2.5 Future Pollution Load

2.5.1 Future Trend of Socioeconomic Factors for Pollution Load Analysis

(1) Municipal Wastewater

Daily discharge volume and daily pollution loads of municipal wastewater is determined by several factors, such as population, coverage of drainage system, and discharge volume and pollution loads per capita per day. These factors are discussed below.

a) Population

Population projection in 1999 – 2010 is shown in Table 2.22. The estimation on population and annual average population growth rate of Altamira Municipality, Madero City, Tampico City, Panuco Municipality and Pueblo Viejo Municipality are described below.

- Altamira Municipality

Altamira Municipality has a number of communities such as Miramar (51,462 people in 1995), Altamira (34,523 in 1995), Cuauhtemoc (5,474 in 1995), Esteros (2,062), La Colonia (1,448), Rio Tamiahua (1,371 in 1995), Lomas del Real (1,195 in 1995), Maclovio Herrera (1,133), La Pedrera (1,038 in 1995), Ricardo Flores Magon (1,035 in 1995) as shown in Figure 2.13. Except Miramar and Pedrera, all the other communities are located north from Altamira City. Total population of Altamira Municipality in 1995 was 111,889. The annual average population growth rate in Altamira Municipality of 4.35% was employed from CONAPO's projection. Especially, the north and northeast portion of Altamira City are expected to have rapid population growth. The estimated population around Miramar is 60,000 and its population growth rate is 1.5% between 1999 and 2010.

According to CONAPO, the population and annual average growth rates were 170,282 with 0.94% in Madero, and 278,364 with 0.40% in Tampico.

- Pueblo Viejo Municipality

Pueblo Viejo Municipality is divided into several communities, such as Cuauhtemoc, Las Margaritas, La California, Anahuac, Lindavista, Mata Redonda, Miguel Hidalgo, Primera de Mayo and so on. CONAPO's population estimation for Pueblo Viejo Municipality in 1999 is 52,820 with the annual average growth rate of 1.40%

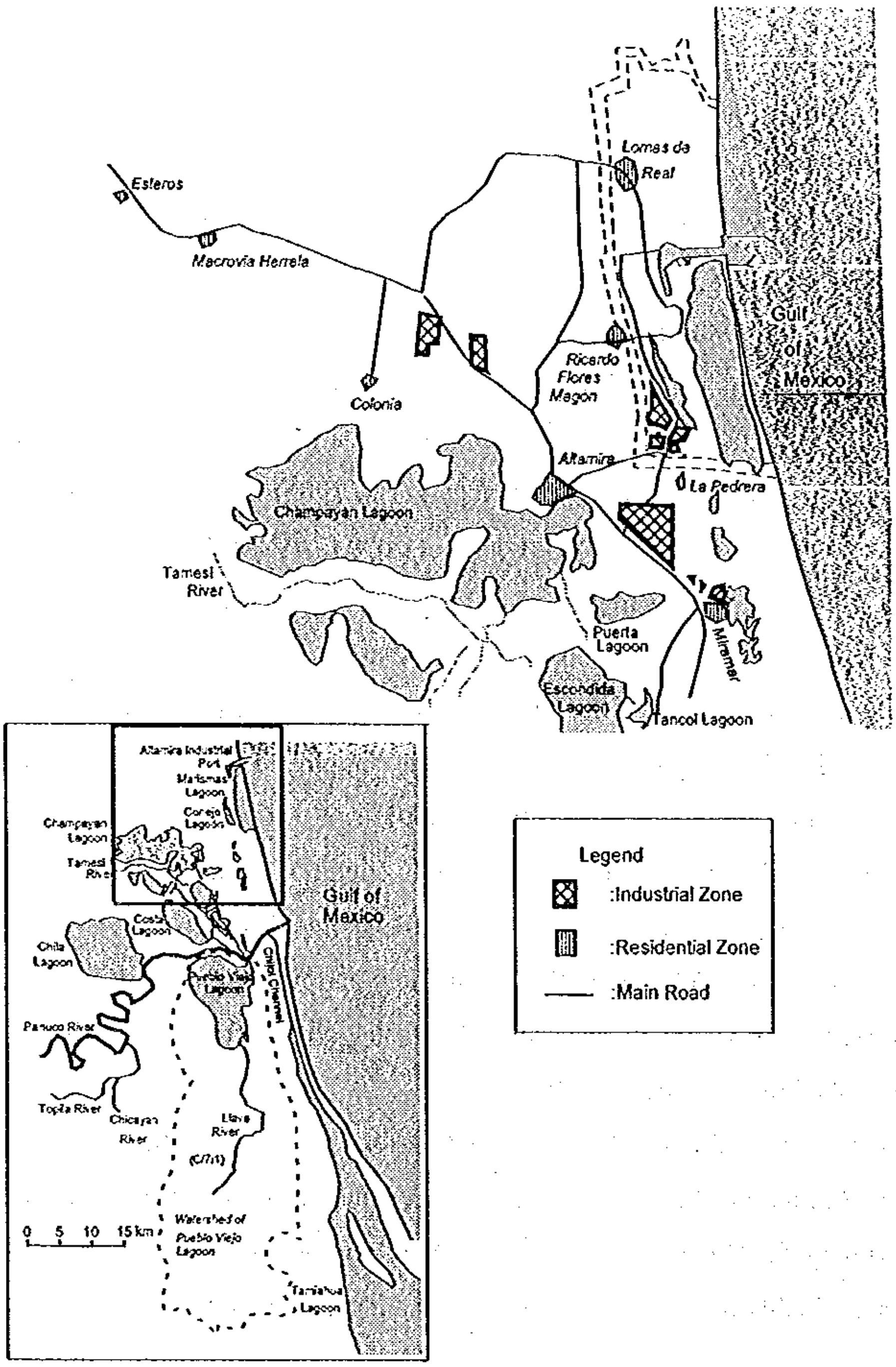


Figure 2.13 Central Part of Altamira Municipality

b) Coverage of Drainage System

The coverage of drainage system is different by each municipality in the Tampico Area.

- Altamira Municipality

According to COMAPA, the coverage of drainage system in Altamira Municipality is 100%. However, according to Altamira area, there are a lot of places without drainage system. Altamira area (population 34,523 in 1995; total population of Altamira City was 113,810 in 1995) has a drainage system with oxidation pond. Recently, Miramar area (population 51,462 in 1995) had installed a drainage system, which was extended into Tieranegra oxidation pond. The coverage of drainage system in Altamira area, Miramar area and Altamira Municipality is about 95%, 80%, and 75% as of 1999, and will increase to 95%, 95% and 90% by 2010, respectively.

- Tampico City and Madero City

Coverage of drainage system in Tampico City and Madero City in 1995 was estimated to be 86% (Estudio Complementario para el Sistema de Plantas de Tratamiento de Agua para las Ciudades de Tampico, Madero y Altamira, COMAPA, 1994). According to the CNA's project of environmental impact, coverage of drainage system in Tampico City and Madero City in 1999 is about 95%. The coverage is expected to stay at the present level in 2010.

- Pueblo Viejo Municipality

The coverage of drainage system is 5.7% in 1999 (Comision Municipal de Agua Potable y Saneamiento) or 12% in 1995 (Anuario Estadistico del Estado de Veracruz (1998)). In Lindavista and Mataredonda there are open channels into which domestic wastewater is discharged. However, these channels have dried up because discharged volume is too small to maintain a constant current. Generally the wastewater infiltrates into the ground. In other communities, septic tanks or latrines are used and the wastewater infiltrates into the soil. According to the CNA's project of environmental impact, wastewater (80 l/s) will be sent from Tampico to Pueblo Viejo before 2005. Water supply into Pueblo Viejo will double in rainy season and triple in dry season. The quantity of municipal wastewater will rapidly increase in the near future. No information on future projection of drainage system in Pueblo Viejo Municipality has been obtained. It is supposed that 5.7% of population with drainage coverage in 1999 will increase to 11% by 2010.

c) Daily Discharge Volume per Capita and Daily Pollution Loads per Capita

- Altamira Municipality

The wastewater from Altamira City flows into the Altamira oxidation pond. This wastewater has been generated basically from domestic discharge. The discharge volume was 7,048 m^3/day in 1998. The coverage ratio of drainage system in Altamira City is supposed to be about 95%. Based on the following assumption, the daily pollution loads per capita for the domestic wastewater are estimated:

- Population covered with drainage system: 37,200 in 1998
- Daily discharge volume: 7048 m^3/day in 1998
- Water quality: the values shown in Table B.25 (effluent) (in 1995)

Based on the estimation, daily discharge volume, BOD_5 and COD are calculated as follows:

- Daily discharge volume: 189 (l/capita/day) in 1998
- BOD_5 : 48 (g/capita/day) in 1995 (51(g/capita/day) in 1999)
- COD : 89 (g/capita/day) in 1995 (94(g/capita/day) in 1999)

CNA evaluated the domestic wastewater pollution load per capita for a family with drainage system as follows (Evaluacion de la Calidad del Agua en Cuencas Hidrologicas, Primera Etapa, CNA, 1996);

- BOD_5: 53 (g/capita/day)
- COD: 120 (g/capita/day)
- Total-N: 9.03 (g/capita/day)
- Total-P: 1.09 (g/capita/day)

The daily pollution load per capita for Altamira Municipality in 1999 is used as follows:

- BOD_5: 51 (g/capita/day)
- COD: 94 (g/capita/day)
- Total-N: 8.7 (g/capita/day)
- Total-P: 1.04 (g/capita/day)

and 195 (l/capita/day) is used as the daily discharge volume per capita. It is supposed that annual growth rate of daily discharge volume per capita is 3% and annual growth rate of the daily pollution load per capita is 1.5% for Altamira Municipality.

- Tampico and Madero

In 1995 the estimated daily discharge volume from Tampico City and Madero City was 0.837 m^3/s (Estudio Complementario para el Sistema de Plantas de Tratamiento de Agua para las Ciudades de Tampico, Madero y Altamira, CONAPO (1994)), total population of Tampico and Madero is 448,646, and coverage of drainage system is 86%. Calculated daily discharge volume per capita in Tampico and Madero is 187 (l/capita/day) (including industrial, commercial and institutional use). In 1998 estimated daily discharge volume was 1.23 m^3/s (1.043 m^3/s into Panuco River, 0.187 m^3/s into Tieranegra) total population of Tampico and Madero was 461,689, and coverage of drainage system was 95%. Calculated daily discharge volume per capita in Tampico and Madero was 242 (l/capita/day) in 1998. Annual growth rate of the daily discharge volume per capita was 9.0% between 1995 and 1998. It is supposed that average annual growth rate of daily discharge volume in Tampico and Madero will be 4% from 1999 to 2010.

Table B.34 shows the 1998 daily pollution loads per capita in Tampico and Madero that serve a combined population of 371,922. The daily pollution loads per capita (including industrial, institutional and commercial contributions) in Tampico and Madero are as follows:

- BOD_5: 68.6 (g/capita/day)
- COD: 106 (g/capita/day)
- Total nitrogen: 18.3 (g/capita/day)
- Total phosphorus: 2.3 (g/capita/day)

It is supposed that average annual growth rate of daily pollution loads per capita is 2%.

- Pueblo Viejo Municipality

Flow rate of wastewater into Cuauhtemoc Oxidation Pond is about 5 l/s in 1995-6 (source: Comision Nacional del Agua, Gerencia Estatal en Veracruz). It is supposed that daily discharge volume per capita is 150 l/capita/day in 1999 and its average annual growth rate is 3%. There is

d) Treatment of Municipal Wastewater

Maximum permissible limit for contaminants in wastewater discharged into water area is shown in Appendix A. Municipal wastewater, which is discharged from a community whose population is larger than 50,000, should be able to comply with the maximum permissible limit by January 1, 2000. Those communities whose population range from 20,001 to 50,000 should comply by January 1, 2005, and those ranging from 2,501 to 20,000 have until January 1, 2010.

- Altamira Municipality

Residential areas in Altamira Municipality are shown in Figure 2.13. Industrial zones separate Miramar from other communities. The wastewater of Miramar is discharged into Tieranegra oxidation pond, and will be treated with wastewater of Tampico and Madero.

The wastewater from Altamira City is treated in Altamira oxidation pond. However, the treated wastewater does not fulfill the maximum permissible limit (natural reservoir, urban public use; maximum permissible limit of BOD_5 and total suspended solids is 30 mg/l and 40 mg/l for monthly average). In 1995, average BOD_5 and total suspended solids were 83 mg/l and 122 mg/l, respectively. Fecal coliform also exceeded the maximum permissible limit. The wastewater treatment system is required to fulfill the maximum permissible limit by 2005.

- Tampico and Madero (including Miramar)

Tampico City and Madero City has a plan for fulfilling the maximum permissible limit by January 1, 2000. According to this plan, the treatment plant with the capacity of 900 l/s should have been installed by 1995. The capacity of this plant was to increase to 1200 l/s by 1998 and 1500 l/s by 2007. The concentrations of BOD_5, COD, and total suspended solids of effluent (wastewater) are as follows:

- BOD_5: 300 mg/l
- COD: 500 mg/l
- Total suspended solids: 300 mg/l

And concentrations of these parameters in treated wastewater would be:

- BOD_5: 30 mg/l
- COD: 60 mg/l
- Total suspended solids: 30 mg/l

This plan includes the reuse of treated wastewater as industrial water. However, financial problem has been hindering the progress of this plan.

It is supposed that a wastewater treatment facility, which will have a capacity of 1200 l/s, will be constructed until 2010 for Tampico City, Madero City and Miramar.

- Pueblo Viejo Municipality

Only Cuautemoc area will have a drainage system. The rest of Pueblo Viejo will continue to use septic tanks or latrines. It is necessary to expand the capacity of Cuauhtemoc oxidation pond.

Table 2.22 Municipal Wastewater Projection in the Tampico Area between 1999 and 2010

Local Body	Population*		Daily discharge volume per capita ***		Daily BOD_5 load per capita***		Daily COD load per capita***		Daily total N load per capita***		Daily total P load Per capita***	
	1999 (person)	2010 (person)	1999 (l /capita /day)	rate# (%)	1999 (g /capita /day)	rate# (%)	1999 (g /capita /day)	rate# (%)	1999 (g /capita /day)	rate# (%)	1999 (g /capita /day)	rate# (%)
Altamira Municipality	136,339	212,054	195	3	51	1.5	94	1.5	8.7	1.5	1.04	1.5
Miramar(South Part of Altamira Municipality)	60,000	70,667	195	3	51	1.5	94	1.5	8.7	1.5	1.04	1.5
Tampico City **	285,765	295,622	251	4	70	2	108	2	18.7	2	2.35	2
Madero City **	179,721	200,625	251	4	70	2	108	2	18.7	2	2.35	2
Pueblo Viejo Municipality	52,820	60,871	150	3	45	1.5	82	1.5	7.6	1.5	0.91	1.5

* Source: CONAPO except Miramar, population of Miramar and small communities around Miramar: approximate value from 51,462 (only Miramar) in 1995

** Including wastewater from commercial, and industrial origin

*** Estimation from data on municipal wastewater # Annual growth rate

(2) Industrial Wastewater

The chemical and petrochemical production in Tampico Area has increased annually by about 10% from 1996 to 1998. It is supposed that annual growth of production will reach 4% from 1999 to 2010. Abundant water from Tamesi River and freshwater lagoons will continue to attract water intensive industries. Petroleum raw material produced in Refineria Madero will also induce the development of chemical and petrochemical industries in this area.

Existing industries should comply with the maximum permissible limit for contaminants in wastewater discharged into public water bodies by 2010. The majority of chemical and petrochemical industries have already installed wastewater treatment facilities as shown in Table 2.7, but some of those facilities do not have sufficient capacity to eliminate contaminants. These industries have until 2007 to reduce the contaminants in their wastewater.

It is presumed that a factory is going to reduce contaminants to 70% of the maximum permissible limit by 2007 if wastewater of the factory exceeds 70% of the maximum permissible level for the monthly average of a parameter. It is difficult to estimate the reduction level of other parameters. Therefore, it is supposed that the level of other parameters will be also be reduced to the same proportion as that of the objective parameter. Any production facilities yet to be installed in the Tampico Area shall be required to fulfill the maximum permissible limits of wastewater from the beginning of their operation. Reuse of treated wastewater is also considered in the Tampico Area.

a) Altamira Industrial Port

No industry discharges wastewater that exceeds the maximum permissible limit for contaminants into Altamira Industrial Port except Pittsburgh Plate Glass Industry, which discharges excessive total suspended solids, and the thermal power plant.

The discharge volume from Administracion Portuaria Integral de Altamira, Pittsburgh Plate Glass Industry, Polycyd and Negromex will increase by an annual growth rate of 4%, and the concentrations of BOD_5, COD, total nitrogen and total phosphorus will keep their present levels. A new thermal power plant will be constructed at Altamira Industrial Port in the near future. Discharge volumes and concentrations of BOD_5, COD, total nitrogen and total phosphorus from the old thermal power plant will keep their present levels, while the new one will discharge the same volume and pollution loads in 2010. There is no information on whether new factories will be constructed in Altamira Industrial Port by 2010.

b) Conejo Lagoon

There are some industries whose wastewater quality exceeds the maximum permissible limit for contaminants in wastewater discharged into Conejo Lagoon (BOD_5: 75 mg/l, total nitrogen: 40 mg/l, total phosphorus: 20 mg/l, total suspended solids: 75 mg/l). These industries are assumed to reduce contaminants to 70% of the maximum permissible limit by 2007.

It is presumed that the discharge volume from industries around Conejo Lagoon will increase at an annual growth rate of 4%, and that concentrations of BOD_5, COD, total nitrogen and total phosphorus will keep their present levels.

c) Panuco River

- Seafood Processing Industries

The future projection of fishery indicates that the fishery production except aquaculture will not increase at least until 2010. Therefore, the volume and quality of water discharged by the seafood processing industry is presumed to stay at the present level.

- Refineria Madero

The wastewater from Siete y Media drainage exceeds the maximum permissible limit of total suspended solids and grease and oil. The wastewater from Varadero drainage exceeds the maximum permissible limit of BOD_5, total nitrogen, total suspended solids and grease and oil. It is supposed that BOD_5 and total nitrogen will be reduced at least 70% of the maximum permissible limit (52.5 mg/l for BOD_5 and 28 mg/l for total nitrogen) by 2010.

d) Coastal Area of Gulf of Mexico

The wastewater from Novaquim exceeds the maximum permissible limit of BOD_5 and total suspended solids. Novaquim has a wastewater treatment facility; but since it uses a manual method, reducing the level of BOD_5 is difficult. It is assumed that Novaquim will install a new wastewater treatment facility to reduce BOD_5 to 52.5 mg/l.

The wastewater from Negromex exceeds the maximum permissible limit of BOD_5. It is assumed that Negromex will reduce BOD_5 to 52.5 mg/l.

The wastewater discharge from the factories into coastal area of the Gulf of Mexico will increase at annual growth rate of 4%.

(3) Non-point Sources

Increase of population will induce the conversion of land use from pasture/crop land to low density residential area. In Pueblo Viejo Municipality and Altamira Municipality, a low density residential area will expand in proportion to the increase of population. There is no information on the expansion of Altamira Industrial Port until 2010. Therefore, the change in land use accompanied by the expansion of Altamira Industrial Port was not considered. Area of future land use is shown in Table 2.23.

Table 2.23 Non-point Pollution Source and its Area in 2010

unit: ha

Land Use Category	Pollution Source Number									
	A/3/4	B/1/7	C/2/1	C/3/1	C/4/6	C/4/7	C/5/5, C/8/3	C/6	C/7/1	C/9
Low density residential	80	-	70	150	-	510	1278	165	366	106
Medium density residential	-	-	-	-	-	-	267	-	-	-
Commercial	-	-	-	-	-	-	106	-	-	-
Industrial	240	80	-	-	50	-	304	120	-	-
Recreation/open	-	-	-	-	50	-	126	-	-	-
Crop-land/pasture	6520	260	3990	-	-	-	-	565	94044	2114
Lakes and stream	-	-	300	-	-	-	80	-	-	60
Wetland	-	-	1700	-	-	-	-	25	4160	370
Total	6840	340	6060	150	100	510	2161	865	98570	2650

2.5.2 Methods of Future Pollution Load Analysis

Pollution load was analyzed separately for point pollution sources and non-point pollution sources, same as in section 2.4.1.

(1) Point Pollution Sources

Point pollution sources were separately analyzed for industrial wastewater and municipal wastewater. Daily discharge volume and daily pollution loads from Panuco River upstream and Tamesi River are supposed to remain at their present levels.

a) Industrial Wastewater

The present structure of chemical/petrochemical industry in Tampico Area will not change in the near future. Therefore, the future pollutant composition of industrial wastewater is presumed to be same as the present. Future pollution loads from industrial wastewater were analyzed by the same method as existing point pollution load analysis. It is supposed that daily discharge volume will increase in proportion to annual growth rate of 4%. It is assumed that the concentrations of pollutants in the industrial wastewater will keep their present levels if the current concentration of any parameter is within 70% of the maximum permissible limit of discharge. If the current concentration of a parameter exceeds 70% of its maximum permissible limit, the concentration is presumed to be reduced to 70% of the maximum permissible limit with an appropriate treatment.

b) Municipal Wastewater

The future pollution load of municipal wastewater was analyzed in the following process.

First, daily discharge volume per capita, daily pollution loads per capita, population, and coverage of drainage system at present were estimated.

Second, annual growth rate of daily discharge volume per capita, daily pollution loads per capita, and population were estimated.

Third, daily discharge volume per capita, daily pollution loads per capita, population, and coverage of drainage system in 2010 were estimated.

Fourth, daily discharge volume of municipal wastewater and daily pollution loads from municipal wastewater were calculated.

Fifth, if there will be wastewater treatment facilities, the daily pollution loads from the treated wastewater were calculated.

(2) Non-point Pollution Sources

Future pollution loads from non-point pollution sources were estimated with the same method as existing non-point pollution loads (see section 2.4.2 (2)).

2.5.3 Future Pollution Load Units

(1) Point Pollution Source

a) Altamira Industrial Port

Table 2.24 shows the estimated daily discharge volume and concentration of pollutants into Altamira Industrial Port Area.

Table 2.24 Daily Discharge Volume and Concentration of Pollutants into Altamira Industrial Port in 2010

Pollution Source Number	Point Pollution Source	Discharge Volume m^3/day	BOD_5 mg/l	COD mg/l	Total Nitrogen mg/l	Total Phosphorus mg/l
A/1, S	Administracion Portuaria Integral del Altamira	128	28.0	117.6	-	-
A/2, I	Pittsburgh Plate Glass (PPG) Industry	5,013	1.2	17.0	-	-
A/3/1, I	POLYCYD	1,727	17.8	39.5	2.1	0.7
A/3/2, I	Comision Federal De Electricidad	4,771	5.2	81	0.5	1.5
A/3/3, I	NEGROMEX (Planta Solucion)	759	14.8	41.4	0.7	2.7
A/4, I	New thermal plant (Comision Federal de Electricidad)	4,771	5.2	81	0.5	1.5

b) Conejo Lagoon (B/1) and Marismas Lagoon (B)

Grupo Primex, Internacional de Papeles del Golfo, Fibras Nacionales de Acrilico and Tecno Asfalto del Golfo shall reduce the concentration of BOD_5 to 52.5 mg/l (70% of maximum permissible level). Table 2.25 shows the estimated daily discharge volume and concentration of pollutants into the Conejo Lagoon.

Table 2.25 Daily Discharge Volume and Concentration of Pollutants into Conejo Lagoon in 2010

Pollution source number	Point pollution sources	Discharge Volume m^3/day	BOD_5 mg/l	COD mg/l	Total Nitrogen mg/l	Total Phosphorus mg/l
B/1/1, I	BASF Mexicano	1,195	34.0	153	21.0	0.864
B/1/2, I	Grupo Primex	5,975	52.5	98.4	0.30	0.047
B/1/3, I	Internacional de Papeles del Golfo	493	52.5	122	-	-
B/1/4, I	Fibras Nacionales de Acrilico	3,973	52.5	102	14.4	1.23
B/1/5, I	GE Plastic	1,277	8.9	46.4	-	-
B/1/6(1), I	Operadora y Comercializadora Trevi Plus	-	0.8	36.1	-	-
B/1/6(2), I	Johns Manville Industry	12.60	26.4	197	-	-
B/1/6(3), I	Tecno Asfalto del Golfo	1.38	52.5	110	-	-
B/1/6(4), I	Asfaltos y Derivados Mexicanos	2.00	4.2	30.0	-	-

c) Panuco River Upstream (C/1)

The estimations of average discharge volume and concentration of pollutants in the upstream end of Panuco River are shown in Table B.31.

d) Tamesi River and freshwater lagoons (C/2)

The estimations of average discharge volume and concentration of pollutants from Tamesi River and freshwater lagoon are shown in Table B.32.

e) Seafood Processing Industries (C/3/1)

The fishery production except aquaculture will not increase at least until 2010. Therefore, the discharge volume and water quality of wastewater from seafood processing industries are supposed to keep their present levels. The estimations of discharge volume and concentration are the same as shown in Table 2.12.

f) Municipal Wastewater from Tampico City, Madero City and Miramar (Altamira Municipality (C/5/5 and C/8/3)

It is difficult to identify the respective proportion of wastewater discharge from the cities of Tampico and Madero and by Miramar. Part of the wastewater from the northern part of Tampico City and Madero City and from Miramar is discharged into Tieranegra oxidation pond. The rest of municipal wastewater from the cities of Tampico and Madero is discharged into Panuco River without treatment. If a new wastewater treatment facility is constructed in Tieranegra, a part of municipal wastewater, which is currently discharged into Panuco River, will be sent to Tieranegra. Other portions of wastewater will continue to be discharged into Panuco River.

Projected daily discharge volume and average concentration of pollutants of municipal wastewater from Tampico, Madero and Miramar in 2010 are shown in Table 2.26. Perr capita volume and annual changes of pollution load of municipal wastewater from this region are shown in Table B.85 and B86 of Appendix B.

Table 2.26 Daily Discharge Volume and Average Concentration of Pollutants of Municipal Wastewater from Tampico City, Madero City and Miramar in 2010

Item	Unit	Tampico City and Madero City	Miramar
Daily discharge volume	m^3/day	182,164	18,124
BOD_5	mg/l	225	223
COD	mg/l	348	410
Total nitrogen	mg/l	60.2	38
Total phosphorus	mg/l	7.56	4.52

g) Cuauhtemoc Oxidation Pond (C/7/2, M)

In Pueblo Viejo Municipality, drainage and wastewater treatment systems will be installed only in Cuauhtemoc area. The other areas will continue to use septic tanks and latrines, and living conditions will be further deteriorated.

In order to estimate the quality and quantity of municipal wastewater from Pueblo Viejo Municipality in 2010, population, daily discharge volume per capita, daily pollution loads per capita and growth rate of these parameters are projected in Table B.88 in Appendix B:

- Population in 1999 is 52,820 and its average annual growth rate is 1.4%;
- Daily discharge volume per capita in 1999 is 150 l/capita/day and its annual growth rate is 3%.
- Daily BOD_5 load per capita is 45 g/capita/day, daily COD load per capita is 82 g/capita/day, daily total nitrogen load per capita is 7.6 g/capita/day and daily total phosphorus load per capita is 0.91 g/capita/day in 1999. Annual growth rate is 1.5%.

h) Refineria Madero (C/10, I)

The daily wastewater volume will increase from 534 m^3/day to 889 m^3/day for Siete y Media, and from 5468 m^3/day to 9104 m^3/day for Vanadero with the increment of production (annual growth rate 4%). BOD_5 and total nitrogen of wastewater from Vanadero drainage exceeds their maximum permissible limit (75 mg/l for BOD_5 and 15 mg/l for total nitrogen). Estimated figures in 2010 are shown in Table 2.27.

Table 2.27 Daily Discharge Volume and Concentration of Pollutants in Wastewater from Rifeneria Madero in 2010

Parameter	Unit	Siete y Media	Vanadero
BOD_5	mg/l	43.1	18.4
COD	mg/l	599	201
Total Nitrogen	mg/l	10.5	10.5
Total Phosphorus	mg/l	0.81	0.19
Daily Discharge Volume	m^3/day	1,556	9,104

i) Industrial wastewater by Quimica del Mar (C/11, I)

This factory is supposed to be closed by 2010.

j) Industrial wastewater flows into the Gulf of Mexico

The daily discharge volume and concentration of pollutants by the factories in 2010 are shown in Table 2.28.

Table 2.28 Pollution Load Units from Industries which Discharge Wastewater into Coastal Water in 2010

Pollution Source Number	Point Pollution Source	Flow rate m^3/day	BOD_5 mg/l	COD mg/l	Total N mg/l	Total P mg/l
D	Petrocel	13,800	35.8	82	0.5	-
E	Novaquim	580	52.5	99	10.0	-
F(1)	Negromex (Emulcion)	4,590	52.5	405	17.9	-
F(2)	NHUMO	1,130	51.0	100	3.0	-
G	Dupont	10,700	21.0	-	-	-

(2) Non-point Pollution Sources

The pollution loading rates are shown in Table 2.17.

2.5.4 Pollution Load Analysis by Each Pollution Source

(1) Point Pollution Sources

Table 2.29 shows the daily discharge volume and daily pollution loads from each point pollution source of municipal and industrial wastewater in 2010.

The daily discharge volume and daily pollution loads from the upstream end of Panuco River and Tamesi River are shown in Table 2.30 (in dry season) and in Table 2.31 (in rainy season).

Table 2.29 Daily Discharge Volume, Concentration and Daily Pollution Load of Pollutants in Industrial and Municipal Wastewater in Future (2010)

Pollution Source Number	Daily discharge volume (m^3/day)	BOD_5 Average Conc. (mg/l)	BOD_5 Pollution load (kg/day)	COD Average conc. (mg/l)	COD Pollution load (kg/day)	Total nitrogen Average conc. (mg/l)	Total nitrogen Pollution Load (kg/day)	Total phosphorus Average conc. (mg/l)	Total phosphorus Pollution load (kg/day)
A/1	128	28.0	3.58	118	15.1	-	-	-	-
A/2	5,010	1.2	6.0	17.0	85.2	-	-	-	-
A/3/1	1,730	17.8	30.8	39.5	68.2	2.1	3.68	0.7	1.28
A/3/2	4,770	5.2	25.0	81.0	386	0.5	2.5	1.5	7.09
A/3/3	759	14.8	11.2	41.4	31.4	0.7	0.57	2.7	2.08
A/4*	4,770	5.2	25.0	81.0	386	0.5	2.5	1.5	7.09
B/1/1	1,200	34.0	40.6	153	183	21.0	25.1	0.87	1.03
B/1/2	5,975	52.5	314	98.4	588	0.3	1.79	0.047	0.28
B/1/3	493	52.5	25.9	122	60.1	-	-	-	-
B/1/4	3,973	52.5	209	102	405	14.4	57.2	1.23	4.88
B/1/5	1280	8.9	11.4	46.4	59.3	-	-	-	-
B/1/6(2)	12.6	26.4	0.332	197	2.48	-	-	-	-
B/1/6(3)	1.38	52.5	0.073	110	0.15	-	-	-	-
B/1/6(4)	2.00	4.2	0.01	30.0	0.06	-	-	-	-
C/3/1	250	-	110	-	202	-	-	-	-
C/4/1	13,000	55.4	720	80	1,040	-	-	-	-
(C/4/2-4, C/5/1-4, C/8/1-2)	95,000	-	21,400	-	33,000	-	5,730	-	704
C/10(1)	1,560	43.1	67	599	932	10.5	16.4	0.81	1.17
C/10(2)	9,100	168	545	201	1,830	10.5	95.6	1.73	5.61
D	13,800	35.8	494	82.3	1,136	0.5	6.9	-	-
E	580	52.5	30.5	99	57	10.0	5.8	-	-
F(1)	4,590	52.5	241	405	1,860	17.9	82.2	-	-
F(2)	1,130	51	57.6	100	113	3	3.39	-	-
G	10,700	21	224	-		-		-	-

* A/4: a new thermal power station in Altamira Industrial Port

(2) Non-point Pollution Sources

Daily pollution loads from the following non-point pollution sources are estimated in Tables 2.30 and 2.31 for dry season and rainy season respectively. Details are shown in Tables B.65, B.38, B.66, B.40, B.41, B.42, B.43, B.67, B.68, and B.69.

Table 2.30 Daily Discharge Volume, Concentration of Pollutants and Daily Pollution Load from Rivers and Non-point Pollution Sources in Dry Season in the Future (Year 2010)

Pollution Source Number	Daily Discharge Volume (m^3/day)	BOD_5		COD		Total nitrogen		Total phosphorus	
		Average conc. (mg/l)	Pollution load (kg/day)	Average conc. (mg/l)	Pollution Load (kg/day)	Average conc. (mg/l)	Pollution Load (kg/day)	Average conc. (mg/l)	Pollution load (kg/day)
A/3/4	-	-	27.3	-	69.5	-	11.7	-	1.79
B/1/7	-	-	4.36	-	8.95	-	1.07	-	0.18
C/1	16,000,000	1.81	29,000	20.7	332,000	0.788	12,600	0.090	1,440
C/2	1,200,000	1.90	2,280	15.3	18,300	0.905	967	0.075	89
C/2/1	-	-	22.6	-	67.1	-	10.9	-	1.43
C/3	-	-	1.18	-	2.24	-	0.421	-	0.054
C/4/6	-	-	4.00	-	7.61	-	1.43	-	0.18
C/4/7	-	-	2.42	-	4.59	-	0.503	-	0.078
C/5/5 and C/8/3	-	-	36.5	-	69.7	-	9.13	-	1.33
C/6	-	-	7.98	-	17	-	2.25	-	0.35
C/7/1	-	-	134	-	400	-	74.4	-	10.8
C/9	-	-	8.14	-	24	-	4.2	-	0.58

Table 2.31 Daily Discharge Volume, Concentration of Pollutants and Daily Pollution Loads from Rivers and Non-point Pollution Sources in Rainy Season in the Future (Year 2010)

Pollution Source Number	Daily Discharge Volume (m^3/day)	BOD_5		COD		Total nitrogen		Total phosphorus	
		Average conc. (mg/l)	Pollution Load (kg/day)	Average conc. (mg/l)	Pollution Load (kg/day)	Average conc. (mg/l)	Pollution Load (kg/day)	Average conc. (mg/l)	Pollution load (kg/day)
A/3/4	-	-	142	-	359	-	61	-	9.4
B/1/7	-	-	22.7	-	47	-	5.59	-	0.92
C/1	66,600,000	1.02	68,000	24.7	1,645,000	1.036	17,500	0.149	9,930
C/2	3,630,000	1.18	4,260	16.4	59,300	0.62	2,250	0.073	265
C/2/1	-	-	118	-	350	-	56.9	-	7.4
C/3	-	-	6.14	-	11.7	-	2.19	-	0.28
C/4/6	-	-	20.9	-	39.7	-	7.46	-	0.96
C/4/7	-	-	12.6	-	23.9	-	2.62	-	0.41
C/5/5 and C/8/3	-	-	190	-	364	-	47.6	-	6.92
C/6	-	-	44.2	-	93	-	12.5	-	1.93
C/7/1	-	-	745	-	2,220	-	412	-	60
C/9	-	-	45.1	-	131	-	23.3	-	3.21

(3) Total Amount of Pollution Load

a) Altamira Industrial Port Area (A)

Discharge volume, pollution loads of COD, BOD_5, total nitrogen, and total phosphorus from pollution sources into Altamira Industrial Port are shown in Figures B.11, B.12, B.13, B.14 and B.15, respectively. Figure 2.14 shows an outline for daily pollution loads from the area.

- Discharge volume

If only one thermal power plant were to be newly constructed in Altamira Industrial Port Area, discharge volume in 2010 is estimated to double. Two thermal power plants are estimated to discharge 9540 m^3/day of wastewater (56% of total daily discharge volume from all the point pollution sources). Pittsburgh Plate Glass Industry is estimated to discharge about 5000 m^3/day (29% of total discharge volume from point pollution sources).

- COD

If it is supposed that only one new thermal power plant would be constructed in Altamira Industrial Port, and it is estimated that 470 kg/day will be added to the daily COD load between 1999 and 2010. Daily pollution load of COD from point pollution sources will be 93% in dry season and 73 % in rainy season, or 84% in a whole year. Major source of COD in Altamira Industrial Port will be two thermal power plants (74% in dry season and 58% in rainy season, or 66% in a whole year).

- BOD_5

About 46 kg/day will be added to the daily BOD_5 load during from 1999 to 2010. Daily pollution load of BOD_5 from point pollution sources will be 78% of the total daily load of BOD_5 in dry season and 42% in rainy season, or 57% in a whole year. Major sources of BOD_5 will be Polycyd and two thermal power plants.

- Total nitrogen

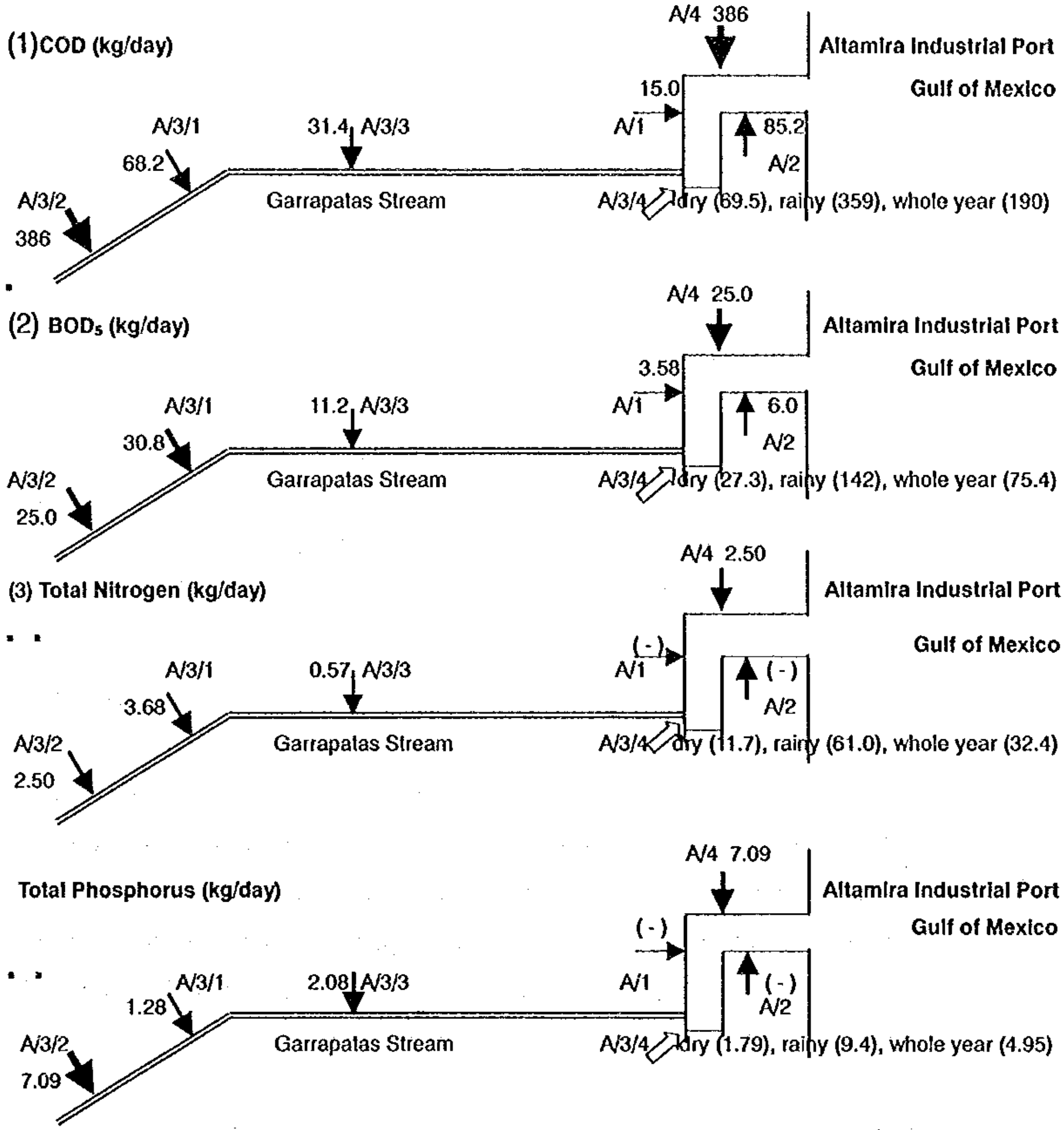
About 4.2 kg/day will be added to the daily total nitrogen load from 1999 to 2010. Daily pollution load of total nitrogen from point pollution sources will be 44% in dry season and 13% in rainy season, or 22% in a whole year, if the pollution load of total nitrogen from PPG Industry is not considered. Major sources of nitrogen are non-point pollution sources.

- Total phosphorus

About 8.4 kg/day will be added to the daily total phosphorus load from 1999 to 2010. Major source of total phosphorus will be two thermal power plants and non-point sources

Table 2.32 Average Daily Discharge Volume and Daily Pollution Loads from Chemical and Petrochemical Industries in Tampico Area in 2010

Chemical and Petrochemical Industries	Daily Discharge Volume (m^3/day)	BOD_5 (kg/day)	COD (kg/day)	Total nitrogen (kg/day)	Total phosphorus (kg/day)
PPG	5,013	6	85.2	-	-
POLYCYD	1,727	30.8	68.2	3.68	1.28
Negromex	759	11.2	31.4	0.57	2.08
BASF	1,195	40.6	183	25.1	1.03
Grupo Primex	5,975	314	1088	5.92	0.96
Finacril	3,973	209	509	77.5	13.2
GE plastic	1,277	11.4	59.3	-	-
Refineria Madero	4,997	258	4136	52.5	4.82
Petrocel	13,800	494	1136	6.9	-
Novaquim	580	30.5	104	17.9	-
Negromex	4,590	241	2171	98.7	-
NHUMO	1,130	57.6	113	3.39	-
Dupont	10,700	224	-	-	-
Average	4,286	148	807	29.2	3.90
Concentration	(mg/l)	34.6	188	6.82	0.91



A/1: Administracion Portuaria Integral del Altamira
A/2: Pittsburgh Plate Glass (PPG) Industry
A/3/1: Polycyd
A/3/2: Thermal Power Plant (Comision Federal Electricidad)
A/3/3: Negromex (Planta Solucion)
A/3/4: Non-point sources of Watershed of Garrapatas Stream
A/4: New Thermal Power Plant

Legend
→ : Point Pollution Source
⇨ : Non-point Pollution Source

Figure 2. 14 Pollution Loads into Altamira Industrial Port in 2010

b) Conejo Lagoon (B/1)

Daily discharge volume, daily pollution loads of COD, BOD_5, total nitrogen, and total phosphorus from pollution sources into Conejo Lagoon in 2010 are shown in Figures B.16, B.17, B.18, B.19 and B.20, respectively. Figure 2.15 shows an outline for daily pollution loads in this area.

- Discharge volume

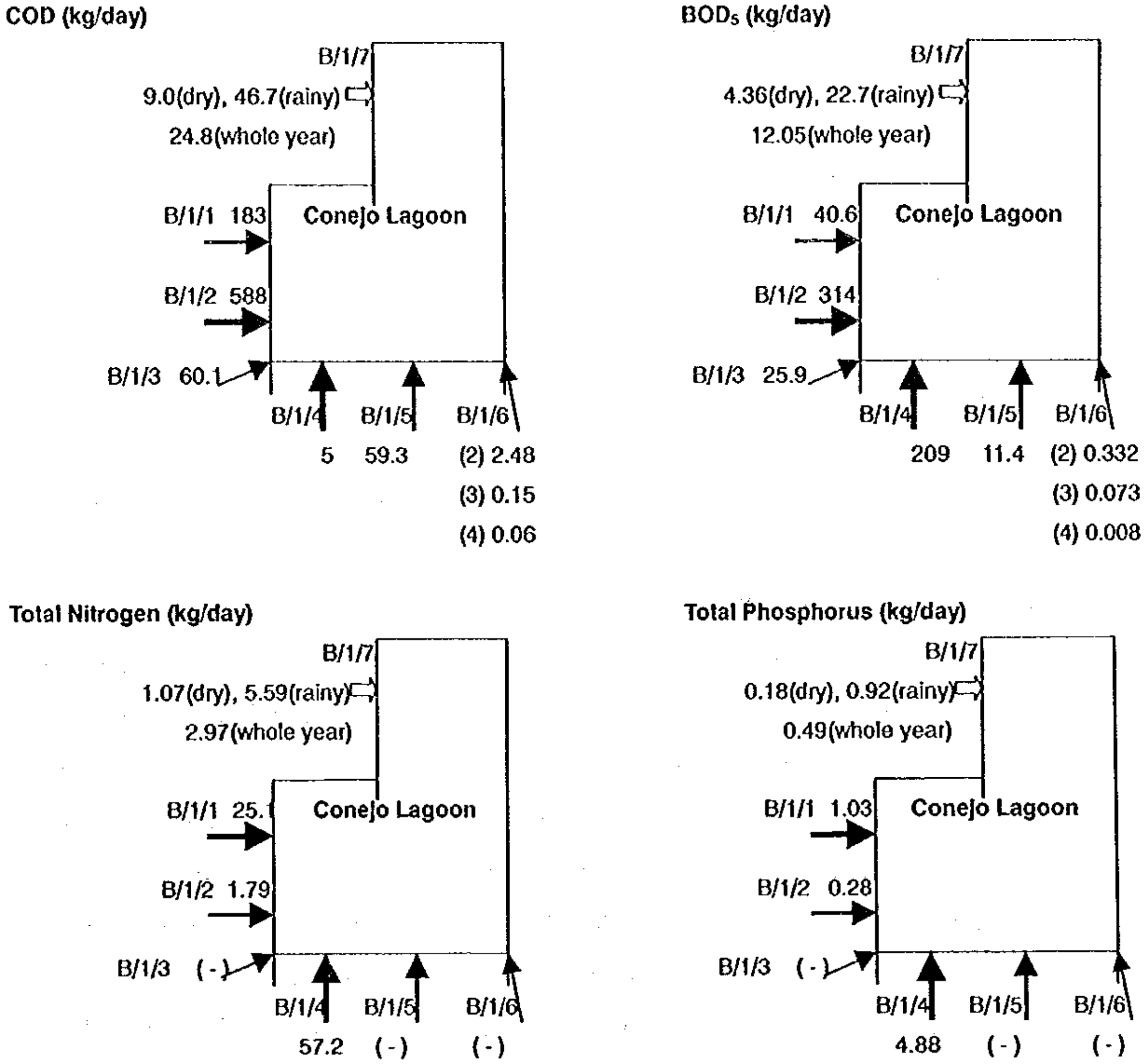
No information has been obtained on the discharge volume from the watershed to Conejo Lagoon. Daily discharge volume from point pollution sources into Conejo Lagoon is shown in Figure B.16. Total daily discharge volume will increase by 67% from 1997/98 to 2010. The major sources are Grupo Primex (46%) and Fibras Nacionales de Acrilico (31%). Total discharge volume from point pollution sources to Conejo Lagoon (12,929 m^3/day) is lower than that to Altamira Industrial Port (17,169 m^3/day). Discharge volume from Small and Medium Sized Industrial Estate (B/1/6) is much less than that of large industries near Conejo Lagoon.

- COD

Total daily pollution load of COD in 2010 will be reduced to 33% of that in 1997/98, because BOD_5 level should be less than maximum permissible limit of BOD_5 (NOM-001-ECOL-1996) and COD will be reduced with treatment for BOD_5. Daily pollution load of COD from point pollution sources is 99.3% of total pollution load in dry season and 96.5% in rainy season, or 98.1% in a whole year. The major source is Grupo Primex (about 43 – 45%). Total daily pollution load of COD from point pollution sources to Conejo Lagoon (1298 kg/day) is larger than that from point pollution sources to Altamira Industrial Port (972 kg/day).

- BOD_5

Total daily pollution load of BOD_5 in 2010 will be reduced to 29% of that in 1997/98, because BOD_5 level should be less than maximum permissible limit of BOD_5 (NOM-001-ECOL-1996). Daily pollution load of BOD_5 from point pollution sources is more than 96 - 99% of total pollution load. A major source is Grupo Primex (about 51%). Total daily pollution load of BOD_5 from point pollution sources to Conejo Lagoon (601 kg/day) is still much larger than that from point pollution sources to Altamira Industrial Port (101 kg/day).



B/1/1: BASF B/1/2: Grupo Primex B/1/3: International de Papeles del Golfo
B/1/4: Fibras Nacionales de Acrilico B/1/5: GE Plastic
B/1/6(1): Operadora y Comercializadora Trevi Plus
B/1/6(2): Johns Manville Industry B/1/6(3): Tecno Asfalto del Golfo
B/1/6(4): Asaltos y Derivados Mexicanos

Legend
→ : Point Pollution Source
⇨ : Non-point Pollution Source

Figure 2.15 Daily Pollution Loads into Conejo Lagoon in 2010

- Total nitrogen

Total daily pollution load of total nitrogen in 2010 will increase to about 116% of that in 1997/98. Daily pollution load of total nitrogen from point pollution sources may be lager than 94% of total daily load. The major source is Fibras Nacionales de Acrilico (about 70% of total load).

- Total phosphorus

Total daily pollution load of total phosphorus in 2010 will be reduced to about 62% of that in 1997/98. Pollution load from point pollution sources is from 83 to 93%. A major source is Fibras Nacionales de Acrilico.

c) Panuco River

Daily discharge volume, pollution loads of COD, BOD_5, total nitrogen, and total phosphorus from pollution sources into Panuco River in dry season, in rainy season, and in a whole year in 2010 are shown in Tables B.70, B.73, and B.76, respectively. Percentage of daily pollution loads from pollution sources in dry season, in rainy season, and in a whole year are shown in Table B.71, B.74, and B.77, respectively. Here, daily pollution loads from Costa Lagoon, Pueblo Viejo Lagoon, and Chijol Channel to Panuco River are not considered, because their pollution load is much smaller than total pollution loads into Panuco River and tide effect makes the distribution of pollution load complex. Furthermore, it is supposed that 1.2 m^3/s of wastewater from Tampico City, Madero City, and Miramar would be treated in the new Tieranegra wastewater treatment facility. Treated wastewater is supposed to be reused in chemical industries or be discharged into one of the lagoons in Marismas.

- Discharge volume

Rivers (upstream end of Panuco River and Tamesi River) will discharge more than 99.4% in total discharge volume. Municipal wastewater of Tampico and Madero will account for 0.55% of total discharge volume in dry season and 0.14% in rainy season, or 0.24% in a whole year. Altavista Water Supply Plant will discharge 0.075% in dry season and 0.018% in rainy season, or 0.033% in a whole year.

- COD

The percentages of pollution loads of COD from major pollution sources are illustrated in Figure 2.16 (1) (in dry season), 6.16 (2) (in rainy season), and 6.16 (3) (in a whole year). Pollution loads of COD from the upstream end of Panuco River will be 85.8% in dry season and 94.5% in rainy season, or 92.4% in a whole year. Municipal wastewater of Tampico and Madero will account for 8.5% of total COD load in dry season and 1.9% in rainy season, or 3.5% in a whole year. Tamesi River will discharge 4.7% in dry season and 3.4% in rainy season, or 3.7% in a whole year. Pollution load of COD from Refineria Madero is 0.61% in dry season and 0.14% in rainy season, or 0.25% in a whole year. Pollution load of COD from non-point pollution sources will be 0.03% as shown in Tables B.72, B.75, and B.78. Pollution load of COD from point pollution sources into Panuco River will be 28 times larger than that into Conejo Lagoon.

As municipal wastewater from Tampico City and Madero City in 2010 will have lower concentrations of COD than that in 1998, the COD load will be reduced to 75% of COD level in 1997/98. Refineria Madero will also reduce COD to 53% of that in 1997/98, because of a new wastewater treatment plant.

- BOD_5

The percentage of pollution loads of BOD_5 from major pollution sources are illustrated in Figure 2.16 (1) (in dry season), 6.16 (2) (in rainy season), and 6.16 (3) (in a whole year). Pollution load of BOD_5 from the upstream end of Panuco River will be 53.9% of total BOD_5 load in dry season and 71.6% in rainy season, or 63.8% in a whole year. Pollution load from municipal wastewater of Tampico and Madero will be 39.8% of total BOD_5 load in dry season and 22.5% in rainy season, or 30.1% in a whole year. Tamesi River will discharge 4.3% of total BOD_5 load in dry season and 4.5% in rainy season, or 4.4% in a whole year. Refineria Madero will discharge 0.38% of total BOD_5 load in dry season and 0.22% in rainy season, or 0.29% in a whole year. Pollution load from non-point pollution sources will be 0.10% in dry season and 0.29% in rainy season, or 0.20% in a whole year as shown in Tables B.72, B.75, and B.78, respectively. Pollution load of BOD_5 from point pollution sources into Panuco River will be 37 times larger than that into Conejo Lagoon.

As municipal wastewater from Tampico City and Madero City in 2010 will have lower concentrations of BOD_5 than that in 1998, the BOD_5 load will be reduced to 79% of BOD_5 level in 1998. Refineria Madero will also reduce BOD_5 to 35% of that in 1997/98, because of a new treatment of wastewater.

- Total nitrogen

The percentages of daily pollution loads of total nitrogen from major pollution sources are illustrated in Figure 2.16 (1) (in dry season), 6.16 (2) (in rainy season), and 6.16 (3) (in a whole year). The upstream end of Panuco River will discharge 64.8% of daily pollution load of total nitrogen in dry season and 68.1% in rainy season, or 66.4% in a whole year. Daily pollution load of total nitrogen from municipal wastewater of Tampico and Madero will be 29.4% of total load of total nitrogen in dry season and 22.3% in rainy season, or 26.4% in a whole year. Tamesi River will discharge 5.0% of total load of total nitrogen in dry season and 8.8% in rainy season, or 6.8% in a whole year. Refineria Madero will discharge 0.54% of total load of total nitrogen in dry season and 0.41% in rainy season, or 0.48% in a whole year. Daily pollution load from non-point pollution sources will be 0.07% in dry season and 0.28% in rainy season, or 0.17% in a whole year as shown in Tables B.72, B.75, and B.78, respectively. Daily pollution load of total nitrogen from point pollution sources into Panuco River is 70 times larger than that into Conejo Lagoon.

As municipal wastewater from Tampico City and Madero City in 2010 will have lower concentrations of total nitrogen than that in 1998, the total nitrogen load will be reduced to 79% of total nitrogen level in 1998. Refineria Madero will also reduce total nitrogen to 33% of that in 1997/98, because of a new treatment of wastewater for reduction of total nitrogen and reuse of treated wastewater.

- Total phosphorus

The percentages of daily pollution loads of total phosphorus from major pollution sources are illustrated in Figure 2.15 (1) (in dry season), 2.15 (2) (in rainy season), and 2.15 (3) (in a whole year). The upstream of Panuco River will discharge 64.2% of total phosphorus in dry season and 91.0% in rainy season, or 85.0% in a whole year. Daily pollution load of total phosphorus from municipal wastewater of Tampico and Madero will be 31.4% of total daily load of total phosphorus in dry season and 6.5% in rainy season, or 12.0% in a whole year. Tamesi River discharges 4.0% of total daily load of total phosphorus in dry season and 2.4% in rainy season, or 2.8% in a whole year. Refineria Madero will discharge 0.11% of total daily load of total phosphorus in dry season and 0.02% in rainy season, or 0.04% in a whole season. Daily pollution load of total phosphorus from non-point pollution sources will be 0.09% in dry season and 0.10% in rainy season, or 0.09% in a whole year as shown in Tables B.72, B.75, and B.78, respectively. Daily pollution load of total phosphorus from point pollution sources into Panuco River will be 115 times larger than that into Conejo Lagoon.

As municipal wastewater from Tampico City and Madero City in 2010 will have lower concentrations of total phosphorus than that in 1998, the total pollution load of total phosphorus will be reduced to 78% of total phosphorus level in 1998. Refineria

Madero will also reduce total phosphorus to 38% of that in 1999, because of a new treatment of wastewater for reduction of BOD_5 and total nitrogen.

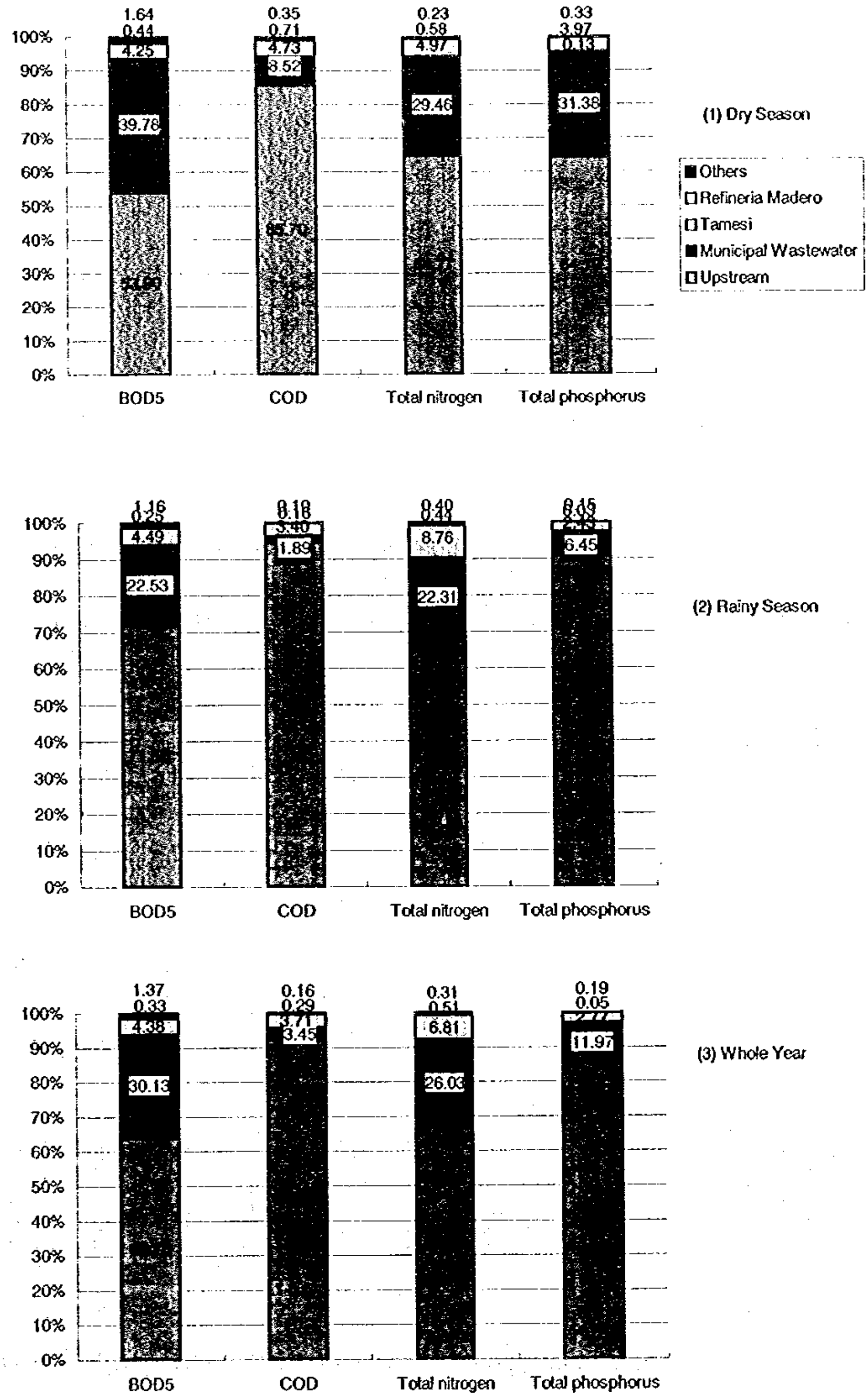


Figure 2.15 Principal Sources oF Pollution Loads into Panuco River

Madero will also reduce total phosphorus to 38% of that in 1999, because of a new treatment of wastewater for reduction of BOD_5 and total nitrogen.

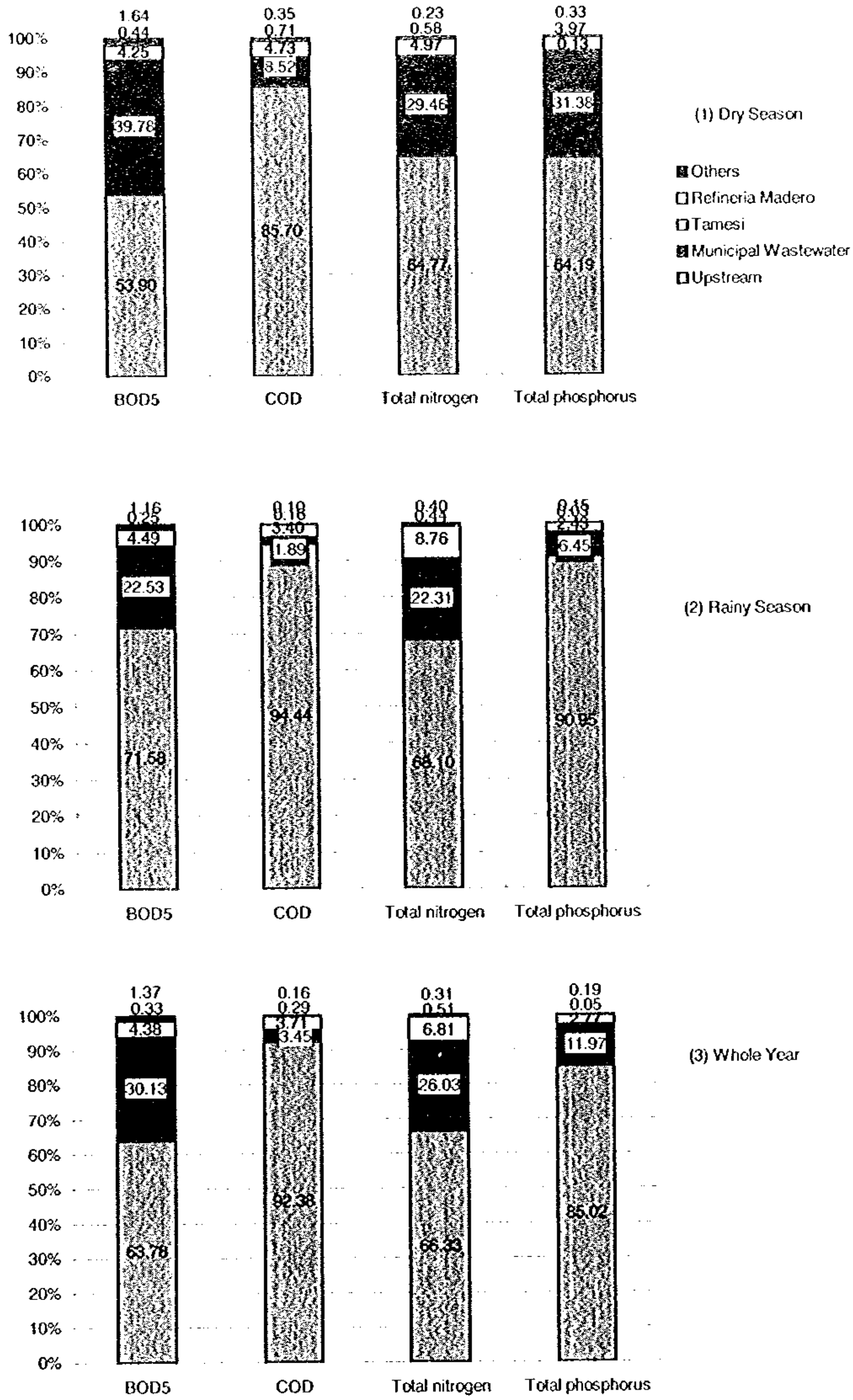


Figure 2.15 Principal Sources oF Pollution Loads into Panuco River

d) Pueblo Viejo Lagoon

Daily pollution loads of COD, BOD_5, total nitrogen, and total phosphorus from pollution sources into Pueblo Viejo Lagoon are shown in Table 2.33. The majority of people in Pueblo Viejo Municipality will still be using septic tanks and latrines in 2010. Some part of wastewater will be discharged into channels, which may reach water areas such as Pueblo Viejo Lagoon, Panuco River and Chijol Channel. However, most of the wastewater will infiltrate into the soil. Pollution load from this type of wastewater and from Panuco River is not considered in Table 2.33. The municipal wastewater only from Cuauhtemoc Area will be drained and treated. If Cuauhtemoc oxidation pond is expanded in order to treat wastewater from Cuauhtemoc area, pollution loads from Cuauhtemoc oxidation pond into Pueblo Viejo Lagoon will be negligible in 2010. Most of pollution loads will come from non-point pollution sources in 2010 excluding from Panuco River.

Table 2.33 Daily Pollution Loads from Point and Non-Point Sources to Pueblo Viejo Lagoon in 2010

Pollution Source Number	Pollution Source	Type	BOD_5		COD		Total Nitrogen		Total Phosphorus	
			(kg/day)	(%)	(kg/day)	(%)	(kg/day)	(%)	(kg/day)	(%)
(Dry Season)										
C/7/2	Cuauhtemoc Oxidation Pond	Point	negligible							
C/7/1	Watershed of Pueblo Viejo Lagoon	Non-point	134	100.0	400	100.0	74.4	100.0	10.77	100.0
	Total		134	100.0	400	100.0	74.4	100.0	10.77	100.0
(Rainy Season)										
C/7/2	Cuauhtemoc Oxidation Pond	Point	negligible							
C/7/1	Watershed of Pueblo Viejo Lagoon	Non-point	745	100.0	2,218	100.0	412	100.0	60	100.0
	Total		745	100.0	2,218	100.0	412	100.0	60	100.0
(A whole Year)										
C/7/2	Cuauhtemoc Oxidation Pond	Point	negligible							
C/7/1	Watershed of Pueblo Viejo Lagoon	Non-point	390	100.0	1,162	100.0	216	100.0	31.4	100.0
	Total		390	100.0	1,162	100.0	216	100.0	31.4	100.0

e) Coastal Area

Daily discharge volume, daily pollution loads of COD, BOD_5, total nitrogen, and total phosphorus from pollution sources into the coastal area of Gulf of Mexico are shown in Tables B.79, B.80 and B.81 for dry season rainy season, and a whole year.

Figure 2.17 shows an outline for daily pollution loads in this area.

- Discharge volume

The majority of discharge volume will be from Panuco River as shown in Tables B.79, B.80, and B.81. Industrial wastewater directly discharged into the coastal area of Gulf of Mexico (from D to G) in 2010 will increase to 174% of that at present.

- COD

Most of daily pollution load of COD is from Panuco River is shown in Figure 2.17 (1). The concentration of COD at the Panuco River mouth is similar to that of its junction with Tamesi River. Daily pollution load of COD from Petrocel (D), Novaquim(E), Negromex (F), NHUMO (F) and Dupont (G) will be much smaller than that from Panuco River. The daily COD load from industrial wastewater directly discharged into the coastal area of Gulf of Mexico (from D to F) in 2010 will increase to 142% of that at present.

- BOD_5

Most of the daily pollution load of BOD_5 is from Panuco River as shown in Figure 2.17 (2). The concentration of BOD_5 in the Panuco River mouth is determined by two factors, the upstream end of Panuco River and the municipal wastewater of Tampico and Madero. Daily pollution loads of BOD_5 from Panuco River will be reduced if the municipal wastewater from Tampico City, Madero City and Miramar will be treated with a new wastewater treatment facility. Daily pollution load of BOD_5 from the wastewater of Petrocel (D), Novaquim(E), Negromex (F), NHUMO (F) and Dupont (G) will be much smaller than that from Panuco River. The BOD_5 load from industrial wastewater directly discharged into the coastal area of Gulf of Mexico (from D to G) in 2010 will increase to 145% of that at present.

- Total nitrogen

Most of the pollution load of total nitrogen is from Panuco River as shown in Figure 2.17 (3). The concentration of total nitrogen in the Panuco River mouth will be determined by two factors: the upstream end of Panuco River and the municipal wastewater of Tampico and Madero. Daily pollution load of total nitrogen from Panuco River will be reduced a little if 1.2 m^3/s of municipal wastewater from Tampico City, Madero City and Miramar will be treated with a new wastewater treatment facility. Daily pollution loads of total nitrogen from the wastewater of Petrocel (D), Novaquim(E), Negromex (F), NHUMO (F) and Dupont (G) will be much smaller than that of Panuco River. The total nitrogen load from industrial wastewater directly discharged into the coastal area of the Gulf of Mexico (from D to F) in 2010 will increase to 117% of that in 1999.

- Total phosphorus

Most of the pollution load of total phosphorus is from Panuco River as shown in Figure 2.17 (4). The wastewater from the upstream of Panuco River and the urban areas of Tampico and Madero will determine the concentration of total phosphorus in the Panuco River mouth. Daily pollution loads of total phosphorus from Panuco River will be reduced a little if 1.2 m^3/s of municipal wastewater from Tampico City, Madero City and Miramar will be treated with a new wastewater treatment facility. Information on pollution load of total phosphorus from Petrocel, Novaquim, Negromex, and NHUMO and Dupont has not been obtained.

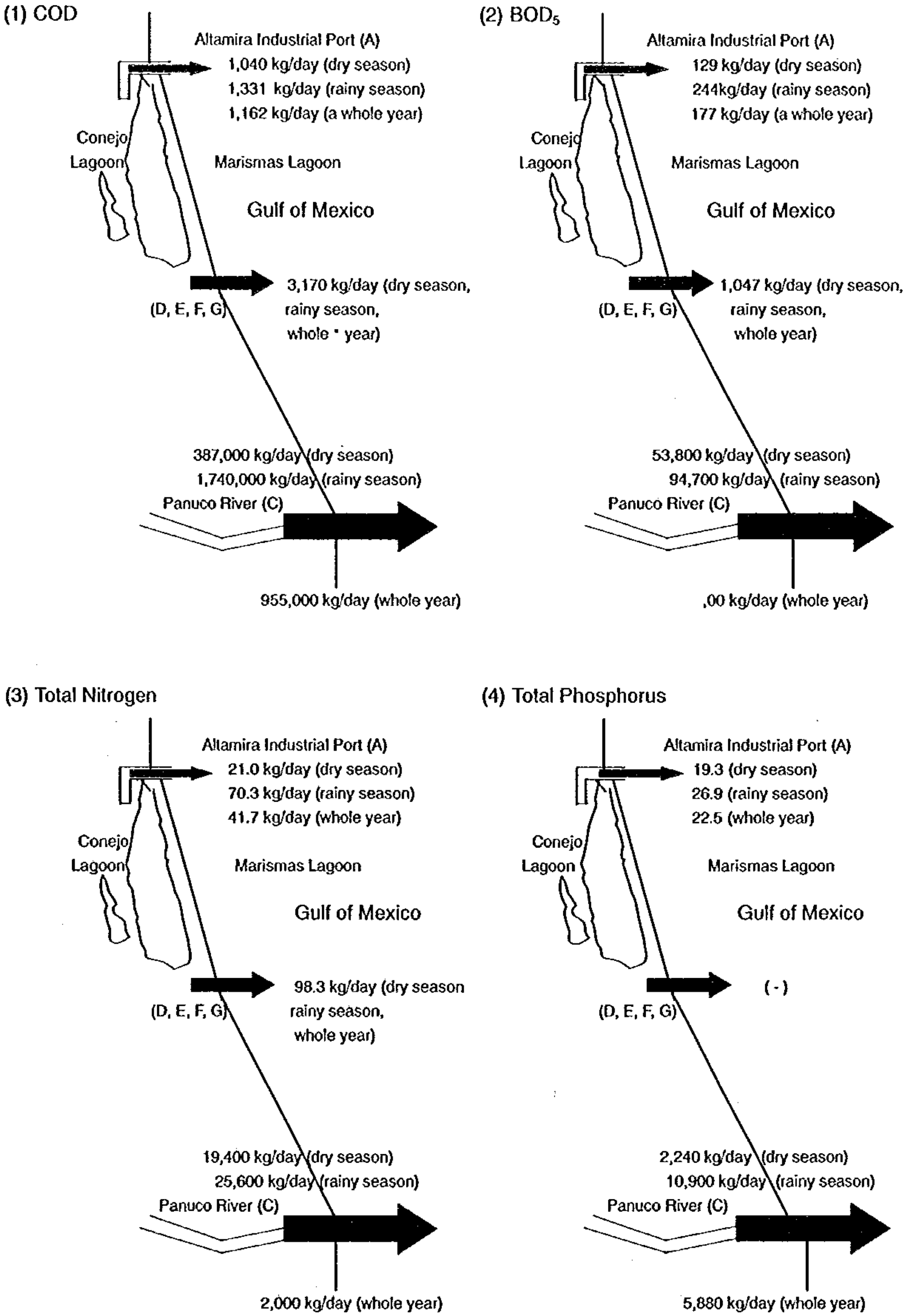


Figure 2.16 Daily Pollution Loads into the Coastal Area of Gulf of Mexico

Chapter 3 Development of Water Quality Simulation Model

3.1 Model Description

3.1.1 Model Classification

The prediction of water quality should be conducted using an appropriate model in accordance with the objectives. Table 3.1 shows a classification of simulation models.

Table 3.1. Classification of Simulation Model

Classification	Example
Analytical solution	• Nitta's formula • Hirano's formula • Okubo-Prichard's solution • Iwai-Inoue's solution
Numerical simulation	• Box model • 1-dimensional model(horizontal) • 1-dimensional model(vertical) • 2-dimensional model(horizontal) • 2-dimensional model(vertical) • 3-dimensional model

The models are roughly classified into two groups of analytical solutions and numerical simulations.

(1) Analytical Solutions

Analytical solutions are empirical formula based on observational data or analytical solutions derived from the fundamental diffusion equations based on the assumptions of simplified situations. Analytical solutions are applicable in simplified situations such as uniform bathymetry and current conditions. Analytical solutions are useful for quick assessment of pollutant diffusion. However, they are not applicable in realistic situations where the coastal line and bathymetry are complex and the water currents are not uniform and are changeable.

(2) Numerical Simulations

In numerical simulations, the hydrodynamic equations and/or the advection-diffusion equations are solved numerically using the finite difference method or the finite element method. The characteristics of numerical simulations are in contrast with analytical solutions. A lot of input data are required to execute a numerical simulation, so that it will take much time to prepare the data and to execute the simulation. In addition, expert skills are required for simulation results to be correctly interpreted. On the other hand, numerical simulations are flexible and widely applicable to any situation.

Horizontal one-dimensional models can be applied to rivers. In non-tidal rivers, it is usual that the flow velocity is large and the water depth is shallow, so that the water is well mixed vertically and the difference of water quality over the vertical is negligible. In rivers, the lateral length is very small as compared with the longitudinal length, thus it is often possible to neglect the lateral dimension. Accordingly, horizontal one-dimensional models can be applied to non-tidal rivers. A simulation model of hydrodynamics and water quality named QUA2EU, which was developed by the Environmental Protection Agency of USA (USEPA), is a typical horizontal one-dimensional model. This model is used to analyze water quality of rivers by the National Water Commission of Mexico (CNA).

Vertical one-dimensional models can be applied to lakes. In lakes and reservoirs, it is often observed that the water quality is uniform in the horizontal and has a distribution only in the vertical direction. In these cases, vertical one-dimensional models are applicable.

In horizontal two-dimensional models, it is possible to have many applications. This model is formulated as a depth-averaged model, which is obtained by integrating vertically the three-dimensional equations. A typical application of the two-dimensional model is the simulation of hydrodynamics and water quality in coastal and/or lagoon water bodies that are relatively shallow. This depth-averaged model is applicable to water bodies where the water is well mixed vertically, so that the water quality is relatively uniform in the vertical. There are many applications whereby the depth-averaged two-dimensional models were used for environmental assessments in Japan.

Typical application of a vertical two-dimensional model is for the mouth of river where the vertical circulation of water current is often formed. In this case, the water in the upper layer, which mainly consists of fresh water, flows toward the sea and the water in the lower layer, which mainly consists of dense seawater, flows toward the opposite direction. In this situation, the water quality reflects the flow pattern, namely the water quality in the upper layer has the characteristics of fresh water and the water quality in the lower layer has the characteristics of seawater. Near the mouth of rivers, the lateral dimension is small as compared with the longitudinal dimension. Thus it is often possible to neglect the lateral dimension, however the vertical dimension should be taken into consideration. Accordingly, it is appropriate that vertical two-dimensional models are used for tidal rivers.

Three-dimensional models are the most comprehensive version of simulation models because these models have resolution in the three dimensions, thus there are few constraints in using them. For example, these models are capable of almost correctly taking into consideration important factors in hydrodynamics such as tidal, wind driven and density currents. However, they demand many input parameters, as well as expert skills in order to make use of them effectively.

3.1.2 Model Selection

Taking into account the above mentioned characteristics of each numerical simulation model, it is considered that the horizontal two-dimensional model would be the appropriate model applicable to Pueblo Viejo Lagoon and the coastal water along the Tampico coast.

The two water bodies occupy a horizontally broad area. The water depth of Pueblo Viejo Lagoon is very shallow ranging from 1 to 2 meters in the dry season. The bed slope in the coastal section is considerably gentle, namely a depth contour line of 20 meters running almost parallel to the coast is located nearly 7km offshore from the coast and a depth contour line of 50 meters is located nearly 30km offshore from the coast. In both Pueblo Viejo Lagoon having very shallow water depth and the seacoast area with relatively shallow depth widely open to the broad ocean, the density stratification is expected to have a minor role in determining the characteristics of hydrodynamics and water quality of these water bodies. Therefore the depth-averaged two-dimensional model is considered to be applicable.

One of the objectives of using numerical simulation is to enable the appropriate selection of water quality monitoring points. To meet this objective, it is at least necessary that horizontal distribution of water quality be one of the outputs of simulation. The depth-averaged two-dimensional model meets that requirement.

As mentioned in the previous section, the most comprehensive simulation model is the three-dimensional model, which can be applied in almost any situation. However, high skills are required to use a three-dimensional model, thus it is likely that the use of simulation method in the context of the coastal water quality monitoring program does not come in wide use. In contrary, a package computer program of the depth-averaged two-dimensional model is relatively easy to use. Therefore, it is recommended also, at this point, that the depth-averaged two-dimensional model be used until such time that enough skills are obtained to use model simulations.

3.1.3 MIKE21 ELP

The MIKE21 ELP, which was developed by the Danish Hydraulics Institute (DHI), is one of two-dimensional hydrodynamics and water quality modeling systems. This system has been chosen as a tool to simulate the hydrodynamics and water quality owing to its worldwide usage and relatively low-cost package that includes the following:

- PP : Pre- and Post-processing Module,
- HD : Hydrodynamic Module, and
- AD : Advection-Dispersion Module.

The fundamental equations used in the MIKE21 HD and AD are shown in the main report.

3.2 Setting up Conditions of Hydrodynamic Model

In order to carry out the numerical simulation, we need to set up conditions such as the simulation domain, the grid system, water depth at each grid, boundary conditions, parameters required in the simulation and inflows from river to sea.

3.2.1 Pueblo Viejo Lagoon

(1) Model Area and Model Grid Size

The computational area of Pueblo Viejo Lagoon is shown in Figure 3.1. The original figure was taken from the Ministry of Agriculture and Hydraulic Resources (1981)[1]. Pueblo Viejo Lagoon is a closed water body, thus the entire region will be included in the computational area. The open boundary is located at the connection point between the exit of Pueblo Viejo Lagoon and Panuco River. The maximum grid size that can be used in MIKE21 is limited to less than 500m. A grid size of 300m will be used. The horizontal axis (east-west direction) of the computation area is 12km, thus the horizontal axis is divided into 40 meshes. The vertical axis (north-south direction) of the computation area is about 15km, thus the vertical axis is divided into more than 50meshes. The grid size of 300m is considered adequate to capture the main feature of shoreline and bathymetry of Pueblo Viejo Lagoon.

[1] The Ministry of Agriculture and Hydraulic Resources (1981), Water Quality Analysis and Evaluation for Sanitary Certificate in Exploitation Zones of Marine and Lacustrine Resources (in Spanish).

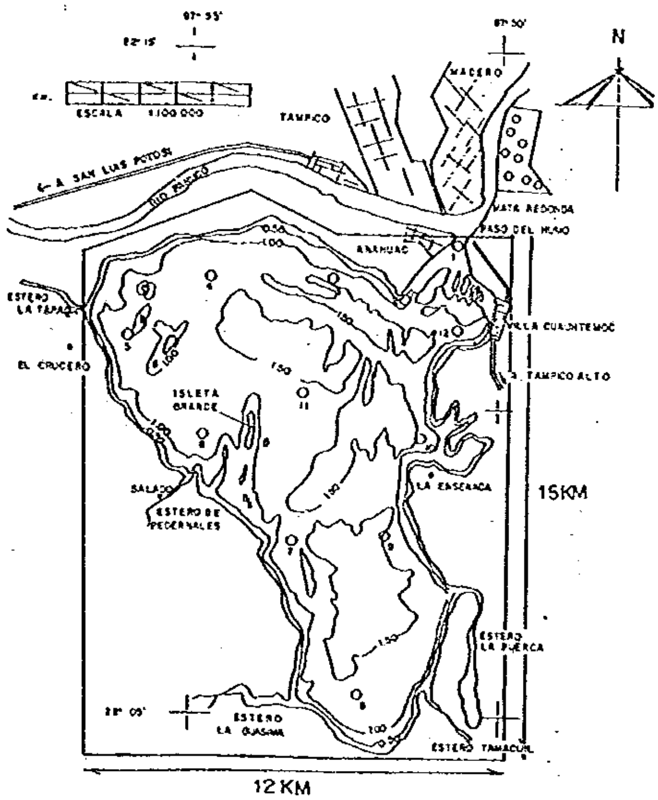


Figure 3.1 Computational Area of Pueblo Viejo Lagoon

Note: The contour lines indicate water depth(m). The original figure was taken from the Ministry of Agriculture and Hydraulic Resources(1981)

(2) Model Bathymetry and Water Depth

The model bathymetry and water depth of Pueblo Viejo Lagoon is shown in Figure 3.2.

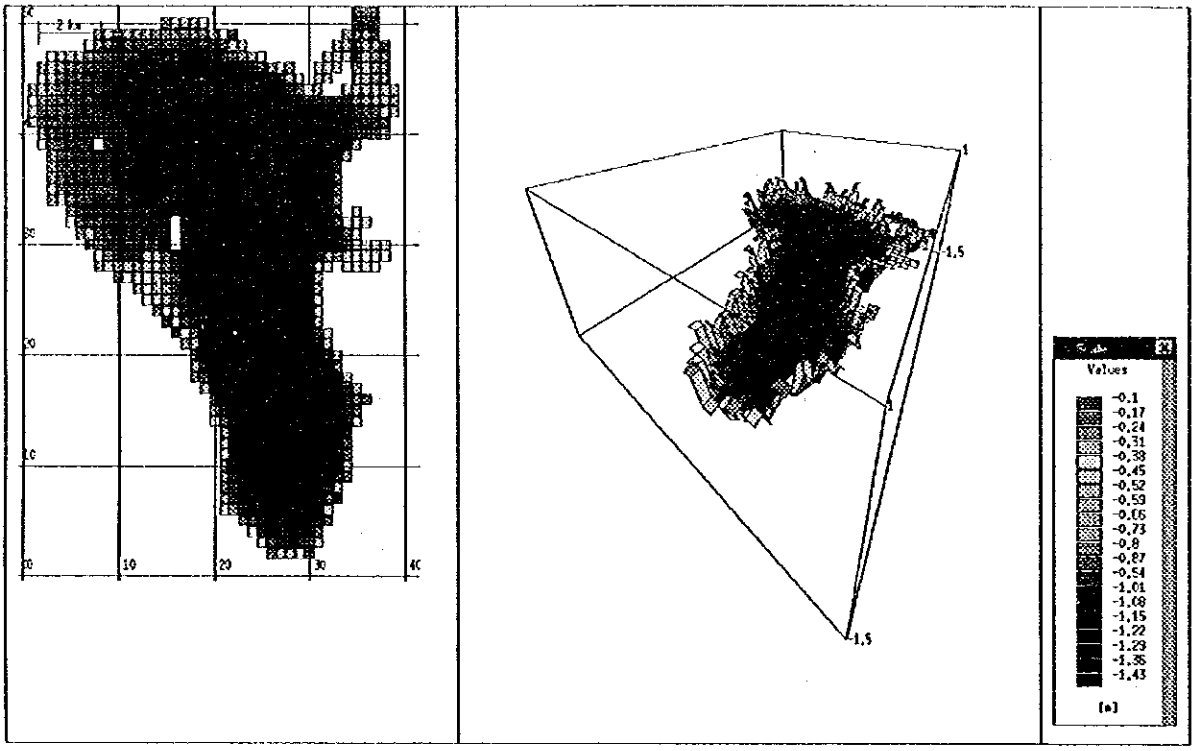


Figure 3.2 Model Bathymetry and Water Depth of Pueblo Viejo Lagoon

(3) Locations of Freshwater Discharges

Figure 3.3 shows the locations of discharge in Pueblo Viejo Lagoon.

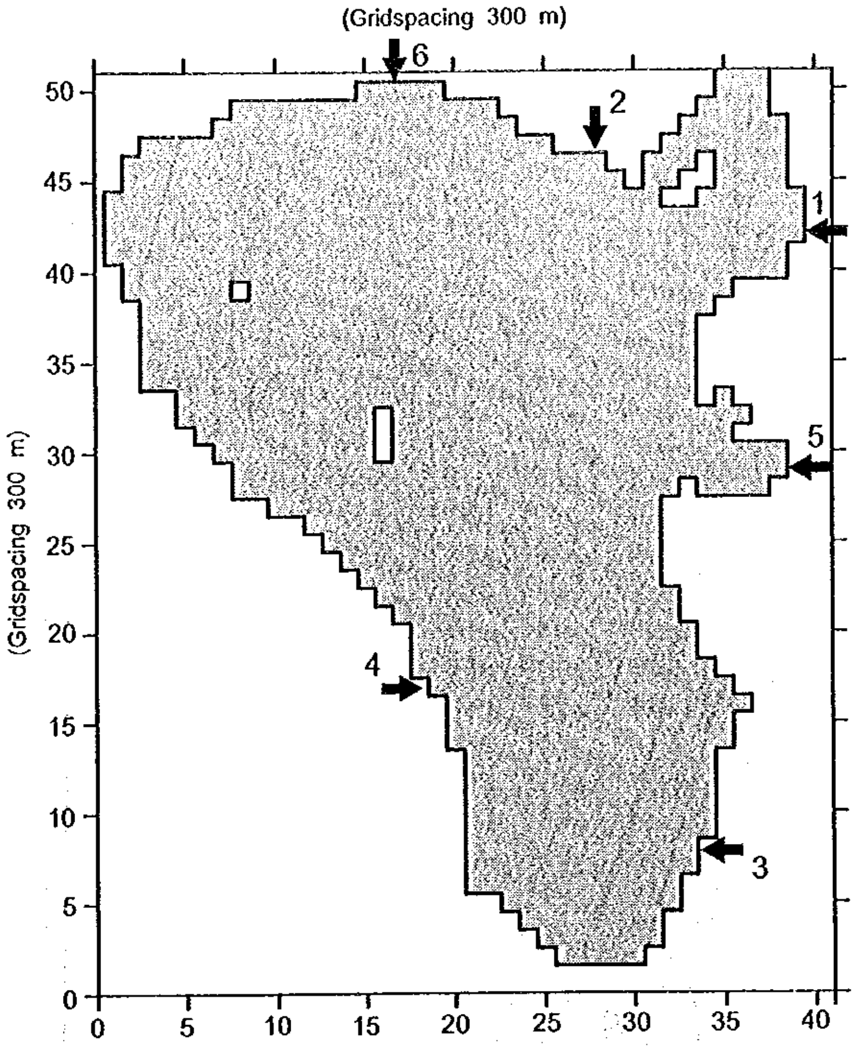


Figure 3.3 Locations of Discharge in Pueblo Viejo Lagoon

3.2.2 Coastal Water

(1) Model Area and Model Grid Size

The computational area of coastal water is shown in Figure3.4. The area is taken parallel to the coastline. The area is 40km along the shore including Panuco River mouth in the south and Altamira port in the north. The offshore extent of the area is 20km from the shore covering a shallow sea area of depth less than 30m. A grid size of 500m will be used. Because the shoreline and bathymetry of the area are relatively simple, the grid size of 500m is considered adequate to represent the topographic feature of the area. The horizontal axis (offshore direction) of the computation area is 20km, thus the horizontal axis is divided into 40 meshes. The vertical axis (along shore direction) of the computation area is about 40km, thus the vertical axis is divided into about 80 meshes.

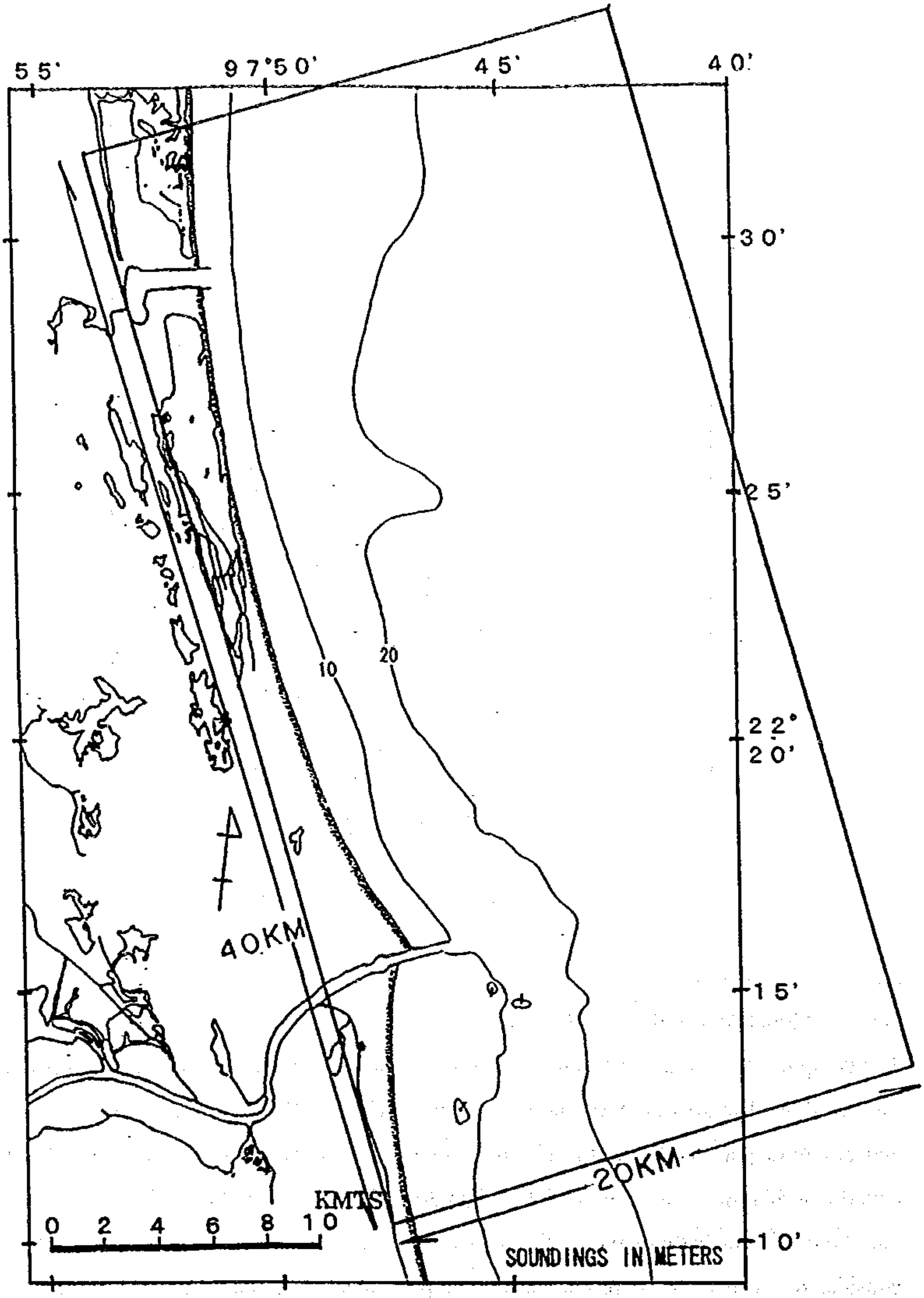


Figure 3.4 Computational Area of Coastal Water

(2) Model Bathymetry and Water Depth

The model bathymetry and water depth of Coastal Water is shown in Figure 3.5.

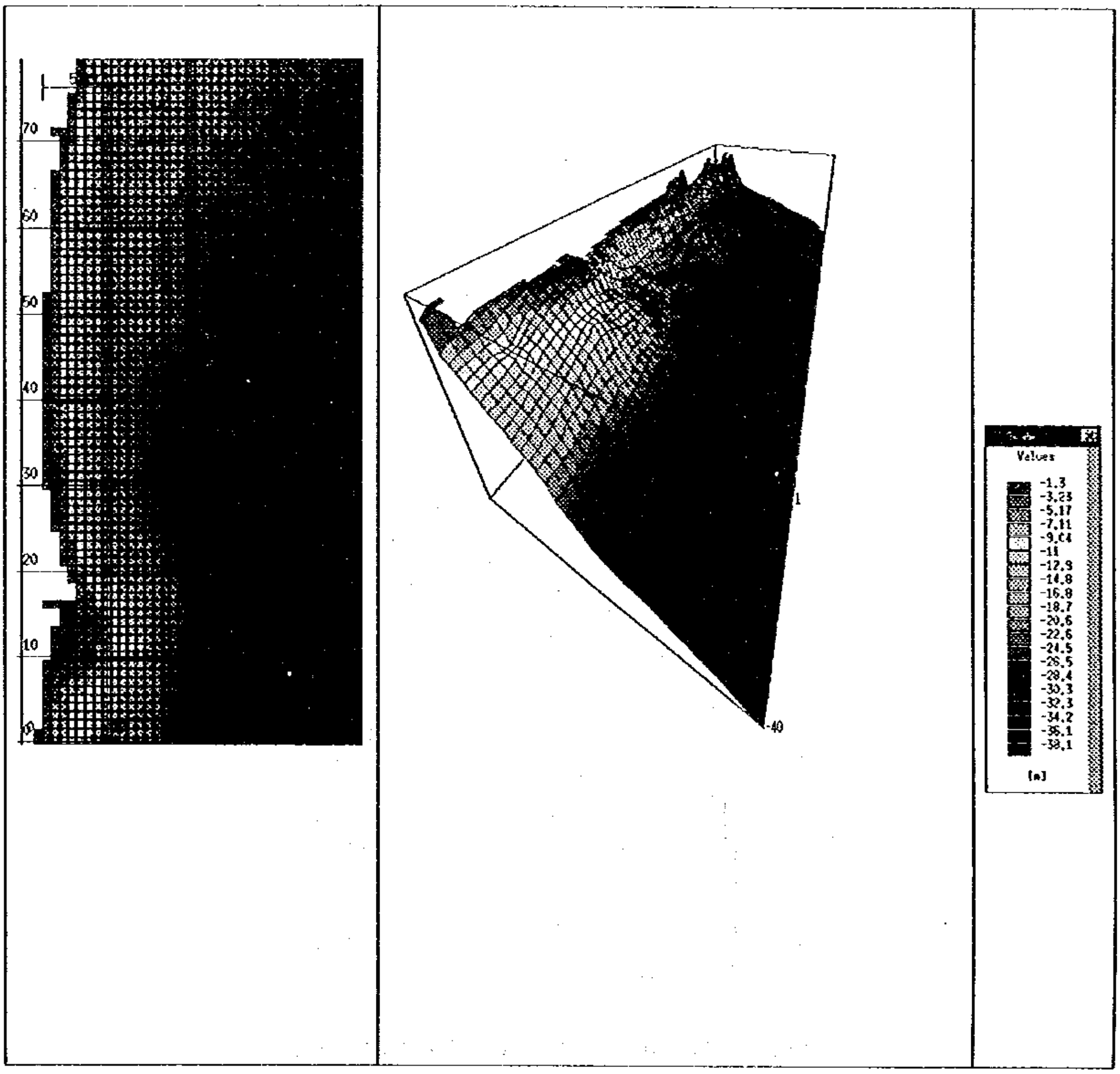


Figure 3.5 Horizontal View and 3-D View of Water Depth Used in Numerical Simulation of Coastal Water

(3) Location of Freshwater Discharge

Figure 3.6 shows the locations of freshwater discharge in the coastal region.

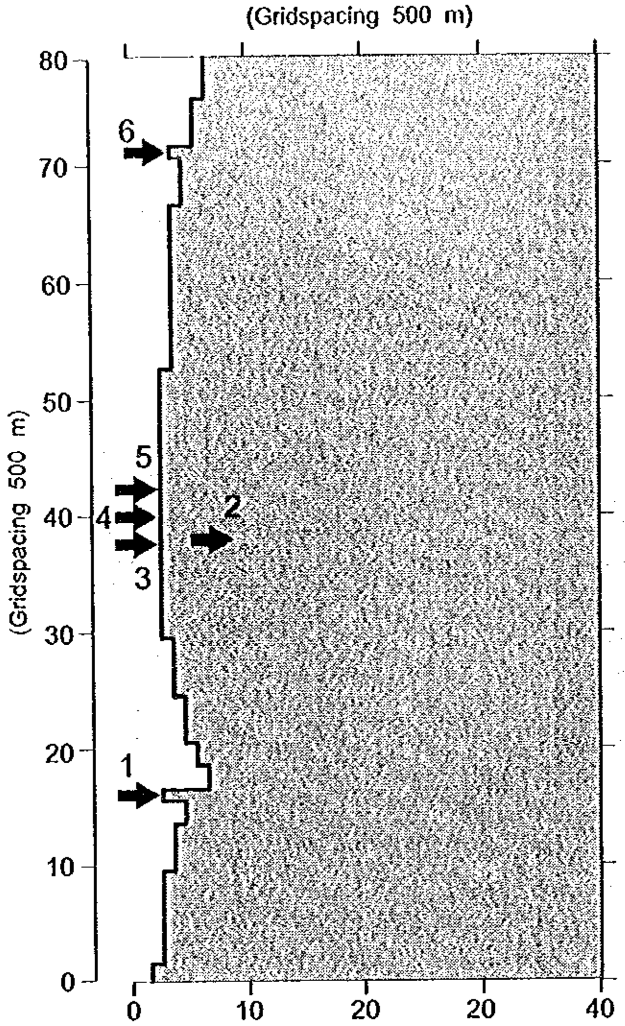


Figure 3.6 Locations of Freshwater Discharges

3.3 Results of Simulation

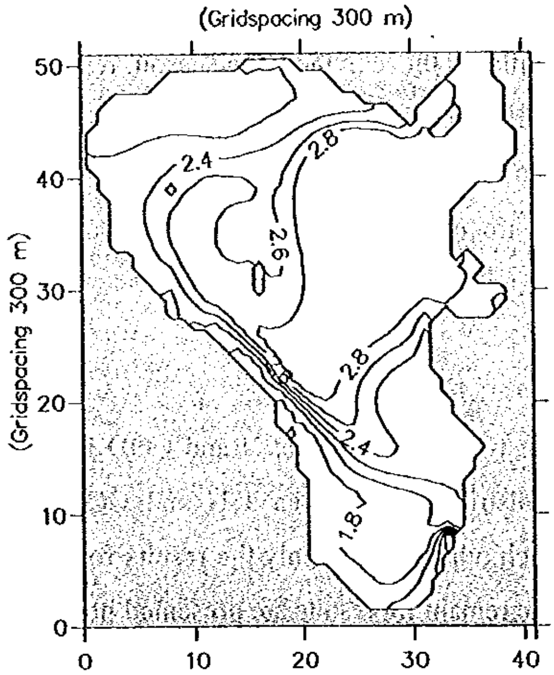
Results of the water current simulations in the dry season for both Pueblo Viejo Lagoon and the coastal water are not shown because they are similar to those in the rainy season, results of which are shown in the main report. The only difference in the computational conditions between the dry and rainy seasons is the distinction of water discharge in both seasons.

Results of the water quality simulations, which are not shown in the main report, are presented here.

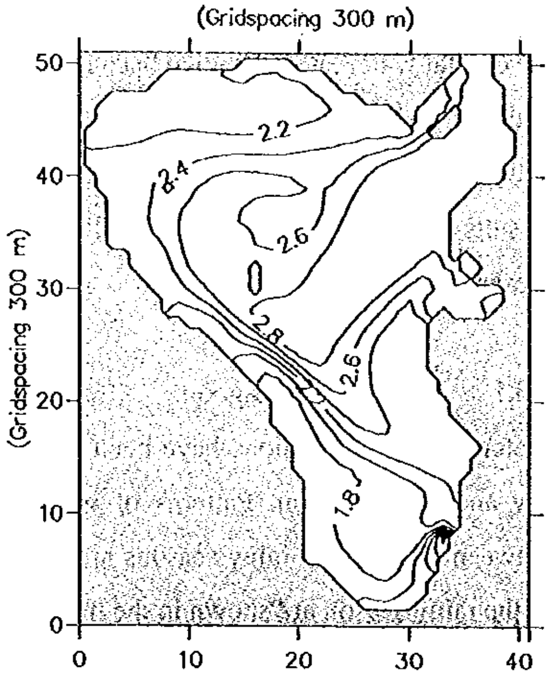
3.3.1 Pueblo Viejo Lagoon

Water quality simulations have been carried out for two items of Total-N and COD in each dry and rainy season. Patterns of water quality distribution between T-N and COD and between the dry and rainy seasons are similar to each other, so that only the results for COD in the rainy season are shown in the main report. The remaining results are presented here.

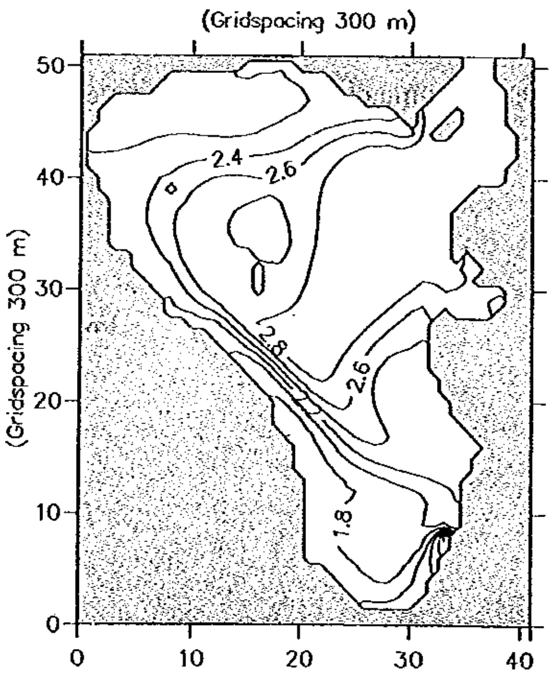
Figure 3.7 shows the simulated distribution of COD concentration in the dry season. The COD concentrations in the dry season near the open boundary are low compared with the rainy season, which reflects that COD concentrations in Panuco River water in the dry season are less than that in the rainy season. On the contrary, COD concentrations in the head are higher than that in the rainy season due to the low water volume discharge rate of Liave River with low COD concentration.



a. High tide



b. Low tide



Unit:mg/L

c. 24 hours mean

Figure 3.7 Simulated Distribution of COD Concentration in Pueblo Viejo Lagoon at High Tide, Low Tide and 24-Hour Mean in the Dry Season

Figure 3.8 shows the simulated distribution of T-N concentration in the rainy season. The concentration is high near the open boundary, reflecting the boundary concentration of 0.7 mg/L set in the simulation, and the concentration is low in the head of the lagoon due to the dilution effect caused by the low concentration discharge of 0.13 mg/L from Llave River. In the concentration for the high tide, an area with high concentration of more than 0.65 mg/L extends around the north-east portion of the lagoon due to the inflow of Panuco River water with high concentration.

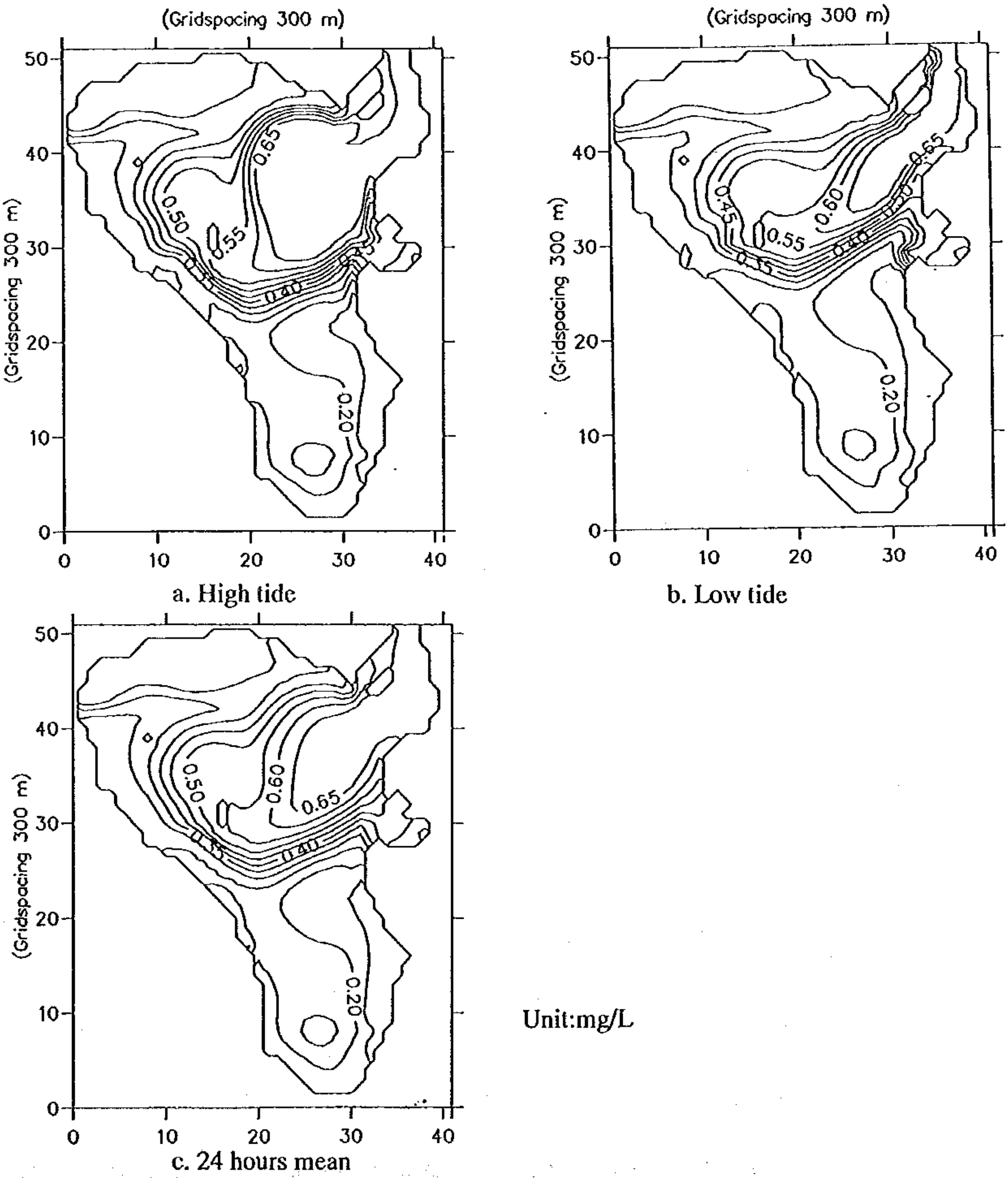


Figure 3.8 Simulated Distribution of T-N Concentration in Pueblo Viejo Lagoon at High Tide, Low Tide and 24-Hour Mean in the Rainy Season Season

Figure 3.9 shows the simulated distribution of T-N concentration in the dry season. The contrast in T-N concentration between the north-east part and the head of the lagoon is diminished considerably compared with the T-N distribution in the rainy season due to the lower water volume discharge rate of Llave River in the dry season.

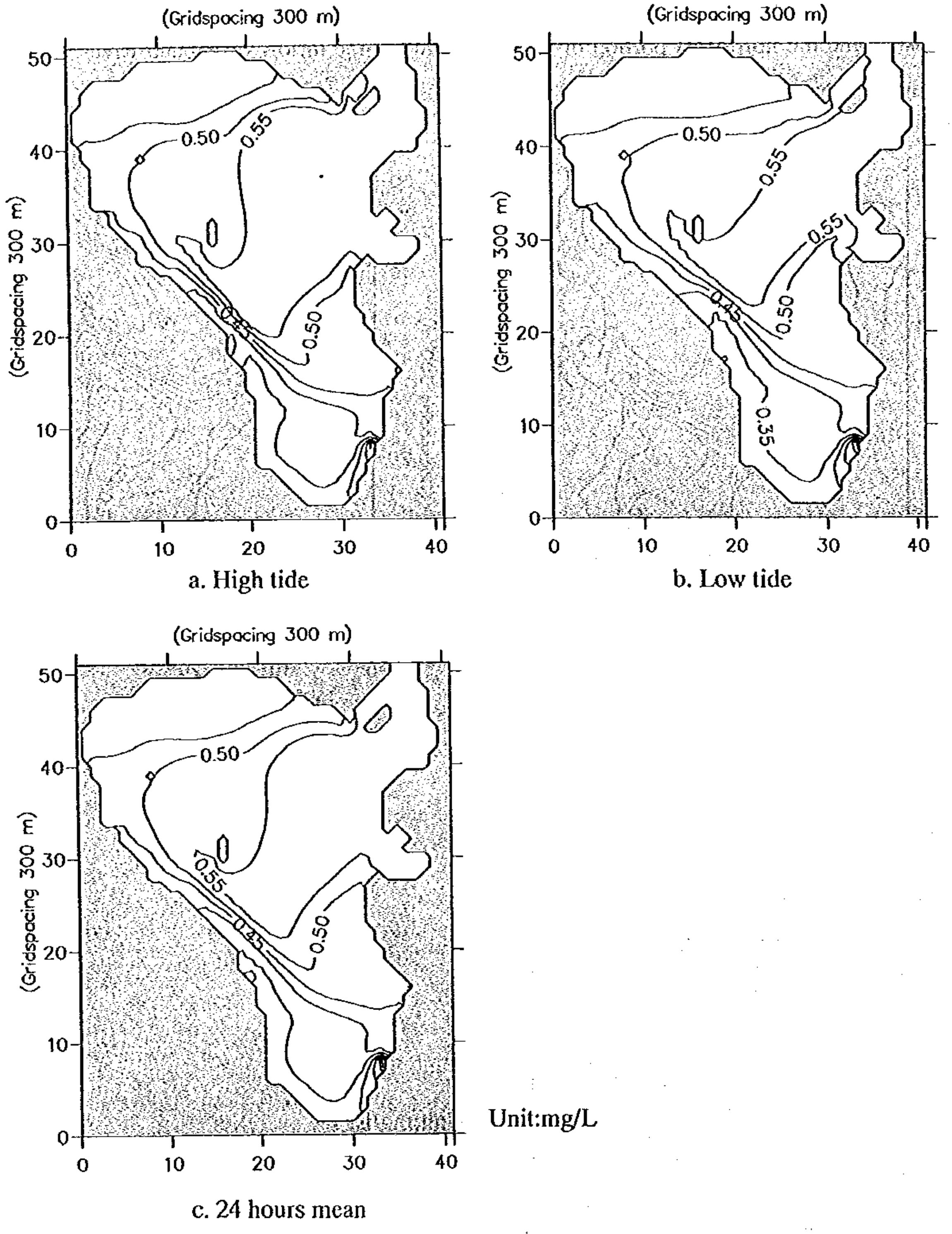


Figure 3.9 Simulated Distribution of T-N Concentration in Pueblo Viejo Lagoon for the High Tide, Low Tide and 24-hour Mean in the Dry Season

3.3.2 Coastal Water

Figure 3.10 shows the simulated time series of COD in rainy season. There is no meaning in particular dates in the horizontal axis. Locations of the three points are shown in Figure 4.1(1) in the main report. The COD concentrations at the three points reach stationary states after 10 days. There is no tidal variation in the concentration because only the mean current is represented in the advection term in the coastal water quality simulation.

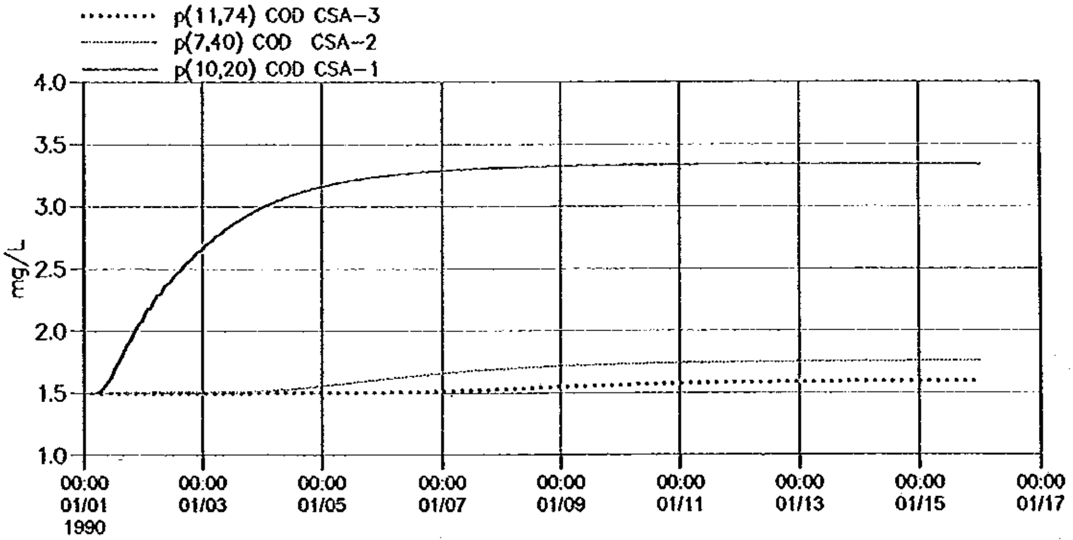
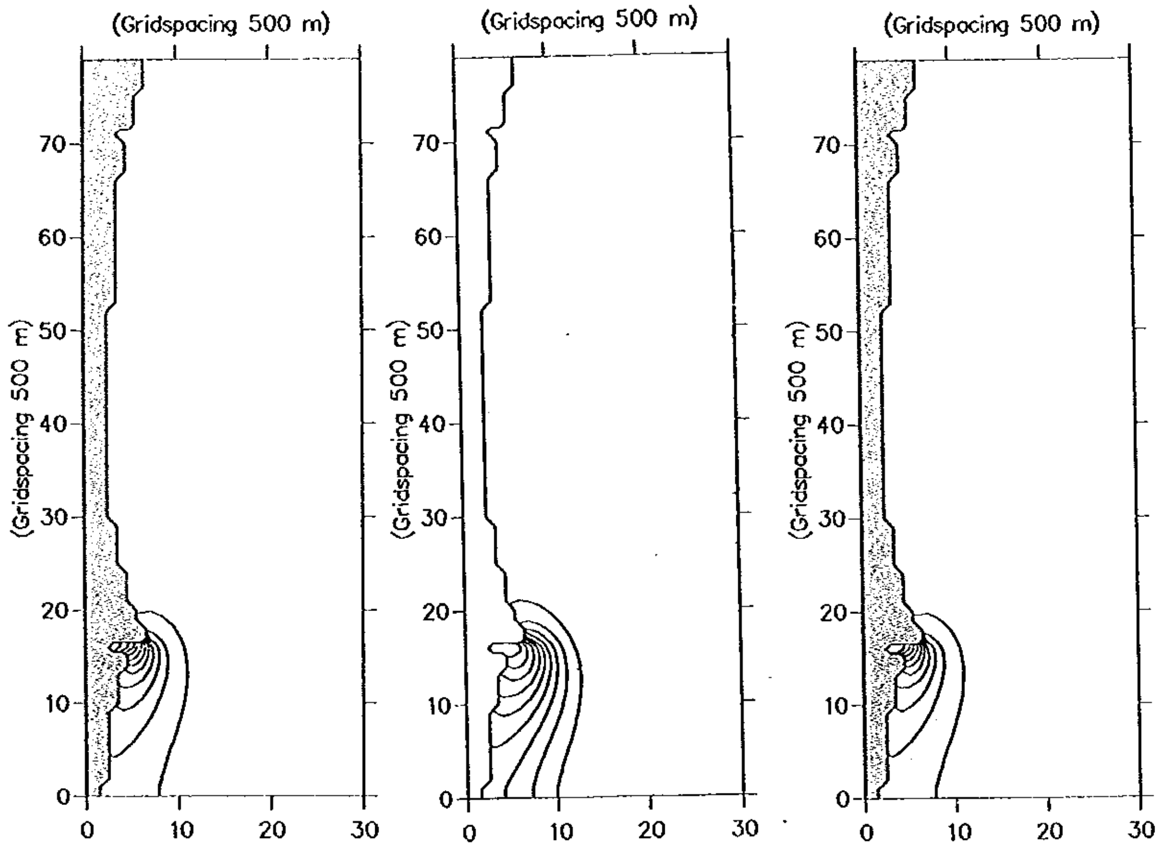


Figure 3.10 Simulated Time Series of COD Concentration in the Coastal Water in the Rainy Season. Locations of three points, CSA-1, CSA-2 and CSA-3, are shown in Figure 4.1(1) in the Main Report.

Figure 3.11 shows the simulated distribution of COD concentration in the dry season and of T-N concentrations in and dry season and rainy season. All distributions of concentration show that high concentration from the Panuco River spreads mainly southward due to the advection effect of the mean current directing southward around the Panuco River mouth.



a. COD in dry season b. T-N in rainy season c. T-N in dry season

Figure 3.11 Simulated Distribution of Concentrations in the Coastal Water. Unit:mg/L

In a, the maximum contour line is 22mg/L, the minimum 2mg/L, and the interval 2mg/L.
In b, the maximum contour line is 0.38mg/L, the minimum 0.22mg/L, and the interval 0.02mg/L.
In b, the maximum contour line is 1.1mg/L, the minimum 0.2mg/L, and the interval 0.1mg/L.

Chapter 4 Pilot Water Quality Monitoring in the Tampico Area

4.1 Objective

The pilot water quality monitoring was carried out in the Tampico Area during dry and wet weather conditions. Objectives of this pilot monitoring survey are to:

- Identify water quality conditions in the pilot monitoring area;
- Utilize the result of the pilot water quality monitoring for the formulation of coastal water quality monitoring plan for the Tampico Area;
- Transfer the technology of coastal water quality monitoring to the counterparts through daily work.

Survey parameters are related to water and sediment quality and biological accumulation. Water and sediment have a close relationship because of the exchange of material between them. Weather conditions, biological process and inland activities can always affect the water quality. It is necessary to monitor the sediment conditions in order to identify environmental changes because sediment quality is closely related to the historical changes of water quality. Since the water areas provide habitats of aquatic fauna, a biological accumulation test can present important information concerning the impact of water quality on organisms

Monitoring areas shown in Table 4.1 cover various water bodies such as coastal area, river water area, a brackish water area, and freshwater area. Details of this survey are given in Chapter 4 of the Supporting Report.

Table 4.1 Pilot Quality Monitoring Areas

Type of water body	Monitoring area
Coastal water area	Coastal area from the mouth of Panuco River to Altamira industrial Port
River water area	Panuco River
Brackish water area	Pueblo Viejo Lagoon
Freshwater area	Conejo Lagoon

4.2 Environmental Profile of Water Quality in the Tampico Area.

4.2.1 Vertical Profile

Before measuring the vertical profile of water quality in the coastal area, it is necessary to investigate the characteristics of seawater. The most conspicuous difference between seawater and river water is that seawater contains much salt. Salinity can be regarded as conservation parameter because it is not affected by chemical changes. In other words, the distribution of salinity depends only on mixture and diffusion of water bodies.

Seawater and fresh water have different densities and are therefore comparatively difficult to mix. Therefore, the mixing condition of seawater and river water can be estimated from their salinity level. This theory is adapted to the pilot monitoring area, Panuco River and near coastal area. The mixture of river water and seawater is supposed to influence the water quality in these areas. And the degree of mixture depends on the water movement caused by multiple factors such as changes of tidal level.

Salinity was measured by STD system for three times—during the pilot monitoring survey in dry season and rainy season, and the preliminary survey in February. Detailed survey for salinity was done in February. The tidal levels recorded during those surveys are shown in Figure 4.1, and the survey dates are indicated in Table 4.2.

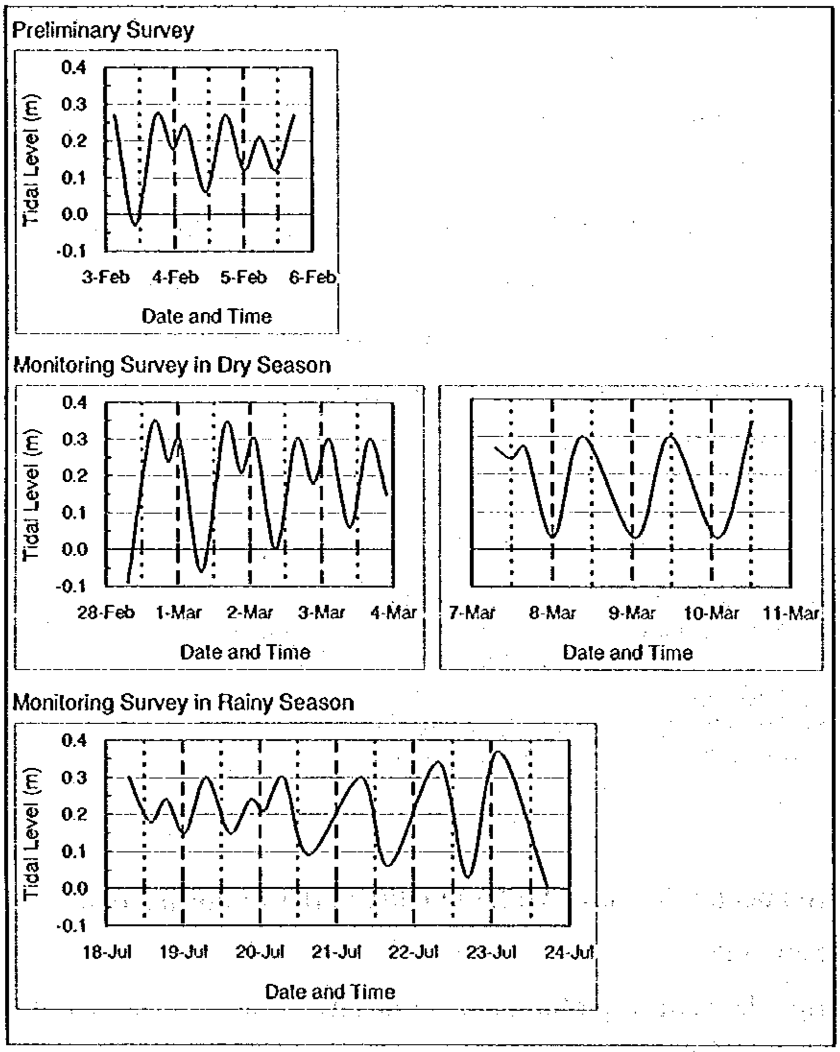


Figure 4.1 Tidal Levels in Tampico Area

Table 4.2 Tidal Conditions by Survey Dates

Survey	Area	Date	Tidal condition
Preliminary survey	Panuco River	Feb. 3, 1999	Ebb tide to Low tide
	Coastal area near the mouth of Panuco River	Feb. 4, 1999	Low tide to flood tide
Pilot monitoring survey in dry season	Panuco River	Mar. 1, 1999	Low tide to flood tide
	Coastal area near the mouth of Panuco River	Mar. 8, 1999	High tide
Pilot monitoring survey in rainy season	Panuco River	July 21, 1999	High tide to ebb tide
	Coastal area near the mouth of Panuco River	July 19, 1999	High tide to low tide

Preliminary survey in Panuco River was carried out from ebb tide to low tide, and that in coastal area was done from low tide to flood tide. Pilot monitoring in dry season was done from low tide to flood tide, while that in coastal area was done at high tide. In rainy season, the pilot monitoring survey in the Tampico Area was carried out from high tide to low tide. The vertical profile of salinity measured in the preliminary survey and pilot monitoring survey during the rainy season in Panuco River is shown in Figure 4.2.

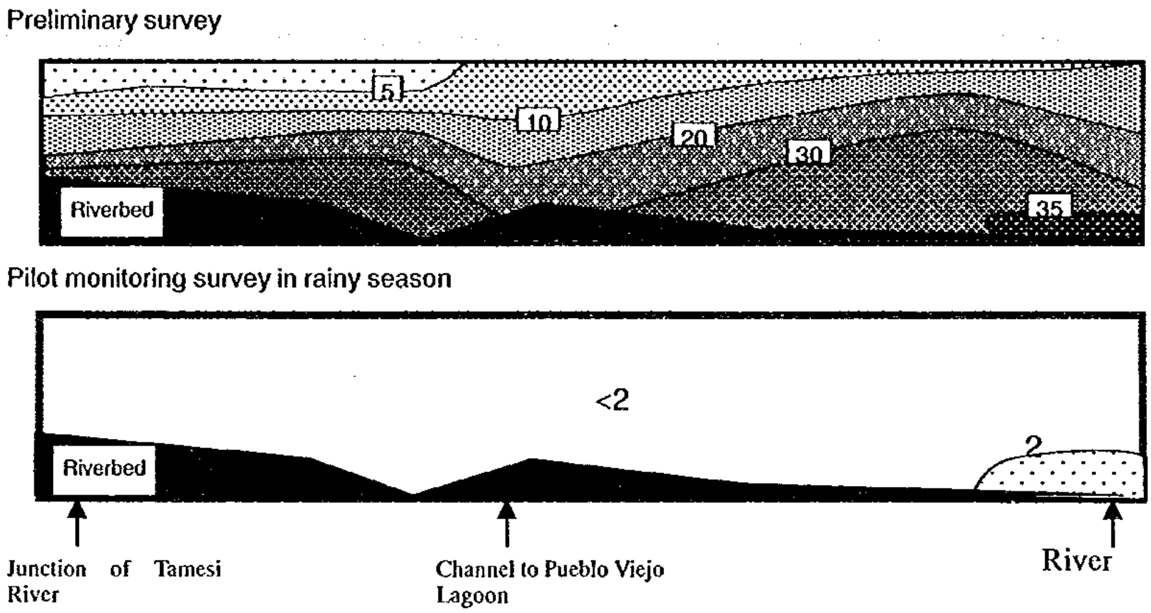


Figure 4.2 Vertical Profile of Salinity in Panuco River

The upper figure shows that seawater is creeping up near the riverbed. Seawater above salinity level of 35 occupies the water area up to 3 km from the mouth of Panuco River. Water of 30 salinity reaches the upper stream, up to the junction of Tamesi River. River water covers the seawater, and fresh water of below 5 salinity was not able to reach the river mouth and it was stopped at the channel of Pueblo Viejo Lagoon. In the downstream area from this channel, salinity of the surface water (about 1 m below the surface) was about 10, and that of 3 m below the surface was over 20.

On the other hand, in rainy season, saline water with salinity of less than 2 occupied the whole river water area, and evidence of rising seawater was seen just at the river mouth.

Now let us examine the vertical profile of coastal area near the mouth of Panuco River. Vertical profile of salinity in the preliminary survey is shown in Figure 4.3. The C-line, which was recognized from the river mouth toward east, showed that river water reached up to 2 km upstream from the river mouth. Water with less than 30 salinity reached up to 4 km away from the mouth. Also in the rainy season survey, river water reached up to the offshore as shown in Figure 4.4.

Salinity of surface water (1 to 2 m below the surface) in the south side of the river mouth tended to be lower than that in the north side when compared along four lines radially set from the river mouth to the offshore. The results of water current survey in rainy season indicated that the southward water current surpassed the northward current (See chapter 3 of this report and chapter 4 of the supporting report). It shall be concluded that mixing condition of different water bodies, high saline water (seawater) and low saline water (river water) mainly controls the vertical profile of water quality.

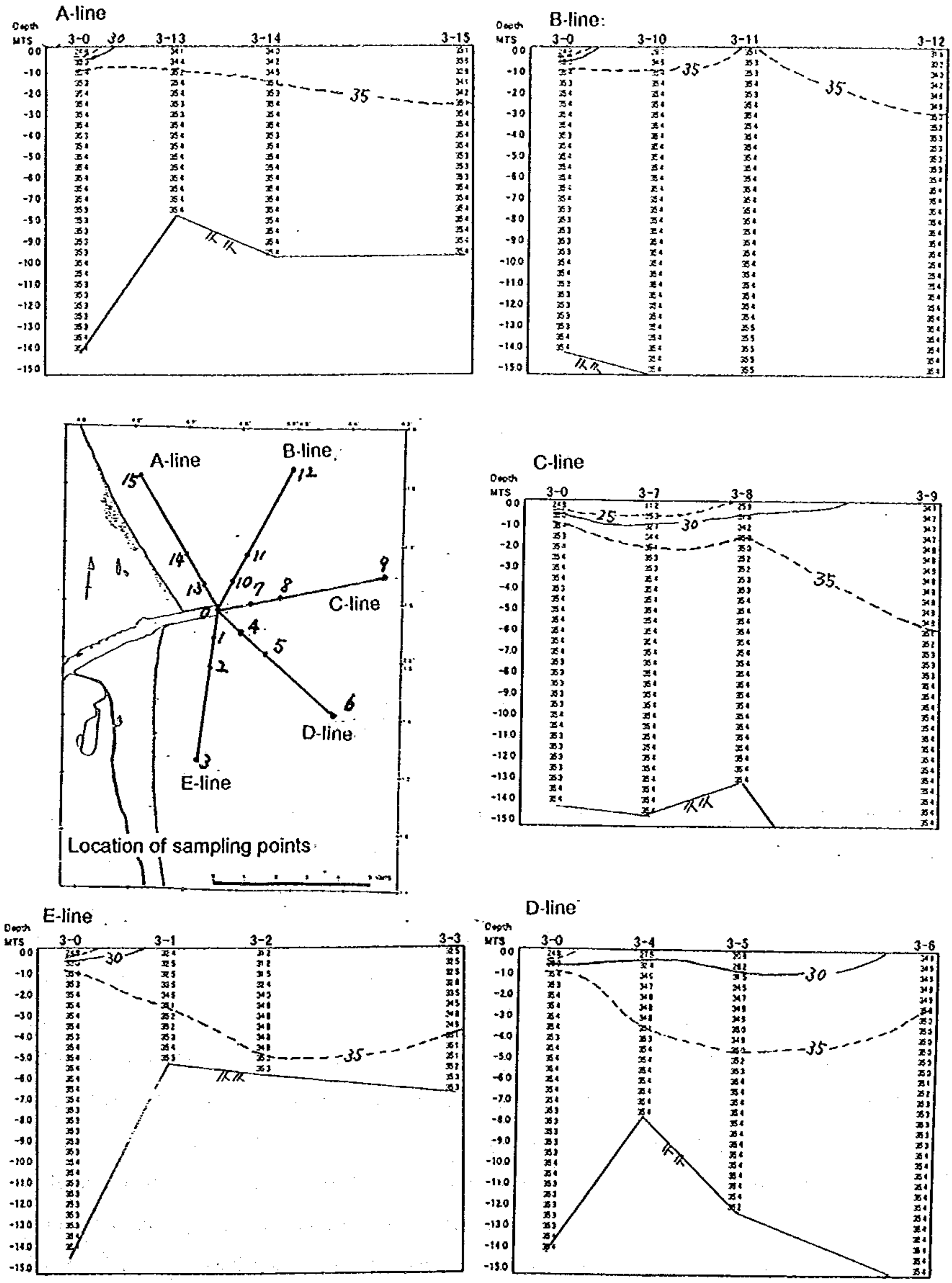


Figure 4.3 Vertical Profile of Salinity in Coastal Area (Preliminary Survey)

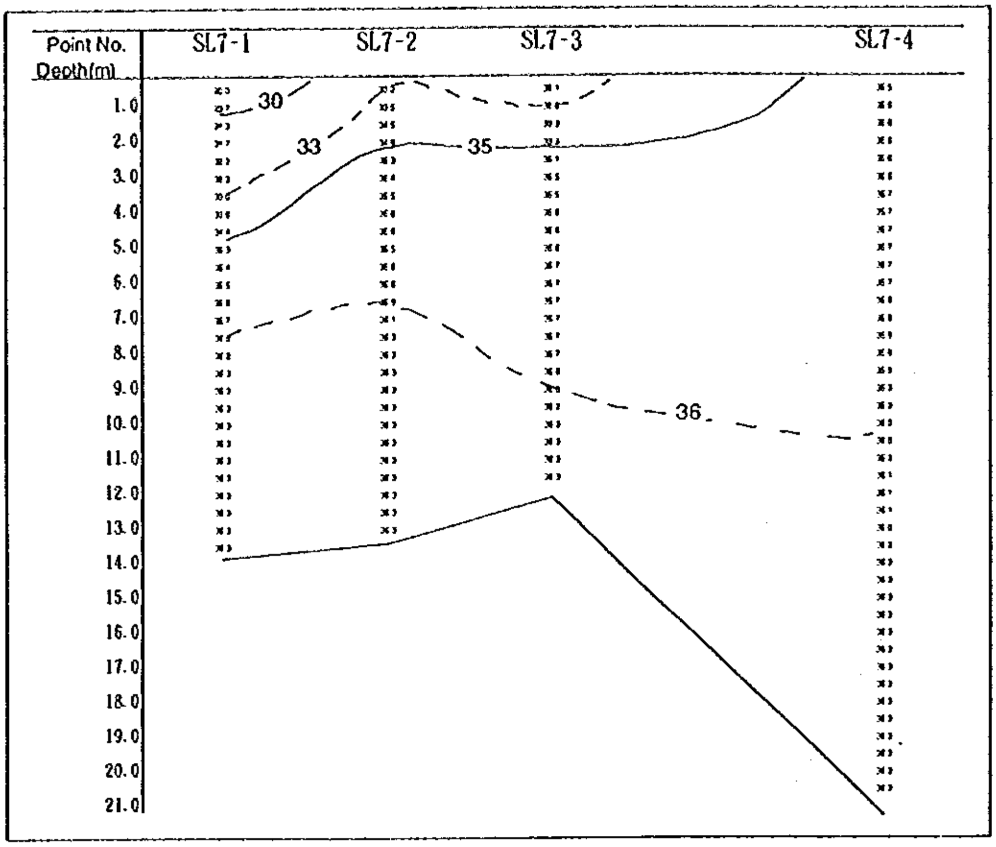


Figure 4.4 Vertical Profile of Salinity in Coastal Area
(Pilot Monitoring Survey in Rainy season)

The other parameters of water quality are discussed subsequently. Vertical profile of salinity, COD, nitrate nitrogen and chlorophyll-a in Panuco River are shown in Figure 4.5. Concentrations of COD in the surface layer were from 2.7 to 7.8 mg/l and those in the bottom layer were from 0.8 to 1.0 mg/l during the dry season. As mentioned above, water with high salinity was found in the layer near the riverbed and river water piled over the saline water. Consequently, seawater with low COD concentration was observed underneath the river water with high COD concentration. On the other hand, during the rainy season, there was little difference between the COD levels of upper and bottom layers, and both showed relatively high concentrations. COD concentrations of the upper layer were from 3.6 to 4.4 mg/l, while those of bottom layer were from 4.1 to 5.4 mg/l. Concentrations of nitrate nitrogen of the surface layer were from 0.16 to 0.21 mg/l, and those of bottom layer were below 0.1 mg/l in dry season. The concentration of nitrate nitrogen is higher during the rainy season rather than the dry season. The reason is attributed to the fact that river water has a greater influence during the rainy season than the dry season. As for the chlorophyll-a profile, the difference of concentration between upper layer and bottom layer in dry season was higher than that in rainy season; this trend was also observed for COD.

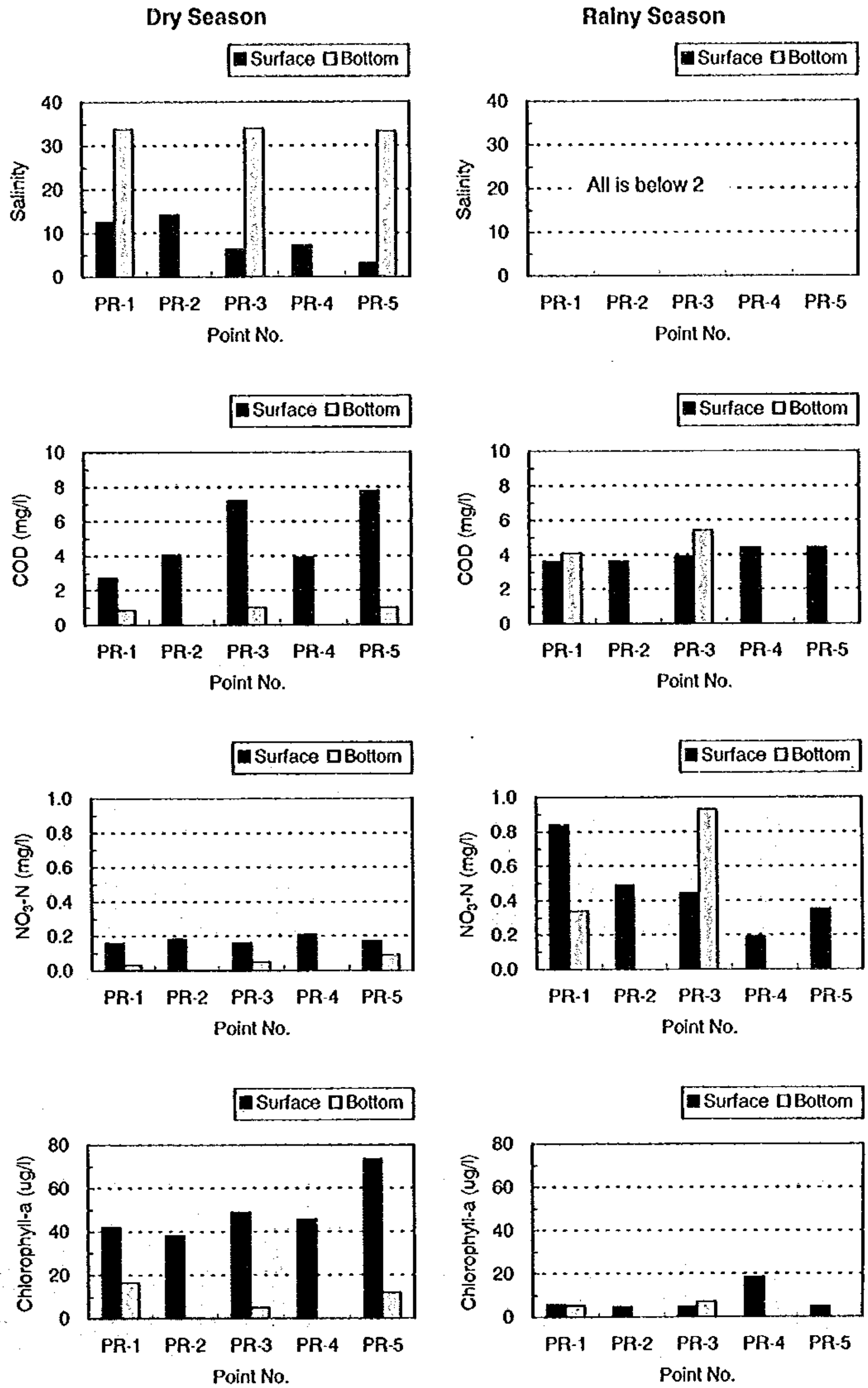


Figure 4.5 Vertical Profile of Salinity, COD, Nitrate Nitrogen and Chlorophyll-a in Panuco River

In terms of the coastal area, vertical profile of salinity, COD, nitrate nitrogen and chlorophyll-a in this area. The line from SL7-1 to SL7-4 was recognized from the river mouth towards east, as shown in Figure 4.6.

COD concentrations of the upper layer in dry season were from 0.8 to 1.6 mg/l, those of bottom layer were from 0.7 to 1.3 mg/l. COD concentrations of the upper layer within the radius of 2 km from the river mouth were above 1 mg/l and those of seawater more than 2 km from the river mouth were below 1 mg/l. Therefore, river water with high COD concentration is expected to spread in the coastal area. This trend was especially apparent in the rainy season. COD concentration of the upper layer within 2 km from the river mouth was about 3 mg/l, which was comparatively high. Value of the bottom layer was half that of the upper layer. This result indicates that the influence of Panuco River in rainy season was stronger than in dry season.

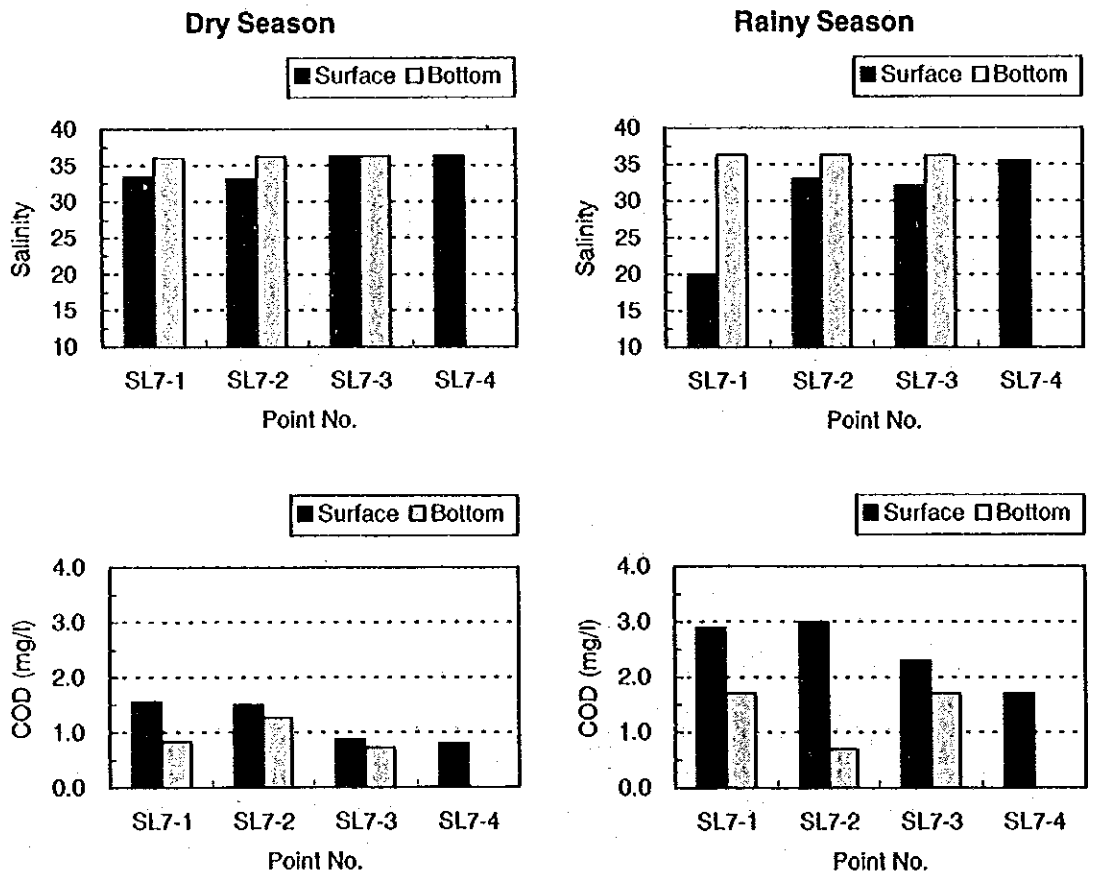


Figure 4.6(1) Vertical Profile of Salinity and COD in the Coastal Area

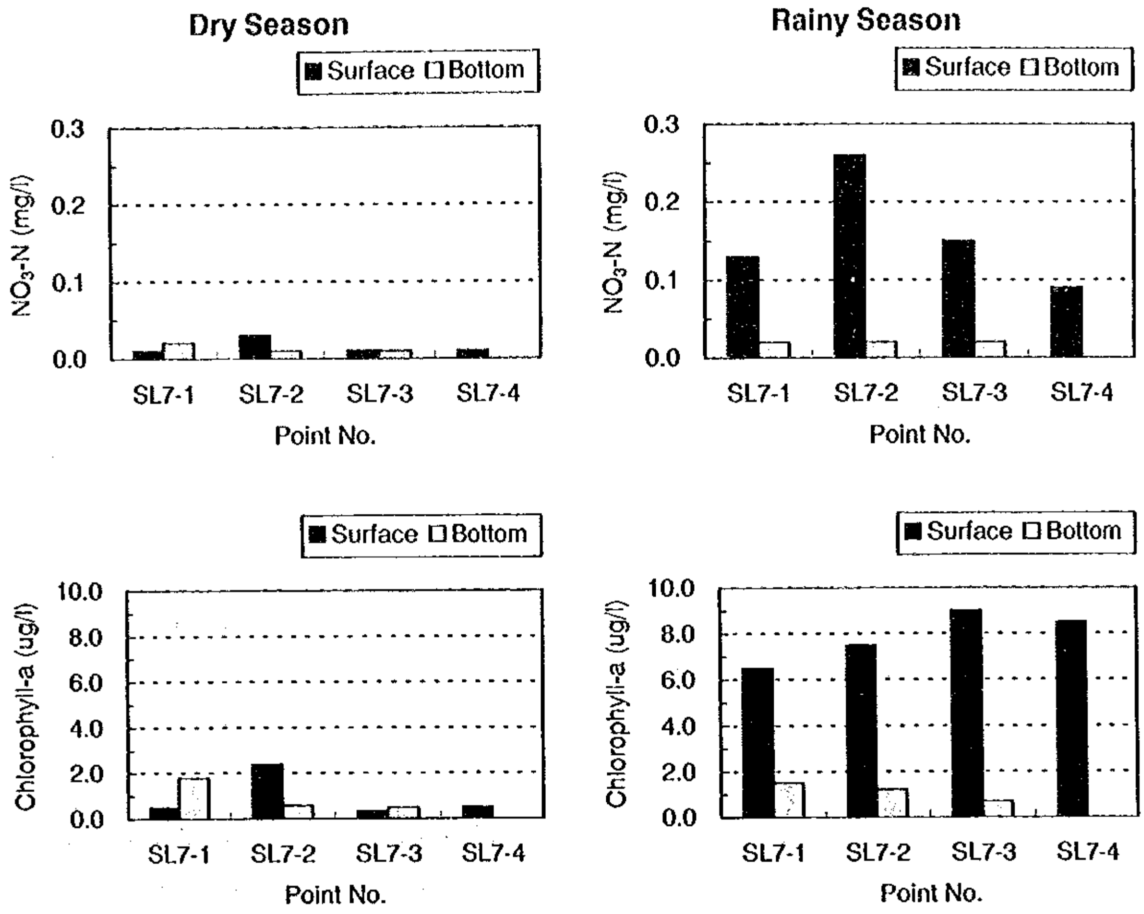


Figure 4.6(2) Vertical Profile of Nitrate Nitrogen and Chlorophyll-a in Panuco River

However, in terms of nitrate nitrogen and chlorophyll-a profiles, the differences between the upper layer and the bottom layer in dry season were not very clear, while the concentrations in rainy season showed large differences between the two layers.

From what has been discussed above, it is concluded that:

- In general, the mixing of seawater and river water controls seawater conditions as shown in Figure 4.7.
- Characteristics of water condition are mainly dependent on this mixture.
- Distribution of pollutants, e.g. COD, or other parameters is also mainly dependent on this mixture.

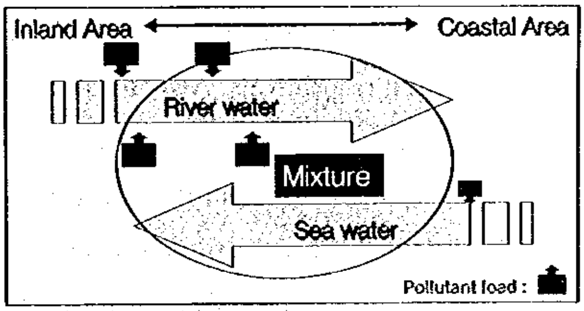


Figure 4.7 Mechanism of Mixing River Water and Seawater

4.2.2 Horizontal Profile

Horizontal profiles of monitoring areas are described subsequently. Meanwhile, horizontal profiles of water quality are shown in Figure 4.8.

(1) Coastal Area

a) Altamira Industrial Port

In summary, all parameters showed normal levels in dry season, but in rainy season transparency was lower (1.0-2.6 m), with decreased salinity. The bottom water of inner part of the port was oxygen deficient. On the other hand, high coliform groups were observed at the surface layer of the same point in rainy season. Therefore the area should be carefully monitored because this is a sign of seasonal eutrophication in this part of the study area.

In rainy season, the difference of water temperature between surface and bottom layer was about 4 •, and salinity of surface was about 3 lower than the bottom. So it was thought that pycnocline was formed. As a result, the bottom water of inner part was oxygen deficient.

Inner points were a little low in salinity, and coliform was detected at the surface layer of the same points in rainy season. As mentioned above, it was thought that the effect of urban pollution was apparent in this area. Therefore, this area should be carefully monitored because it is showing signs of seasonal eutrophication.

b) Coastal Area (North Area)

Generally speaking, transparency is decreasing in this area, accompanying the decrease of salinity in coastal area and the estuary. However, the transparency was higher in rainy season than in dry season, contrary to the drop in salinity in rainy season. It means that the factor affecting transparency is not suspended substances originating inland, but rather, other factors like fine sediments rising from the bottom of the water.

As for other parameters, TOC and COD were both at low concentrations of 2-4 mg/l, 1-3 mg/l, respectively. Also, the concentrations of nitrogen and phosphorus were low. Coliform group number was almost negligible in both seasons.

c) Coastal Area (Near Panuco River Mouth)

Distribution of water from around the Panuco River mouth is not clear, except at the point 1 km thereat in dry season. But in rainy season, low saline surface water extends to the whole coastal area, and water with salinity level of 32 distributes within a radius of 4 km from the mouth of the river.

Other characteristics of the area in rainy season were high concentrations of chlorophyll-a around the mouth of the river, and total coliform group numbers detected at 2.0×10^3 - 5.0×10^3 Col./100ml. Although lesser in number in dry season, bacterial contamination had spread around the mouth of the river by river water runoff.

Concerning heavy metals, there was higher concentration around the mouth of Panuco River than in other coastal points.

(2) Panuco River

As discussed earlier, there is a large difference in water mass structure between dry and wet weather conditions.

In dry season, a high salinity of over 20 had presented 3-5 meters of thickness at the riverbed, but it was ejected from the river to the sea area by high water in rainy season. In rainy season, therefore, the vertical difference of salinity disappeared.

The transparency of Panuco River was usually below 1m, and the SS content accounted for 10-30 mg/l during the pilot monitoring including *CNA*'s single observation in May. However, in rainy season, the river became muddy, and the turbidity increased to 0.3 m for transparency and 300-560 mg/l for SS.

COD and TOC, as parameters of organic pollution, were a little higher in value in rainy season at 3-8 mg/l and 2-7 mg/l, respectively. Concerning nutrient elements, there is a higher concentration of nitrate nitrogen in Panuco River than in other water areas, but this condition is typically observed at mouth of big rivers. Concentration of total nitrogen was 0.4-1.2 mg/l, and it was high in rainy season. On the other hand, total phosphorus was detected at approximately 0.1-0.3 mg/l, and it was a little high in dry season than rainy season.

One of the characteristics of Panuco River is the high coliform group numbers detected at all points during three times of observation, including CNA's single observation. Especially at the points of PR-1, and PR-2 located near the mouth of the river, it was detected that there were 2.0×10^3 – 5.0×10^3 col./100ml. Those river areas have been contaminated with bacteria.

(3) Pueblo Viejo Lagoon

Pueblo Viejo Lagoon is a brackish water lagoon that is connected to Panuco River through a canal at the northeast part of the lagoon. Its salinity is about 17-18 in dry season. But in rainy season it is remarkably influenced by the river water of Panuco as it even becomes fresh water in the northeast area. And the salinity of its central part drops to half of the dry season level. The quality of its water quality is similar to Panuco's: muddy condition, about 0.5 m for transparency and high concentration of SS. But the lagoon is more contaminated with coliform, which has been detected in both seasons.

(4) El Conejo Lagoon

El Conejo Lagoon is a small, slender-shaped freshwater lagoon with salinity below 2. However, it is the most contaminated water body among the study areas as it recorded the highest concentrations of TOC, COD, total nitrogen, total phosphorus and chlorophyll-a in both seasons. Dissolved oxygen in the surface layer is deficient, and inorganic nitrogen like nitrate nitrogen shows a low concentration in rainy season. This is a typical eutrophic phenomenon.

It is supposed that nutrients were transferred from inorganic to organic form by phytoplankton. Besides, it was contaminated with bacteria because total coliform group number was detected at a maximum 2.0×10^3 Col./100ml.

(5) Marismas Lagoon

The monitoring survey in Marismas Lagoon was carried out on time during the rainy season. Salinity was measured at 10 to 12, same as those in Pueblo Viejo Lagoon.

Since water depth is very shallow, water temperature was deeply affected by weather conditions. The water temperature in Marismas Lagoon was high reading during the survey.

DO and chlorophyll-a showed high concentrations. This meant that photosynthesis was active. Nitrogen and phosphorous also showed high concentration, thus eutrophication is expected to occur.

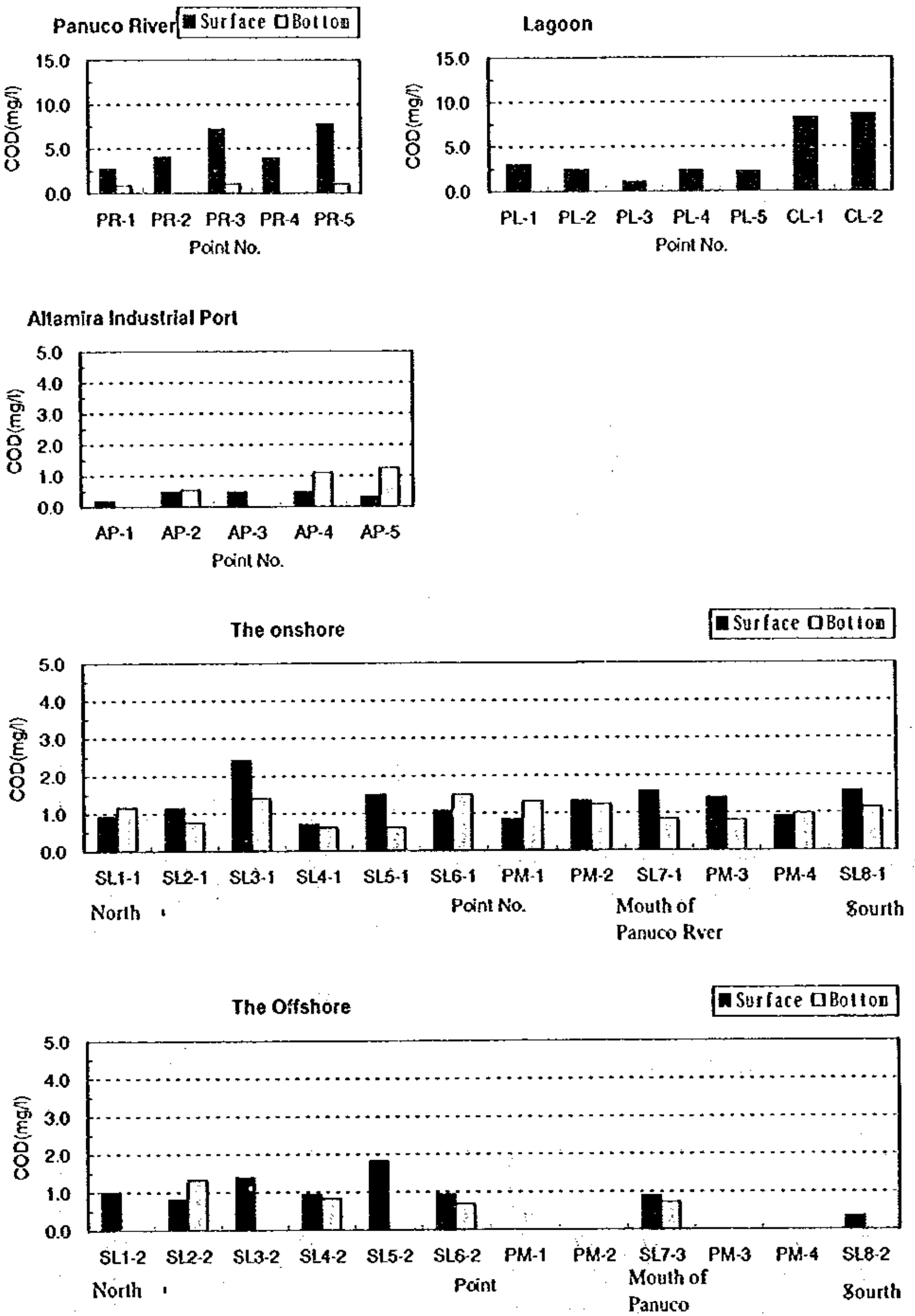


Figure 4.8(1) Horizontal Profile of COD in Dry Season

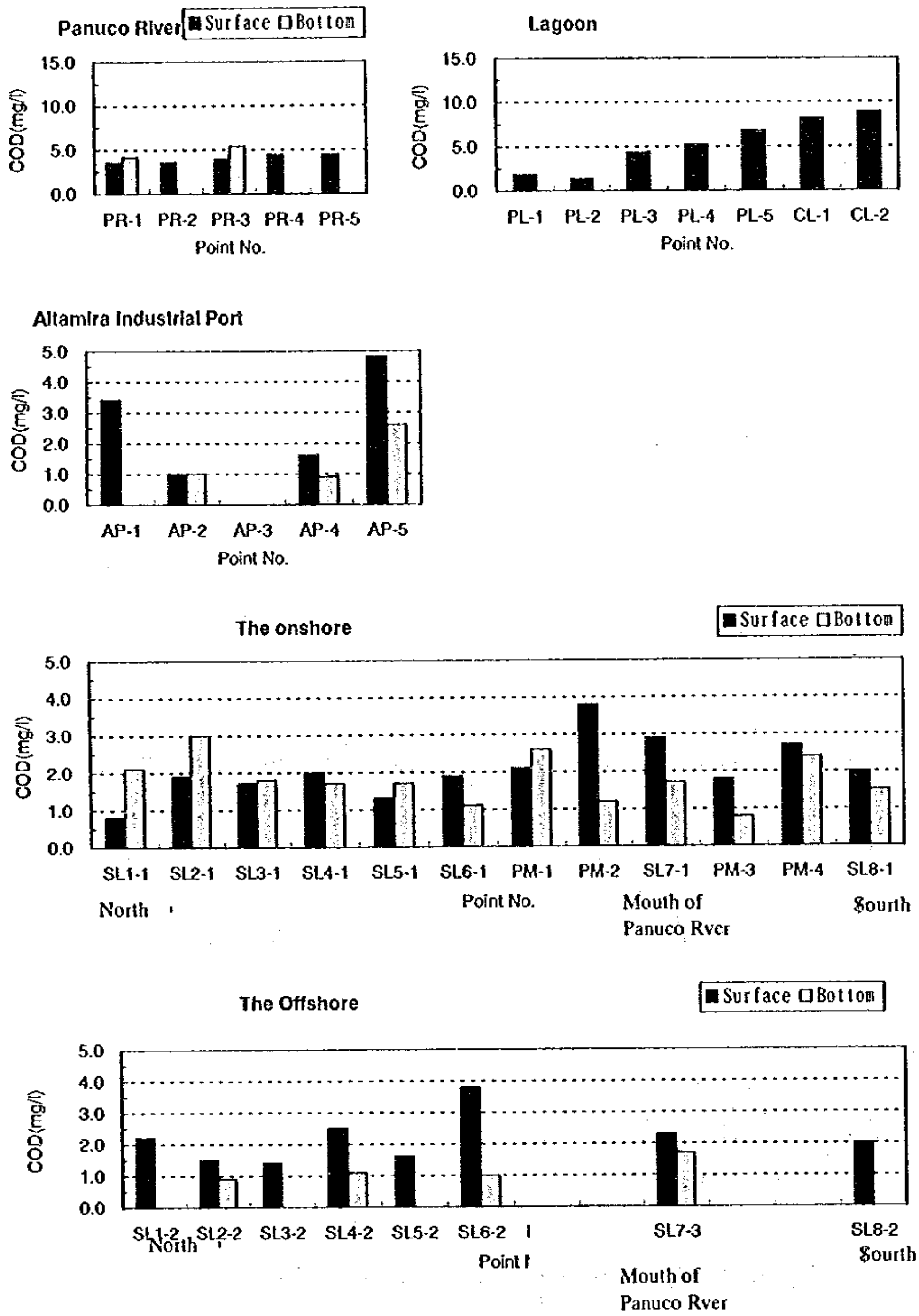


Figure 4.8(2) Horizontal Profile of COD in Rainy Season

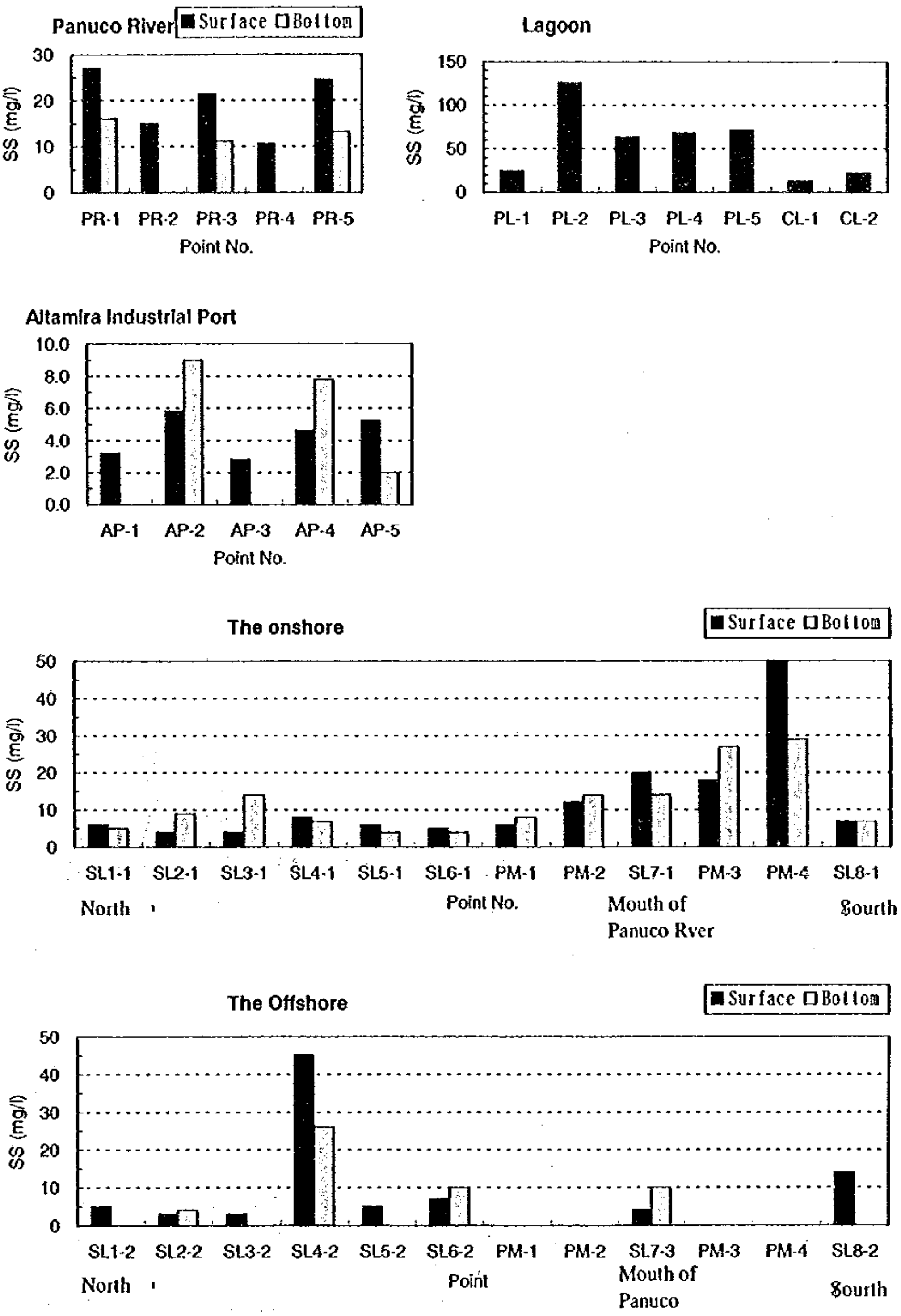


Figure 4.8(3) Horizontal Profile of SS in Dry Season

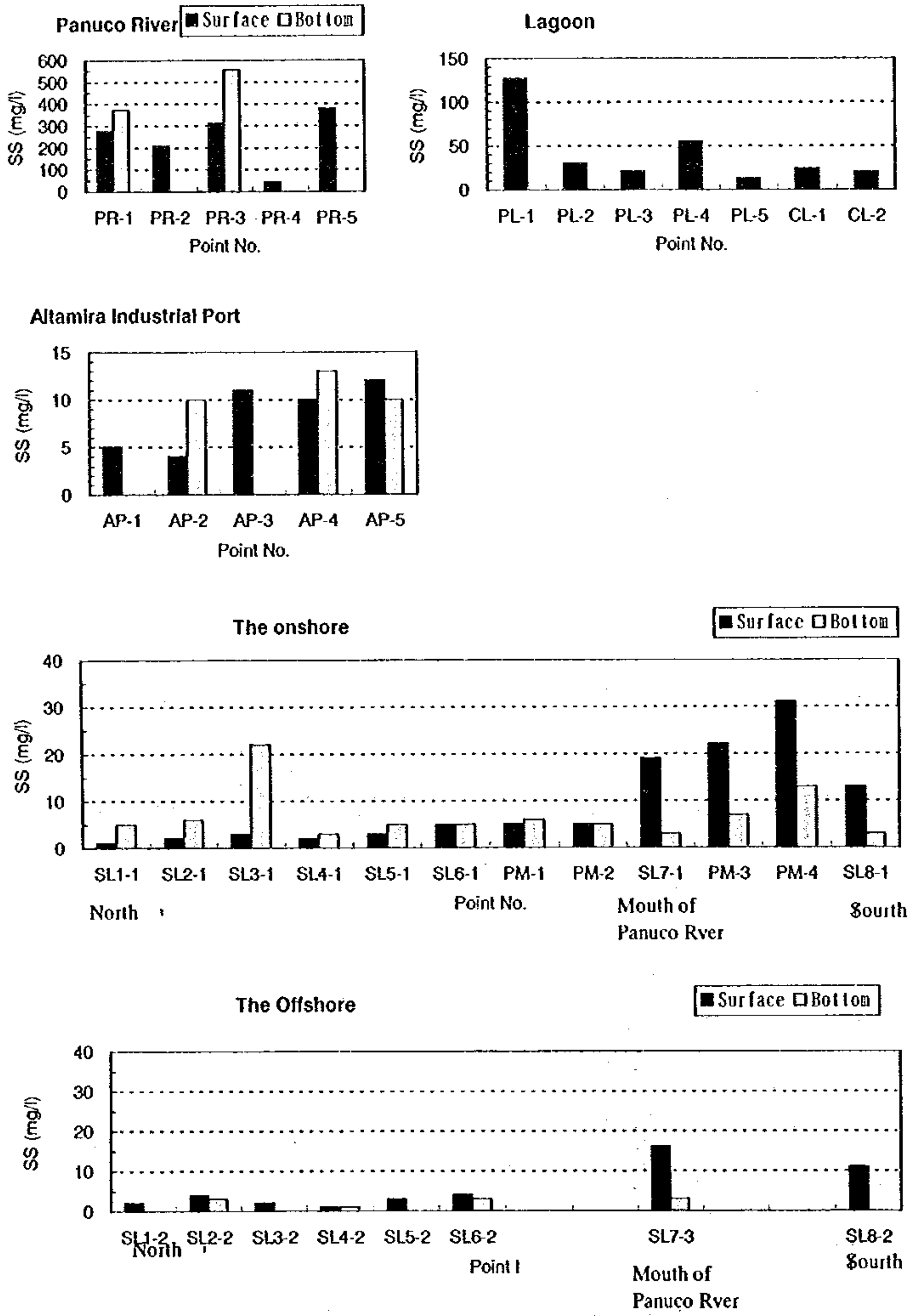


Figure 4.8(4) Horizontal Profile of SS in Rainy Season

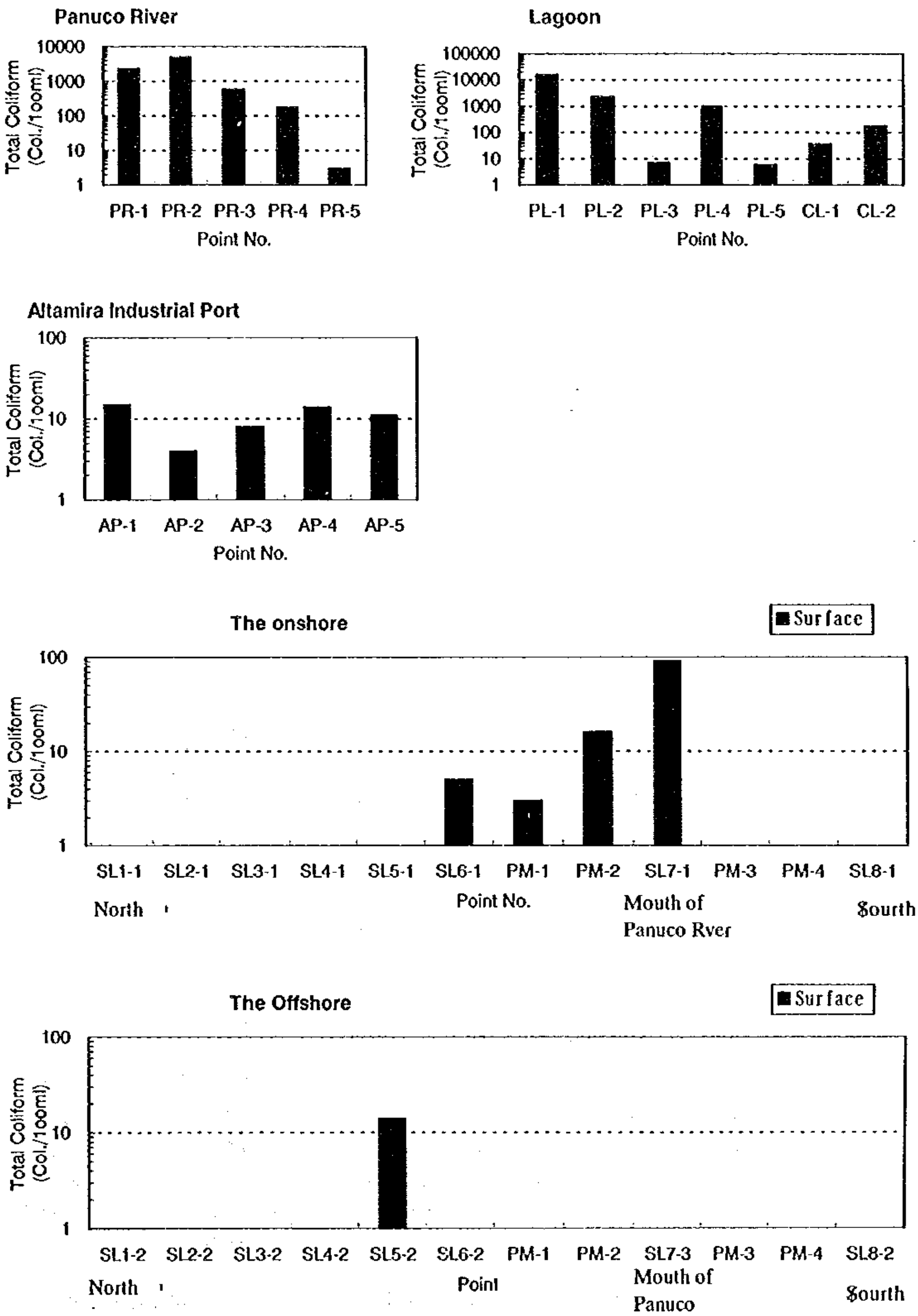


Figure 4.8(5) Horizontal Profile of Total Coliform in Dry Season

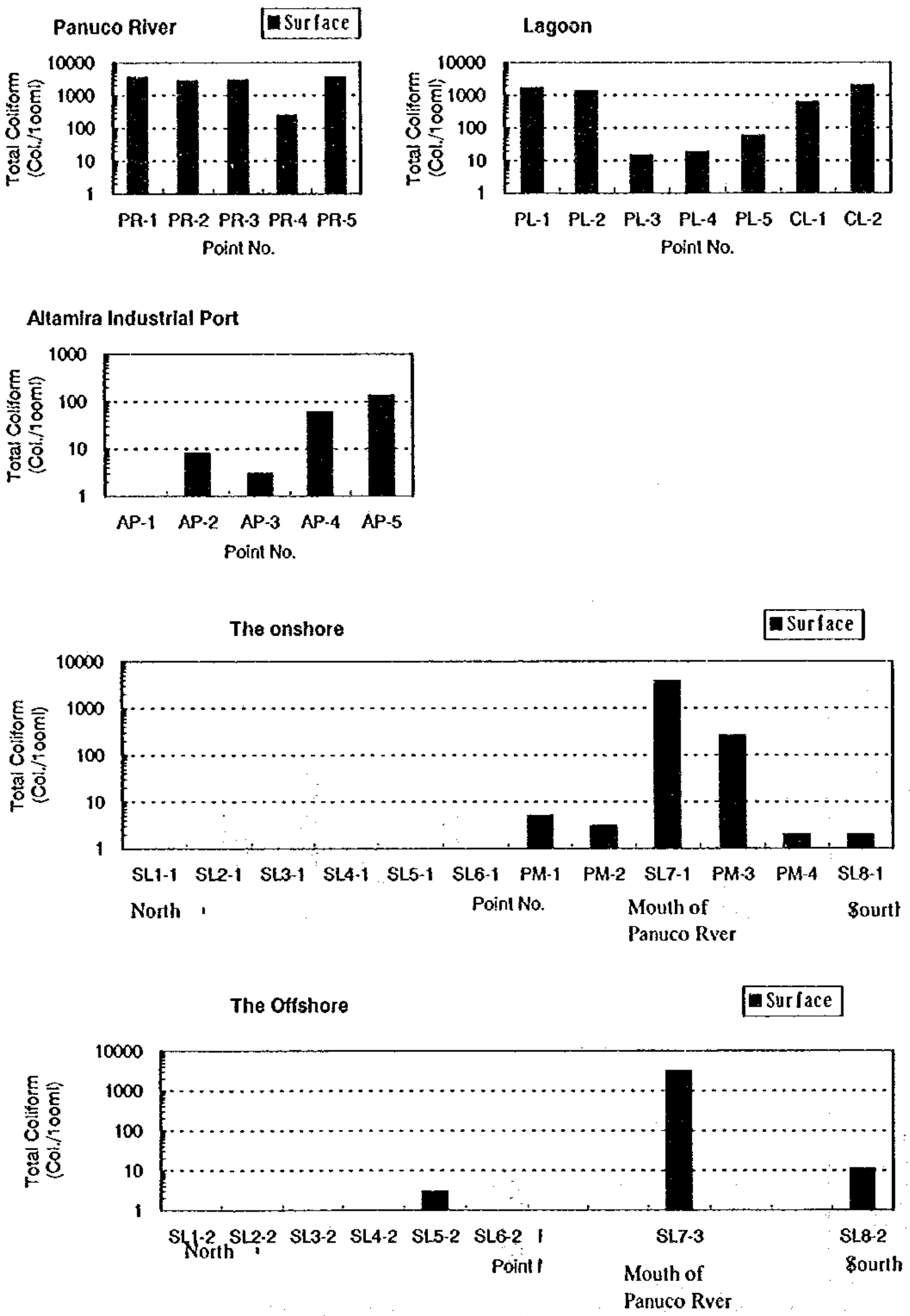


Figure 4.8(6) Horizontal Profile of Total Coliform in Rainy Season

4.2.3 The Relationship between Each Parameter

The distribution of chemical parameters is shown in Figure 4.9.

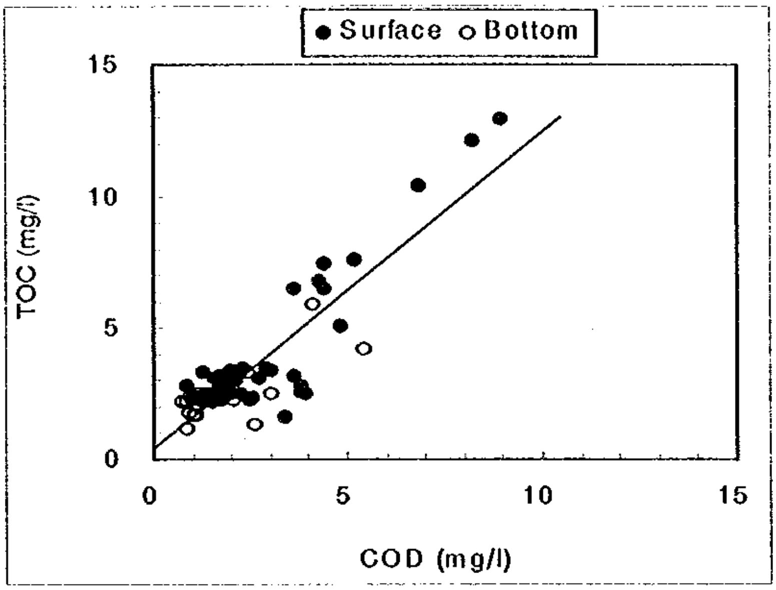


Figure 4.9 Relation between COD and TOC in Water

The above figure demonstrates that COD and TOC has a strong correlation (correlation coefficient of 0.877). It means that COD can be considered as an indicator for organic matters containing carbon. As a result of this monitoring, the following formula was obtained.

$$TOC = 1.2 \times COD \cdot 0.4$$

This formula means the concentration of TOC tended to be higher than that of COD. And it is possible to estimate the concentration of TOC from COD by this formula.

Meanwhile, the relationship of other parameters was investigated as follows:

- Relationship between salinity and COD
- Relationship between nitrogen, phosphorous and chlorophyll-a

As mentioned above, the distribution of salinity indicates the mixing condition of fresh water and seawater. And it is possible to project the profile of chemical parameters from the salinity data. The relationship between salinity and COD during dry and wet weather conditions is shown in Figure 4.10. COD concentration of SL1-1 in dry season was especially high at 8.7 mg/l. On the other hand, that of Panuco River in rainy season was comparatively low. Omitting these points as exceptions, other data points showed a tendency that the higher the salinity value, the lower the COD value. This trend is explained by the mixing of fresh water of high COD concentration with seawater of comparatively low COD concentration.

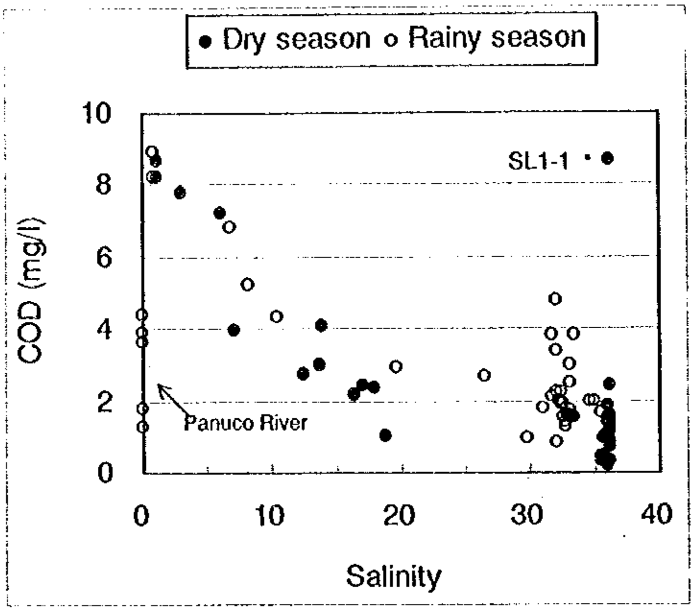


Figure 4.10 Relation of Salinity and COD in Water

Figure 4.11 shows nitrogen and phosphorous cycle in the coastal area.

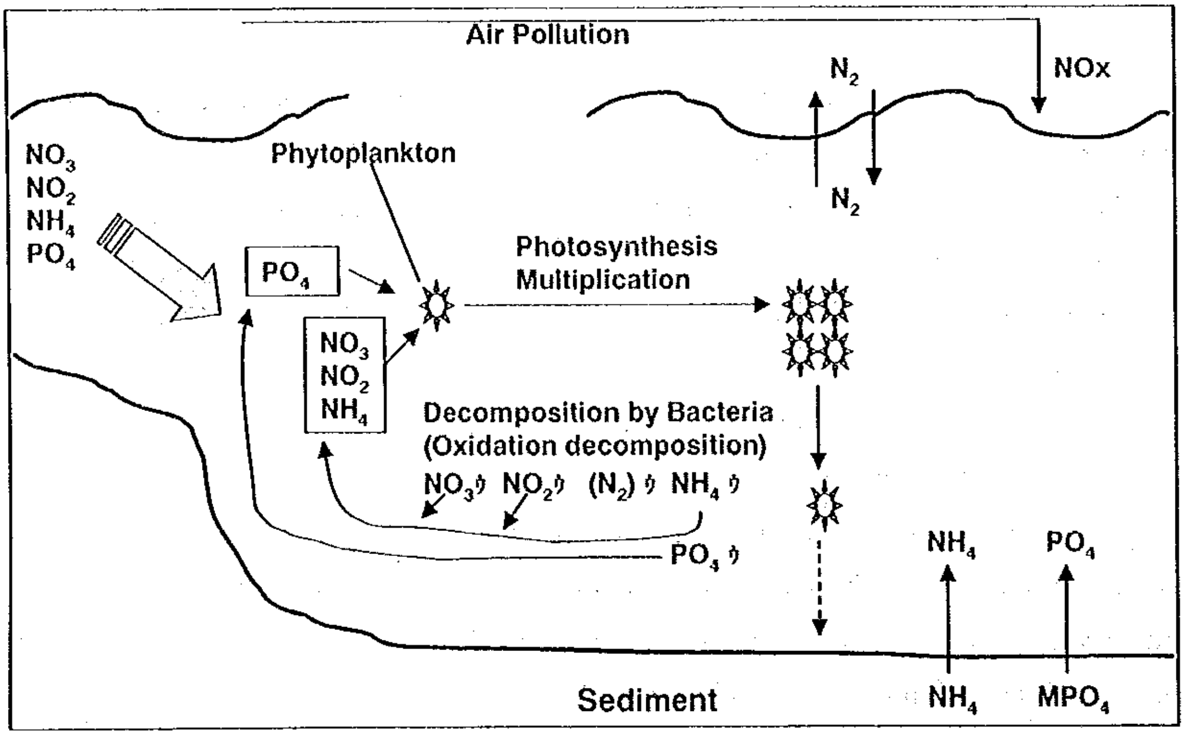


Figure 4.11 Nitrogen and Phosphorous Cycle in the Coastal Area

Nitrogen and phosphorous are the basic requirements for organisms. These substances have close correlation with biological activities. Phytoplankton needs nutrient salts for photosynthesis multiplication. Mortal bodies and fecal pellets of plankton are decomposed by bacteria, and provide nutrient salts to the hydrosphere. With enough concentration of oxygen, organic nitrogen is oxidized and decomposed through ammonium nitrogen, and nitrite nitrogen to nitrate nitrogen. In general, inorganic nitrogen in the coastal area is mostly formulated out of nitrate nitrogen. On the other hand, if there is low concentration of oxygen, oxidation does not proceed to nitrate nitrogen. As a result, concentration of ammonium nitrogen will become higher.

The supply of nitrogen and phosphorous to coastal area is explained as follows:

Supply of nitrogen and phosphorous

= Pollutant + Biological activity + Released from sediment + Provided from air

Both nitrogen and phosphorous are essential elements. The ratio, N/P, will be constant in an individual phytoplankton. It is called "Redfield Ratio" (Redfield, Ketchum and Richards, 1963), which means the atomic ratio of carbon, nitrogen and phosphorus in phytoplankton. It has been said that it is based on the following formula:

$$(CH_2O)_{106}(NH_3)_{16}H_3PO_4+138O_2 \blacksquare 106H_2CO_3+16NO_3^-+H_2PO_4^-+17H^++16H_2O$$

So if the ratio of carbon, nitrogen and phosphorous is almost constant in organisms, the value can be expressed as follows:

$$C:N:P=106:16:1$$

The relationship between nitrogen and phosphorous is shown in Figure 4.12. A straight line in the figure indicates N/P ratio (N/P = 16). Note that the unit is not mg/l but 'g-at/ l.

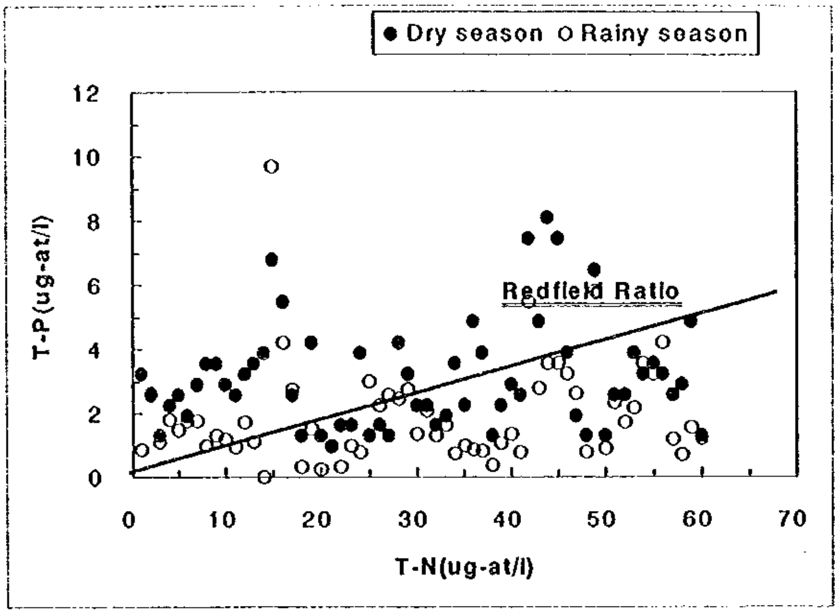


Figure 4.12 Relation between T-N and T-P

The figure shows that the phosphorous concentration increases in proportion to the nitrogen. Its slope is similar to the Redfield ratio. The higher biological activity in dry season is supposed to explain the existence of more phosphorous compared to rainy season.

4.2.4 Comparison with Criteria

Environmental quality standards of Japan, United States, and Mexico are shown in Table 4.3 and Figure 4.4.

(1) Basic Parameters

In the pilot monitoring survey, the parameters that showed high concentration within established criteria were COD, SS, total nitrogen and total phosphorous. Total coliform showed high concentrations even though it was not compared with the standard because of the difference of unit.

Table 4.3 Criteria of Quality Standards and Results of Pilot Monitoring Survey (Basic Parameters)

		Japan				Mexico	USA		Result of Pilot monitoring	
		Environmental quality standard for water pollution[1]	Standard of fisheries water		Water quality standard for drinking water	Environmental quality standard for water pollution[2]	National Recommended water quality criteria[3]			
Parameter	Unit		Fresh water	Sea water			Fresh water	Sea water	Dry season	Rainy season
Salinity	psu								<2-36.3	<2-36.3
pH		7.8-8.3	6.7-7.5	7.8-8.4	5.8-8.6		6.5-9.0	6.5-8.5	7.97-8.55	7.01-8.27
COD	mg/l	2			10				<0.5-8.7	0.7-8.9
DO	mg/l	7.5				5.0			3.0-15	<0.5-9.2
SS	mg/l								1-125	1-556
NH_4-N	mg/l					0.01			<0.01-0.06	<0.007-0.040
NO_2-N	mg/l		0.03	0.06	10	0.002			<0.01-0.02	<0.005-0.012
NO_3-N	mg/l		10	10	10	0.04			<0.01-0.21	0.01-0.93
Total-N	mg/l	0.2							0.016-1.6	0.04-1.3
PO_4-P	mg/l					0.002			0.01-0.15	<0.003-0.13
Total-P	mg/l	0.02							0.04-0.25	0.007-0.51
Chlorophll-a	mg/l								<0.5-73	0.5-103
Total coliform	mg/l	1000MPN/100mL							0-16000[4]	0-4800[4]
Fecal coliform	mg/l									
Hexane extracts	mg/l	ND	ND	ND					0.6-2.8	<0.5

(1) Criteria were established for coastal water and by area.
(2) Criteria were established by CNA in 1989.
(3) This was recommended by EPA in December 10, 1998 in "National Recommended Water Quality Criteria; Notice; Republication"
(4) Unit is COL/100ml.

(2) Toxic Parameters

Standards for toxic parameters are different from each country. For instance, that of Japan will indicate comparatively higher concentrations.

The toxic parameters, which showed higher concentrations compared with the criteria, were copper, lead and nickel, aldrin and endrien. However, a confirmation test by GC-MS method or any other method was not conducted for aldrin and endrien. Concentrations of some heavy metals were a little higher than the standard of Japan and the United States.

Table 4.4 Criteria of Quality Standards and Results of Pilot Monitoring Survey (Toxic Parameters)

		Japan				Mexico	USA		Result of Pilot monitoring	
		Environmental quality standard for water pollution(1)	Standard of fisheries water		Water quality standard for drinking water	Environmental quality standard for water pollution(2)	National Recommended water quality criteria(3)			
Parameter	Unit		Fresh watei	Sea water			Fresh water	Sea water	Dry season	Rainy season
Phenols	mg/l				0.005	0.06			<0.001	<0.001
Cr^{6+}	mg/l	0.05	0.003	0.01	0.05	0.05	0.011	0.05	<0.01	<0.003
Cyanide	mg/l	ND	ND	ND	0.01	0.001	0.0052	0.001	<0.006	
As	mg/l	0.01	0.01	0.01	0.01	0.04	0.15	0.036	<0.001-0.004	<0.02
Cd	mg/l	0.01	0.0001	0.0001	0.01	0.0009	0.0022	0.0093	<0.002	<0.0005
Cu	mg/l		0.001	0.005	1	0.003	0.009	0.0031	<0.005	<0.0002-0.0058
Pb	mg/l	0.01	0.001	0.003	0.05	0.006	0.0025	0.0081	<0.01	0.0002-0.0049
Hg	mg/l	0.0005	0.0002	0.0001	0.0005	0.00002	0.00077	0.00094	<0.001	<0.0003
Ni	mg/l	0.01	0.01	0.01		0.002	0.052	0.0082	<0.005-0.007	0.0001-0.005
Zn	mg/l		0.001	0.01	1	0.09			0.002-0.050	<0.0005-0.0021
Cr	mg/l								<0.01-0.02	<0.003
Alkyl-Hg	mg/l	ND	ND	ND					ND	ND
Aldrin	mg/l					0.001			ND	ND-0.002
CCl_4	mg/l	0.002	0.002	0.002	0.002	0.5			ND	ND
Chlordane	mg/l					0.00009	0.0000043	0.000004	ND	ND
4,4 DDT	mg/l					0.0001	0.000001	0.000001	ND	ND
Dieldrin	mg/l					0.0007	0.000056	1.9E-06	ND	ND
Endrin	mg/l					0.00004	0.000036	2.3E-06	ND	ND-0.0008
HCB	mg/l					0.0016			ND	ND
Methyl parathion	mg/l	0.01				0.00004			ND	ND
Paration	mg/l					0.00004			ND	ND
PCB	mg/l	ND	ND	ND		0.00003	0.000014	0.00003	ND	ND
Terachloroethylene	mg/l	0.01	0.01	0.01	0.01	0.1			ND	ND
Trichloroethylene	mg/l	0.03	0.03	0.03	0.03	0.02			ND	ND

(1) The criteria were established by CNA in 1989.

(2) This was recommended by EPA in December 10, 1998 in "National Recommended Water Quality Criteria; Notice; Republication".

4.3 Environmental Profile of Bottom Sediment in the Tampico Area

4.3.1 Horizontal Profile

The horizontal profile of sediment in the monitoring area is described below and the horizontal profile of sediment are shown in Figure 4.13.

(1) Coastal Area

a) Altamira Industrial Port

Except for its inner part (AP-5), the vertical profile of Altamira Port was unclear because of the change of particle size of one of the two points set and this occurred twice during observation. At this point, ORP in sediment showed reduced condition for both seasons though sand component was about one-third of the whole. The value of COD, IL, and TOC were 7-8 mg/g, 12-13%, 2.6 mg/g, respectively.

Concentrations of these parameters were comparatively low against fine particle ratio.

b) Coastal Area (North Area)

Two representative points of sediment quality held 88-96% ratio of sand above 75 'm particle size, and silt ratio in sediment was only 1-4%. So each parameter of the pollution index showed low values. For instance, IL was below 2%; COD was below 1 mg/g. and TOC, 1.3 mg/g. There was no evidence that contaminants have accumulated on the sea bottom.

c) Coastal Area (Near Panuco River Mouth)

Areas 1 to 2 km offshore from the river mouth have accumulated silt sediment at the ratio of 70-100%; ORP showed the value from minus 218 to minus 227mV. Concentrations of COD and IL were 15-20 mg/g and 11-15% respectively. Generally they are not seen as signs of sediment contamination.

Each of the two observation points arranged along lines of 1 km offshore, south and north from the river mouth, had above 90% sand sediment. It was thought that the topographical condition is not favorable to accumulation of fine sediment because of waves. IL was below 3% and COD was below 2mg/g, which indicated a low level of contamination.

Contamination by heavy metals, such as copper and mercury, was higher in SL7-1 and SL7-3, which is near the mouth of Panuco River, at concentrations ranging from 4.1 to 39 mg/jk and 0.1 to 0.76 mg/kg respectively. Arsenic was comparatively higher near the river mouth and in Altamira Industrial Port. The other coastal areas showed lower content. This means that heavy metals originated through Panuco River to the coastal area.

(2) Panuco River(PR-1,2)

Silt sediment below 75 'has accumulated on the bottom. Oxidation Reduction Potential (ORP) ranged from minus 140 to minus 320 mV in both seasons and it showed reduced condition. Ignition loss (IL) was very high ranging from 14 to 21%, and TOC was comparatively high. COD, at 15-25 mg/g, was not so high judging from the ratio of fine particle size. After considering those parameters, it was thought that there was an accumulation of contaminants on the bottom sediment.

Heavy metal content showed a tendency to be higher in PR-3, which is near the urban area rather than in the mouth and upstream ends of the river.

(3) Pueblo Viejo Lagoon

Many fine particles were accumulated on the bottom, and over 85% were silt. ORP values were from minus 286 to minus 114 mV and reduction condition in sediment is a little relaxed than in Panuco River.

IL was high to some extent at 10-15%; COD and TOC were 9-17 and 7-9 mg/g respectively. These values indicate normal conditions for sediment.

Heavy metal contamination showed a tendency to be higher in the north area than in the south area. It seems reasonable to conclude that pollution source of heavy metals is the urban area near Panuco River, spreading from north to south in Pueblo Viejo Lagoon.

(4) El Conejo Lagoon

Sediment samples of El Conejo Lagoon contain a lot of sand (75 - 425 μm:39-77%) with silt.

During dry weather conditions, COD showed a high value of 28 mg/g to low silt ratio, but IL was not very high. In rainy season, pollution indices like IL and COD were remarkably high. They were extremely high against fine particle ratio because some foreign matter like wooden tips in sediment was included. Therefore it was thought that the result during dry weather conditions adequately described sediment condition. Anyway eutrophication of the lagoon is expected to subsequently follow.

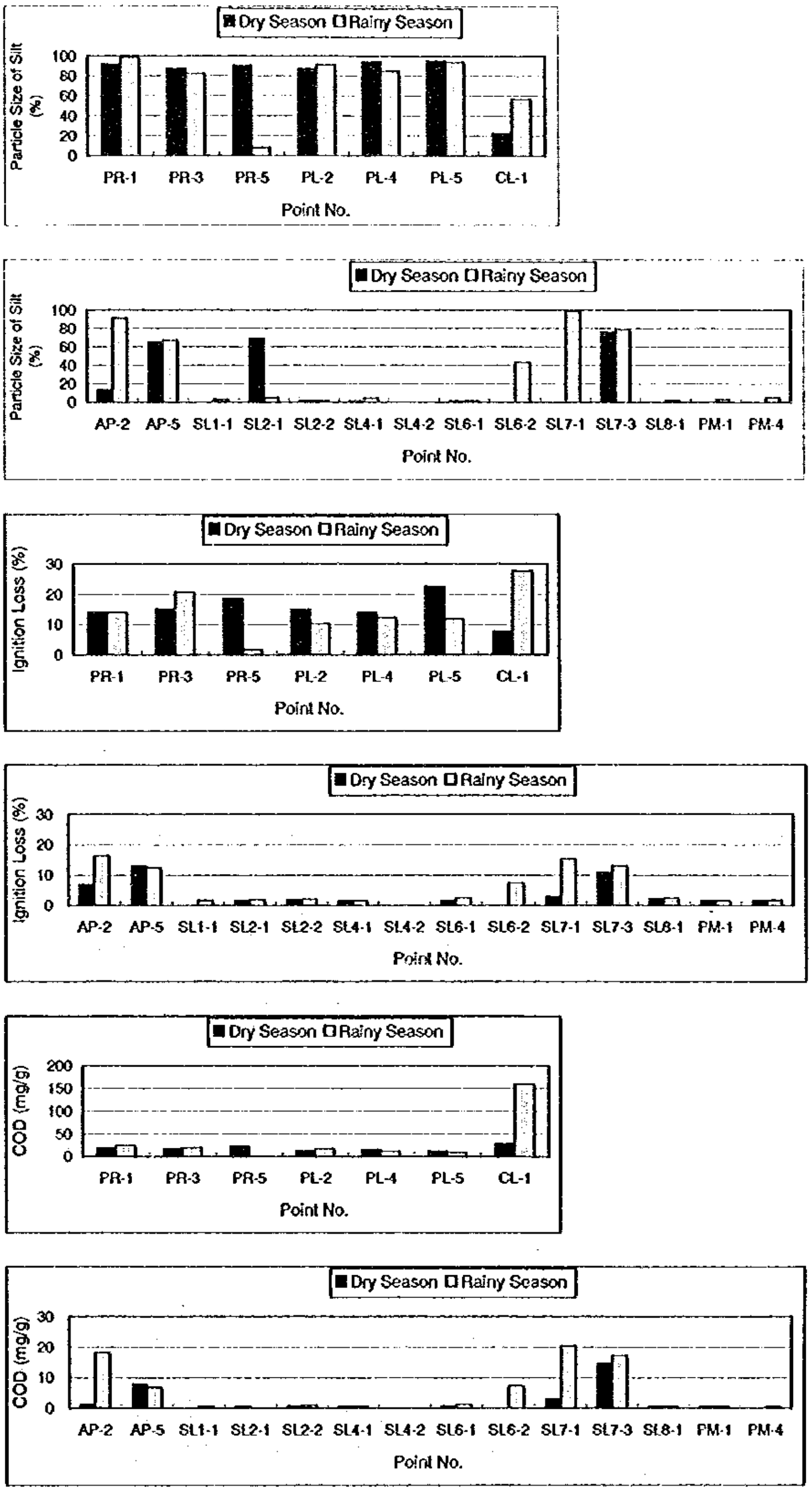


Figure 4.13(1) Horizontal Profile of Sediment (Basic Parameters)

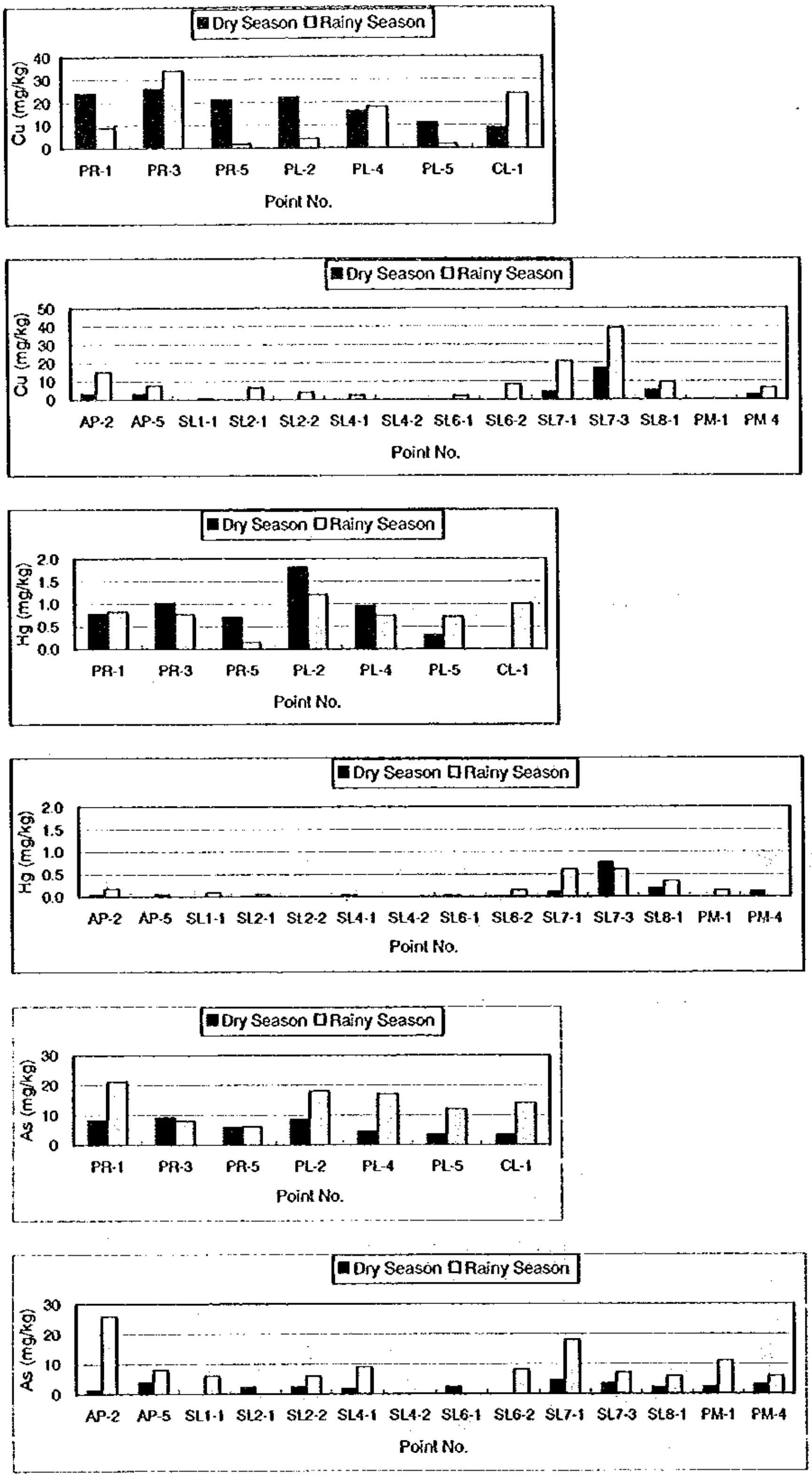


Figure 4.13(2) Horizontal Profile of Sediment (Toxic Parameters)

4.3.2 Relation between Each Parameters

Sediment quality was basically determined by particle size of sediment. The higher the ratio of fine particles (particle size below <75 µm), the greater the pollutant substances commonly included. In the coastal area and river mouth where current conditions are affected by topography or weather, it is well known that a change in particle size of sediment occurs a little every sampling time, even the sediment was taken at the same point. Therefore it was thought that constant sediment quality was appeared at the points as particle size ratio of sediment unchanged during dry and rainy season.

Table 4.5 shows the correlation coefficients of silt content (below 75 µm) and other parameters. The relation between silt content and ignition loss, COD, As and Hg are shown in Figure 4.14.

Table 4.5 Correlation Coefficient of Particle Size and Other Parameters

Parameter	Correlation Coefficient	Parameter	Correlation Coefficient
Ignition Loss	0.826	Pb	0.603
COD	0.288	Cu	0.643
TOC	0.277	Zn	0.782
Hexane Extracts	0.261	As	0.530
Cr	0.783	Hg	0.710
Cd	0.401		

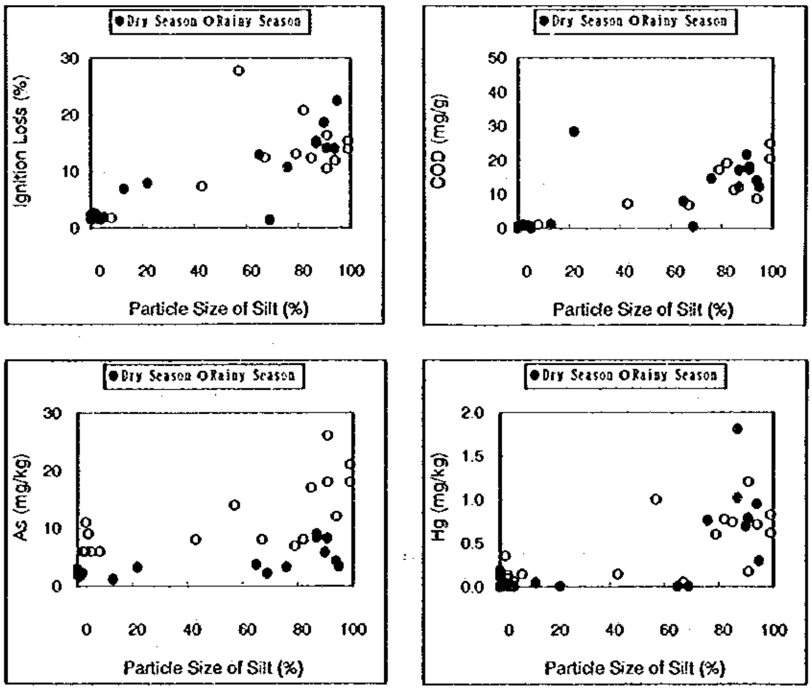


Figure 4.14 Relation Between Silt Content and Ignition Loss, COD, As and Hg

Particle size and other parameters have strong relation within a 5%-level of significance, except for COD, TOC and hexane extracts. The correlation coefficients of COD and TOC were comparatively lower because of the high concentration of organic matter in Conejo Lagoon.

The relation between ignition loss and copper and between zinc and mercury is shown in Figure 4.15.

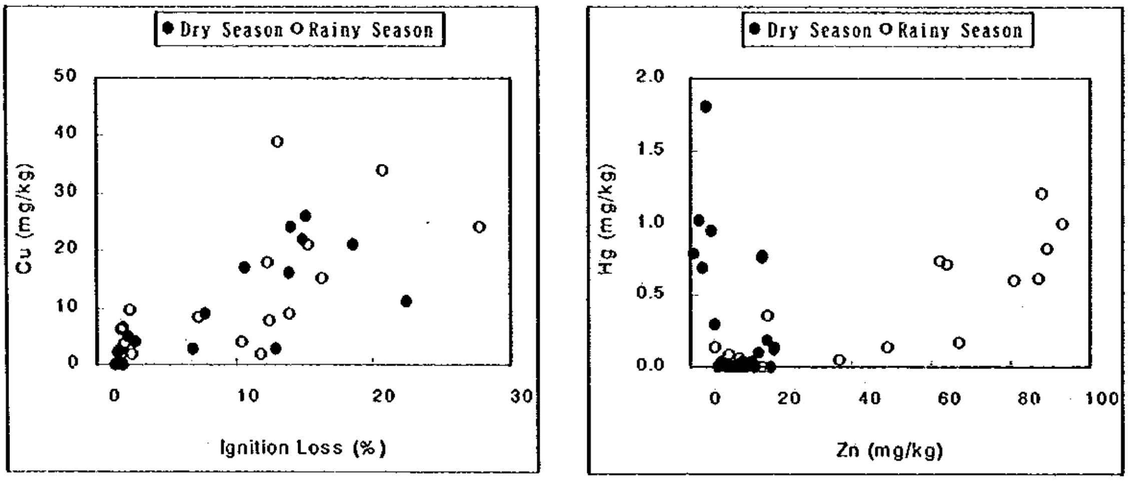


Figure 4.15 Relation of Ignition Loss and Cu, Zn and Hg

Ignition loss and copper have strong relation, indicating that organic matter and heavy metals exhibit the same behavior. There is no clear correlation between zinc and mercury in dry season, but in rainy season, a strong correlation is observed, same as ignition loss and copper. The introduction of heavy metals into the water mainly originates from the wastewater discharge by industrial areas and from the earth's crust and atmosphere. Furthermore, the type of heavy metals depends on how they are used in human activities. On the other hand, the composition of heavy metals in the earth's crust is fixed, so the relation between them and IL is constant in water.

4.4 Results of Biological Accumulation Test

4.4.1 Horizontal Profile.

Unlike heavy metals, organic compounds, e.g. pesticides, HCB and PCB were not detected in all samples.

The results of heavy metals in biological accumulation test are shown in Figure 4.16.

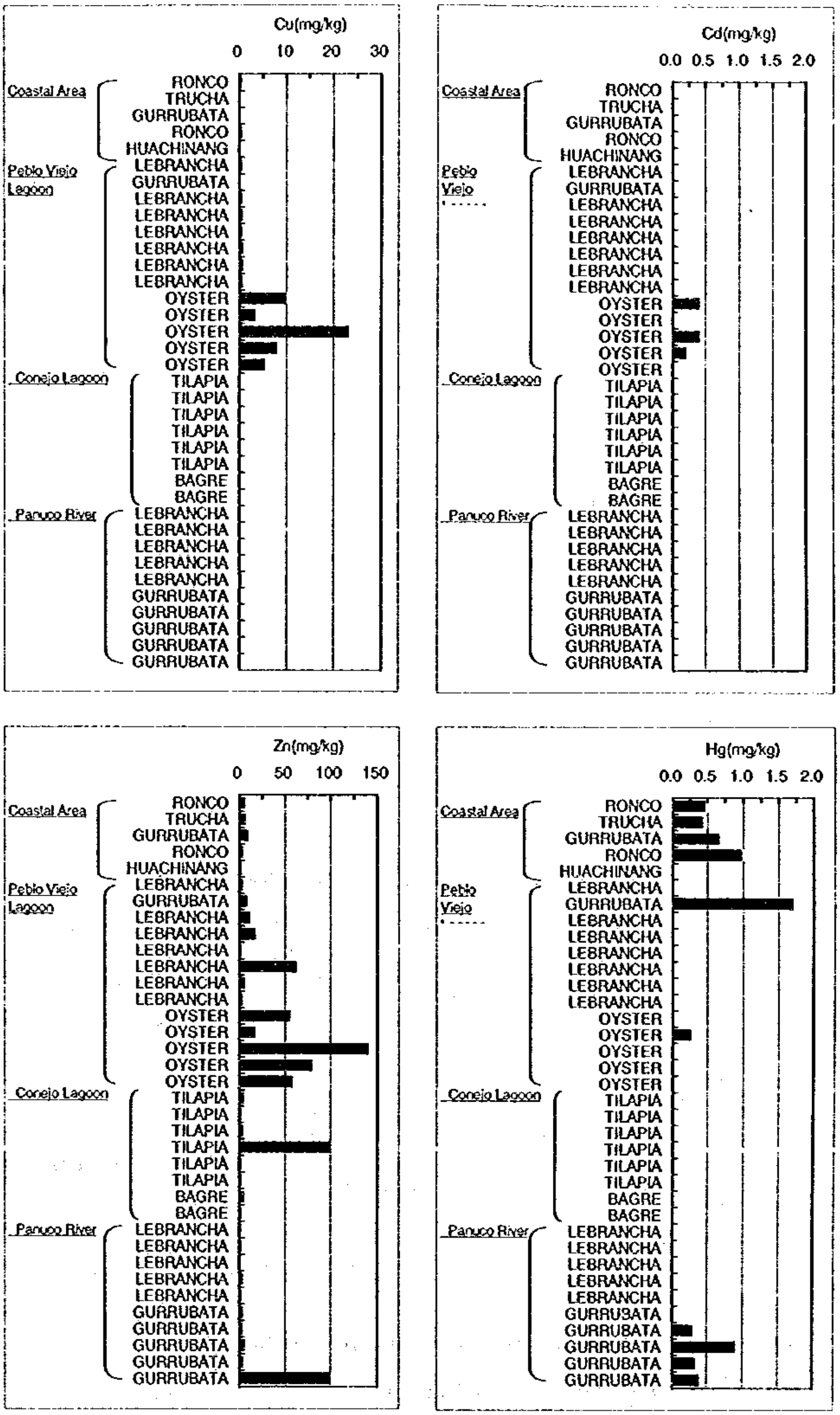


Figure 4.16 Result of Biological Accumulation Test (Heavy Metals)

Copper and Zinc indicated higher content in oyster samples taken in Pueblo Viejo Lagoon, i.e. 3.2 to 23 mg/wet kg for copper and 17 to 140 mg/wet kg for zinc. Zn also indicated high contents in Gurrubata in Panuco River and Tilapia in Conejo Lagoon.. However these contents are within the normal average level. And in general, organisms living in superior rank of food chain will more susceptible to accumulate toxic substances.

Besides, mercury indicated higher contents in fishes in the coastal area, in Gurrubata in Pueblo Viejo Lagoon and Panuco River. Oyster samples that contained high copper and zinc contents had lower mercury content. This mercury content is higher than would normally be found in a simple food chain (which is not contaminated) as shown in Table 4.5 and Table 4.6. The Tampico Area will have a little problem about mercury pollution.

Table 4.5 Average Mercury Content under Simple Food Chain
(Knauer and Martin. 1972)

Types	Average of mercury accumulation (mg/wet kg)
Phytoplankton	0.028
Zooplankton	0.012
Anchovy	
Skin	0.010
Reproductive glands	0.015
Scale	0.030
Muscle	0.040
Liver	0.090

Table 4.6 Mercury Content of Biological Accumulation

Area	Species	Mercury accumulation (mg/wet kg)	Quotation
Tasmania	Flad head (*Platycephalus bassensis*)	0.05 to 0.9	Dix and Martin, 1975
California, United States	Sea mussel (*Mytilus clifornianus*)		Eganhouse and Young, 1976
	Reproductive glands	<0.01 to 0.03	
	Muscle	<0.01 to 0.08	
	Digestive glands	<0.01 to 0.18	
Coastal area in Japan (e.g. Osaka Bay, Tokyo Bay)	Fishes	0.03 to 0.23 (Average data)	Yoshida, 1976
	Shells	0.01 to 0.07 (Average data)	

4.5 Characteristics of Water Quality in the Tampico Area

From what has been discussed above, it is concluded that:

1) Chemical parameters have an effect on each other. This characteristic is not peculiar to Tampico Area; it could also be observed in other areas.
2) It is possible to verify data by the above theory.
3) The measuring results of COD, SS, nitrogen and phosphorous, caused by domestic wastewater, showed high concentration, some of them even exceeding

the criteria of water quality in Japan, United States and Mexico.

4) Contrary to these basic parameters, the concentration of heavy metals in water was relatively high in Panuco River and near the river mouth compared with the other areas, but their values were low and exceeded the criteria of water quality only in Japan and the United States. Pesticide, PCB and other volatile organic matter (VOC) were almost below the detection limit.

5) The concentrations of pollutants in water have the tendency to be higher in Panuco River, especially PR-2, PR-3, than in the other areas. In Pueblo Viejo Lagoon, it was assumed that pollutants originated from Panuco River, because the concentrations of pollutants showed high value in the northern area (PL-1, PL-2) and it decreased in the southern area.

6) On the other hand, in the coastal area, the concentrations of each parameter showed higher values near the mouth of Panuco River than in the other areas. The reason is that pollutant substances are provided from Panuco River.

7) Dissolved oxygen and chlorophyll-a in Marismas Lagoon showed high concentrations. And since water temperature was high at above 30 ', there is high photosynthesis activity. As a result, eutrophication has occurred. The result of nitrogen and phosphorous also indicated it.

8) The contents in sediment were related with particle size. That is to say, the more silt in sediment, the more the pollutants, e.g. COD, heavy metals. The reasons are as follows:
   - Pollutants easily gather on the bottom where fine particle substances are accumulated, because water movement is not active.
   - Silty sediment easily adsorbs pollutants, because its particle size is small and surface area is extremely large.

9) Sediment polluted by organic substances, such as COD, and heavy metals, have higher concentrations in Panuco River than in the other areas, same as water quality. It is supposed that pollution sources are mainly from urban and industrial discharge.

10) PCB, VOC and alkyl-mercury content of pesticides are below detection limit in sediment, the same as in water quality.

11) The result of elution test showed that the concentrations of all toxic parameters were below detection limit or just exceeded it. So serious problem by elution was not seen.

12) In biological accumulation test, relatively high values were detected for some heavy metals. Copper and zinc content is the same level as the normal average level. However, a few samples, Ronco in the coastal area, Gurrubata in Panuco River and Pueblo Viejo Lagoon, contained high concentrations of mercury. This number is higher than in other results of monitoring survey, for example in Japanese coast.