 16.8-5**.

Table 16.8- 5 Assumption for Cost Estimation of Multicellular Stabilization Pond

Item		Case 1	Case 2	Case 3
Population	(hab)	1,000,000	500,000	250,000
Inflowing Wastewater	(m^3/day)	200,000	100,000	50,000
	(m^3/sec)	2.31	1.16	0.58
Retention Time	(day)	30	30	30
Depth of Pond	(m)	2.5	2.5	2.5
Area of Pond	(ha)	240	120	60
Number of Cells		6	6	6
Trunk Sewer	(km)	50	30	20
Collecting Sewer Network	(km)	1,000	600	300
Pumping Station		10	5	3

(2) Unit Cost of Construction

The following unit cost prepared by SABESP in Brazil was used for the cost estimation of the stabilization pond.

Stabilization Pond : **Fig. 16.8-9**
Trunk Sewer : **Fig. 16.8-2**
Collecting Sewer Network : US$ 80./m
Pumping Station : **Fig. 16.8-3**

(3) Cost of Land Acquisition

We supposed the Land acquisition cost as US$ 4,000/ha.

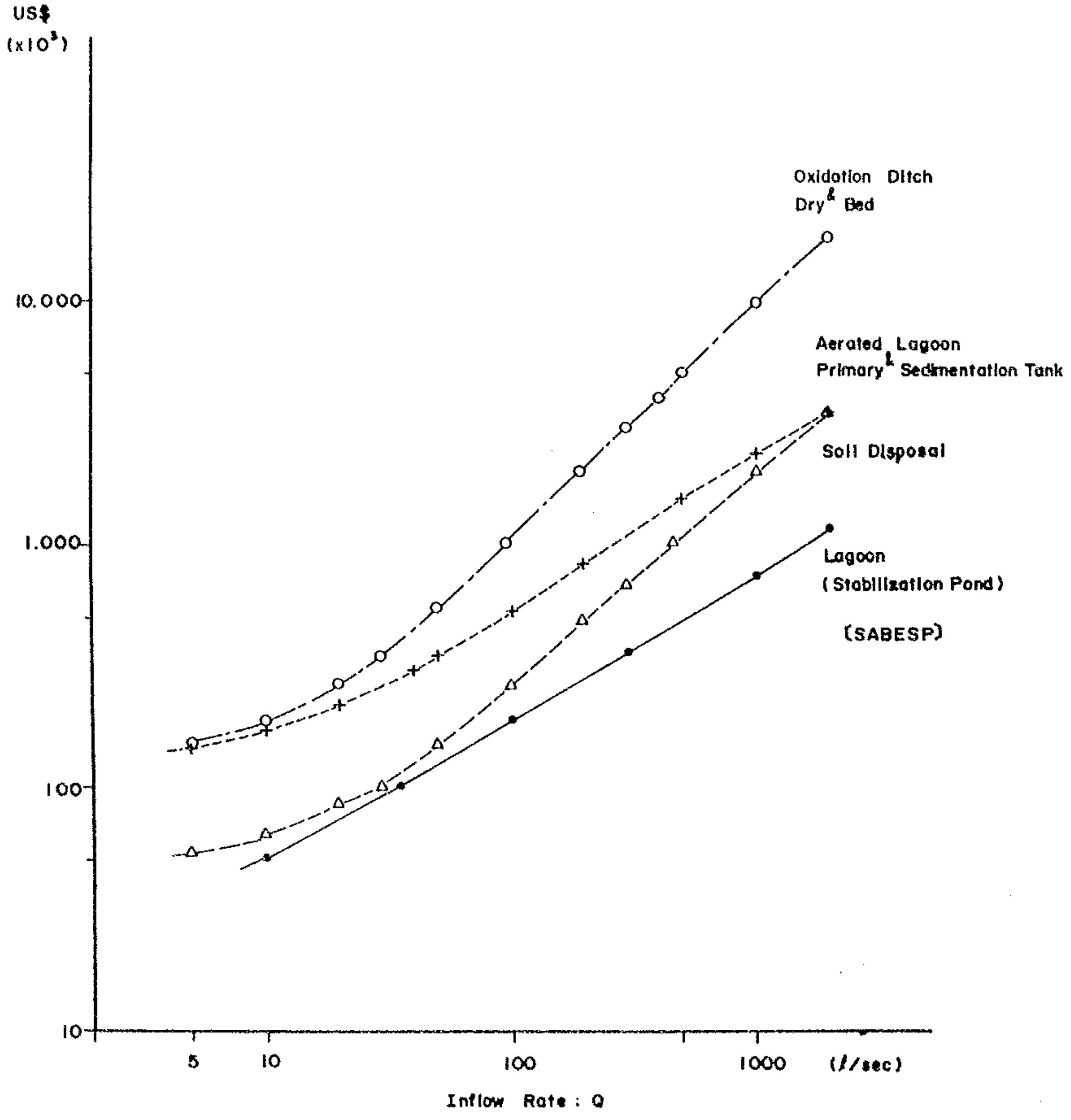


Fig.16.8-9 Cost of Oxidation Ditch, Lagoon and Soil Disposal

(4) Indirect Cost

Referring to CEDAE's data, we supposed the indirect cost as follows;

Engineering and Administration : 10 % of direct cost
Additional Cost : 5 % of direct cost

(5) Estimation of Construction Cost

Under the assumptions mentioned above, the initial cost for the construction of stabilization pond was estimated as shown in **Table 16.8-6** and **Fig. 16.8-10**.

Table 16.8-6 shows that the large-scale pond (Case-1) is effective comparing with the medium to small-scale ones (Case 2 & 3) from the construction cost both per habitant and per unit wastewater volume.

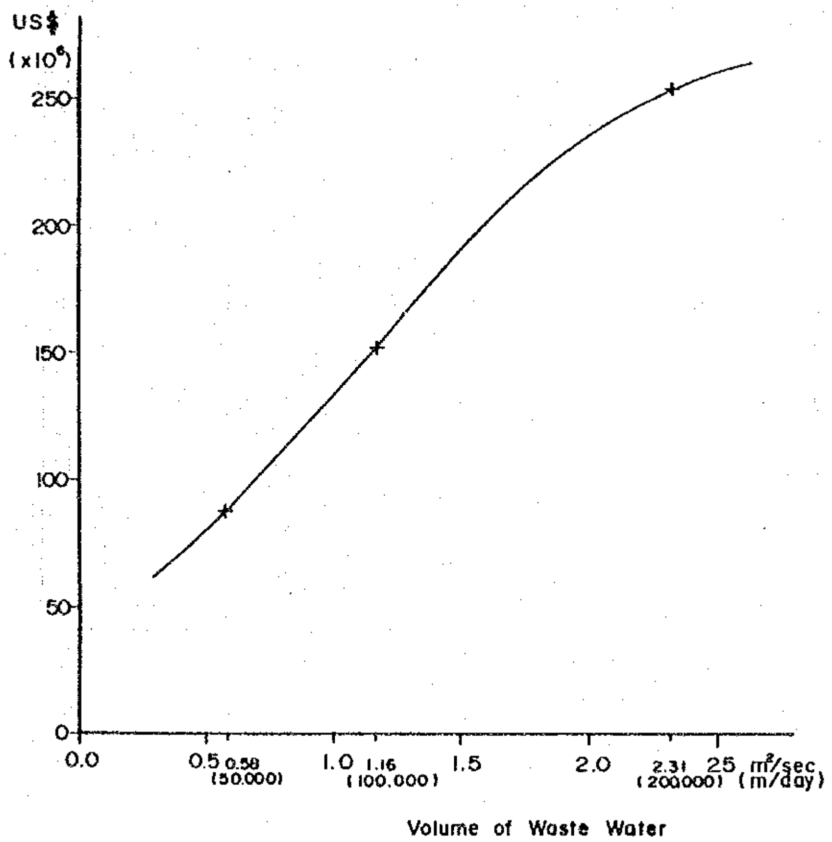


Fig.16.8-10 Construction Cost of Stabilization Pond

Table 16.8- 6 Construction Cost of Stabilization Pond

Item	Cost (US$ x 10^6)		
	Case 1	Case 2	Case 3
1. Direct Cost	220.5	132.0	76.3
1.1 Stabilization Pond	12.0	6.0	3.6
1.2 Trunk Sewer	122.5	75.0	47.5
1.3 Collecting Sewer Network	80.0	48.0	24.0
1.4 Pumping Station	5.0	2.5	1.0
1.5 Land Acquisition	1.0	0.5	0.2
2. Indirect Cost	33.1	19.8	11.4
2.1 Engineering and Administration	22.1	13.2	7.6
2.2 Additional Cost	11.0	6.6	3.8
Total (US$ x 10^6)	253.6	151.8	87.7
(US$ per habitant)	254.	304.	351.
(US$ per m^3/day)	1,268.	1,518.	1,754.

16.8.4 Cost Comparison among Principal Measures

The comparison of the construction costs for principal measures such as sewage treatment systems, ocean outfall system and stabilization pond is shown in **Table 16.8-7**, together with the loads in terms of BOD and T-P that can be reduced under each system.

The costs and potential reduction load were calculated by using a population size of 500,000, to facilitate comparison. Attention should be paid, however, that the cost calculation of the ocean outfall system does not based on the population size but on the length of the sewers to be laid, because the construction cost would largely depend on the length of the sewers to be laid.

Table 16.8-7 shows that the construction cost for the stabilization pond is the cheapest while the ocean outfall system requires the most expensive if the length of the sewer is 26 kilometers. However, the cost of ocean outfall system will be equal to the cost calculated for the construction of the sewer treatment system (tertiary) if a sewer length of about 13 kilometers is used in stead.

On the other hand, the potential reduction loads are estimated to be the highest in the ocean outfall system, followed by the sewage treatment system (tertiary), in terms of nutrient salts (T-P), and high in the ocean outfall system and the stabilization pond in terms of BOD.

Table 16.8- 7 Cost Comparison among Principal Measures

Item		Sewage Treatment System			Ocean Outfall System	Stabilization Pond
		Case 1 of Table 16.8-1			Route 2 of Fig.16.8-6	Case 2 of Table 16.8-5
		Primary	Secondary	Tertiary		
Initial Cost		(Beneficial Pop.: 500,000) US\$ 170x10^6	US\$ +35x10^6	US\$ +55x10^6	(B.Pop: 1,900,000) (Length of Sewer: 26km) US\$ + 140x10^6	(B.Pop.: 500,000) US\$ 152x10^6
		170x10^6	205x10^6	225x10^6	310x10^6	
Poten tial Reduc tion Load	BOD	(Whole Western Basin: 2010 Beneficial Pop.: 4,200,000) - 40 t/d	- 70 t/d	(if 90%) - 80 t/d	(Alegria ETE) (B.Pop.: 1,900,000) - 90 t/d	
		(Beneficial Pop.: 500,000) - 5 t/d	- 8 t/d	(if 90%) - 10 t/d	(B.Pop.: 500,000) - 25 t/d	(B.Pop.: 500,000) (if 90%) - 25 t/d
	T-P	(Whole Western Basin: 2010) Beneficial Pop.: 4,200,000) + 0.6 t/d	+ 1 t/d	(if 80%) - 4 t/d	(Alegria ETE) B.Pop.: 1,900,000) - 2 t/d	
		(Beneficial Pop.: 500,000) +0.07 t/d	+ 0.1 t/d	(if 80%) - 0.4 t/d	(B.Pop.: 500,000) - 0.5 t/d	(B.Pop.: 500,000) (if 50%) - 0.3 t/d

16.9 Optimum Combination of the Measures for Recuperation of the Guanabara Bay Ecosystem

The preceding sections dealt with studies on several different measures which have taken into account sub-basin characteristics. This section, by combining these different measures, deals with the selection of an optimum measure in each basin.

Firstly, the possible combination of measures (alternatives) consisting of hardware-type measures which meet the target loads for organic matter in terms of BOD set for each basin were examined (Section 16.9.1).

Secondly, the optimization of the possible combination of measures were examined considering the potential reduction loads in nutrient salt, the cost for construction and maintenance and so forth. In addition to the hardware-type measures, indispensable software-type measures such as land use control were also examined and selected taking into account the characteristics of the basin concerned (Section 16.9.2).

16.9.1 Examination of Possible Combinations of Measures in Each Basin

We have studied the effects of applicable individual measures and the costs of principal alternative measures in the previous sections. Based on the results of these studies, we examine the possible combinations of measures for the western, eastern, northwestern and northeastern basins and the island.

(1) Western Basin

The western basin including Rio de Janeiro municipality discharges the highest loads into the Bay, 164 tons/day of BOD at present (46 % of all loads) and we expect it to increase up to 186 tons/day by the year 2010 (42 %). By trial calculations using a numerical simulation method, the target runoff load was computed to be around 98 tons/day (see **Table 16.6-1**).

In order to meet the target runoff load for the year 2010, the following three possible combinations of measures (alternatives) were drawn up:

Alternative 1: IDB/OECF Program (1st stage and 2nd stage)

Alternative 2: IDB/OECF Program (1st stage), plus
Ocean Outfall System for the Alegria STS
(STS: Sewage Treatment System)

Alternative 3: IDB/OECF Program (1st stage), plus
Ocean Outtfall System for the Alegria STS and
Ocean Outfall System for the Penha STS

Alternative 4: IDB/OECF Program (1st stage), plus
Tertiary Treatment System (IDB/OECF (3))

The potential reduction load for each alternative is shown in **Table 16.9-1** and **Fig. 16.9-1.**

In the case of Alternative 1 and 4, the load is still 19 ton/day and 8 ton/day in excess of the target load. We expect that it will be reduced by other measures such as a tightening in the monitoring of industrial loads, improvement of garbage collection system etc.

Alternative 2 almost meets the target load and Alternative 3 is estimated to meet it.

Table 16.9- 1 Possible Combination of Measures in the Western Basin

Alter-native	Combination of Measures	Potential Reduction Load (BOD)	Initial Cost	Mainten. & Opera. Cost	Target Reduction Load (BOD)	Reduc. Load by Other Measures (BOD)
1	IDB (1) IDB (2)	- 40.6 t/d - 28.0	$ 115x10^6 $ 280	High	- 88 t/d	- 19 t/d
	Total	- 68.6 t/d	$ 395x10^6			
2	IDB(1) OOS(Alegria)	- 40.6 t/d - 45.0	$ 115x10^6 $ 140	Low	- 88 t/d	- 2 t/d
	Total	- 85.6 t/d	$ 255x10^6			
3	IDB(1) OOS(Alegria) OOS(Penha)	- 40.6 t/d - 45.0 - 7.7	$ 115x10^6 $ 140 $ 200	Low	- 88 t/d	-
	Total	- 93.3 t/d	$ 455x10^6			
4	IDB(1) IDB(3)	- 40.6 t/d - 39.1	$ 115x10^6 $ 420	High	-88 t/d	-8 t/d
	Total	- 79.7 t/d	$ 535x10^6			

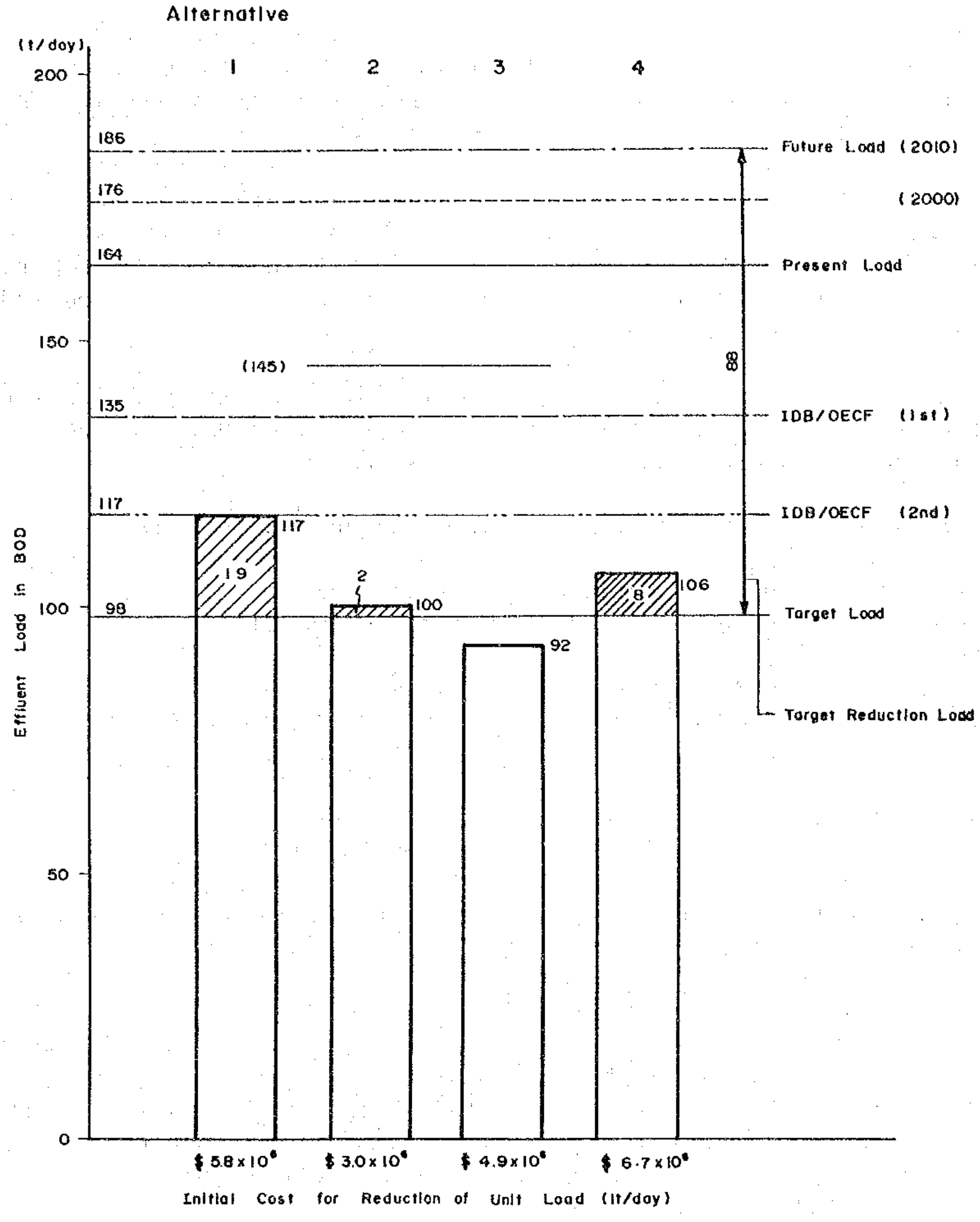


Fig. 16.9- 1 Reduction Load by Possible Combination of Measures in the Western Basin

(2) Eastern Basin

The eastern basin including Niteroi municipality does not discharge much load into the Bay, 40 ton/day of BOD at present (11 % of all loads) and we expect it to discharge 47 ton/day by the year 2010 (11 %) by our estimation in terms of BOD.

The recreational beaches along the Jurujuba inlet are situated between this basin and Guanabara Bay. From this viewpoint, the reduction of the effluent load from the eastern basin is important. By trial calculations, the target runoff load was computed to be around 24 ton/day in this basin.

In order to meet the target effluent load for the year 2010, the following three alternatives were considered to be the most possible combinations of measures for the eastern basin:

Alternative 1: IDB/OECF Program (1st stage and 2nd stage)

Alternative 2: IDB/OECF Program (1st stage),plus
Ocean Outfall System for the Icarai STS

Alternative 3: IDB/OECF Program (1st stage), plus
Ocean Outfall System for the Icarai STS and
Ocean Outfall System for the Toque STS

Alternative 4: IDB/OECF Program (1st stage), plus
Tertiary Treatment System (IDB/OECF (3))

The potential reduction load for each alternative is shown in **Table 16.9-2** and **Fig. 16.9-2**.

For Alternatives 1, 2, 3 and 4 there still remain loads of 5 ton/day to 10 ton/day in excess of the target loads. We expect the necessary reductions to come from other measures, in particular the tightening of the monitoring of industrial loads, including the construction of joint treatment plants for food processing factories (especially those dealing with sea products).

Table 16.9- 2 Possible Combination of Measures in the Eastern Basin

Alter-native	Combination of Measures	Potential Reduction Load (BOD)	Initial Cost	Mainten. & Opera. Cost	Target Reduction Load (BOD)	Reduc. Load by Other Measures (BOD)
1	IDB (1)	- 8.8 t/d	$ 65x10⁶	High	- 23 t/d	- 8 t/d
	IDB (2)	- 6.8	$ 30			
	Total	- 15.6 t/d	$ 95x10⁶			
2	IDB(1)	- 8.8 t/d	$ 65x10⁶	Low	- 23 t/d	- 10 t/d
	OOS(Icarai)	- 4.5	$ 200			
	Total	- 13.3 t/d	$ 265x10⁶			
3	IDB(1)	- 8.8 t/d	$ 65x10⁶	Low	- 23 t/d	- 8 t/d
	OOS(Icarai)	- 4.5	$ 200			
	OOS(Toque)	- 1.8	$ 12			
	Total	- 15.1 t/d	$ 277x10⁶			
4	IDB(1)	- 8.8 t/d	$ 65x10⁶	High	-23 t/d	- 5 t/d
	IDB(3)	- 9.4	$ 55			
	Total	- 18.2 t/d	$120x10⁶			

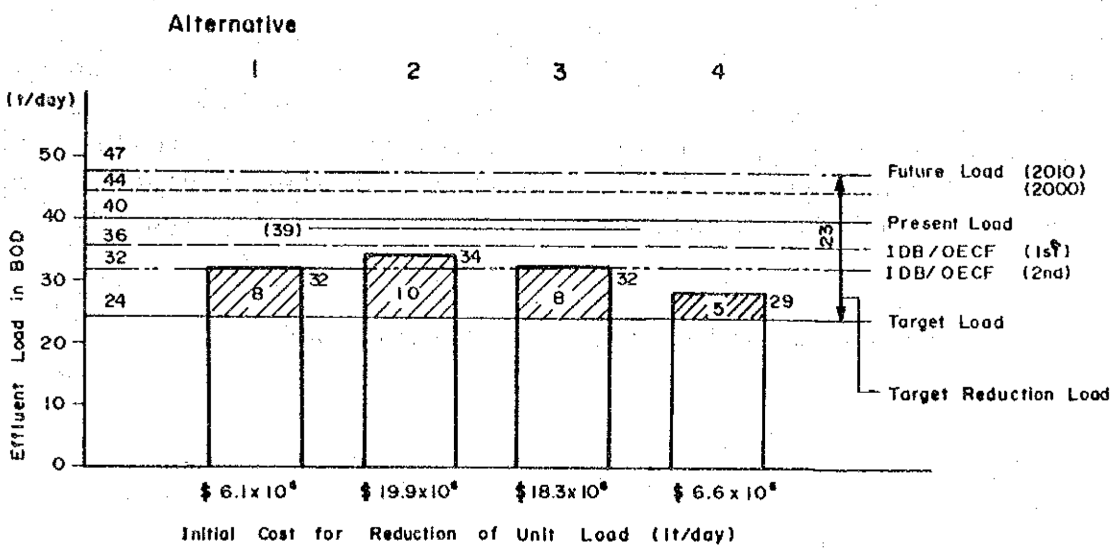


Fig. 16.9- 2 Reduction Load by Possible Combination of Measures in the Eastern Basin

(3) Northwestern Basin

The northwestern basin discharges the second highest load into the Bay 98 ton/day of BOD at present (28 % of all loads), and we expect it to discharge 133 ton/day by the year 2010 (30 %), accompanying the increase of population.

Therefore, it follows that the target reduction load is large in this basin too. By trial calculations, the target effluent load was computed to the around 59 ton/day.

In order to meet the target runoff load for the year of 2010, the following three alternatives were considered to be the most possible combinations of measures for the northwestern basin:

Alternative 1: IDB/OECF Program (1st stage and 2nd stage)1, plus
Stabilization Ponds along the Iguacu River

Alternative 2: IDB/OECF Program (1st stage), plus
Stabilization Ponds along the Iguacu River and
Stabilization Ponds along the Sarapui River

Alternative 3: IDB/OECF Program (1st stage and 2nd stage), plus
Three New STSs with the treatment capacity
of 1.2 m^3/sec (secondary treatment)

The potential reduction load for each alternative is shown in **Table 16.9-3** and **Fig. 16.9-3**.

For Alternatives 1 and 3, there still remain loads of 17 ton/day to 29 ton/day in excess of the target loads. We expect the necessary reductions to come from other measures, in particular the tightening of the monitoring of industrial loads, including the construction of common treatment plants for petrochemical factories.

Alternative 2 is estimated to meet the target load.

Table 16.9- 3 Possible Combination of Measures in the Northwestern Basin

Alter- native	Combination of Measures	Potential Reduction Load (BOD)	Initial Cost	Mainten. & Opera. Cost	Target Reduction Load (BOD)	Reduc. Load by Other Measures (BOD)
1	IDB/OECF(1) IDB/OECF(2) S.Pond(Iguacu)	- 7.8 t/d - 6.5 - 42.7	$ $80x10^6$ $ 150 $ 255	Middle	- 74 t/d	- 17 t/d
	Total	- 57.0 t/d	$ $485x10^6$			
2	IDB/OECF(1) S.Pond(Iguacu) S.Pond(Sarapui)	- 7.8 t/d - 42.7 t/d - 36.1	$ $80x10^6$ $ 255 $ 235	Low	- 74 t/d	-
	Total	- 86.6 t/d	$ $570x10^6$			
3	IDB(1) IDB/OECF(2) STS 1(1.2m^3/s) STS 2(1.2m^3/s) STS 3(1.2m^3/s)	- 7.8 t/d - 6.5 - 10.0 - 10.0 - 10.0	$ $80x10^6$ $ 150 $ 200 $ 200 $ 200	High	- 74 t/d	- 29 t/d
	Total	- 44.3 t/d	$ $830x10^6$			

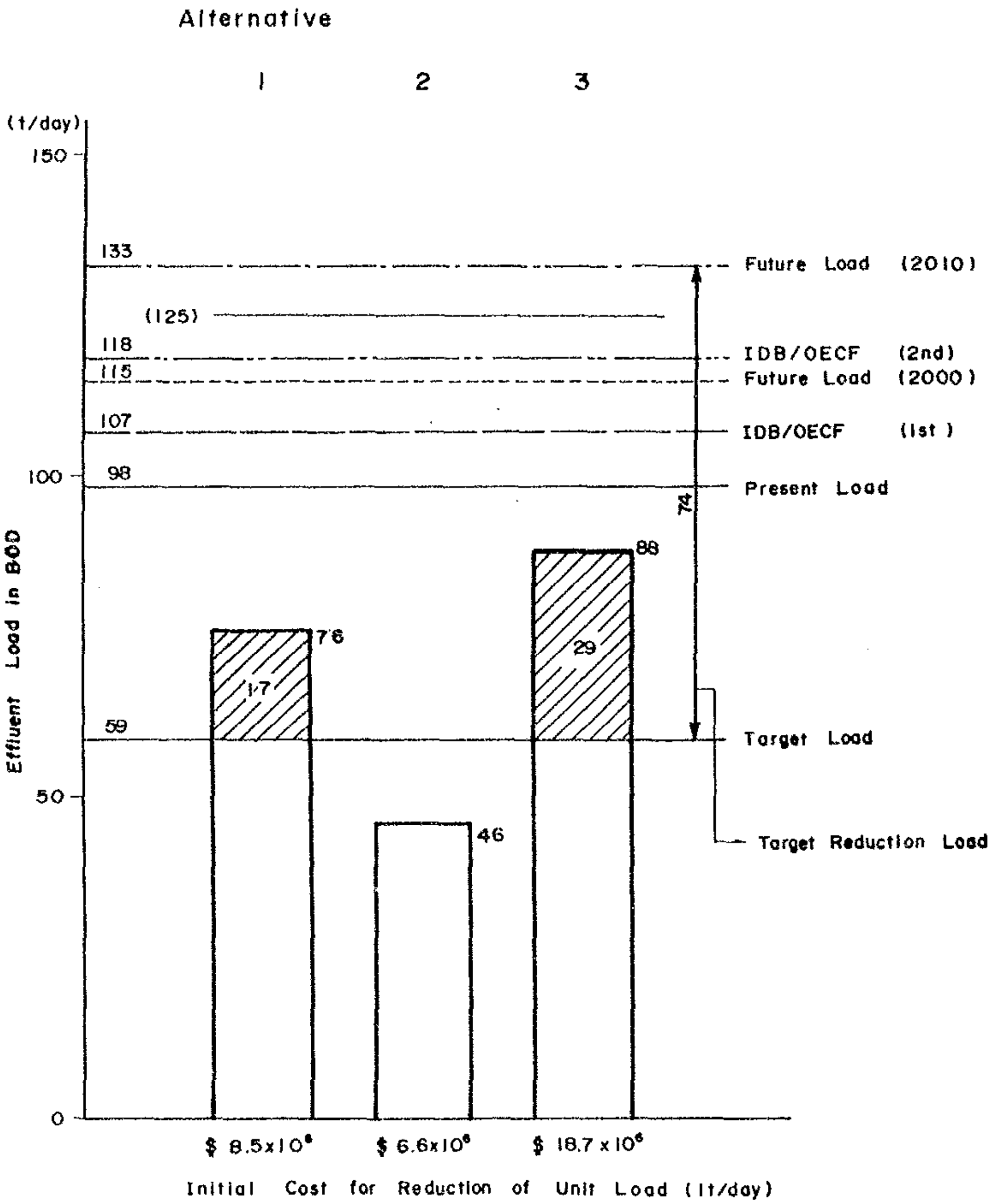


Fig. 16.9-3 Reduction Load by Possible Combination of Measures in the Northwestern Basin

(4) Northeastern Basin

The northeastern basin discharges the lowest load into the Bay 44 ton/day of BOD at present (12 % of all loads) in spite of the large area. We expect it to discharge 64 ton/day by the year 2010 (15 %) accompanying the increase of population in this basin.

The Guapimirim mangrove area exists between this basin and Guanabara Bay and the exchange of water in the area is poor, because it is situated in the inner part of the bay. Therefore, reduction of the effluent load from the northeastern basin is also important. By trial calculations, the target runoff load was computed to be around 44 ton/day in this basin.

In order to meet the target effluent load for the year 2010 the following two alternatives were considered to be the most possible combinations of measures in the northeastern basin:

Alternative 1: Stabilization Pond (the same size as the Sarapui River)

Alternative 2: Two New STSs with the treatment capacity of 1.2 m^3/sec (secondary treatment)

The potential reduction load for each alternative is shown in **Table 16.9-4** and **Fig. 16.9-4**.

Alternative 1 is estimated to meet the target load and Alternative 2 almost meets it.

Table 16.9- 4 Possible Combination of Measures in the Northeastern Basin

Alter-native	Combination of Measures	Potential Reduction Load (BOD)	Initial Cost	Mainten. & Opera. Cost	Target Reduction Load (BOD)	Reduc. Load by Other Measures (BOD)
1	S. Pond (S)	- 36.1 t/d	$ 235x10[6]	Low	- 20 t/d	-
	Total	- 36.1 t/d	$ 235x10[6]			
2	STS 1(1.2m³/s) STS 2(1.2m³/s)	- 10.0 t/d - 10.0	$ 200x10[6] $ 200	High	- 20 t/d	-
	Total	- 20.0 t/d	$ 400x10[6]			

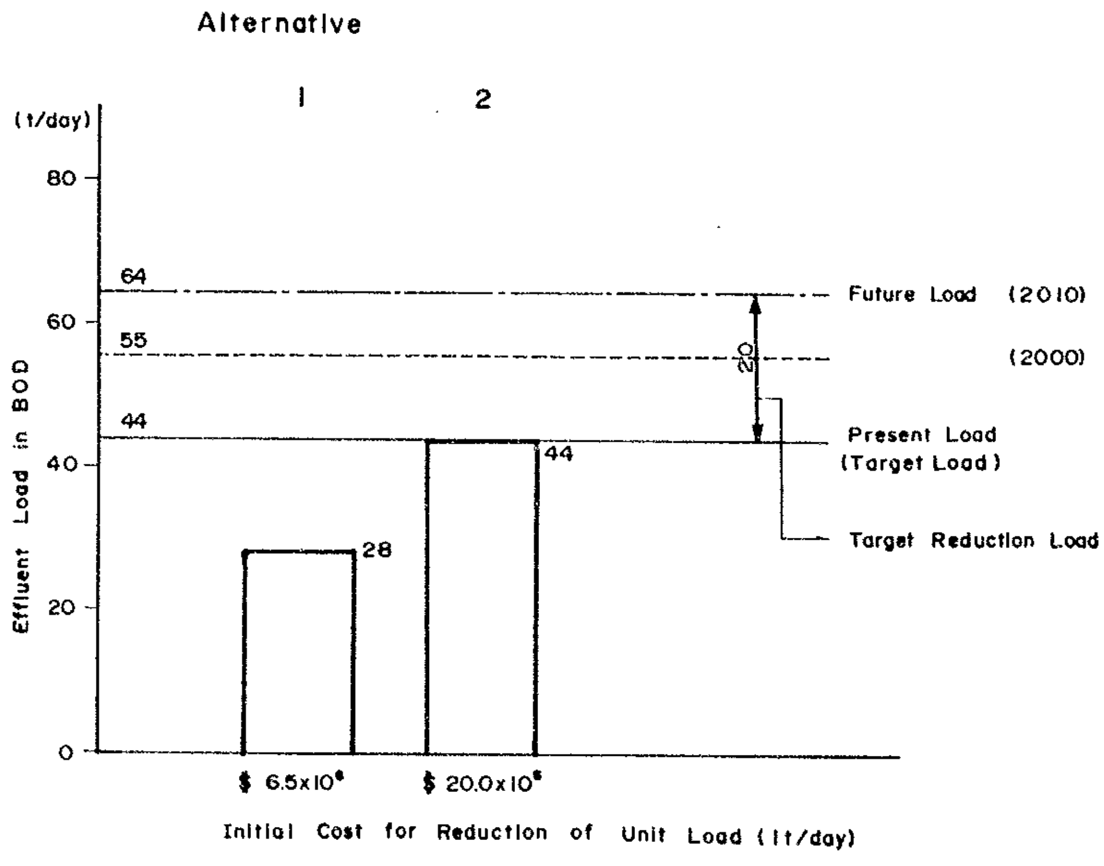


Fig. 16.9- 4 Reduction Load by Possible Combination of Measures in the Northeastern Basin

(5) Islands

At present, the islands of Governador, Fundao, Paqueta, Engenho and S.Cruz discharge 7.8 ton/day of BOD (2% of all loads) into the Bay. These islands are expected to discharge 8.7 tons/day by the year 2010.

We tried to estimate potential reduction loads by the following two alternatives in the islands.

Alternative 1: Secondary Treatment Systems for Governador and Fundao islands
(Beneficial population : 178,000)

Alternative 2: Tertiary Treatment Systems for Governador island
(Beneficial population : 172,000)

The potential reduction load for each alternative is shown in **Table 16.9-5** and **Fig.16.9-5**. Both alternatives are estimated to meet the target load.

Table 16.9- 5 Possible Combination of Measures in the Island

Alter-native	Combination of Measures	Potential Reduction Load (BOD)	Initial Cost	Mainten. & Opera. Cost	Target Reduction Load (BOD)	Reduc. Load by Other Measures (BOD)
1	Primary Secondary	- 1.7 t/d - 1.2	-	High	- 1.7 t/d	-
	Total	- 2.9 t/d	-			
2	Primary Secondary Tertiary	- 1.7 t/d - 1.2 - 0.5	- - $ 25x10⁶	High	- 1.7 t/d	-
	Total	- 3.4 t/d	$ 25x10⁶			

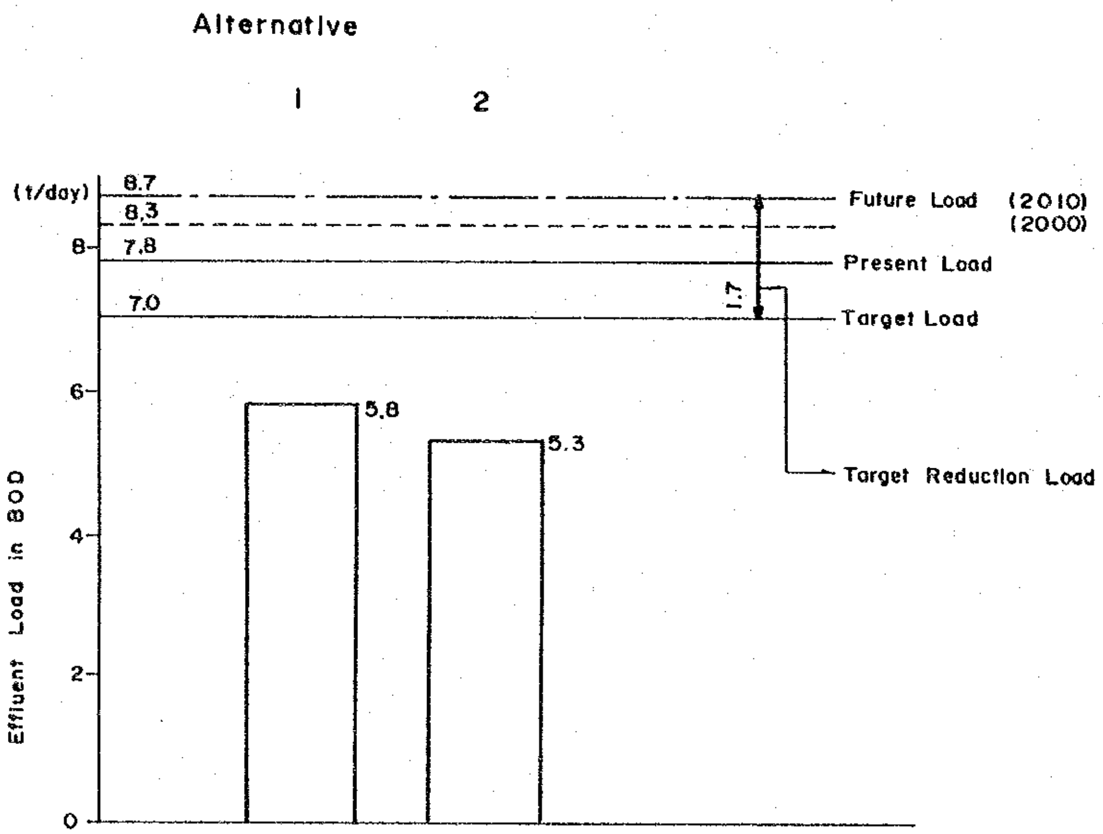


Fig.16.9- 5 Reduciton Load by Possible combination of Measures in the Islands

16.9.2 Optimum Combinations of Measures in Each Basin

We studied the possible combinations of measures for each basin from the viewpoint of the target effluent load in terms of BOD. In this section, we propose the final optimum combinations of measures in each basin not only in regard to the target effluent, load in terms of BOD, but also from the viewpoint of the reduction of inflowing nutrient salts and the initial and maintenance costs of the measures as well as the software-type measures.

(1) Western Basin

As stated before, eutrophication is a serious problem in Guanabara Bay from the viewpoint of aquatic life as well as the water pollution by organic matter. Therefore it is desirable to take measures which are effective in reducing nutrient salts together with organic matter.

Approximations of the reduction T-P loads for Alternatives 1, 2, 3 and 4 in the western basin are as follows:

Alternative 1: - 0.5 ton/day (from 11.9 to 11.4 ton/day in 2010)

Alternative 2: - 3.3 ton/day (from 11.9 to 8.6 ton/day in 2010)

Alternative 3: - 4.2 ton/day (from 11.9 to 7.7 ton/day in 2010)

Alternative 4: - 4.4 ton/day (from 11.9 to 7.5 ton/day in 2010)

Therefore, Alternatives 2 and 3 which employ the ocean outfall system and Alternative 4 which employs the tertiary treatment system are preferable from the viewpoint of the reduction in nutrient salts.

On the other hand, approximations of initial construction costs for the alternatives are shown in **Table 16.9-1** and **Fig. 16.9-1**. It states that the initial cost of the ocean outfall system in case of Alternative 2 is cheaper than the secondary and tertiary treatment systems (Alternative 1 and 4), though it depends on the length of sewer, especially submarine emission-sewer.

Further, the maintenance costs for the ocean outfall system are also lower than that for the secondary and tertiary treatment systems.

As a result, we propose Alternative 2 as an optimum combination of the measures in the western basin accompanied with the improvement in garbage collection and wastewater treatment facilities in the favelas.

Here we want to mention certain matters that should be considered with the introduction of the ocean outfall system.

Firstly, it is necessary to remove heavy metals and polymeric compounds before discharging into the ocean. In Brazil, presently industrial wastewater and domestic wastewater are discharged through the same sewers. Therefore, the separa tion of industrial wastewater which possibly contain heavy metals etc. from the sewer network is necessary.

And secondly, there is some fear regarding the possible effects on the surrounding sea areas into which the primary treated sewage is diffused, especially, on the famous beaches along the coast. Therefore it is necessary to study the currents, aquatic life etc. around the emission areas in order to decide on the location and length of submarine sewers, and to confirm that the discharged wastewater will not pollute the coast using a numerical simulation method.

(2) Eastern Basin

Approximations of the reduction T-P loads for Alternatives 1, 2, 3 and 4 in the eastern basin are as follows:

Alternative 1: - 0.1 ton/day (from 1.9 to 1.8 ton/day in 2010)

Alternative 2: - 0.4 ton/day (from 1.9 to 1.5 ton/day in 2010)

Alternative 3: - 0.6 ton/day (from 1.9 to 1.3 ton/day in 2010)

Alternative 4: - 1.0 ton/day (from 1.9 to 0.9 ton/day in 2010)

Therefore, Alternatives 2 and 3, ocean outfall system, and Alternative 4, tertiary treatment system, are preferable from the viewpoint of reducing nutrient salts.

On the other hand, initial construction costs of the alternatives (**Table 16.9-2** and **Fig. 16.9-2**) show that the cost of Alternative 1 and 4 is cheaper than that of Alternatives 2 and 3, due to the high cost of a long submarine emission-sewer.

Also, the IDB/OECF program (Alternative 1) proposes a partial ocean outfall system that discharges treated sewage in a location near the mouth of the Bay. It is feared that the polluted water will flow into the Bay on the flood stream with this plan, though the water quality in the Jurujuba inlet will be improved.

As a result, we propose Alternative 4, a tertiary treatment system such as a circulating denitrification system accelerated by coagulants after primary treatment, as an optimum combination for the eastern basin.

However, an improved version of Alternative 1 which approaches Alternative 2 and/or 3 is worthy to be considered, though it is difficult to say exactly what length of submarine emission-sewer is required or its route at this point in time, because there are some technical difficulties in the tertiary treatment system.

Moreover, the tightening of the monitoring of industrial effluent loads is an important measure in this basin accompanied with the construction of joint treatment plants for sea-product processing factories.

(3) Northwestern Basin

We proposed a multicellular stabilization pond system as an effective measure in the northwestern basin. With this stabilization pond system, the reduction of nutrient salts is expected to be around 50 % when the retention time is 30 days.

On the other hand, there is a reduction in nutrient salts of around 30 % using the secondary treatment system (activated sludge method).

Therefore, the stabilization pond system is preferable to the secondary treatment system (activated sludge) from the viewpoint of reducing nutrient salts.

With regard to the initial construction costs, approximations for the stabilization pond and secondary treatment system were made (**Table 16.9-3** and **Fig. 16. 9-3**), the cost for the stabilization pond was found to be cheaper than the secondary treatment system;

for the same reduction load, in areas where the cost of land acquisition is cheap. In addition, the maintenance cost for the stabilization pond is also cheaper than that for the secondary treatment system.

Therefore, we propose Alternative 2 as the optimum combination of the measures for the northwestern basin. And the land use control as this area is increasingly urbanizing is also proposed as an effective measure in this basin .

Moreover, the tightening of the monitoring of industrial effluent loads is an important measure in this basin accompanied with the construction of joint treatment plants for the petrochemical factories.

(4) Northeastern Basin

The northeastern basin is not as densily populated as the other three basin areas and serious deterioration of the water quality has not appeared to date. Urbanization, however, has recently started expanding. This increase in population and urban area has caused a decrease in forest area. Therefore, it is desirable to take some measures on this stage.

We propose the same type of multicellular stabilization pond as the most effective measure for the northeastern basin, as we did in the northwestern basin.

With regard to the initial construction costs, approximations for the stabilization pond and secondary treatment system were made (**Table 16.9-4** and **Fig. 16.9-4**), the cost for the stabilization pond was found to be cheaper than the secondary treatment system to attain the same reduction load.

As a result, we propose Alternative 1 as the optimum combination of the measures in the northeastern basin. And strict land use controls are also proposed as an effective measure in this basin.

(5) Islands

The basin of the islands do not presently discharge much polluted runoff loads into the Bay, and only a slight increase in load is estimated in future.

Therefore, the target load will be met by adopting the secondary treatment systems for the islands of the Governador and Fundao.

In terms of nutrient salts, however, it is estimated that the target load (T-P : 0.4 ton/day) will be hardly met by using the secondary treatment systems (0.54 ton/day for T-P in 2010).

The tertiary treatment systems for the Governador island (Alternative 2) is appropriate as it will meet the target load in T-P (0.37 ton/day for T-P in 2010).

(6) Water Areas

As shown in applicable measures and their effects in Chapter 16.7, the widening and deepening of the channels between the mainland and Governador and Fundao Islands were evaluated as the most effective measure in the water area.

Therefore, we strongly propose the widening and deepening of the channels in order to improve the circulation in the inner part of the Bay, though detailed studies should be carried out to ascertain the required width and depth.

(7) Others

Finally, about the reduction of nutrient salts in the Bay, as we have seen in this study, primary production caused by the existence of nutrient salts is a serious problem from the viewpoint of water deterioration as well as the living environment of aquatic life.

As stated before, there is some difficulty meeting the target water quality for BOD, by only deducting inflowing organic matter. Therefore, it is necessary to reduce inflowing nutrient salts in order to meet the target water quality levels which we set in Chapter 16.5.

By our estimation, the flowing nutrient salts in terms of T-P is about 20 ton/day at present into Guanabara Bay and is forecast to be about 26 ton/day by the year 2010 if no measures are taken.

On the other hand, we approximated the target runoff load in terms of T-P at about 13 ton/day. This means that 13 ton/day, the difference between 26 ton/day in 2010 and the target runoff load (13 ton/day), has to be reduced by some measures by the year of 2010.

16.10 Conclusion

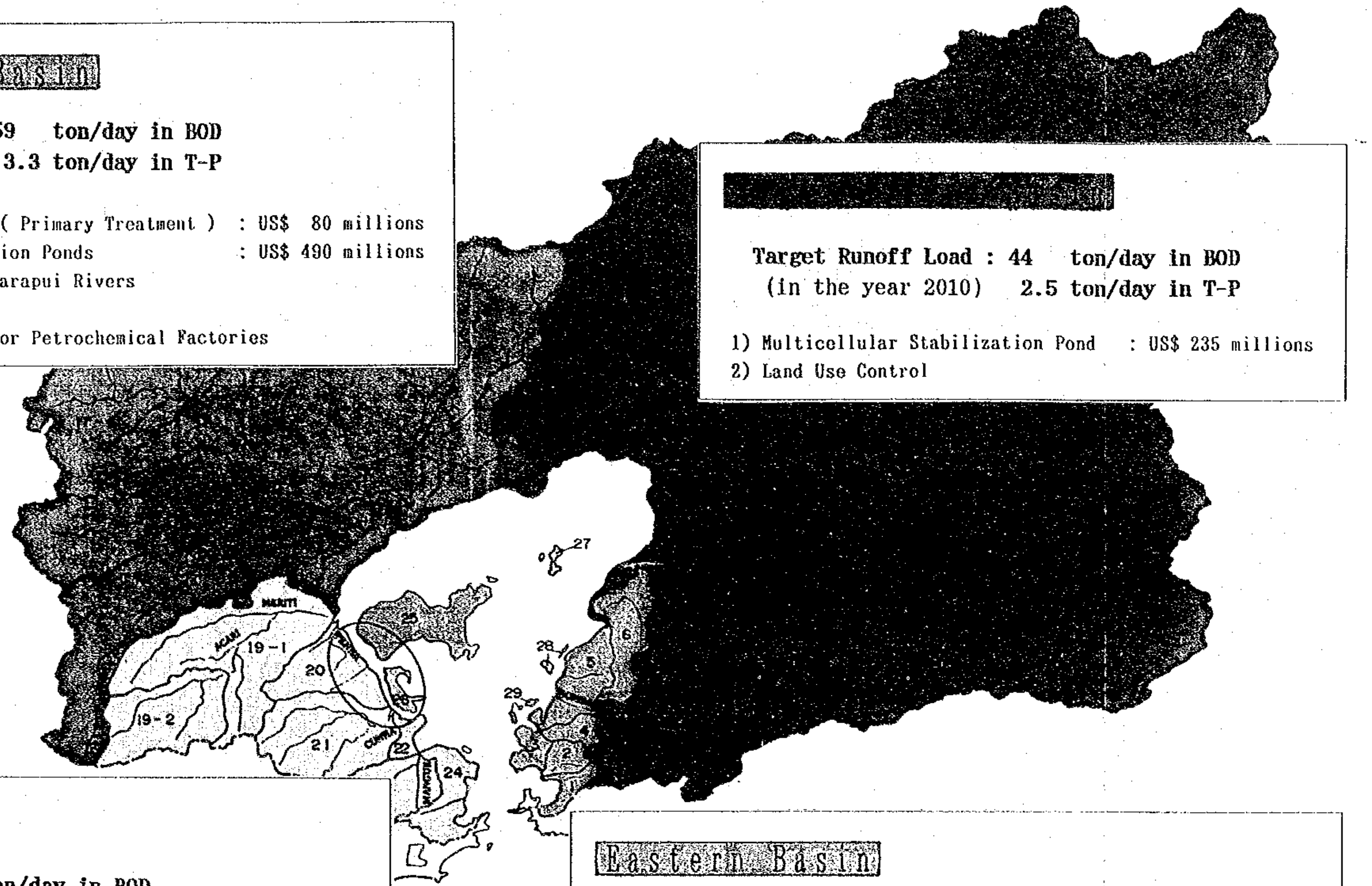
16.10.1 Proposed Measures for Mid to Long-Term Plan

The proposed optimum combinations of measures to meet the target water quality in Guanabara Bay in the year 2010 set for this master plan are summarized in **Fig. 16.10-1** together with rough estimations of costs. These measures, however, are only proposed under conditions that it will be applied in a mid-term plan.

In considering these measures for a long-term plan, including the proposed measures shown in **Fig. 16.10-1**, the treatment function of the sewage treatment plants in the western basin except the Alegria should be graded up in future.

The tertiary treatment system proposed as the optimum measure for the eastern basin is considered for Sub-basin No.1 to 4, small areas with sanitary services plans under the IDB/OECF program. For Sub-basins No.5 and 6, where populations is comparatively large and sanitary services are non-existent, new sewage treatment plants should be prepared in future.

In both northwestern and northeastern basins, additional measures such as the construction of activated sludge treatment plants and/or stabilization ponds will be necessary in accordance with the increase in population.



Northwestern Basin

Target Runoff Load : 59 ton/day in BOD
(in the year 2010) 3.3 ton/day in T-P

1) Sewage Treatment Plants (Primary Treatment) : US$ 80 millions
2) Multicellular Stabilization Ponds : US$ 490 millions
   along the Iguacu and Sarapui Rivers
3) Land Use Control
4) Joint Treatment Plants for Petrochemical Factories

[redacted]

Target Runoff Load : 44 ton/day in BOD
(in the year 2010) 2.5 ton/day in T-P

1) Multicellular Stabilization Pond : US$ 235 millions
2) Land Use Control

Islands

Target Runoff Load : 7 ton/day in BOD
(in the year 2010) 0.4 ton/day in T-P

1) Tertiary Treatment Systems : US$ 25 millions
   for the Governador Island

Western Basin

Target Runoff Load : 98 ton/day in BOD
(in the year 2010) 6.2 ton/day in T-P

1) Sewage Treatment Plants (Primary Treatment) : US$ 115 millions
2) Ocean Outfall System after Primary Treatment : US$ 140 millions
   for the Alegria Sanitary District
3) Improvement of Sanitary Services in Favelas
   (Garbage Collection & Wastewater Treatment Facilities)

Eastern Basin

Target Runoff Load : 24 ton/day in BOD
(in the year 2010) 0.8 ton/day in T-P

1) Sewage Treatment Plants (Primary Treatment) : US$ 65 millions
2) Sewage Treatment Plants (Tertiary Treatment) : US$ 55 millions
   after Primary Treatment
3) Joint Treatment Plants for Sea-Product Processing Factories

Water Areas

1) Widening and Deepening the Channels

Fig.16.10-1 Optimum Combinations of Measures in the Guanabara Bay Basin

Northwestern Basin

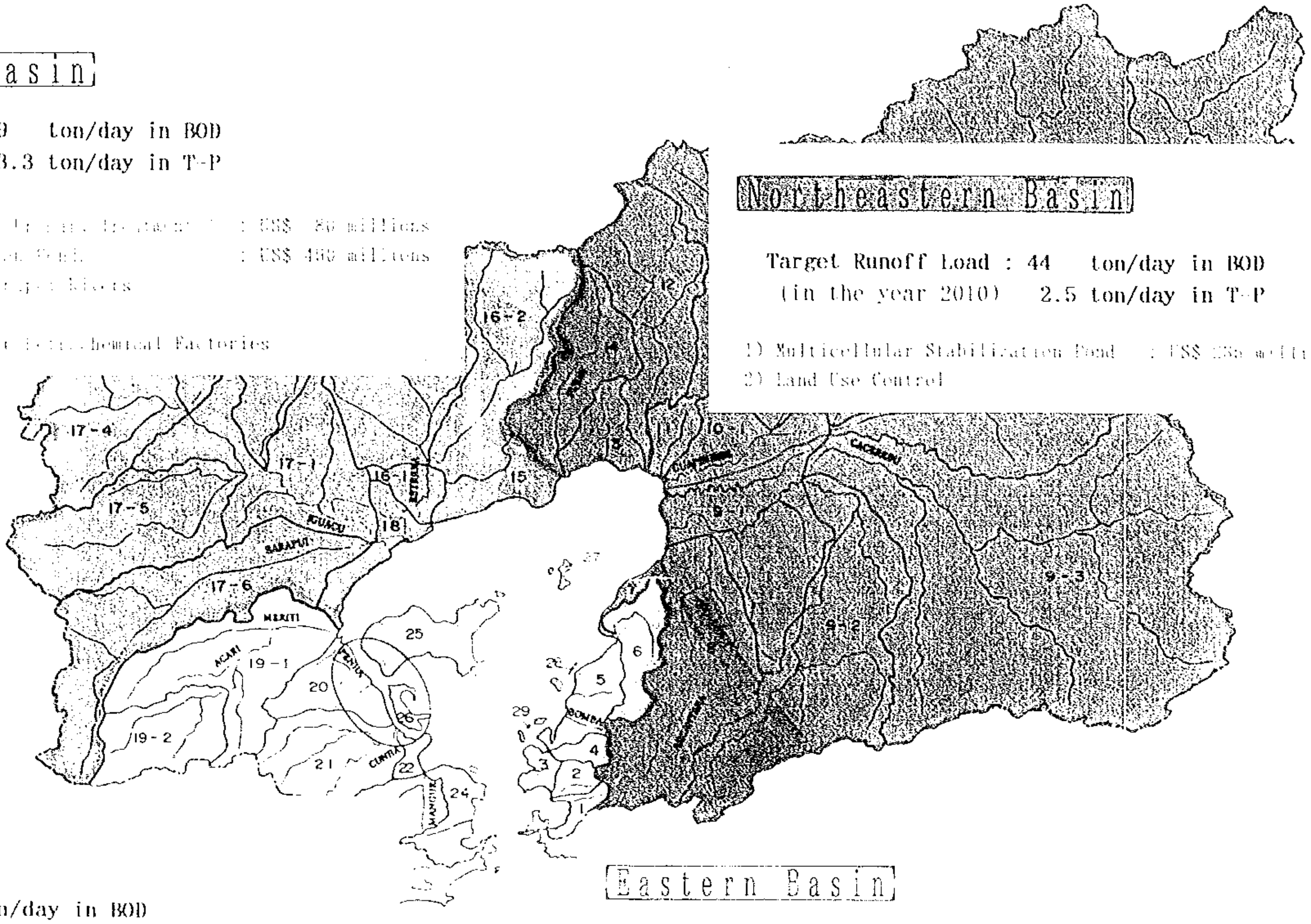
Target Runoff Load : 59 ton/day in BOD
(in the year 2010) 3.3 ton/day in T-P

[illegible]

Northeastern Basin

Target Runoff Load : 44 ton/day in BOD
(in the year 2010) 2.5 ton/day in T-P

1) Multicellular Stabilization Pond : US$ [illegible] millions
2) Land Use Control



Islands

Target Runoff Load : 7 ton/day in BOD
(in the year 2010) 0.4 ton/day in T-P

[illegible]

Western Basin

Target Runoff Load : 98 ton/day in BOD
(in the year 2010) 6.2 ton/day in T-P

[illegible]

Eastern Basin

Target Runoff Load : 24 ton/day in BOD
(in the year 2010) 0.8 ton/day in T-P

[illegible]

[illegible]

Fig.16.10-1 Optimum Combinations of Measures in the Guanabara Bay Basin

16.10.2 Proposed Measures for Short-Term Plan (Urgent Measures)

As mentioned in section 16.6.4, the 20% reduction of organic matters at the northwestern basin and maintaining the present level of organic matters at the northeastern basin together with the IDB/OECF program (first stage) are necessary to meet the target water quality for the short-term plan (2000).

The half-sized treatment plants of those proposed in section 16.9.1(3) and (4) for the northwestern and northeastern basins will be able to satisfy the above mentioned requirement.

Conclusively, the following measures are proposed as urgent measures to meet the target water quality in the short-term plan;

1) Western Basin	: IDB/OECF Program (first stage)	US$ 115 millions
2) Eastern Basin	: IDB/OECF Program (first stage)	US$ 65 millions
3) Northwestern Basin	: IDB/OECF Program (first stage)	US$ 80 millions
	plus Stabilization Pond (inflow of wastewater : 2.0 m^3/sec)	US$ 240 millions
4) Northwestern Basin	: Stabilization Pond (inflow of wastewater : 1.0 m^3/sec)	US$ 120 millions
5) Islands	: IDB/OECF Program (first stage)	

CHAPTER 17

RECOMMENDATIONS FOR THE IMPLEMENTATION OF THE MASTER PLAN

CHAPTER 17

RECOMMENDATION FOR THE IMPLEMENTATION OF THE MASTER PLAN

The water quality deterioration in Guanabara Bay is basically a result of the socioeconomic activities in the basin. Solving these problems would not only require wastewater treatment technology but also the minimization of the generation and effluent loads by reconsidering various factors such as development plans, laws, administrative system, industrial structure, education and life style that govern the socioeconomic activities in the basin.

Further, the implementation of an integrated water quality improvement measure that includes the forementioned software measures will take a long time and therefore require tremendous capital. Fund raising is therefore a subject of importance.

This chapter deals with clues as to how to solve several of the problems particularly considered important in the implementation of the Master Plan proposed in the previous chapter.

17.1 Preparing a Comprehensive Development Plan for the Basin to go with the Master Plan

The water quality contamination problems (refer to **Fig. 16.1-1**) generated by the dense population, excessive industrial activities, insufficient environmental and sanitary infrastructures in the Guanabara basin are also urban problems and regional development problems. Therefore, the improvement of Guanabara Bay's water quality and the recuperation of the ecosystem would necessitate the implementation of urban improvement and regional development plans that take Guanabara Bay's environmental assimilating capacity into consideration.

Several of the municipalities within the basin have formulated regional development plans, however most of these are still ideological. In November 1992, the State of Rio established the "Programa Saneamento Basico da Bacia da Baia de Guanabara" which details the implementation of various environmental and sanitary improvement works such as the sewer system, solid waste disposal, drinking water supply and resettlement for the municipalities in the Guanabara Bay basin. However, the relation between these works and the comprehensive development plan in the basin has not been discussed.

The environmental assimilating capacity of Guanabara Bay (target reduction load) and the countermeasures against surpassing this capacity are specified in the Master Plan which is the fruit of this study. It is necessary, therefore, to formulate a medium and long term comprehensive development plan, which will not be conflict with the Master Plan, hereafter.

This comprehensive development plan will be incorporated with a Land Use Plan, Urban Residential Environment Improvement Plan, Industrial Structure Improvement Plan, Tourism Recreation Base Improvement Plan and Natural Resources Conservation Plan, all of which should be regulated for the improvement of Guanabara Bay's water quality and the recuperation of the ecosystem.

For example, the Industrial Structure Improvement Plan, within the framework of the long term industrial policies of the state or the nation, will basically deal with luring industries that will not adversely affect the use of the water resources in the basin, and to transfer those which would outside the basin area when the rehabilitation of the facilities is needed. The Land Use Plan will classify the land uses with due consideration of the natural and social conditions in each basin, improve the infrastructures for health and sanitation for housing developments, and oblige the joint treatment of the wastewater from the industrial zone.

Naturally, the plan will be mainly formulated by the Government of the State of Rio de Janeiro, but the participation of the municipalities in the basin, researchers and the residents is also very much desired.

17.2 Establishing a Committee for the Utilization and Control of Water Resources in the Basin

There are 12 municipalities in the Guanabara Bay Basin and all have very diverse water demands, environmental and sanitary infrastructures, and financial state. Accordingly, the socio-economic conditions of these municipalities will be taken into account, disadvantages and advantages upstream and downstream will be regulated, and the use of the water resources in the basin will be supervised in order to achieve the target water quality proposed in the Master Plan and to facilitate the implementation of the countermeasures.

Moreover, basic data of each basin unit, such as population, water demand and discharge load, essential to the use and supervision of the water resources are not accurately known, and various informations are not taken care by a specific agency.

The State Environmental Bureau (SEMAMPE) will play the central role and establish the Guanabara Bay Management Committee composed of representative(s) from related state agencies, basin municipalities and of the residents. The Basin Management Committee execution of a water resource use and supervision plan, collection and management of necessary data, study on regulations and standards, and educational and enlightenment activities are most desired after adjusting the interests between municipalities.

17.3 Continuing the Monitoring and Research for Guanabara Bay and its Basin

The Master Plan proposed in this report is based on studies and observations carried out for only a year (1992-1993), and is therefore not accurate and quantitative enough. Consequently, further studies and observations will be successively carried out hereafter to increase the reliability of the data from which the Master Plan's needed revision will be based on.

An example of these inaccurate and insufficient data is the statistics on population. The population data acquired only cover population by municipality, hence sub-basin population is considerably inaccurate. By using the population by sector, land classification and land use area together, a precise sub-basin population can be attained, the domestic effluent load can be measured, and a treatment measure can be studied. It is also advisable to work on attaining favorably accurate values on other socioeconomic indicators by basin.

There are only few river discharge and water quality observations and bay water quality simultaneous observations, and the mean flow and water quality values have not been attained. The same kind observations carried out in this study will be continued in the future, and the accumulation of fully reliable data is necessary as they will be used as basis for pollution mechanism analysis and the design conditions of facilities for the treatment of polluted water.

The observation points established in this study for the measurement of river flow and water quality are mostly in tidal areas, and the calculated flow and load are therefore inaccurate. As it is difficult to find out the more suitable site for river observation than the existing sites, discharge and runoff load shall be calculated from the data obtained by the twenty-four hours observation on main rivers.

There are also some problems concerning the water quality items to be monitored. One of these is this study's inevitable use of BOD as the indicator of organic matters due to various reasons. Since the use of BOD will not accurately reflect the amount of organic matter in water and sediments, analytical results could lead to incorrect conclusions concerning actual polluted conditions. It is necessary, therefore, to use TOC as early as possible, as an indicator, to accurately grasp the relation among the pollution sources, the rivers (fresh water) and the bay (sea water) in water quality and load (see Supporting Report I).

17.4 Raising Funds to Implement the Master Plan

The improvement of the Guanabara Bay water quality and the recupreration of the ecosystem will require more than 10 years and a huge capital. Although sewage treatment in Influential Sub-basin will be materialized through the large-scale financing of IDB and OECF, the results of this study clearly show that the target water quality will not be atained by this measure alone.

The attainment of the target water quality of the Bay would require the combined implementation of treatment of domestic drainage, forest preservation, reduction of industrial effluent load, the widening and dredging of canals in the bay, such as the Potentially Critical Basin, where generation load is increasing. Although some of the funds needed for the implementation of these measures will be covered from increasing revenues and changes in budget distribution, the majority will be covered through international banking organizations.

One of the forms of financing offered by international banking organizations is the "Two Step Loan". The international banking organization loans the concerned country funds for development projects through its banking organization who in turn divides these funds among the country's private industries on a small-lot consignment basis. These funding system is considered to be appropriate for the improvement of private industries' production process and the wastewater treatment facilities.

Although one of the reasons behind the improgressive reduction of industrial effluent loads in the Guanabara Bay basin is the non-thorough implementation of laws and regulations, the incapability of medium and small scale industries to finance necessary counter-measures and the extremely limited financing of domestic banking organizations are also points to be taken into account. The application of the "Two Step Loan" system, therefore, would mobilize the improvement of the production process and the installation and improvement of facilities for the treatment of polluted water, and give impetus to the measures for the reduction of industrial effluent load.

17.5 Defining the State Agencies Related to the Environmental Administration and Strengthening their Finances

In 1975, FEEMA and CECA were established for state environmental management and their roles were distinctively defined. The former was responsible for monitoring and research works, while the latter was responsible for the execution of laws and regulations. The establishment of other organizations like SEMAMPE, CONAMA, FECAM, CODEG, etc., followed suit, and recently sections for environmental management have also been formed even in Municipalities. The increase has not only made the role and responsibilities of government organizations ambigious, but cripples projects, like the use and management of water resources, needing the cooperation of various organizations.

Another one of the problems faced by state environment-related organizations is inactivity due to shortage of funds. The scope of the problem does not only involve the reduction of government salaries but also the obstruction of studies and research works due to interruptions in foreign technical cooperation projects and financial assistance from international banking organizations brought about by the termination of CECA's activities: CECA collects charges hich are distributed by FECAM to FEEMA, IEF and SERLA.

The enthusiasm of the state government in environmental administration and the budget allocation measures that would support this enthusiasm are very important to overcome these problems. However, it is also necessary to stimulate studies and research on the securement of independent financial sources and to review (reorganization of the system) the roles of various environment-related organizations.

Independent financial sources can be secured, for example, in the form of charges for the public services of a Pollution Control Officer (PCO). The government will oblige the industries to employ a PCO for wastewater monitoring works of which periodical reports are to be made and submitted. Funds can be raised in the form of (1) charges for the certification and registration of a PCO, (2) counseling fees for seminars for PCO's, (3) fees for the consignment of the analysis of the water quality of drainage from factories (funds can also be raised by setting up certification and counseling works by private analysts (company)).

17.6 Development and Application of Original Wastewater Treatment Technology

The improvement of the environment of the water area would extremely necessitate the development of techniques for the treatment of wastewater which are suitable to the area. This report carried out a comparative study on various techniques, majority of which were implemented in the developed countries, therefore its application in the bay would not necessarily exhibit maximum effects as natural and socioeconomic conditions are different. In contrast, however, there are also techniques that have not been given importance in the west and Japan but that can be very effective when applied in the bay.

For example, the high temperature (water temperature) and strong sunlight in Guanabara Bay all year round highly activates bacterial process the year round. Therefore, the further use of aerobic and anaerobic treatment techniques, which are not adopted in the west and Japan due to the long residence time, is considered favorable for the treatment of polluted water. The activated sludge method for the construction of the sewage treatment site under the CEDAE program will be carried out in Phase 2, but it is not really considered as the best method for Guanabara Bay basin in consideration of the cost and techniques required for maintenance works.

The methods formerly developed should not be used for anaerobic and aerobic treatment, but new ones should be formulated in full consideration of the various prevailing conditions in the target area. Development of such an original technology is one of the important roles of the environment-related agencies of the nation and the state. However, the efforts poured in this work are lacking due to insufficient funds to finance research development works.

17.7 Establishing New Social and Economic System to Promote Environmental Improvement

The investments needed for the development of an environment without market value can not be promoted solely under laws and regulations. There is a need to establish a system that would be socioeconomically beneficial to the investors.

Drainage regulations have been imposed in the State of Rio de Janeiro. However, sewage is still discharged illegally by most factories who are either without treatment facilities or have extremely inadequate ones. In spite of the fact that it requires a large amount of money, the installation of these facilities is hardly profitable for the private companies.

However, if a production process improvement plan, which can simultaneously reduce effluent load and save water and energy is proposed and if a financial system with long term and low interest rates conditions is prepared, price competition can be strengthened through the depreciation in industrial manufacturing cost, investments will be carried out, and the results will be beneficial to the improvement of the environment. The financial system, Two Step Loan, previously mentioned in 17.4 can be adopted for this plan.

17.8 Raising Resident Awareness of the Environment and Promoting Participation in Improvement Activities

Upon the implementation of this project, the state related organizations should prepare various places to explain to the people of different social classes the condition of the bay, the significance of the project, details of the countermeasures and the benefits that can be derived from the improvement of the bay water quality. This could heighten the peoples' interest in the project and increase support for the implementation works, thereby resulting in compliance in the sharing of the required expenses.

SEMAMPE should vigorously appeal to the public concerning the conditions of the bay and the importance of countermeasures through television and newspapers. FEEMA should publish the study and observation data in academic journal and present them as topics for lectures, and should propose countermeasures based on pollution mechanism.

Attention is being paid to the afforestation projects of IEF and the garbage collection work of COMLURB in Favela which solicit residents participation and increases job opportunities. Likewise, SERLA and FEEMA are suggested to solicit the participation of the residents, intermediate and junior high school students in river and bay water quality monitoring works. The monitoring of many stations through the use of simple indicators and devices for transparency and benthos would enable the simultaneous although slightly inaccurate understanding of vast environmental conditions. Further, through monitoring works, the interest and support of the participating individuals could be heightened.

CHAPTER 18

PROJECTS

RECOMMENDED TO STUDY

THEIR FEASIBILITY

CHAPTER 18

PROJECTS RECOMMENDED TO STUDY THEIR FEASIBILITY

The alternative measures applicable in the influential sub-basins, the important beaches and water areas and the potentially critical sub-basins were stated in the preceding chapter. With the exception of the measures financed by IDB, OECF, WORLD BANK, etc., this chapter will deal with the grounds for the proposal of the measures, the outline of the measures and the main subjects for the feasibility study.

18.1 Planning of the Ocean Outfall System

(1) Grounds for the Proposition

As we mentioned in Chapter 8, there are only 6 sewage treatment plants in the Guanabara Bay basin under the control of CEDAE. The treatment ratio of domestic wastewater is deemed to be less than 15% and the majority of the remaining wastewater drains mostly untreated into the rivers or into the stormwater drains and finally into the Bay. Consequently, in order to improve the water quality in Guanabara Bay, the critical issue of the treatment of domestic wastewater needs to be brought forth.

To help sovling this problem, CEDAE, in 1994, plans to start a sewerage and sewage treatment plant improvement project with IDB and OECF loans. The construction of 6 sewage treatment plants is scheduled in Phase 1 (target year: 20000 and an additional 9 sewage treatment plants in Phase 2 (target year: 2007).

However, it will not be until 2007, when the 6 plants being completed by 2000, start secondary treatment only primary treatment will be carried out between 2000 and 2007. Moreover, all the treated water is expected to be discharged into Guanabara Bay.

Consequently, the water quality in the Bay will not be improved remarkably due to the construction of the new sewage treatment plants up until 2007. And because of the sheer magnitude of internal lproduction in Guanabara Bay, secondary treatment with a low removal rate of nutrient salts will not improve the water quality in the Bay even after 2007, contrary to expectations.

The outfall system, capable of removing nutrient salts and pathogenic bacteria as well as organic material, is deemed very effective for water quality improvement. This system is also advantageous for the fact that the maintenance expenses are lower than those for the fact that the maintenance expenses are lower than those for a secondary treatment system or a tertiary treatment system.

We therefore would like to recommend this system as an alternative measure to the sewage and wastewater treatment improvement project, being financed by the IDB/OECF.

(2) Project planned in 1969 by SARSAN

In 1969, a project to discharge wastewater, from the Guanabara Bay basin, outside the Bay was put forward by SARSAN, then the Sewerage Bureau of the State of Rio de Janeiro. This project planned to collect wastewater from the southern districts (Lagoa, Copacabana, Gloria and Botafogo) of Rio de Janeiro and from the northern districts (Cais de Porto, Mangue, San Cristovao, Alegria and Timbo-Faria) in separate conduits to be discharged offshore of Ipanema. The projected maximum treat volume was 10.38m^3/s for southern district and 37.3m^3/s for northern district.

However, a part of the southern districts is the only section where this ocean outfall system has actually been completed. Currently, 1.9m^3/s of wastewater is being discharged, about 4 km off the Ipanema beach (at a depth of 22 m), but owing to deterioration the sewer pipes, extending along the seabed, wastewater is leaking out and polluting the coast some project it was.

The reason why this project was not fully implemented is said to be because, it was assumed that an activated sludge method was more suitable for the northern districts from the viewpoint of the resultant economic effects, etc. Furthermore, the seriousness of the eutrophication problem had not then been realized.