3.2 Socioeconomic Environment of Each Administrative Unit

The lake basin includes nine districts: Aregua, Capiata, Itaugua, Luque, San Lorenzo, Ypacarai, San Bernardino, Paraguari, and Pirayu. Their boundaries are not defined and there exist almost no maps or statistics by district (Fig. M3201). Accordingly, the socioeconomic environment was understood from interviews with the staff. Land use in the basin was interpreted from aerial photos (Fig. M3202).

Most districts suffer from financial instability because they depend on license plate sales and patent fees from newly opened stores and plants for the annual revenue. Indeed, regional improvement from a long-term viewpoint is impossible.

Though located outside the basin, the capital city Asuncion is a factor which cannot be overlooked when considering water pollution problems. The capital has a population of about 600,000 while encompassing the neighboring Luque and San Lorenzo metropolitan areas. Capiata and Aregua play the roles of commuter towns for Asuncion.

The national highway No.2, which is a main artery not only inside Paraguay, but also for access to Brazil, runs through this basin. Most people and materials within the basin travel via this highway. Most recreation facility visitors, on the other hand, come from Asuncion and neighboring areas.

Consequently, the position of Asuncion needs to be taken into account when the land use plan or pollution control plan of the lake basin are discussed.

Matters closely related to the execution of the water quality conservation measures are described below for the districts within the basin.

3.2.1 AREGUA

The Aregua district has an area of about $100km^2$ and is wholly included in the basin. This district faces the lake directly. The population according to the 1982 census is reported to be 14,558 and estimated now to be about 20,000.

This district was once a prosperous place of summer recreation for the people of Asuncion after construction of a railway in 1870, but was replaced by San Bernardino with the introduction of automobiles. In particular, after the opening of the national highway, No.2, in the 1950s, Aregua became a terminal town of a branch road. However, in the 1980s, the road to Luque was opened and the road to Ypacarai was paved, and close ties with Asuncion were regained. Last year, a jetty for a sightseeing ferry to San Bernardino was constructed on the shore of the lake.

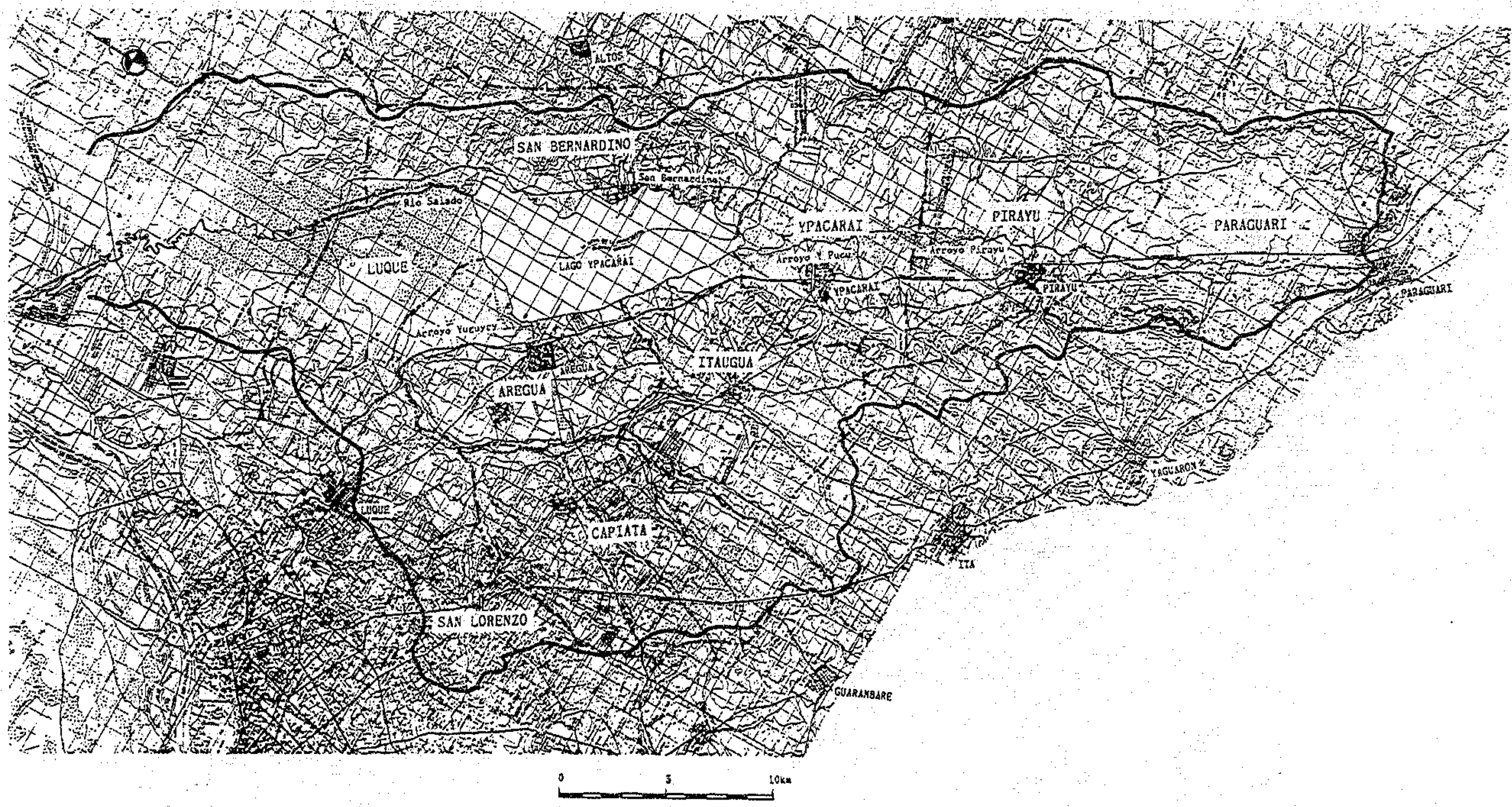
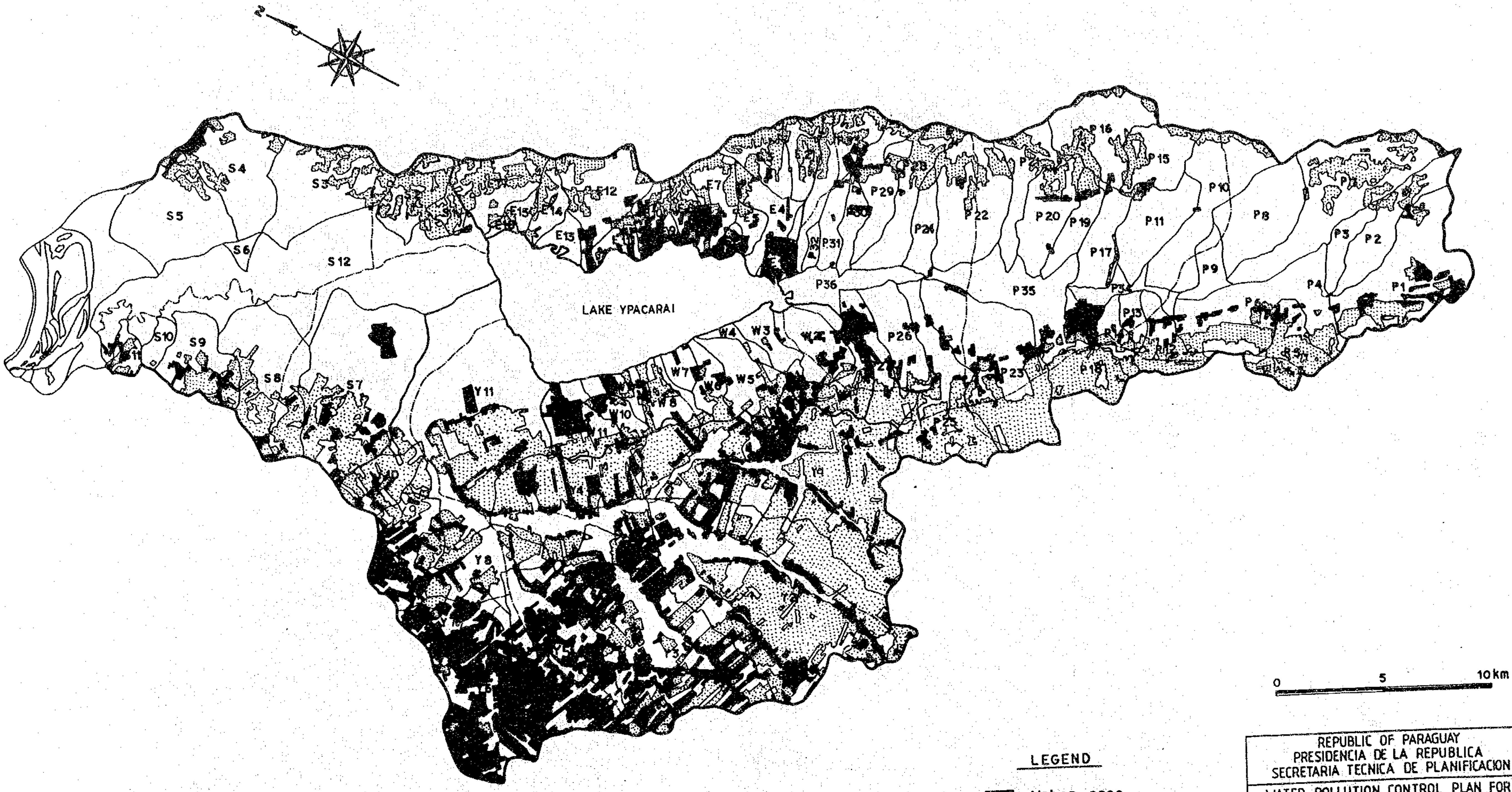


Fig. M3201 Administrative Districts in the Lake Basin



LEGEND

- Urban area
- Cultivated area

REPUBLIC OF PARAGUAY
PRESIDENCIA DE LA REPUBLICA
SECRETARIA TECNICA DE PLANIFICACION

WATER POLLUTION CONTROL PLAN FOR THE LAKE YPACARAI AND ITS BASIN

LAND USE (1988)

DISTRIBUTION OF URBAN AND CULTIVATED AREAS.

DATE		DWG. NO.	

JAPAN INTERNATIONAL COOPERATION AGENCY

Fig. M3202 Present Land Use in the Lake Basin
(Distribution of Urban and Cultivated Areas).

In this district, production of ceramics using clay quarried from hills behind the town is prosperous. There are around 30 clay quarry industries, producing clay at a total of around 60 tons/month. But quarrying of clay and production of ceramics is done at the household level and no large-scale industry exists.

Agricultural products include vegetables, flowers, fruits, dairy products, and honey. In particular, strawberry production here occupies about one half of the total production in Paraguay. Industrial products include cotton yarns, textiles, soap, and foods. Since both agriculture and industry are small-scale, nearly 40% of the labor force of this town is employed in Asuncion.

The hills to the west of the urban area have been developed as arable land, which is rapidly changing into housing land, because this area is only one hour by car from Asuncion. Development of housing land is also underway in the downstream area of the Yuquyry and on the lakeshore, but some places (Nueva Asuncion, etc.) have been abandoned owing to inadequate application of tenants.

Water supply is provided from the wells administered by SENASA, but the sewerage is not yet improved nor expanded.

3.2.2 CAPIATA

Capiata has an area of about 90km^2 and is included entirely within the basin, though does not face the lake directly. The population here is increasing yearly as a commuter town of Asuncion, from 44,629 in 1982 to about 56,000 at present. As a result, the cotton fields once prevailing in this district have been entirely turned into housing land and only some vegetable gardens remain.

The oil refinery (CAPSA, with 1,000 - 1,400 employees), the largest in this basin, is situated along the national highway No.2. This plant absorbs the labor force of the town but is also large source of pollution. In addition, there is a pottery-brickyard and a newly constructed cancer hospital with 200 beds. People employed in Asuncion comprise 10 ~ 15% of the labor force in this district.

Potable water is supplied from SENASA wells while plants and clinics have household deep wells. No water sewage is yet established.

3.2.3 ITAUGUA

The Itaugua district has an area of about 120km^2 and is included entirely within the basin. The east side of the district faces the lake directly. The population, according to the 1982 census, was reported to be 26,000, and now is estimated to be 35,000 to 40,000.

The national highway No.2 runs through the center of the district, offering convenient access to Asuncion. The commuters to Asuncion are around 10% of the labor force. Though this is not a commuter town, those who cannot maintain life in Asuncion flow into this district. Development of housing is active. There are 50 to 60 pieces of land currently under development, each piece has an area of 1 - 30ha. But this development is not well planned.

In spite of increasing housing development, there remains much cultivated land producing various vegetables, manioc, and sugar cane.

The industry includes the production of vegetable oil, bricks, ceramics, cotton yarn, furniture, and foods. Because of the presence of large plants, around 70% of the labor force is absorbed within the district. But the oil refinery discharges untreated waste water while quarries of clay (raw material of bricks and ceramics) become a principal source of sand and soil.

The potable water is supplied from two SENASA wells, but a sewage work is not yet established.

3.2.4 LUQUE

The Luque district has an area of about 203km², most of the urban area lies outside the basin, but it is expanding into it. The population according to the 1982 census was reported to be 64,288 and growing at a high rate because of its proximity to Asuncion. The annual population growth rate had a mean of 4.7% from 1972 to 1982.

Principal agricultural products are vegetables. Milk and flowers are also shipped to Asuncion. This district is known to produce handicrafts (gold/silver wares and musical instruments), as well as electronics, furnitures, and metal plants.

Because of its proximity to Asuncion, there are many schools including nine elementary, seven senior high, and five women's schools.

CORPOSANA supplies city water to 80% of the urban households, but sewerage service is limited to 50%.

3.2.5 SAN LORENZO

The San Lorenzo district has an area of about 40km² and only a part of the district is included in the basin. And the basin portion of this district is mostly urbanized. The population according to the 1982 census was 74,552 and estimated at 120,000 now.

This district makes up the metropolitan circle together with Asuncion and waste handling is a big problem here because there are a lot of houses, plants, and offices. There are a lot of butcheries and food factories in the district portion of the basin, and the San Lorenzo River (a branch of the Yuquyry River) is heavily polluted by waste water from plants and urban wastes.

The service water is supplied from CORPOSANA wells, but not enough to meet the demand. Some district portions claim shortage of water. About 60% of the houses with publicly supplied water are connected to the sewerage system and sewage is collected into the sewage treatment plant with three stages of lagoons. This sewage treatment plant reportedly processes waste water of about 15,000 persons.

3.2.6 YPACARAI

The Ypacarai district has an area of about $110km^2$ and is wholly included in the basin. Only a part of the district faces the lake. The population according to the 1982 census was reported to be 12,057 and estimated to be about 15,000 now. National highway No.2 runs through the center of the district, but migration from the outside is not as large as in the case of Itaugua because of its distance from Asuncion.

The district is mostly pasture land. Food, tanning, and brick plants, and oil refineries in this district are of a small scale. Accordingly, 70 - 80% of the labor force has flowed out to Asuncion.

This district also frequently suffered damage from floods in the past because of a wide area which are the lowlands of the Pirayu River.

Since there is no SENASA well, each household draws service water from individual shallow wells. Raw sewage is treated in the infiltration tank, and children often suffer symptoms possibly attributed to the contamination of underground water (diarrhea, etc.).

3.2.7 SAN BERNARDINO

San Bernardino has an area of about $110km^2$ and is located on the east side of the lake. The shoreline of this district is the longest among the nine districts. This is a resort area with private villas, hotels and clubs. The population is about 7,000, (6,591 according to the 1982 census) and the population here nearly triples in summer with long-term vacationers.

This district has served as a resort place for the past 15 years and the urban population has grown from 17% (in 1972) to 34% (in 1982). Tourism from the outside increases only for three months from December to February.

Apart from sightseeing and recreation facilities, there is an instant coffee plant which provides jobs to 50 or more inhabitants.

The underground water is scarce and contains salt, and is thus not suitable as source of potable water. Consequently, lake water is used as source of potable water here. Lake water is taken where it's 3m deep and about 300m from the shore. Coagulation, filtration, and chlorine treatment are performed by the CORPOSANA water purifying plant. The maximum capacity is $270m^3$/hour and the maximum water supply record is about $60,000m^3$/month. This plant is scheduled to be expanded to meet increasing demand.

A sewerage system is not yet established, but its construction plan was announced this year by CORPOSANA. However, the work will not be easy because of hard rocks lying near the surface. Besides, sewerage treatment with soil (using infiltration tank, etc.) will not be effective due to the shallow depth of the underground water level.

3.2.8 PARAGUARI

This district has an area of about $270km^2$, in which only a portion (upstream of Pirayu River) is included in the basin. The population according to the 1982 census was 13,644 and has since decreased because of fewer job opportunities. Particularly remarkable is the decrease in the male population and the rural community.

Principal industries are agriculture and cattle ranching. There are only small-scale industrial plants for cotton yarn, tanning, charcoal, rum, and bricks.

CORPOSANA supplies city water to the urban area, but in the rural area potable water is obtained from either shallow wells or springs.

3.2.9 PIRAYU

The Pirayu district has an area of about $140km^2$ and is wholly included in the basin. This district does not face the lake directly. The population according to the 1982 census was 11,905 and is estimated to be 14,000 - 15,000 now. Most of the younger generation goes to Asuncion because of few job opportunities here.

The district is mostly comprised of pastureland and forests, with less urbanized area and cultivated land. Clay for bricks is being quarried in various places. Since trees are cut down in neighboring mountains to provide fuelwood for brick production, hills are becoming more and more denuded.

The branch flowing into the Pirayu River from the west is heavily eroded, with gully valley. These rivers often overflow during floods, inundating houses and sweeping away livestocks even inside the city of Pirayu.

This district produces good-quality manioc, and there are around 20 small plants which produce starch from this product. These plants are operated in July and August only, but discharge waste water containing large quantities of organic substances.

This district is not equipped with public water or sewage work.

3.3 Socioeconomic Indices of Each Basin

As described above, various socioeconomic indices of the basin are summarized for each district. For the future forecast of lake water quality or the determination of important districts of applicable measures, it is necessary to calculate the population, number of livestock, land use area by land category, industrial or mine production, number of touristic and recreational facility users. These are necessary for the calculation of generated and discharged loads.

3.3.1 Population

The population was based on the result of a 1982 census. Since census figures were made for each district individually for urban and rural areas, in the case of a city stretching outside of the basin, population of that city inside the basin was estimated by multiplying the number of households inside the basin with the mean number of residents per household. On the other hand, in the case of a rural community stretching outside the basin, population was estimated in accordance with land area. Result of the estimation are shown in Table M3311.

Table M3311 Population in the Lake Ypacarai Basin

Catchment Area	Population	Percentage (%)	Districts
Pirayú Basin	25,157	12.1	Paraguari, Pirayú, Ypacarai, Yaguarón, Itá and Itauguá
East Shore Basin	6,065	2.9	San Bernardino
West Shore Basin	13,664	6.6	Ypacaraí, Areguá and Itauguá
Yuquyry Basin	162,440	78.4	Itá. Areguá, Itauguá, Capiatá, San Lorenzo, Fdo. de la Mora and Luque
Total	207,326	100.0	12 districts

Estimation based on Census Data of 1982

3.3.2 Heads of Livestock

The heads of livestock was based on the results of a 1981 census. Since census figures were made according to districts, in the case of a district stretching outside of the basin, the number of livestock was estimated in accordance with land area. Results of the estimation are shown in Table M3321.

Table M3321 Heads of Livestock in the Lake Ypacarai Basin

Catchment Area	Cattle	Pig	Horse	Sheep	Goat	Donkey	Mule
Pirayú B.	25,404	3,711	1,209	1,234	101	49	64
East Shore B.	2,040	434	60	65	1	2	–
West Shore B.	5,064	1,744	205	54	50	24	5
Yuquyry B.	28,561	8,722	1,343	408	310	98	56
Total	61,069	14,611	2,817	1,761	462	173	125

Estimation based on Census Data of 1981

3.3.3 Land Use Area by Land Category

To understand how land is being used, land categories were first interpreted on the aerial photos and then the results were transferred to the topographical map. Each land classification area was measured with a planimeter and aggregated for each basin. The result is shown in Table M3331.

Table M3331 Area by Land-Use Type in the Lake Ypacarai Basin

Land-use Category / Catchment Area	Forest	Dry grass area	Wet or Shallowly flooded area	Pasture	Culti-vated	Lake, Lagoon, etc.	Urban	Ttotal Catch. area
Pirayú B.	64.82	0.79	13.11	176.52	78.51	1.81	18.14	353.70 (42.5)
East Shore B.	19.75	0.15	0.98	20.54	21.71	0.29	11.78	75.20 (9.0)
West Shore B.	13.00	1.60	1.05	21.33	13.49	0.09	9.64	60.20 (7.2)
Yuquyry B.	20.10	1.21	16.40	83.77	126.80	–	95.62	343.90 (41.3)
Total	117.67 (14.1)	3.75 (0.4)	31.54 (3.8)	302.16 (36.3)	240.51 (28.7)	2.19 (0.3)	135.18(16.2)	833 (100%)

Estimation based on aerial photos of 1988

3.3.4 Industrial and Mining Production

Since no industrial statistics are provided by the administrative authorities, it is not possible to express industrial and mining production in figures. Since the location and outline of individual plants and offices are described in Chapter IV, this section shows only the research results on the scale of the vegetable oil refinery and butchery.

The vegetable oil refining industry with the largest workforce in the basin has four plants of production. The outline of individual plants is shown in Table M3341 and three plants are located along Yuquyry River.

Table M3341 Outline of Vegetable Oil Refining Factories

	CAPSA	Aceitera Itaugua	Matteucci Hnos	LINSA
Factory Location District	Capiata	Itaugua	Itaugua	Ypacarai
Starting Year of Operations	1951	1955	?	?
Number of Employees	900~2,000	about 1,200	about 100	40~160
Production Items	Cooking oil cotton	Cooking oil cotton	Cooking oil	Cooking oil cotton
Raw Materials	Coconut palm, cotton, soybean			
Discharge Water Volume (m^3/day)	2,450 *	1,880 *	300 *	350 *
Water Basin	Yuquyry B.	Yuquyry B.	Yuquyry B.	West Shore B

*Measured value in July 1988

About one butchery is located in each district, with daily capacity shown*

Table M3342 Heads of Slaughtered Cattle per Butchery per day

Butchery	Heads Slaughtered	Catchment Area
San Lorenzo	65	Yuquyry B.
Aregua	10	Yuquyry B.
Itaugua	10	Yuquyry B.
Capiata	25	Yuquyry B.
Pirayu	5	Pirayu B.
Ypacarai	5	Pirayu B.

3.3.5 Users of Touristic and Recreational Facilities

There exists no statistical data concerning the number of visitors to hotels and other recreational facilities.

Hotels in the basin are concentrated in San Bernardino. One hotel each of both 1st and 2nd class, and added pensions would result in a total of 375 beds. There are other sleeping accommodations: 49 beds in San Lorenzo and 26 beds in Fernando de la Mora. The scale of hotels and clubs in San Bernardino is shown in Chapter IV.

CHAPTER IV STATE OF GENERATION / DISCHARGE OF POLLUTANTS IN THE LAKE YPACARAI BASIN

4.1 Classification and Distribution of Pollution Sources

The pollution sources in the basin can be divided into two categories: point source and non-point source. Point source means that the generation of loads can be attributed to certain buildings and facilities. In this report, for convenience, point sources are classified into four groups: domestic sources; tourism sources; public facility sources; and industry sources. Domestic sources include homes in general; tourism sources include hotels and club houses; public facility sources include waste water treatment plant and hospitals; and industry sources include various factories and offices. Non-point sources are those with a two-dimensional spread such as forests, grass lands, grazing lands, farm lands, urban areas and river courses.

Of the point sources, nearly 80% of domestic pollution sources are located along the Yuquyry River, and more than 10% along the Pirayu River, corresponding to the distribution of the population shown in Table M3311. The distribution of main point sources except domestic sources is shown in Fig. M4101. Pollution sources related to tourism are concentrated on the East shore basin, and public facilities pollution sources, which are a national hospital and a public waste water treatment plant are both in the Yuquyry basin. Most of the industry pollution sources are agriculture and livestock product processing facilities, and three of the four vegetable oil refineries, which release large amount of waste water, are located in the Yuquyry basin. Other types of factories and offices are also mostly located in the Yuquyry basin.

Non-point sources are found as can be seen in the land use map shown in Fig. M3202. Land use constitution by basin is shown in Fig. M4102.

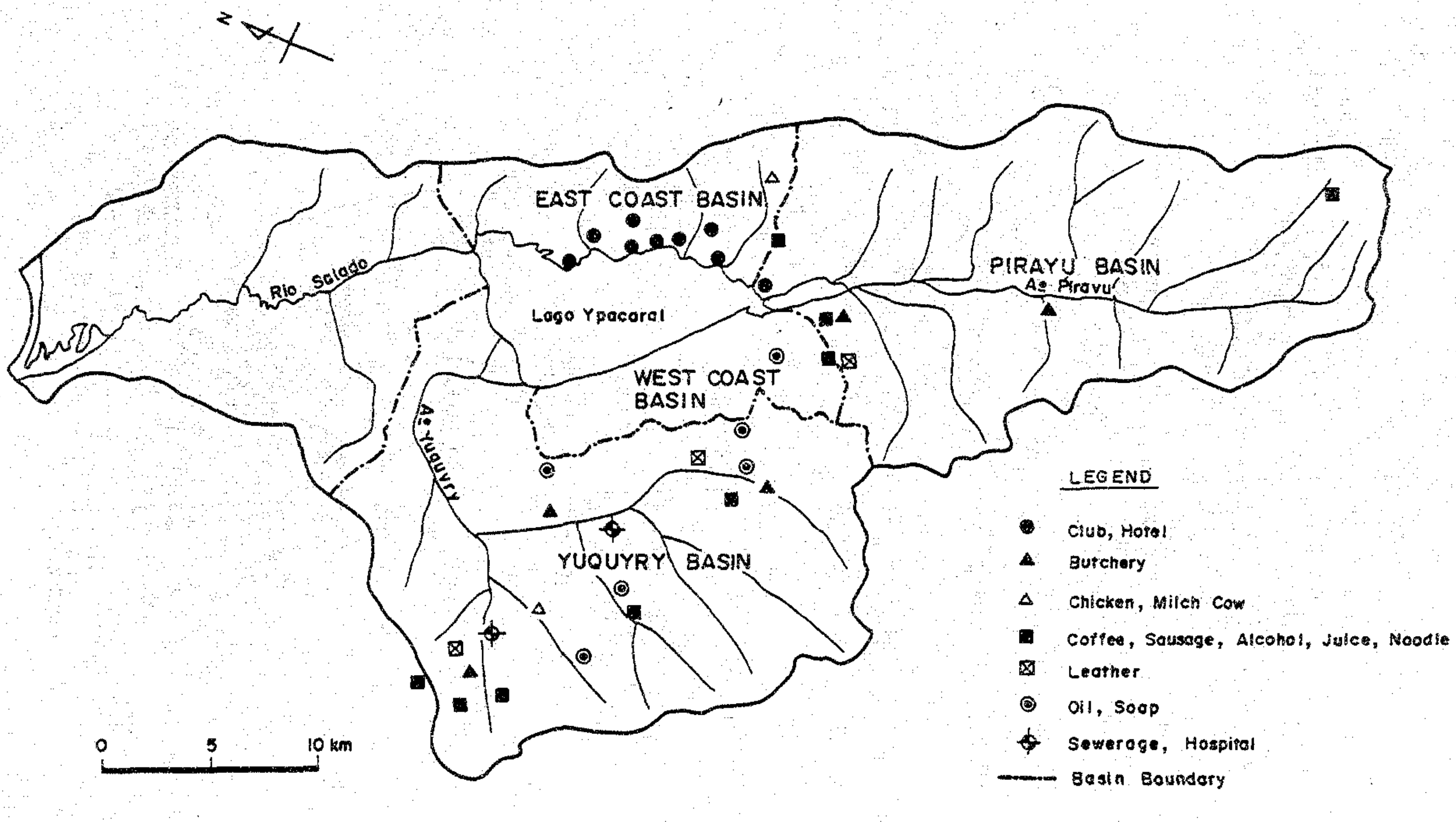
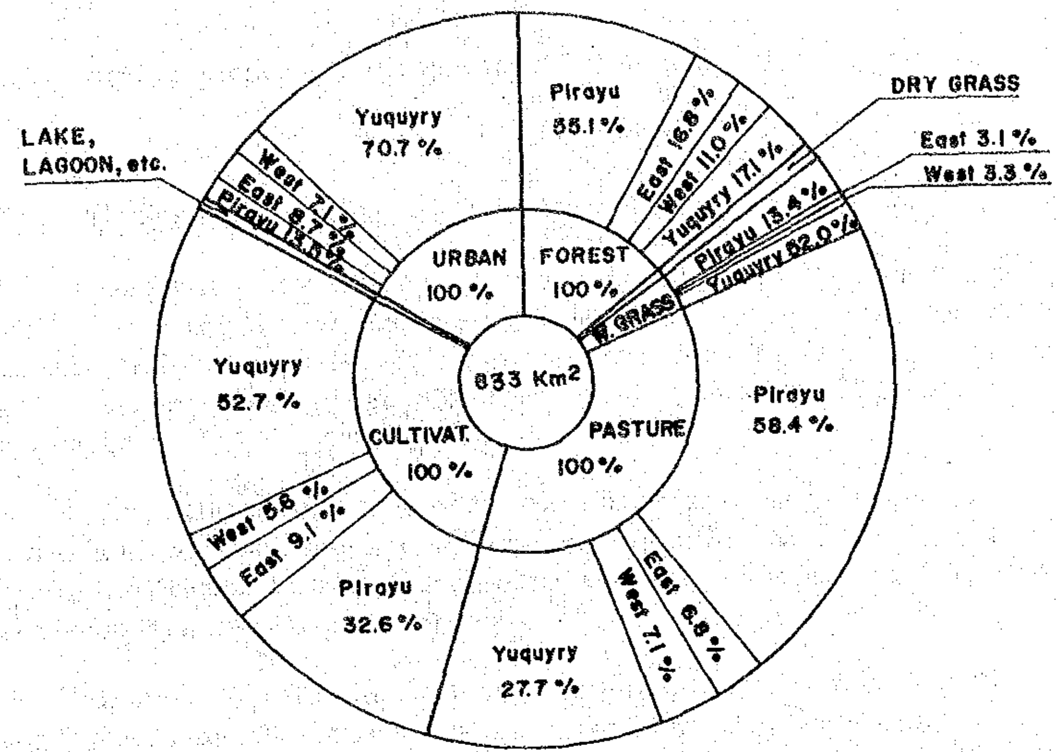


Fig. M4101 Distribution of Main Point-Pollution-Sources in the Lake Basin



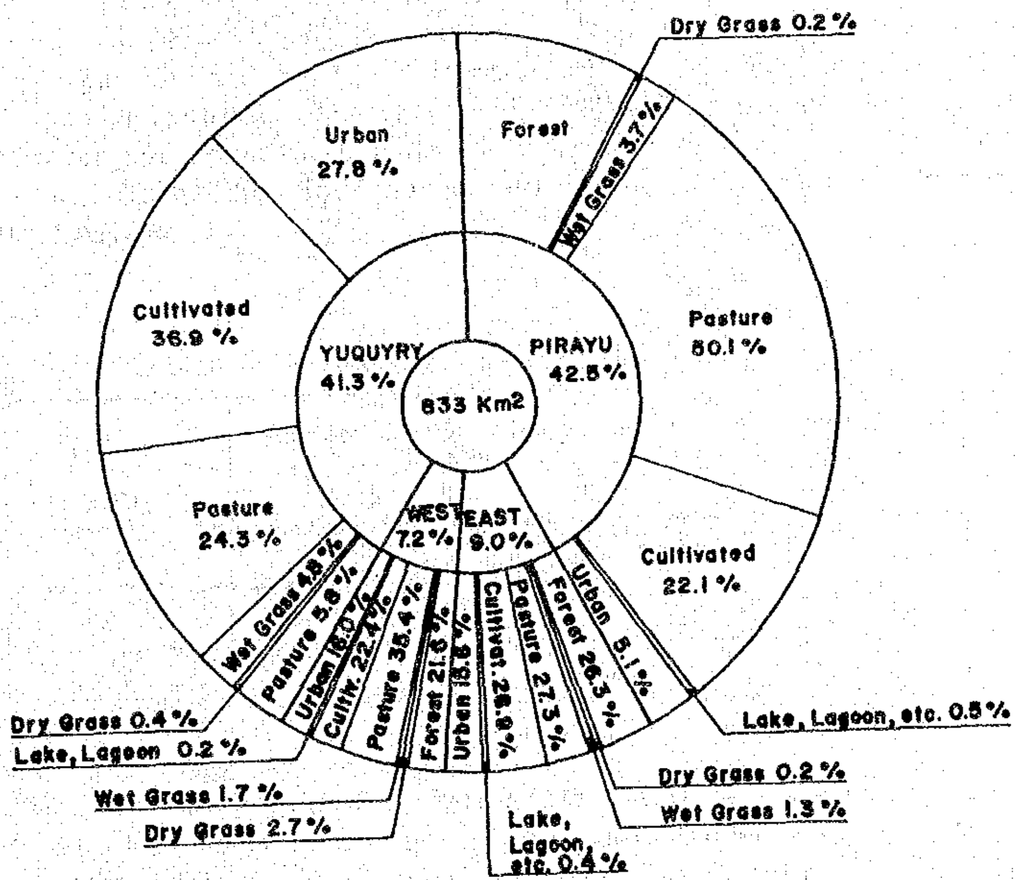


Fig. M4102 Land Use Area by Basin and by Type of Use

4.2 State of Generation/Discharge of Pollutants

4.2.1 Domestic Sources

Domestic waste water is mostly treated by infiltration tanks except in parts of San Lorenzo and Luque where it is treated at waste water treatment facilities. Infiltration tanks are around 1m in diameter and 2 to 6m deep. Some homes treat only raw sewage and others treat other waste water together with raw sewage.

Since the main staple of the people's diet is meat, fat content in raw sewage is high. Consequently, waste clogs the infiltration tanks. The average life of a infiltration tank is 4 or 5 years, and a new one is installed in another place when treatment capacity decreases.

Domestic waste water can be classified into raw sewage and other waste water. Water quality of raw sewage depends on nutrient intake, and water quality of other waste water depends mainly on the use of organic phosphorus detergents in washing. Nutrient intake is not much different in Paraguay than in Japan, so figures used in Japan are used to represent pollution load generation per person. Since detergents containing phosphorous are rarely used in Paraguay, figures much lower than those in Japan were used to represent the pollution load basic unit of waste water (Table M4211). Pollution load generation of waste water per person was calculated by multiplying the basic unit with the amount of water use (130 ~ 150ℓ/person/day) obtained from water supply records by CORPOSANA.

Table M4211 Generation Load Unit from Domestic Waste Water

	Raw Sewage	Other Waste Water	Total
BOD_5	13	22	35
COD	–	–	70
TN	9	2	11
TP	0.57	0.38	0.95

Unit : g/person/day

Domestic waste water draining into the river after bypassing the infiltration tank and seeping through soil was estimated as 12.7% in COD, 2.1% in TN and 2.9% in TP, by actual measurements of water quality at a small river close to Aregua.

4.2.2 Tourism Sources

Main pollution sources related to tourism are hotels and clubs which presently are concentrated at San Bernardino. Most of these facilities have storage tanks and septic tanks, but quite often proper maintenance is not applied and tanks do not function effectively.

Pollution load generation per person in this category (total of raw sewage and other waste water) was estimated for hotels to be the same as domestic waste water since most visitors stay overnight, and for clubs, to be 1/3 of domestic waste water since people only stay during the day.

Considering the fact that the treatment facilities are not functioning effectively, it is estimated that 1/2 of the load drains into waterways, rivers or directly into the lake.

4.2.3 Public Facility Sources

Public facilities with large generation discharge load in the basin are the waste water treatment facility at San Lorenzo and the national hospital at Capiata (there is another hospital under construction at Itagua).

The waste water treatment plant at San Lorenzo has a three stage lagoon (first stage, anaerobic; second and third stages, aerobic; average retention time, approximately 15 days). Though it is now in operation, at time of the study it was not in operation and approx. 1,900m^3/day of waste water was flowing directly into the Yuquyry River. Considering the amount of water use at San Lorenzo, this corresponds to the waste water of 15,000 persons.

The pollution load discharge from the San Lorenzo sewage treatment plant was calculated by multiplying the above-mentioned measured flow rate with the average concentration of intake waste water at Japanese treatment plant.

The national hospital (Hospital del Quemado) was built in 1986, and has a staff of 350 and has 200 beds, of which 70% are normally occupied.

The load generated here is basically identical to domestic waste water, but since treatment by septic tank and sand filter is applied, 1/2 of the pollution load generation is estimated to be released into the waterway, as in the case of hotels and clubs.

4.2.4 Industry Sources

The industries representing Paraguay's economy are agriculture, livestock raising, forestry and their processed products, as explained in Chapter II. Reflecting this fact, the main industry in the basin is the processing of agriculture and livestock products.

Within the processing industry, the most large-scale one is vegetable oil refining from Paraguay coco palm, soybeans and cotton seeds. There are four large oil refineries in the basin, the outline of which is shown in Table M3341 (as mentioned). CAPSA, which has the largest discharge amount has a chemical treatment plant for high concentration waste water (treatment capacity $5m^3$/hour), which was installed in 1979 and was in operation until February 1988, but is now out of operation. There is also a chemical treatment plant in Aceitera Itaugua, but this is not in actual operation. The other two plants have no treatment facilities.

Table M4241 Pollutant Concentration of the Effuluent Water from a Vegetable Oil Refinery

COD	TN	TP
1,940	51.0	11.65

Unit : mg/ℓ

The pollution load discharge from the four oil refineries was calculated by multiplying the pollution concentration of the CAPSA drainage measured in July 1988 (Table M4241) by the amount of drainage at each plant. The waste water quality from the oil refineries varies considerably according to when it is released. Therefore, it is necessary to obtain a number of monitored values to determine the pollution load discharge accurately.

Butcheries are semi-public facilities in Paraguay, and one each is located in most cities in the basin. Waste water and blood from the processing of cattle are discharged from the butchery, mostly with no treatment, into the nearby river.

Pollution load discharge was calculated according to the number of cattle slaughtered (Table M3342), information from questionnaires and the published pollution load basic unit per cattle (Table M4242).

Table M4242 Generation Load Unit from a Slaughtered Cattle

COD	TN	TP
8 kg	0.6 kg	0.1 kg

Average weigh of cattle: 370 Kg

Other than the above, there are pollution sources such as tanneries, sausage production plants, soap factories, dairies, and coffee factories in the basin. The pollution load generation basic unit was established by on-site study, measurement of actual flow rate, and published literature.

There are also poultry farms, distilleries and starch plants but the pollution load release were not calculated, since these operations are small or seasonal and their importance as pollution sources can be considered minimal.

4.2.5 Breakdown of Generation Load from Point Pollution Sources

All load generated by point sources was calculated by the method described in the previous paragraph and is compiled in Fig. M4251 by basins. The weight of the Yuquyry basin is overwhelmingly large and it composes 80% of the load generation in all activity areas.

Comparing the total load generation by pollution source categories, domestic sources is the greatest, representing approx. 50% of the COD, approx. 80% of TN and 60 to 70% of TP (Table M4252). In the industry sources, the vegetable oil refineries' contribution is extremely high (80 to 90% of COD, 60 ~ 70% of TN, and approx. 70% of TP), followed by the load generation at butcheries.

4.2.6 Non-point Sources

Pollution discharge from non-point sources generally depends on land use conditions. For the Lake Ypacarai basin, it is necessary to determine the generation and discharge of pollutants separately for grazing lands, crop fields, forests, urban area and roads. And since pollutants at non-point sources are accumulated during dry weather and released during rainy weather, river water quality must be measured during rain many times at simple land use pattern areas to establish their load discharge. In this study, actual measurement was made only once during a 10mm rain fall, so tentative calculation of the pollution load discharge basic unit was made on the basis of this measurement and by reference to measurements in published literature.

Non-point sources generating pollution in the form of earth and sand are mountain areas where trees are slashed, hills where vegetation coverage is removed for housing development, lateral erosion of rivers lacking bank protection works, open-pit of clay or quarry (Fig. M4261), and unpaved roads. Large generation from these can be expected in mountain areas and at the banks of the tributaries flowing in at the left bank of the Pirayu River, considering the topography and conditions of the area.

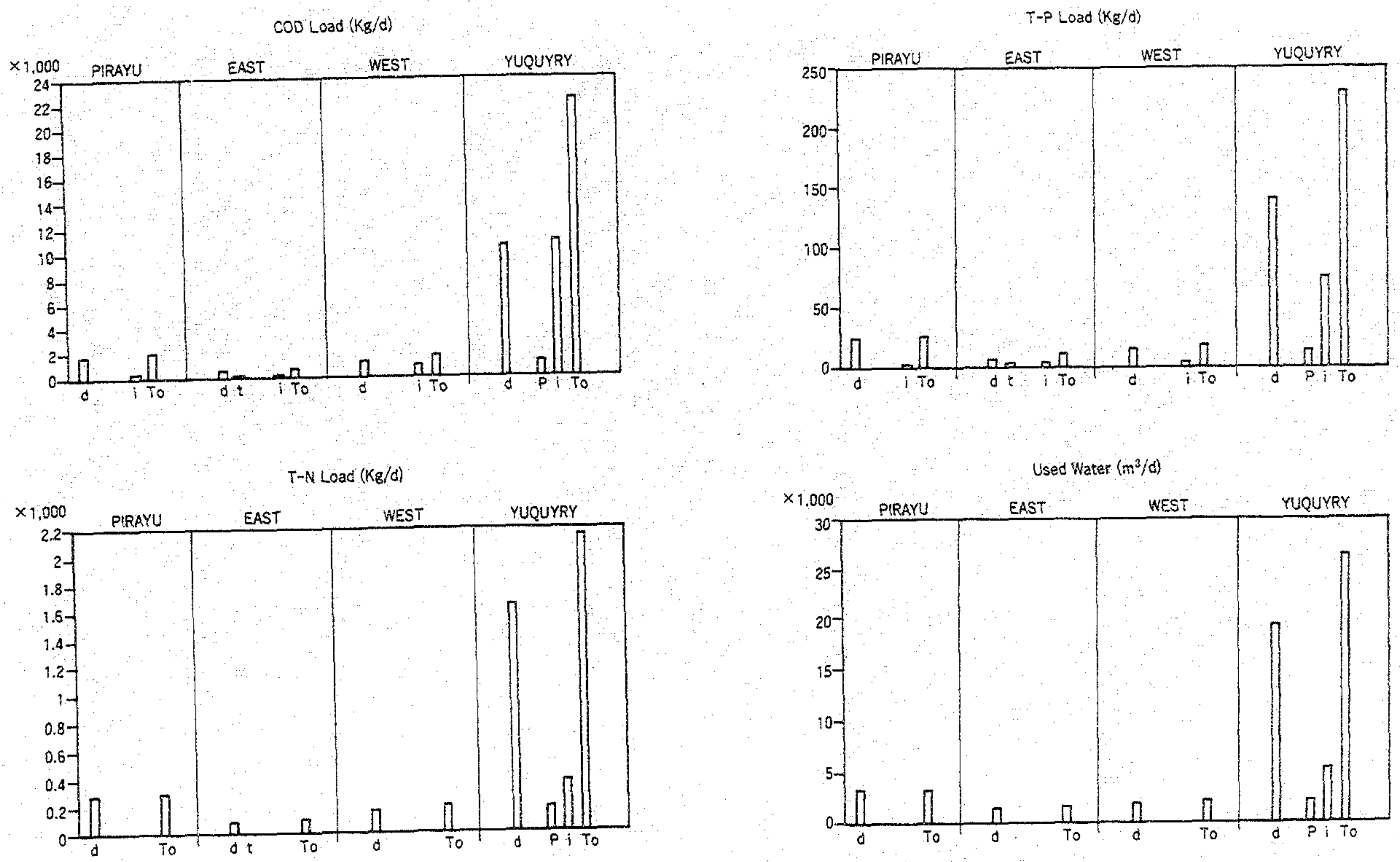


Fig. M4251 Pollution Load Generation from Point Pollution Sources by Basin

d ; Domestic
t ; Hotel & Club
p ; Public
i ; Industry
To ; Total

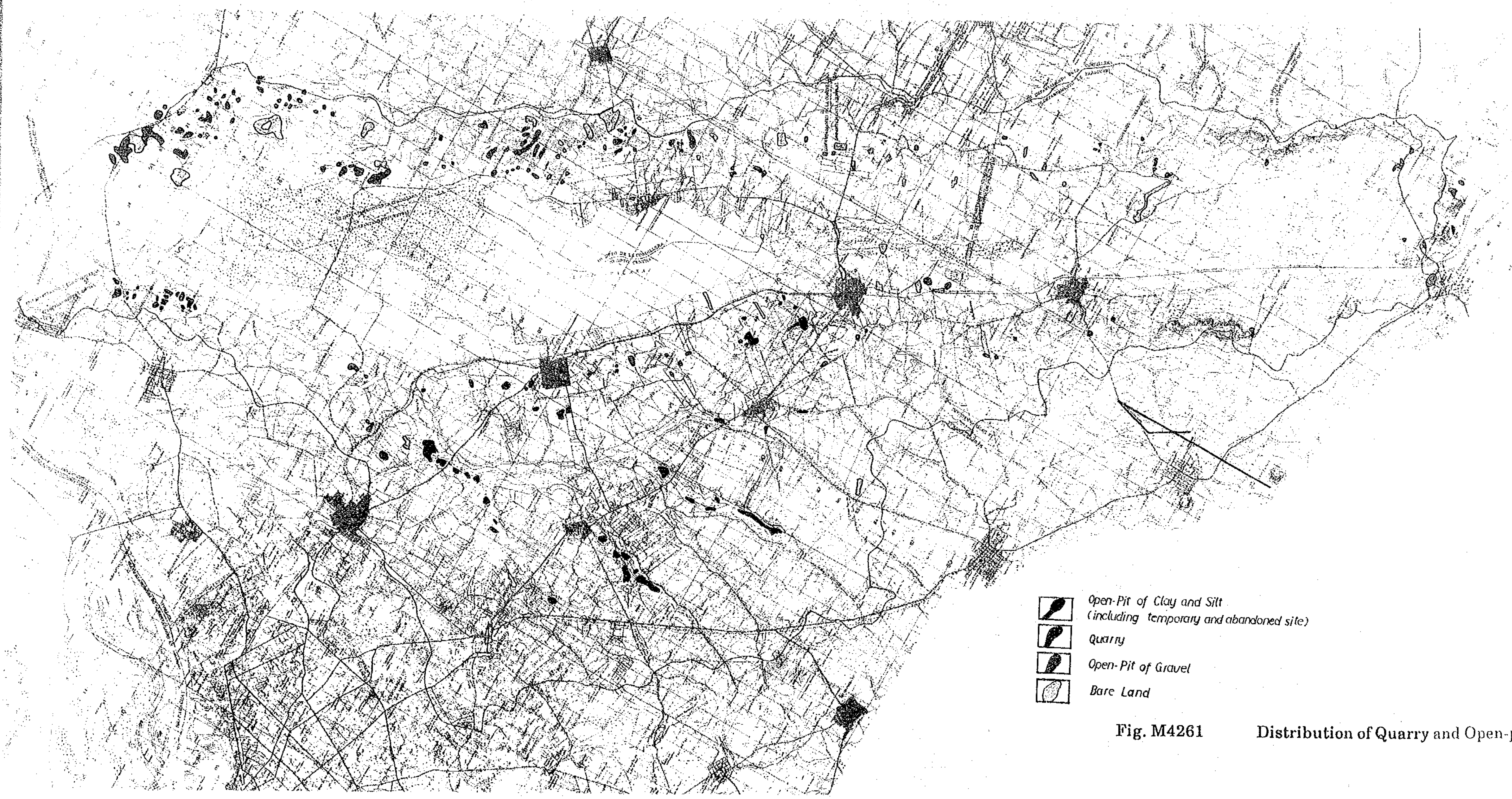


Fig. M4261 **Distribution of Quarry and Open-pit**

4.3 Pollution Runoff from the Basin

4.3.1 Runoff at Normal Water Level

Discharge state of pollutant was analyzed by a water quality study during dry weather at the tributaries of the Yuquyry River, the Pirayu River and the small rivers flowing into the east shore and west shore.

The point of water quality measurement, the location of main point pollution sources, the flow rate and flow load of rivers are shown in Fig. M4311.

Along the Pirayu River, for all the water quality items, pollution load is balanced along the flow, indicating the absence of pollution sources of especially much pollution load release. Factories and offices along this river are all small scale or seasonally operated, and most of the river flow load at normal water level can be attributed to non-point sources.

On the other hand, in the Yuquyry River, water quality flactuates along the flow, indicating that the existence of a point source of large pollution load discharge is exerting a large influence.

4.3.2 Runoff in Flood Time

Load from non-point source is said to be discharged mostly in flood time. Also waste water stored at homes and plants, is often released during the high water period. Therefore, the measurement of flow load of river water in flood time is very important in estimating the flow load into the lake.

In this study, river water quality study in flood time was carried out twice, between Oct. 31 and Nov. 2, 1988 and again between Jan. 21 and 24, 1989. Precipitation during the former period was 70.5mm at San Lorenzo and 115.5mm at Aregua. Precipitation during the latter period was 167mm at Paraguari, 97mm at Ypacarai and 99.5mm at Pirayu. Change of flow rate and water quality of the Yuquyry River and the Pirayu River are shown in Figs. M4321 and M4322.

The maximum flow rate of the Yuquyry River is reached 12 to 24 hours after rainfall, while the maximum flow rate of Pirayu River is observed 36 to 60 hours after rainfall. The reason for Yuquyry River's shorter runoff time may be attributed to a higher ratio of urban areas in its basin.

Flow speed of both rivers in flood time has a maximum of 0.7m/s which is not much different than that of the normal water level. Increase of the flow rate is mostly related to the rise of water level.

At the Yuquyry River, concentration of all water quality items is high at maximum flow rate, ranging between 1.5 to 2 times the normal water level concentration. On the other hand, at the Pirayu River, many water quality items reach maximum concentration before maximum flow rate, reaching several times the normal water level concentration. This indicates that there is not much difference between the two rivers in the transport load per unit hour in flood time, suggesting that the ratio of pollution load discharged from non-point sources in flood time is high in the Pirayu River.

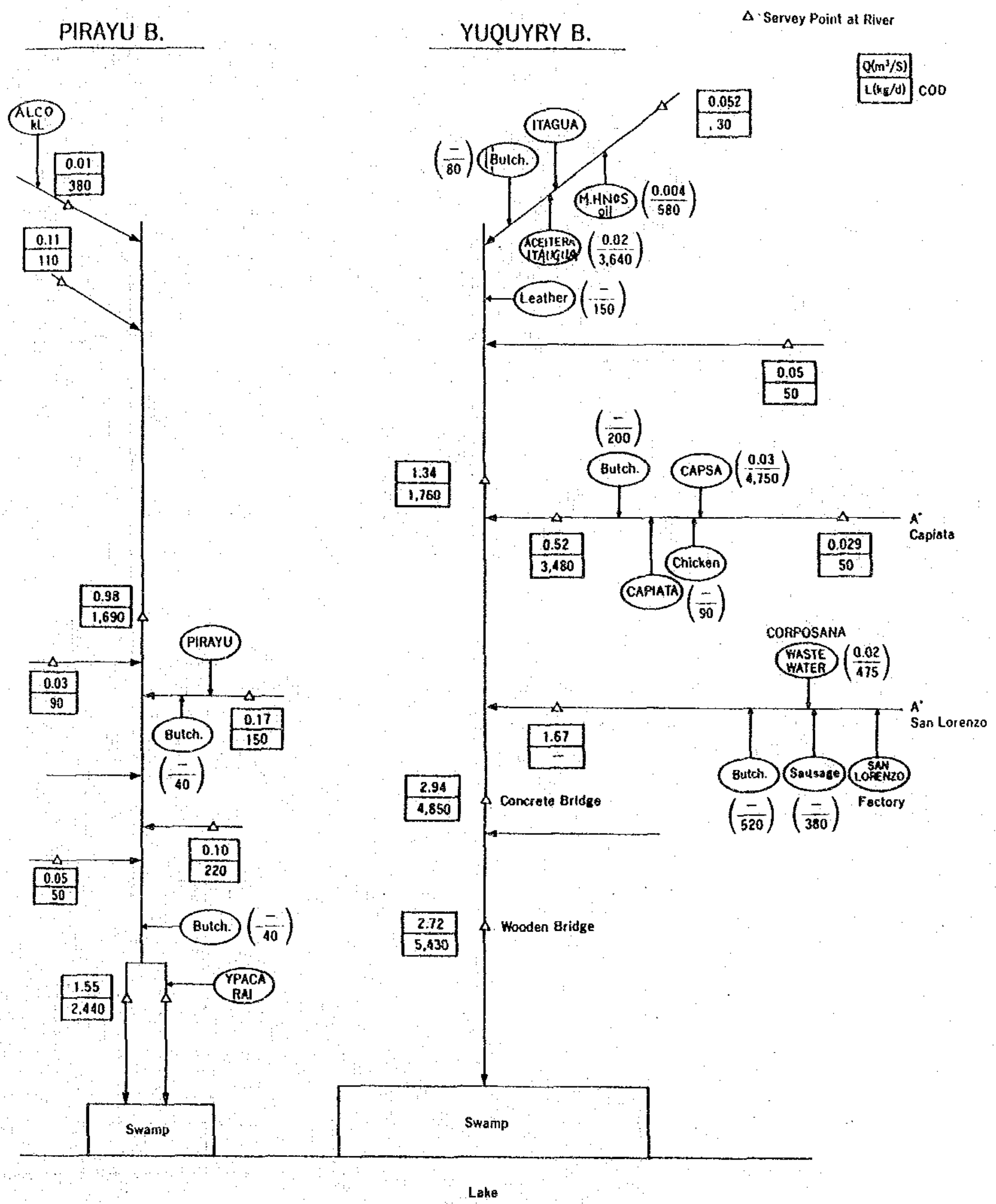


Fig. M4311 Discharge and Inflow Status of Organic Materials (COD) in Normal Time

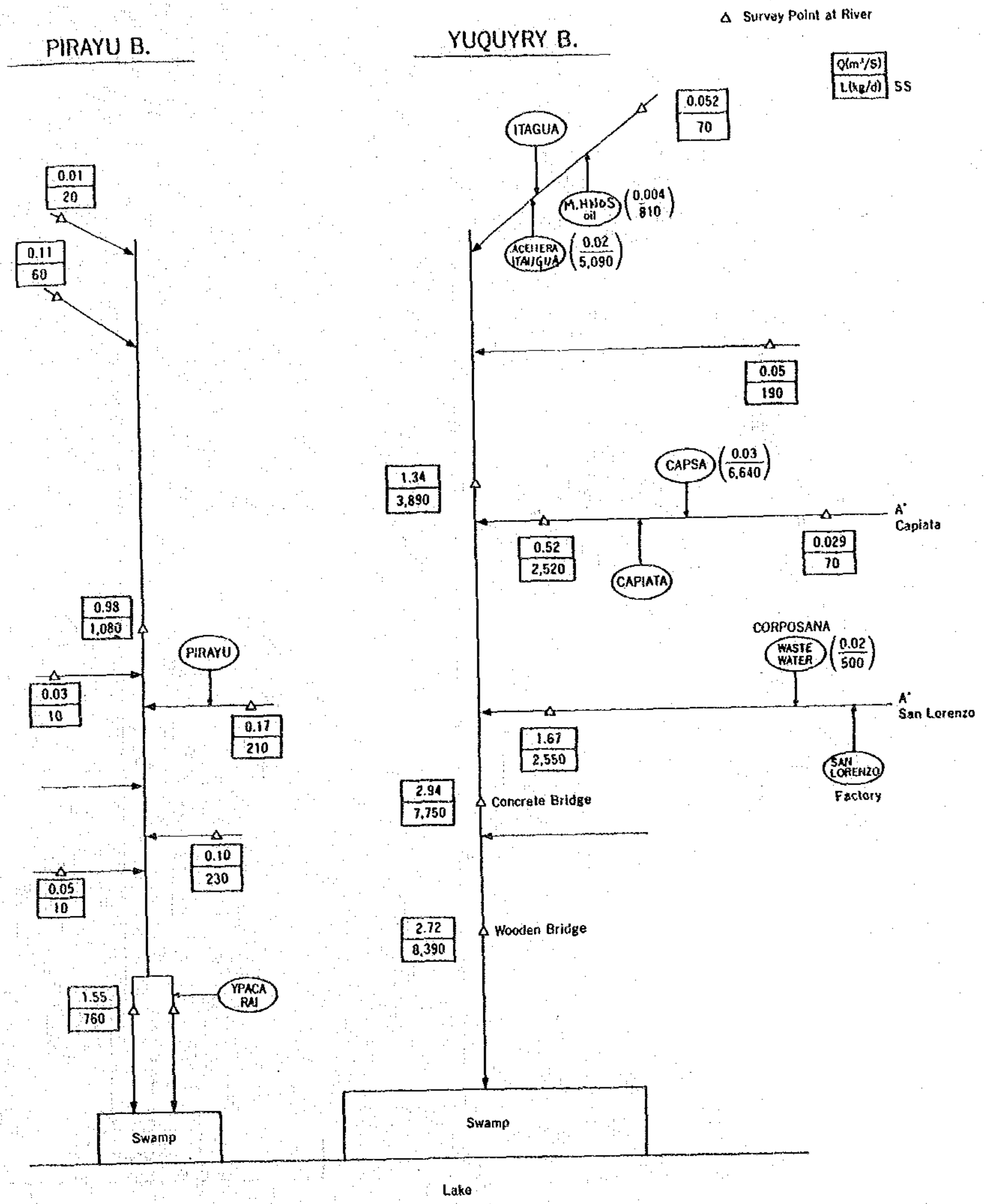


Fig. M4312 Discharge and Inflow Status of Particulate Solids (SS) in Normal Time

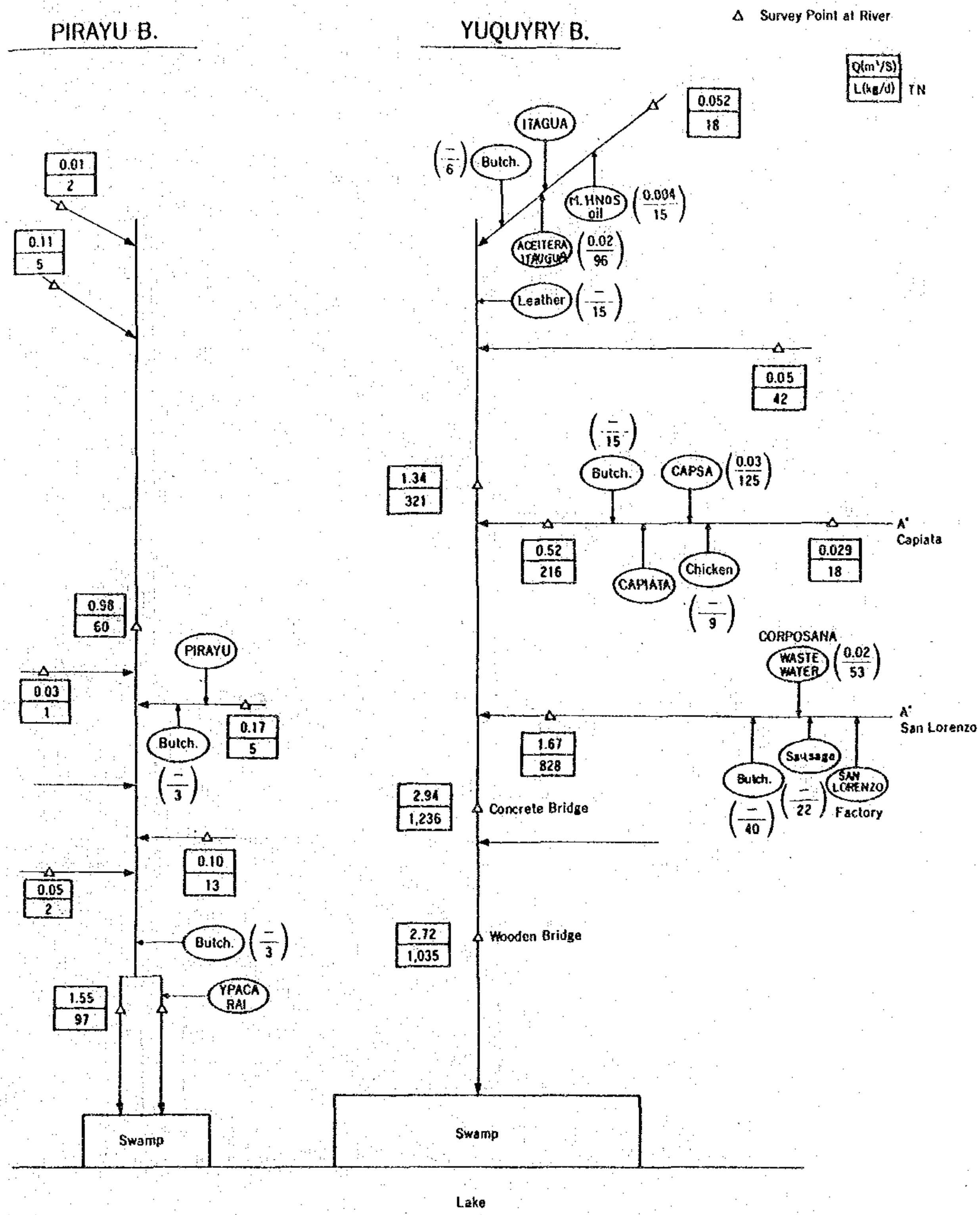


Fig. M4313 Discharge and Inflow Status of Nutrient Salts (TN) in Normal Time

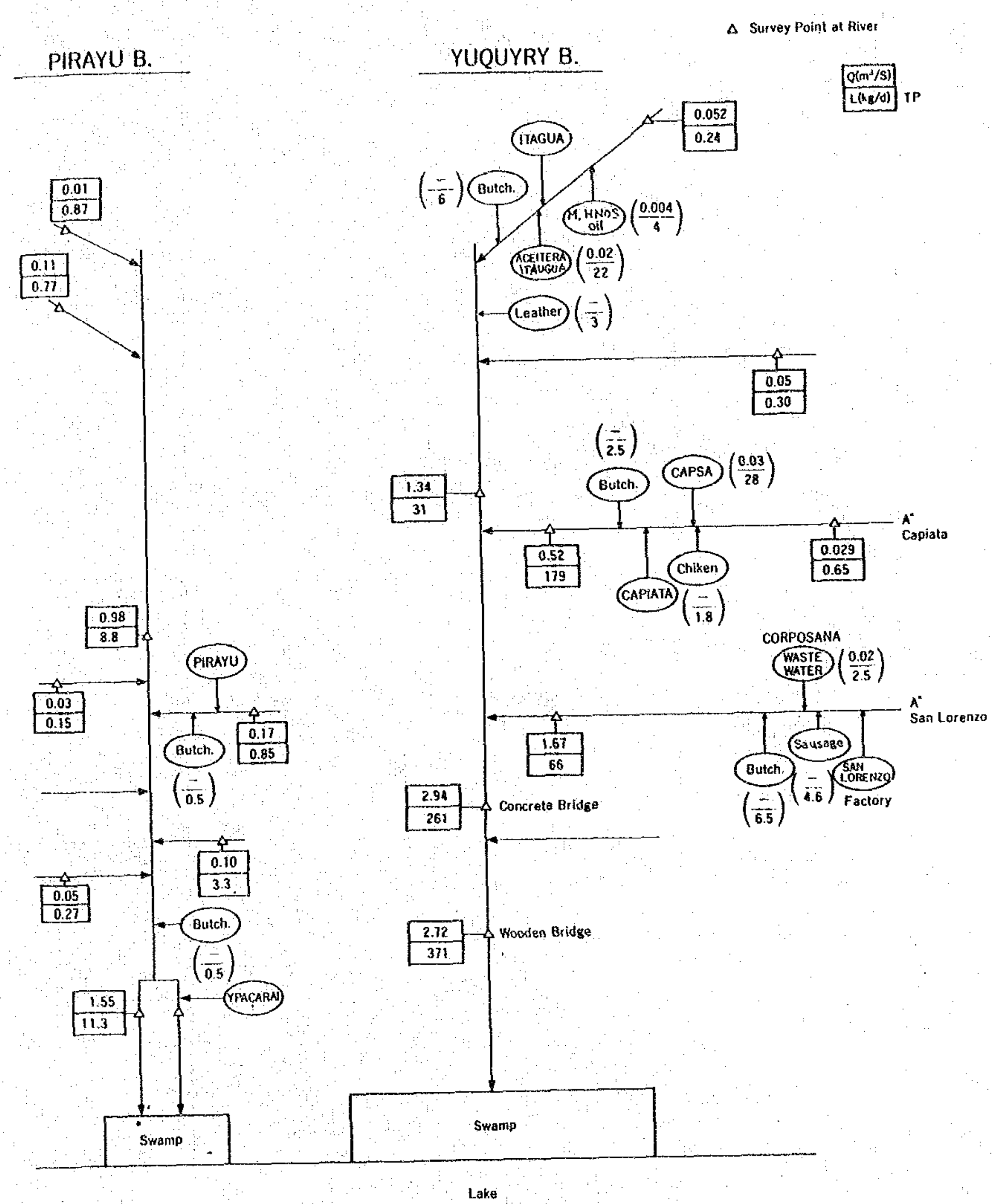


Fig. M4314 **Discharge and Inflow Status of Nutrient Salts (TP) in Normal Time**

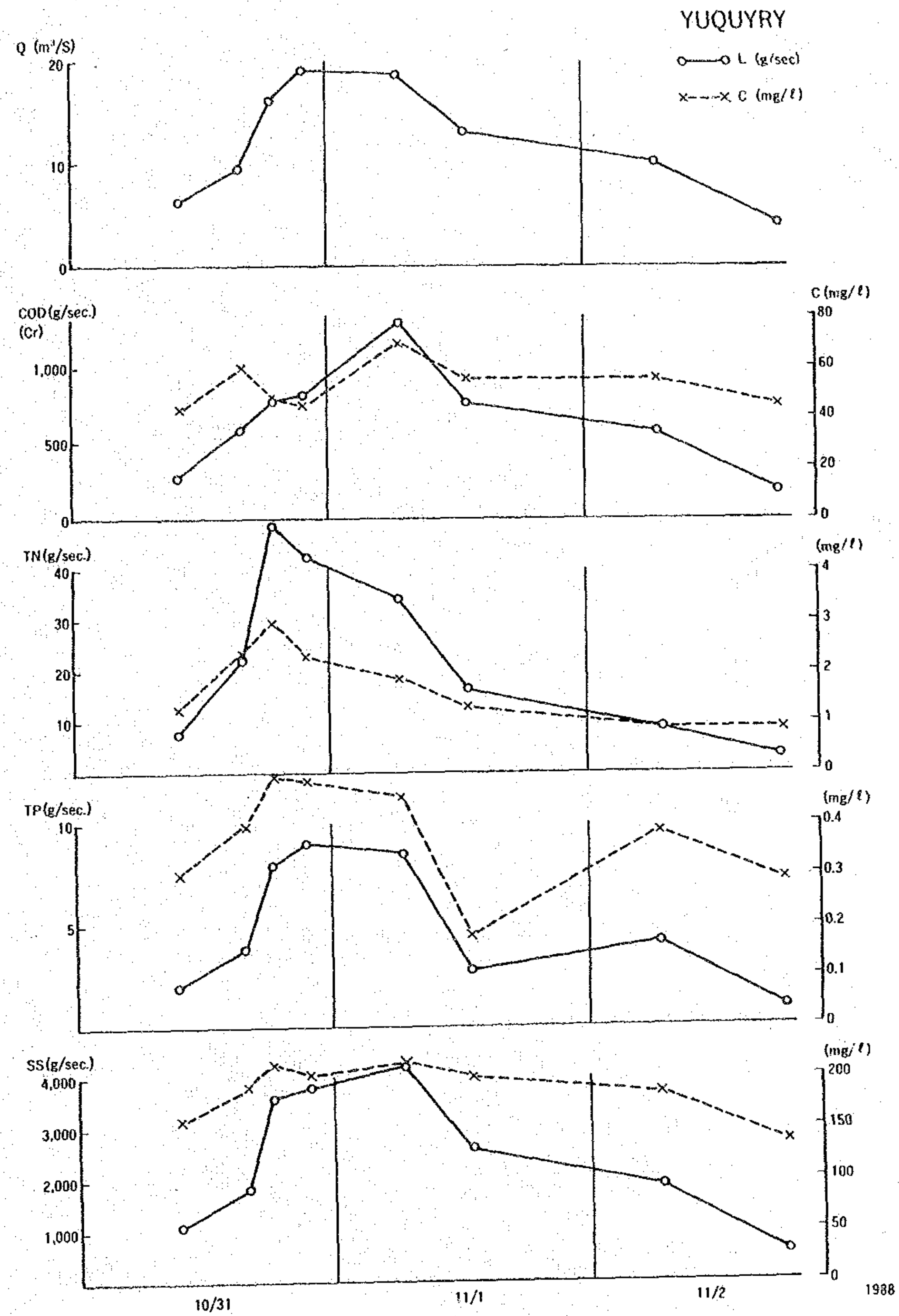


Fig. M4321 **Water Quality and Transporting Load of Yuquyry River in Flood Time**

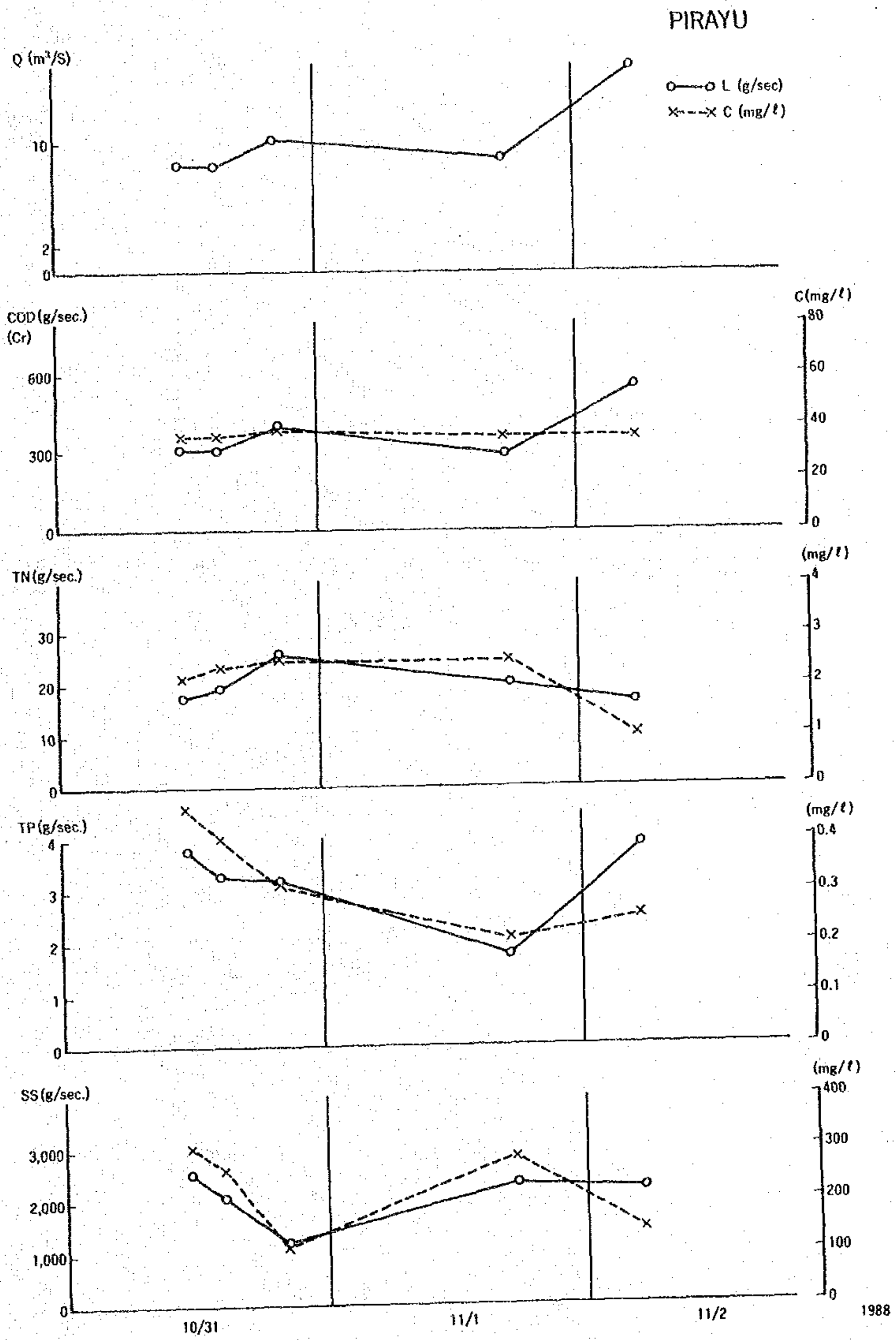


Fig. M4322 Water Quality and Transporting Load of Pirayu River in Flood Time

CHAPTER V POLLUTION STATE OF MAIN RIVERS AND THE LAKE

5.1 Meteorological and Hydrological Conditions of Water and Bottom Material Sampling

The fact that river water quality changes radically between normal water level and flood times has already been described in the previous chapters. Other than such meteorological conditions, operating conditions of plants in the basin are a factor that should have influence on the river water quality. This point could not be examined thoroughly in this study.

On the other hand, water quality of the lake depends, in addition to flow rate and water quality of inflowing rivers, largely on internal production, stir-up of bottom mud and elution from bottom mud, which are influenced by meteorological factors such as water temperature, solar radiation and wind.

Therefore, meteorological and hydrological conditions on the day of sampling water and bottom deposits are very important in studying chemical analysis results.

5.2 Water Quality of Main Rivers

For the main rivers (Yuquyry River, Y-Pucu River and Yagua-Resa-u River), at the water level measuring sites located at downstream positions, sample water was taken one to three times a month with measurements of physical conditions, and the samples were analyzed at the laboratory.

The physical conditions were measured by 7 items: transparency, water temperature, DO, pH, EC, water color and current speed. Water quality analyses were conducted for 19 items: TP, POP, DOP, PO_4P, TNK, PON, DON, NH_4H, NO_3N, TCOD, DCOD, BOD, TR, IL_{TR}, SS, IL_{SS}, Cl^-, alkalinity, number of fecal coliforms (however all items were not analyzed every time).

Figs. M5101~5106 show the monthly changes of six of the above items with reference to the three main rivers and the lake.

5.2.1 Yuquyry River

The water of Yuquyry River is always muddy and brown, and turns reddish brown when the flow rate is high.

The saturation degree of DO of this river is very low with an average of 48%, indicating a large inflow of organic substances. In fact, the concentration of TCOD is high, averaging 32mg/ℓ, increasing to 1.5 times the average at high flow rate. But since BOD concentration is low throughout the year, the main part of the organic substances must be difficult-to-decompose.

The TP concentration changes widely with no connection to season and rainfall (0.2 ~ 1.1 mg/ℓ), and organic and inorganic matter each make up half of the concentration. On the other hand, TN concentration is stable at 2 ~ 2.5 mg/ℓ from summer to winter, but fluctuates from spring to summer often exceeding 3 mg/ℓ. Most part of the inorganic nitrogen is NH_4N.

Fluctuation of SS concentration is large even at normal water level, and organic and inorganic matters are about half and half. The proportion of SS is low compared to TR, and since particles of a diameter below 1 μm make up around 70% of the SS by measurements of the coultar counter, most of the turbidity at normal water level must be due to dissolved substances.

Fluctuation of Cl^- concentration is large but generally is in the range between 50 ~ 80 mg/ℓ, indicating that man-made pollution is playing a large role. Incidentally, the EC value is very high, and the number of fecal coliforms is high at 1,000 ~ several 10,000 No/100 mℓ.

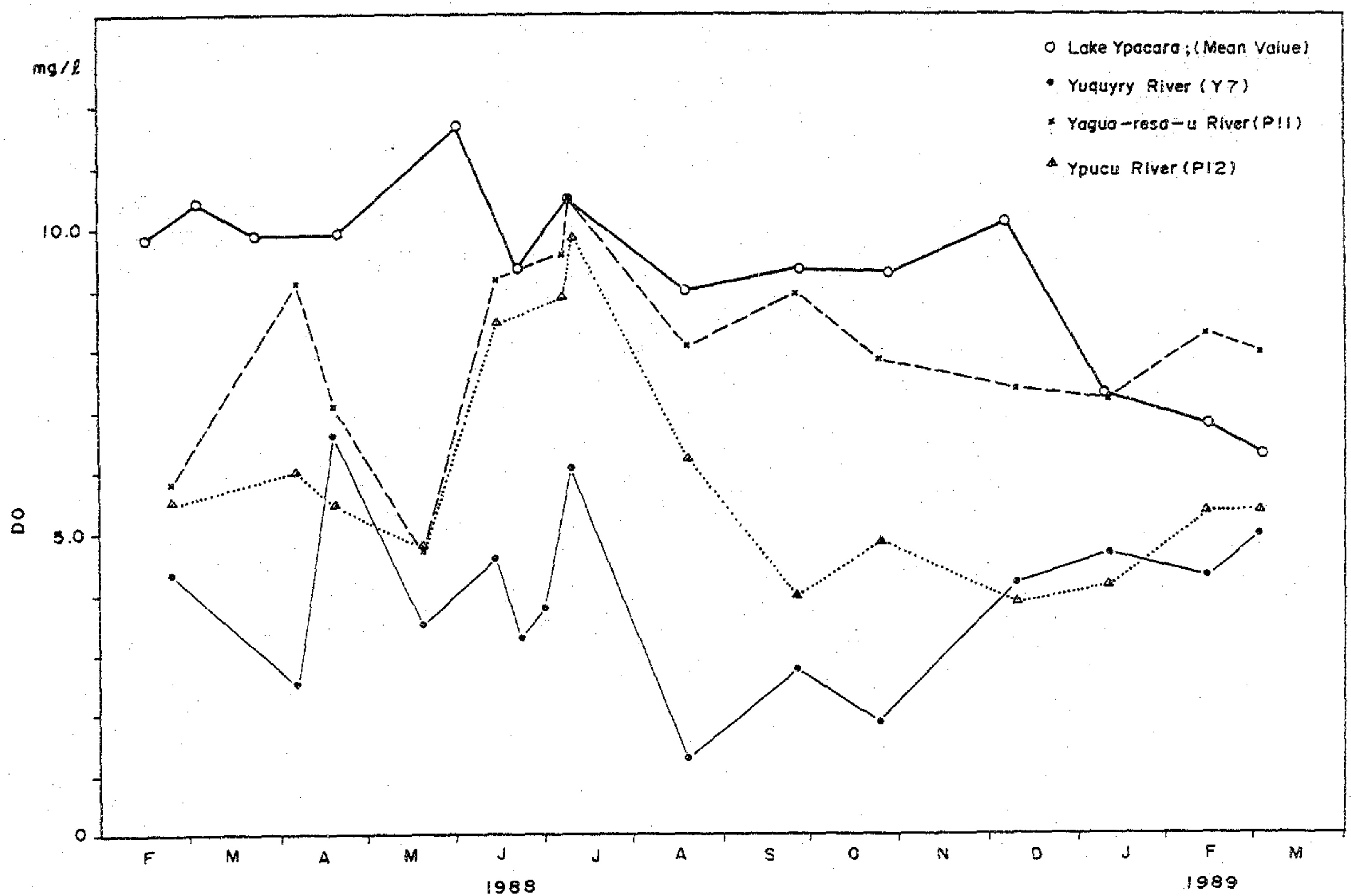


Fig. M5101 Water Quality Fluctuation of the Lake and Rivers during the Study Period (DO)

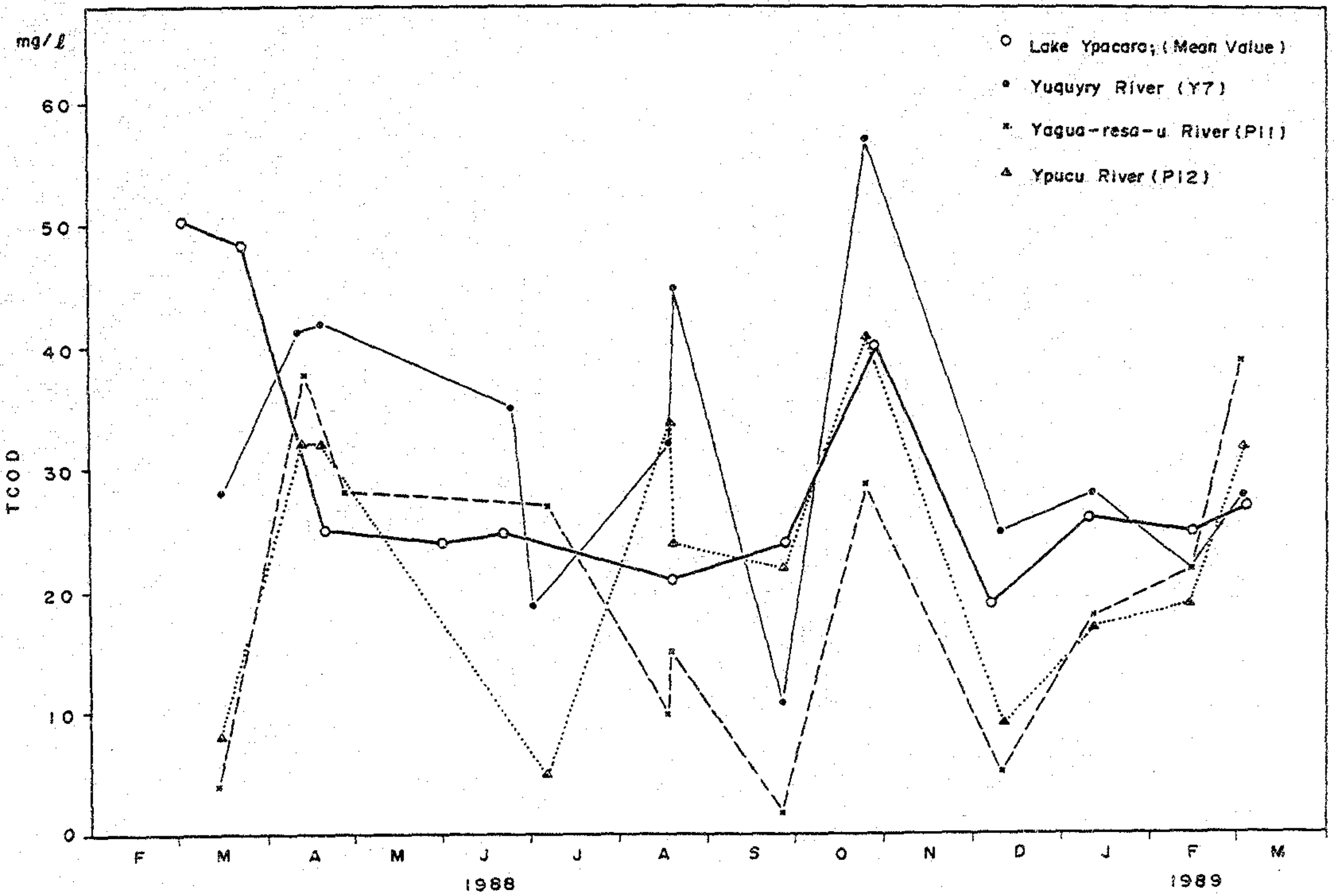


Fig. M5102 Water Quality Fluctuation of the Lake and Rivers during the Study Period (TCOD)

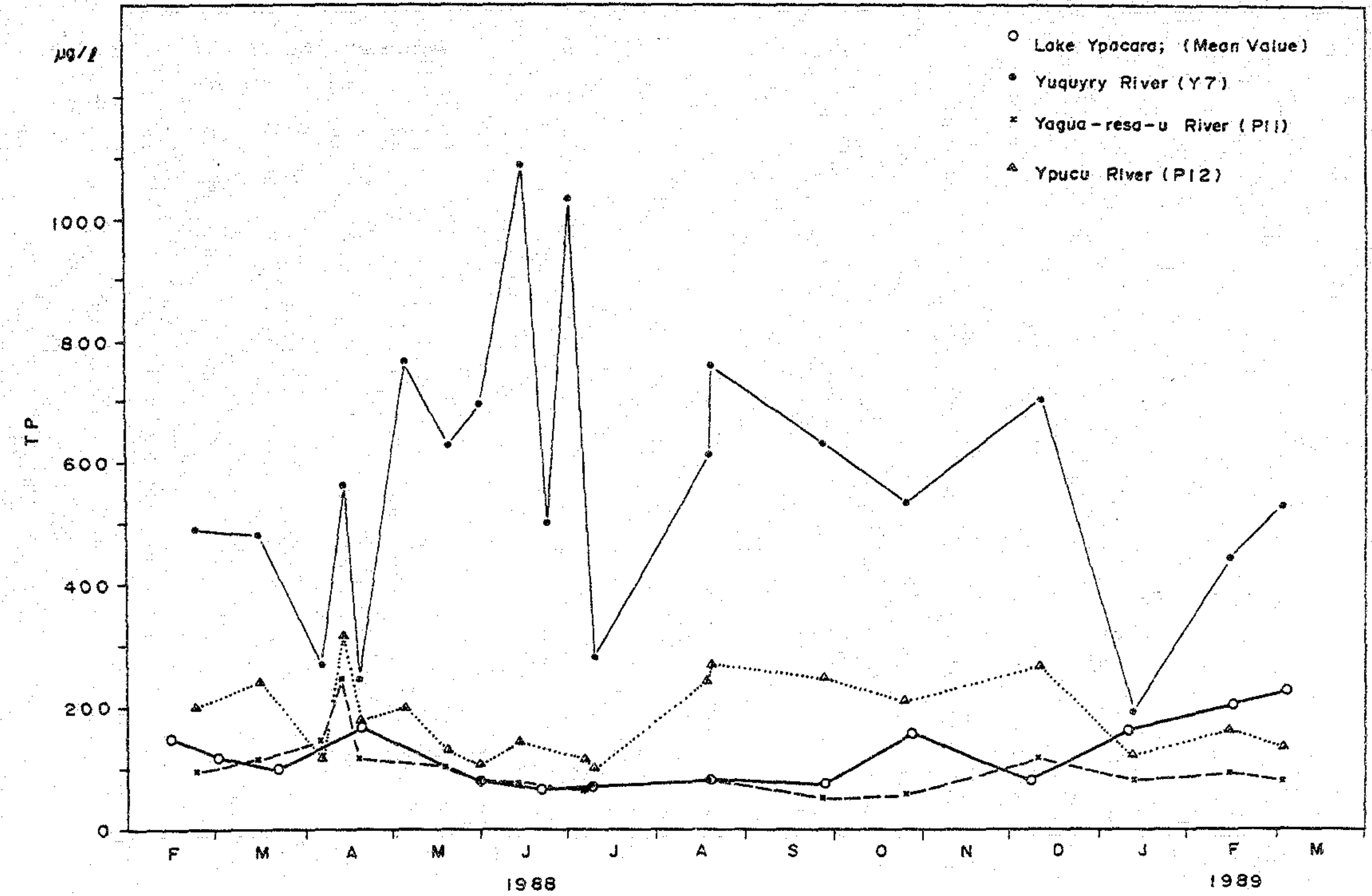


Fig. M5103 Water Quality Fluctuation of the Lake and Rivers during the Study Period (TP)

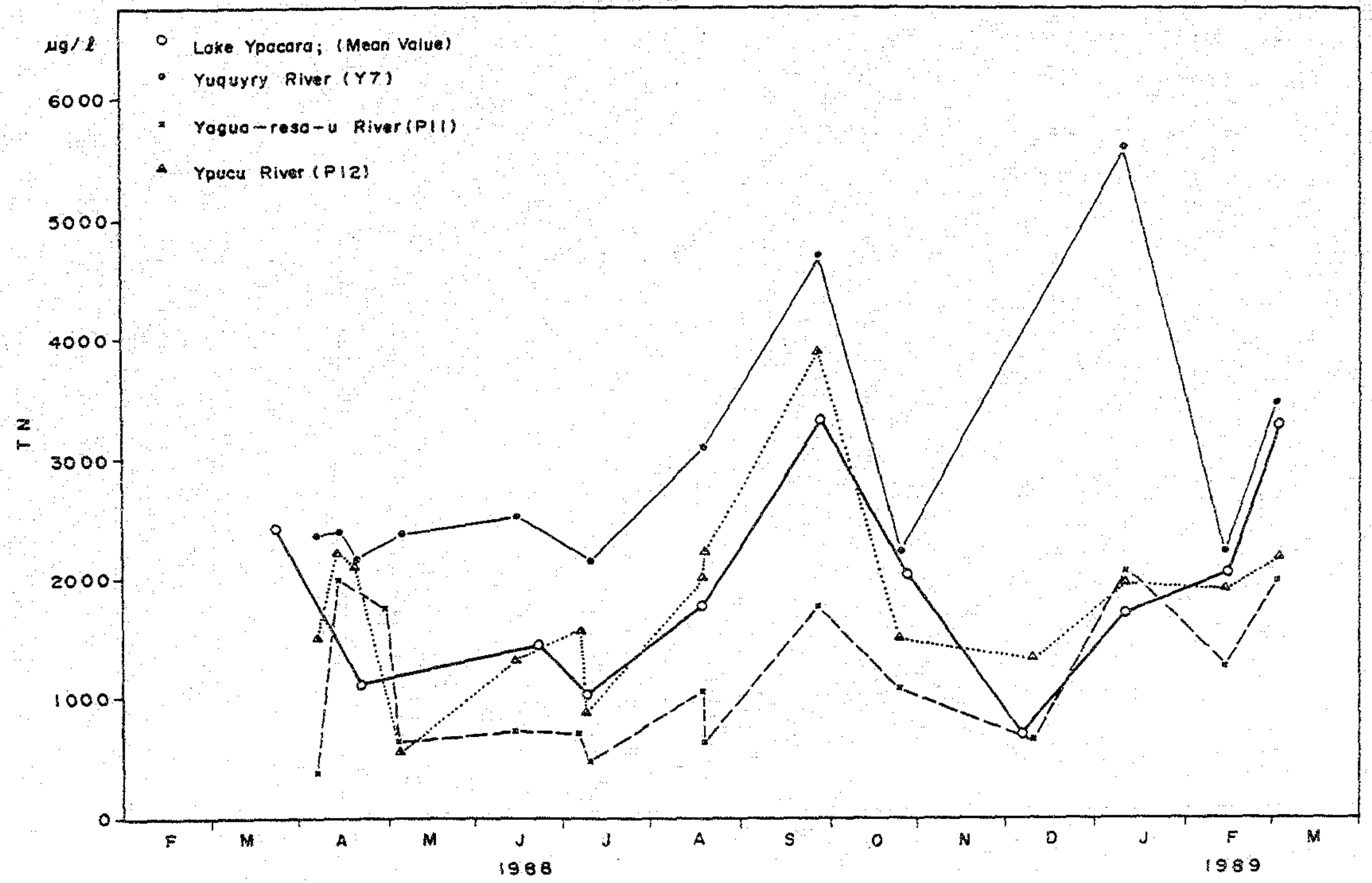


Fig. M5104 Water Quality Fluctuation of the Lake and Rivers during the Study Period (TN)

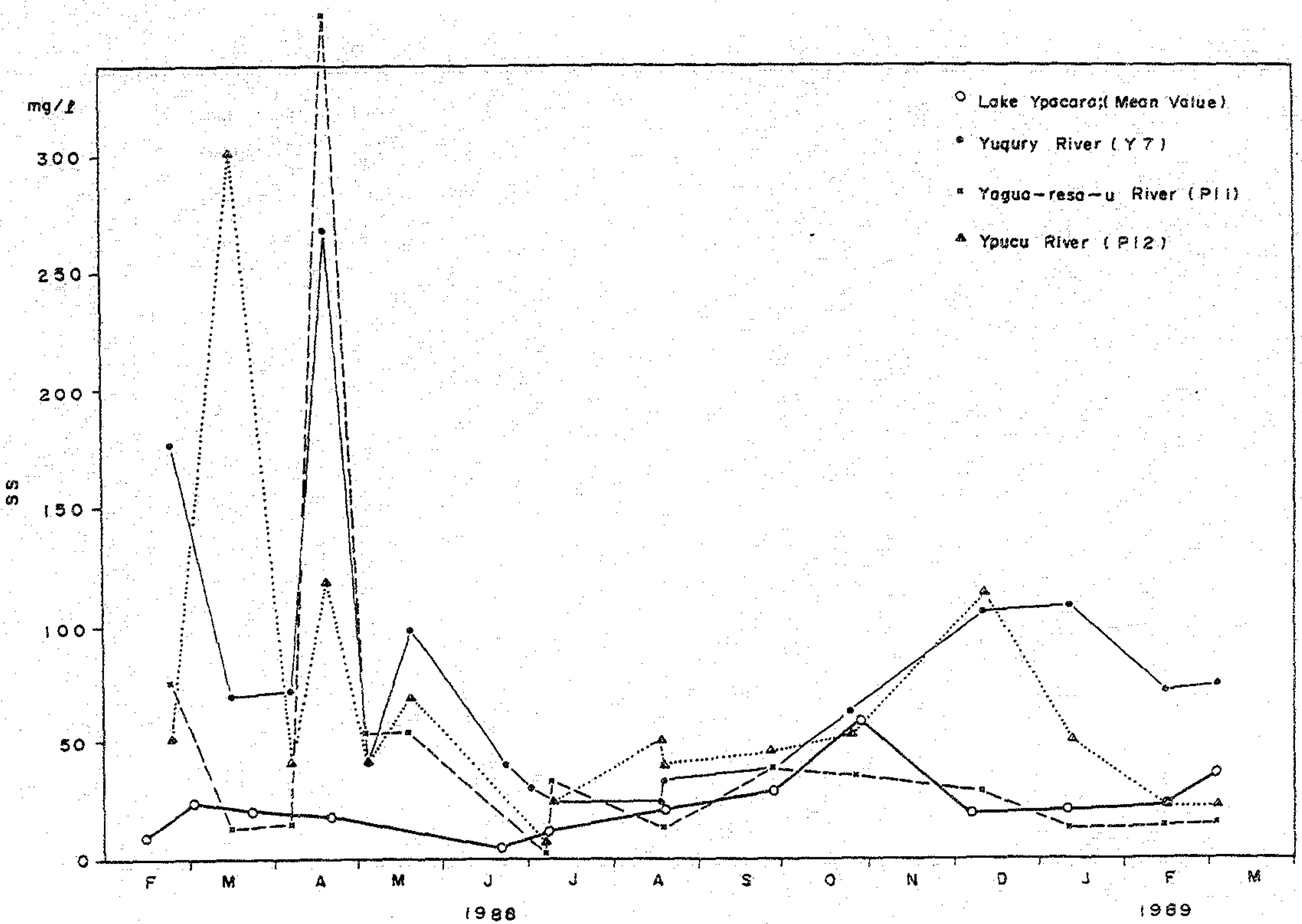


Fig. M5105 Water Quality Fluctuation of the Lake and Rivers during the Study Period (SS)

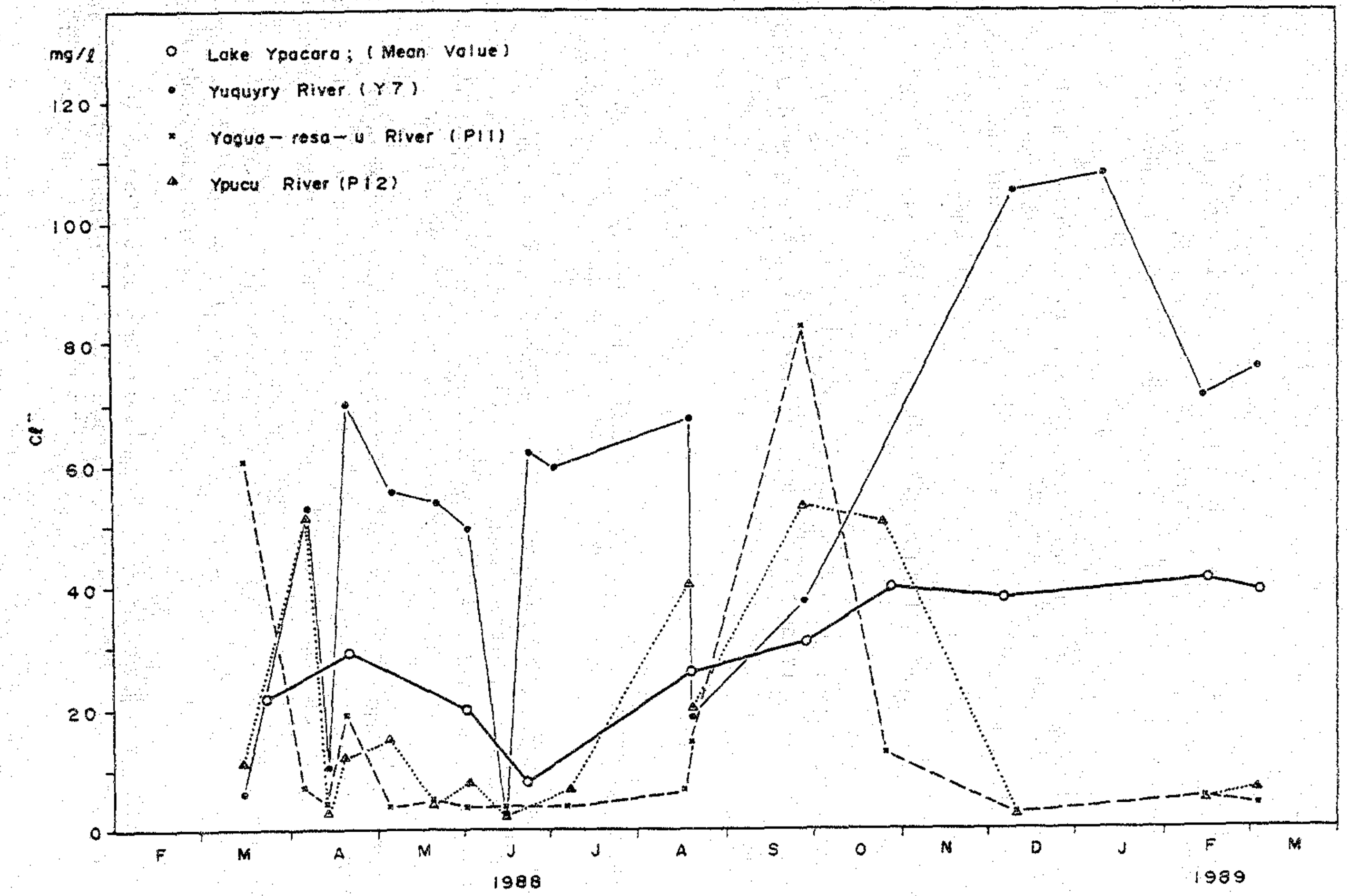


Fig. M5106 Water Quality Fluctuation of the Lake and Rivers during the Study Period (Cl-)

5.2.2 Yagua-Resa-u River

The transparency of the Yagua-Resa-u River is high throughout the year.

The saturation degree of DO is on average 93%, and the inflow of organic substances is within the self-purification capacity of the river. TCOD fluctuates between 2 ~ 40 mg/ℓ, but BOD concentration is low, and organic substance must be mainly of difficult-to-decompose.

TP concentration increases after rainfall, but is stable at around 0.09 mg/ℓ at normal water level. About 2/3 of the TP is organic and about 1/3 inorganic. On the other hand, fluctuation of TN is large and increases after rainfall. About half of TN is DON.

SS concentration is low except after rainfall, and is about 10 ~ 20 % of TR.

Cl^- concentration is very low, and since number of fecal coliforms is also few, it can be said that the degree of man-made pollution is low.

5.2.3 Y-Pucu River

The transparency of this river is not high, but improves somewhat during winter.

DO concentration fluctuates in the 49 ~ 98% range. TCOD also fluctuates within 5 ~ 40 mg/ℓ and increases somewhat after rainfall. Since the ratio of DCOD/TCOD is high and ratio of BOD/TCOD is low, most of the organic substances must be dissolved and difficult-to-decompose.

TP at normal water level is within the 0.10 ~ 0.27 mg/ℓ range and about 45% of it is inorganic. TP increases after rainfall and the ratio of TOP also increases. TN is usually 1 ~ 2 mg/ℓ and around 75% of it is organic.

Fluctuation of SS concentration is large but there is no large increase during rainfall. As SS is about 20% of TR the turbidity is thought to be mostly due to dissolved substance.

Cl^- concentration fluctuates largely, independent of flow rate and other water quality conditions. The number of fecal coliforms exceeded 6,000 No/100 mℓ in September.

5.2.4 Difference in Water Quality by River and its Cause

Comparing the water quality of the main rivers described above, concentrations of organic substance, nutrient salts, ionized substance and number of fecal coliform group are highest at Yuquyry River and lowest at Yagua-Resa-u River. This indicates that man-made pollution is infiltrating the Yuquyry River, and reflects the fact that 80% of the population is distributed along the river – the number of main factories and offices is also large. The fact that the ratio of pollutant concentration in flood time and at normal water level is higher at Yagua-Resa-u River and Y-Pucu River than at Yuquyry River, indicates that, for the former two, the ratio of pollutantant from non-point sources is higher.

5.3 Water Quality of the Lake

During the monthly study, water samples were taken from 10 to 15 fixed points within the lake, together with the measurement of physical conditions, and analyses were conducted at the laboratory.

Physical conditions measured were 6 items: SD, water temperature, DO, pH, EC and water color. Water quality analyses carried out were for 19 items: TP, DTP, PO_4P, TNK, NH_4N, NO_3N, TCOD, DCOD, BOD, TR, IL_{TR}, SS, IL_{SS}, Cl^-, alkalinity, number of fecal coliforms, POC, PON, Chl-a (however all items were not analyzed every time).

5.3.1 Monthly Variation

Water quality of the lake changed drastically twice during the study. The first change occured around Jan. 20, 1988. Clarity of the lake water was very low, but after the heavy rain of Jan. 13 ~ 16, with the increased water level, the lake water became very clear. Supposedly, the local people have never seen such clarity. It is very regrettable that since the water quality analysis of this study started in February, there is no data of water quality just before the change occured.

The second change occured between December 1988 and January 1989. The clear water lost its clarity, the color of the water changed to brown or black as if charcoal had been introduced. TN concentration increased somewhat and TP (mostly PO_4P) concentration doubled, while Chl-a concentration decreased.

In order to study the transition pattern of water quality, and factors determining the change, the water temperature, precipitation, and wind speed together with the average concentration change of main water quality items are shown in Fig. M5302. Phytoplankton in the figure was calculated from Chl-a concentration by a theoretical formula.

In March 1988, clarity and water temperature were high. As fair days continued phytoplankton multiplied and water bloom developed. TCOD concentration in the lake water became extremely high compared to that of the river water, which might be due to the phytoplankton.

Entering April, TCOD concentration decreased and PO_4P increased. This was probably due to the decomposition of the phytoplankton, since April was rainy and water temperature and solar radiation decreased.

The water temperature decreased through May, and the average temperature of July was 13°C. TCOD concentration and TP concentration were stable at 20 ~ 25 mg/ℓ and 0.08 mg/ℓ respectively. The ratio of phytoplankton in SS, TCOD, TN, and TP became lower than half. This is probably because the

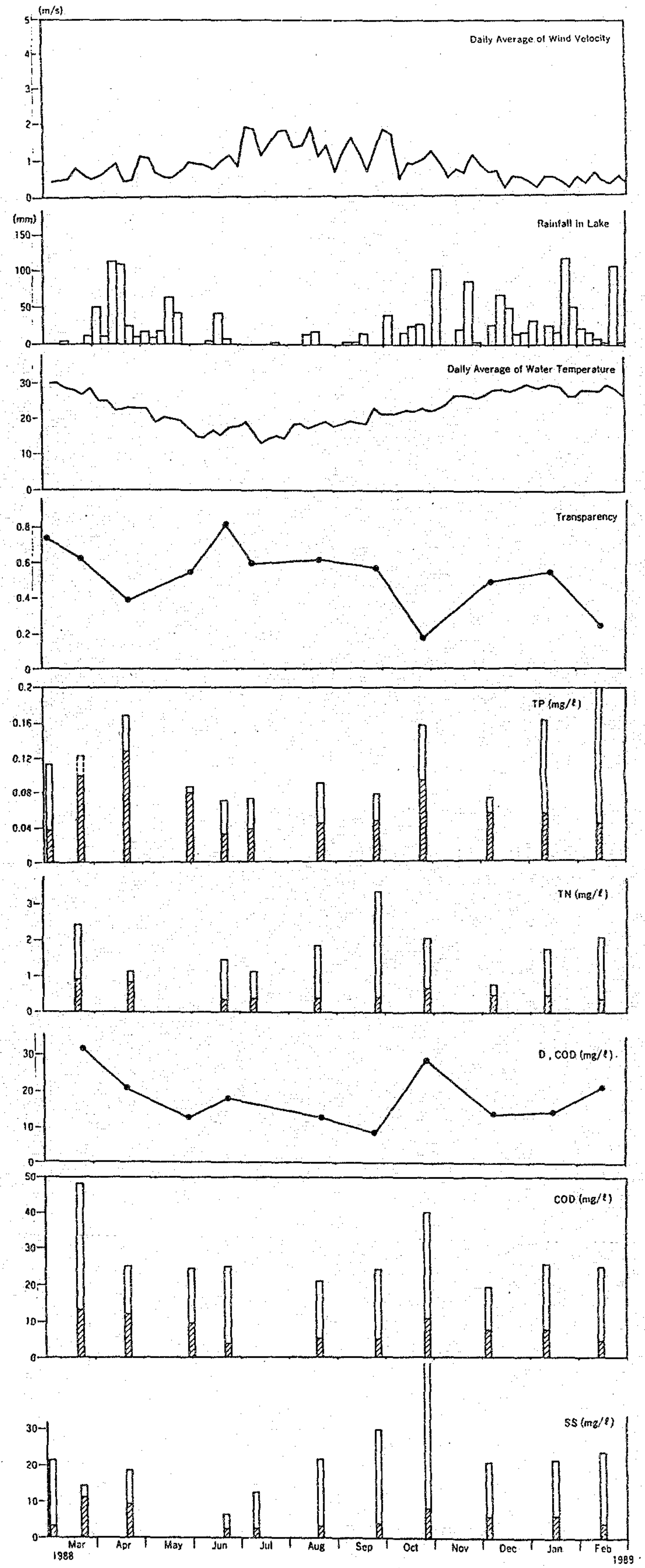


Fig. M5302 Relation between Meteorological Condition and Water Quality in the Lake

production of phytoplankton decreased and came into balance with decomposition.

Water temperature and solar radiation increased after July, but the concentration of TCOD and TP remained at July level until December (except for late October). The high SS concentration level after August, was probably due to dead phytoplankton.

Temporary increases in the concentration of TCOD and TP in late October can be attributed to stir-up of the bottom mud, since the wind was strong for two days just before water sampling.

The fluctuation of TN concentration during the study was wild but it seems to correspond to the TN concentration in the river water. Seventy to 90% of TN is organic, but the ratio of phytoplankton estimated by Chl-a concentration is generally below 30% of the TN. The change in the TN concentration and the change in the DCOD concentration correspond well, and there is only small difference in the DCOD value between river water and lake water. From these facts, it can be estimated that TN in the lake water mainly consists of organic soluble substance flowing in from the area. Nothing definite can be said, since there are other opinions on this point.

Measurements on the number of fecal coliforms in the lake water were made three items during the study, in July and September 1988, and February 1989. In all cases the level was low at below 100 No./100 mℓ.

5.3.2 Differences by Water Area

From the surface distribution of EC and DCOD illustrated in Figs. M5321 and M5322, it can be seen that the difference in concentration between each point on the lake surface is small during all seasons. And the EC concentration which is at a high value—400 μS/cm—at the estuary of the Yuquyry River, drops to average lake value at the measuring point immediately off the shore. This suggests that a very rapid horizontal mixing is occuring.

On the other hand, from the vertical distribution of water temperature, turbidity, pH and EC at summer (January and February) shown in Fig. M5323, it can be seen that there is almost no difference between the surface layer and the bottom layer. The DO concentration decreases from surface towards bottom, but the saturation degree does not drop below 60%. From these facts, it can be said that the lake water is effectively mixed in the vertical direction.

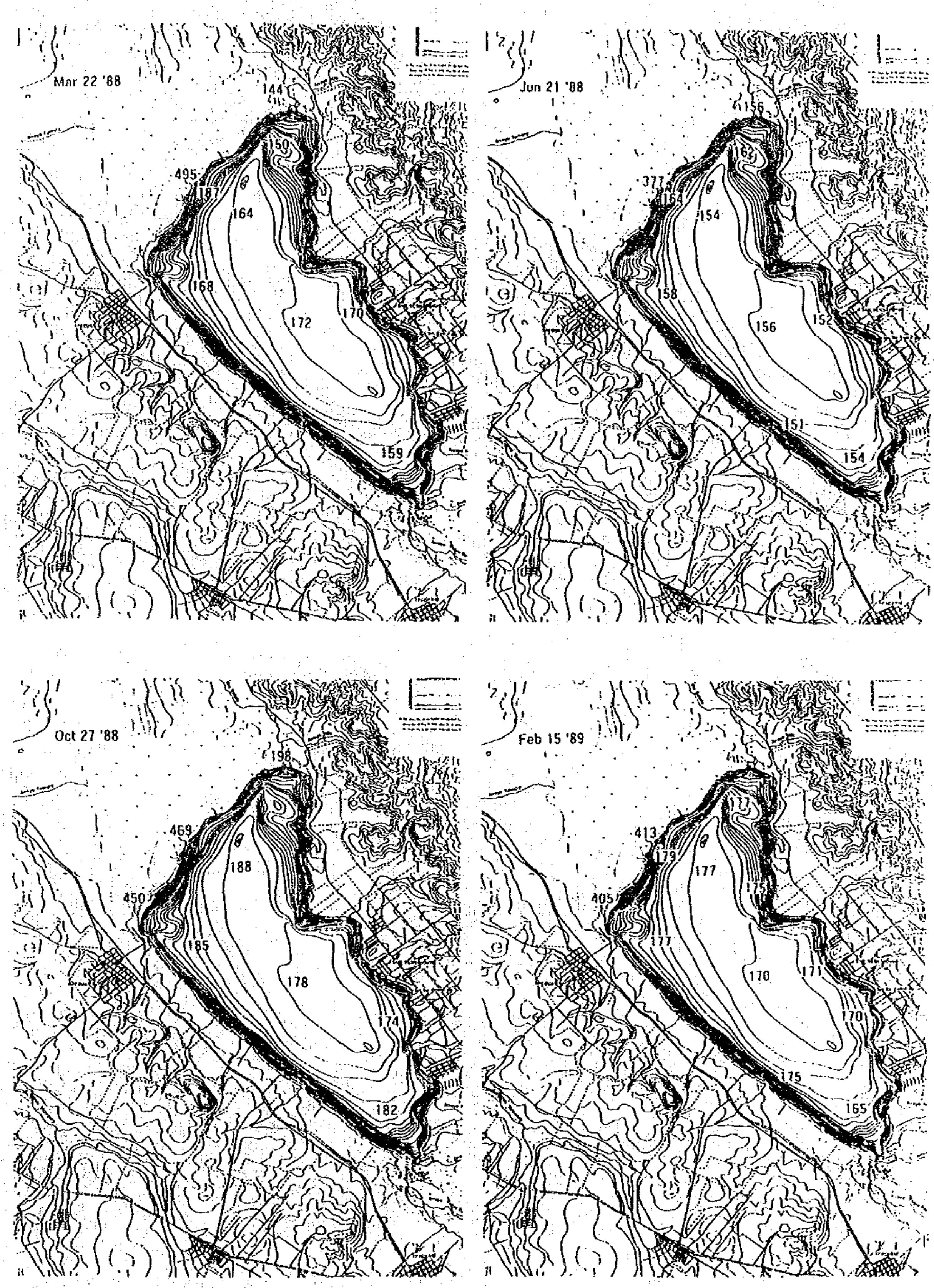


Fig. M5321 **Intra-lake Differences of EC within the Lake**

Fig. M5322 Intra-lake Differences of DCOD within the Lake

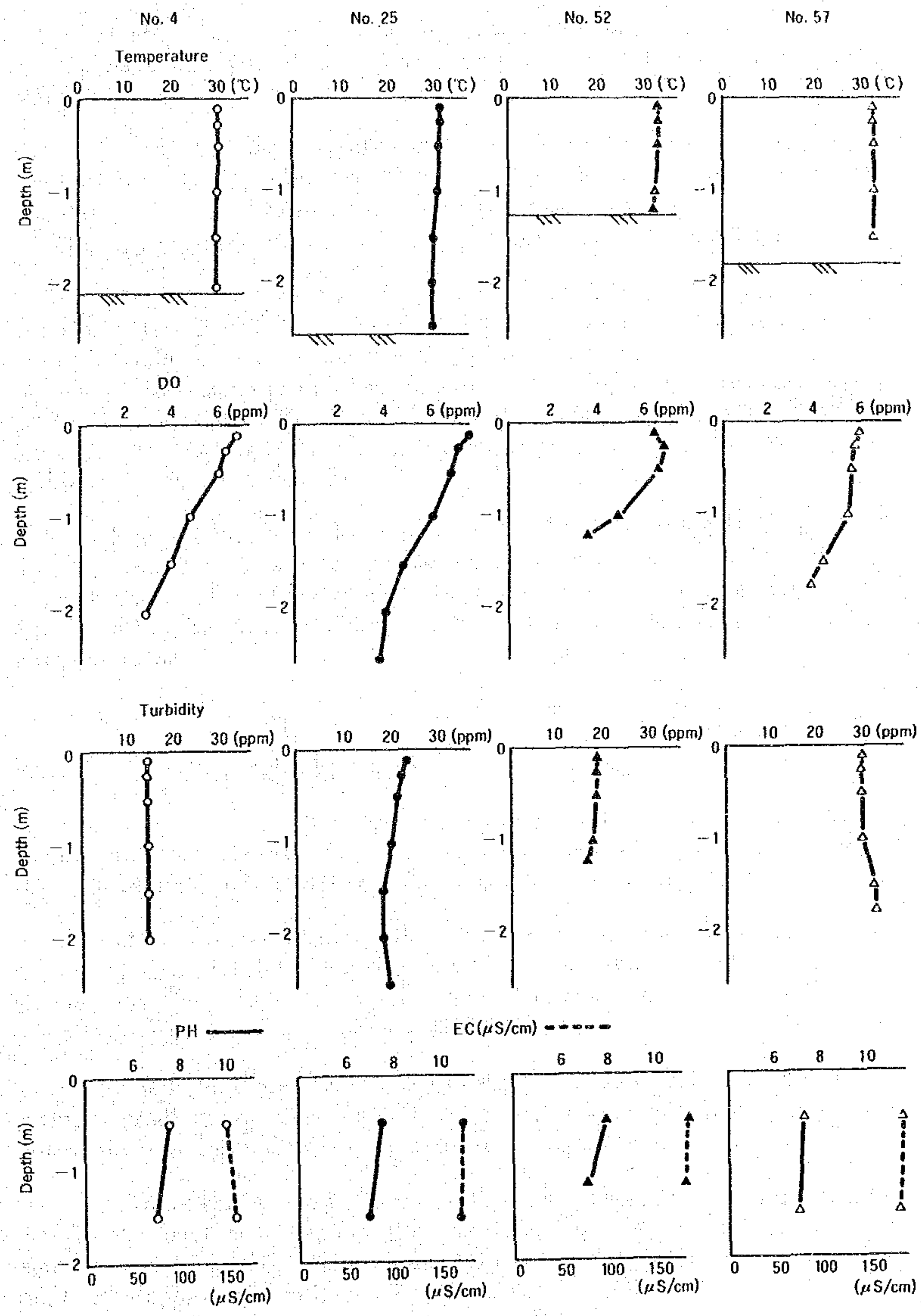


Fig. M5323 **Vertical Change of Water Quality in the Lake**

5.3.3 Correlation among Water Quality Indices

A study has been made on the relations among water quality conditions as a means of clarifying those factors upon which the quality of water in the lake is dependent.

Fig. M5324 shows a relationship between SS and Chl-a. Although their correlation is problematic. An SS concentration in any case is higher than the calculated theoretical value based on the Chl-a concentration. This signifies that something other than phytoplankton is increasing the SS concentration.

Fig. M5325 shows the relationship of TCOD and PCOD to Chl-a. PCOD and Chl-a show a considerably high level of correlativity while something other than phytoplankton is increasing the COD concentration. The fact that the TCOD concentration normally remains at 20 mg/ℓ and above while dispersing to a large degree, signfies that the DCOD is contributing to some extent. The DCOD comes from inflowing rivers, from the decomposition of perished phytoplankton and from the effluents from the bottom mud.

Fig. M5326 shows the relationship of POP and PON to Chl-a. The POP concentration coincides with the theoretical value calculated from the Chl-a concentration. Most of the POP, therefore, may originate from phytoplankton. On the other hand, it indicates that the PON contains things other than phytoplankton.

5.3.4 Comparison with Past Data

According to a report prepared by the ICB, Lake Yapacarai had SD of 10 thru 20 cm, SS of 10 ~ 100 mg/ℓ, pH of 7.5 in summer and about 6 in winter, TN of 0.17 ~ 0.74 mg/ℓ and TP of 0.13 ~ 0.33 mg/ℓ throughout the year of 1984.

Moreover, according to the analytical findings of the water sampled by SENASA in 1981-1982 along the lakesides of Aregua and San Bernardino, SS was found at 300 ~ 400 mg/ℓ, pH at 7.2 ~ 7.7 in summer and 6.8 ~ 7.2 in winter, TN at 0.03 ~ 0.99 mg/ℓ and TP at 0.00 ~ 0.51 mg/ℓ.

The lake, therefore, was reported to be in a normal condition, with few primary products produced, though it has a low level of transparency and it is eutrophic (in particular having an excess of phosphorous).

From February to December in 1988, however, SD was found at 60 ~ 80 cm, SS at a peak of 60 mg/ℓ and normally 30 mg/ℓ or less, pH at 9.0 ~ 9.5 in summer and 7.5 ~ 8.0 even in winter, TN at 0.7 ~ 3.3 mg/ℓ and TP at 0.07 ~ 0.16 mg/ℓ. Phytoplankton proliferated very actively, as well.

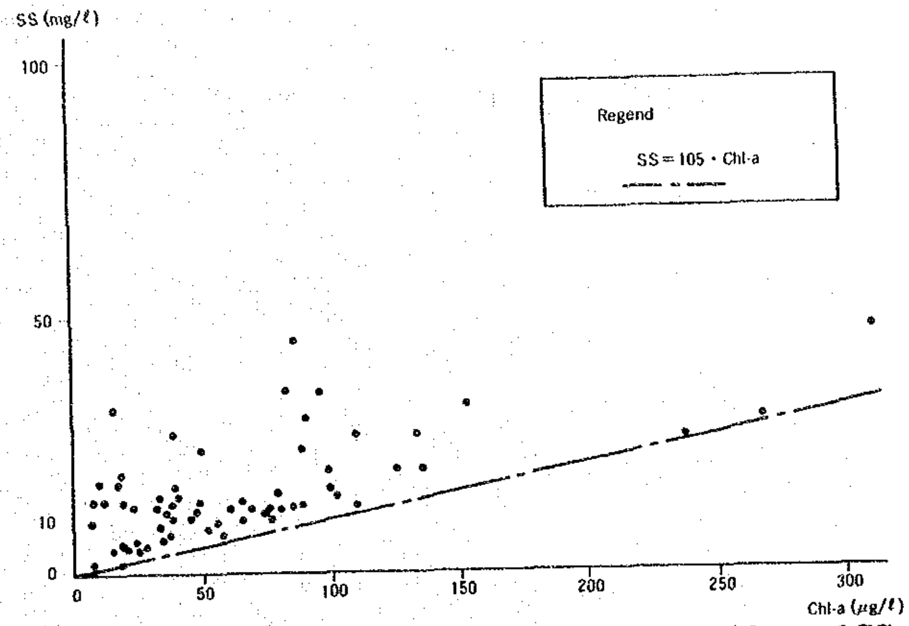


Fig. M5324 Correlation between Chl-a and SS

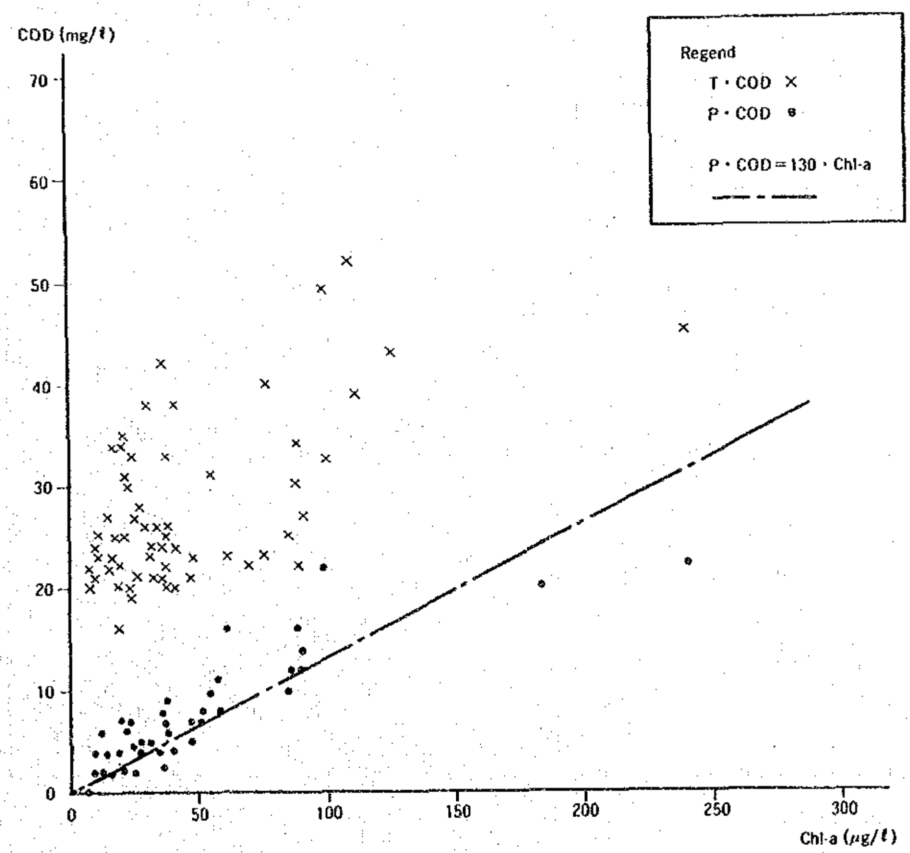


Fig. M5325 Correlation between Chl-a and COD

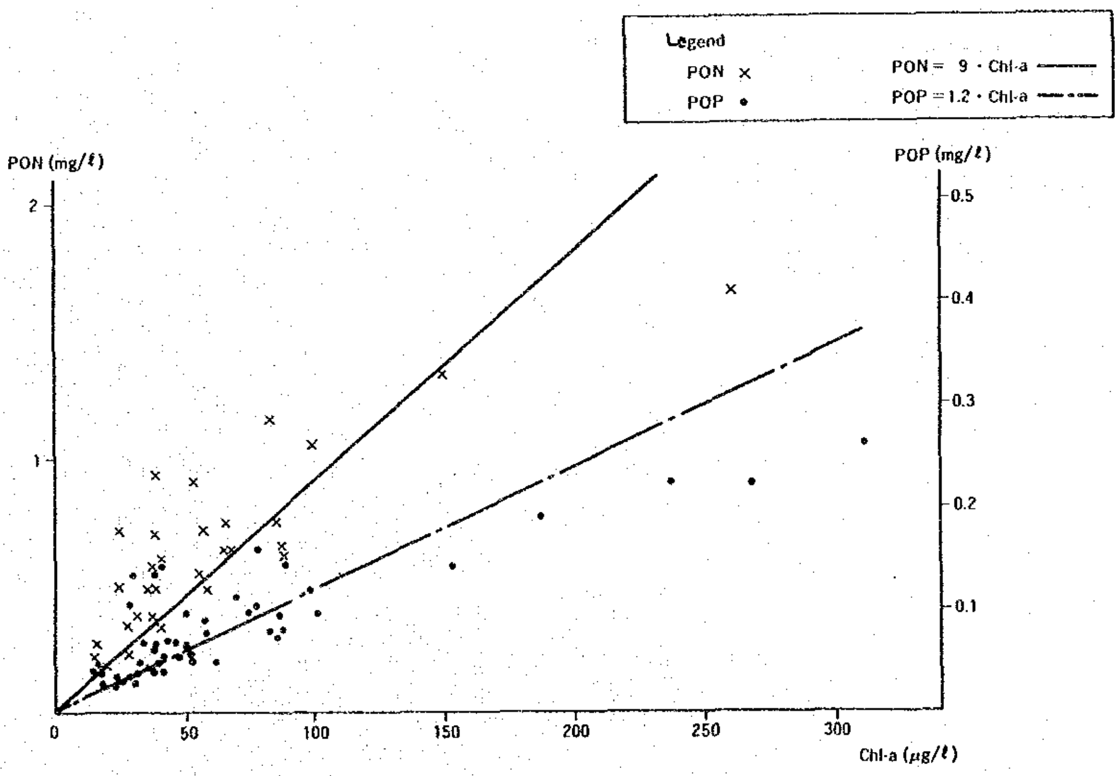


Fig. M5326 Correlation between Chl-a and POP, PON

Since the beginning of 1989, the water color has been blackish while the transparency has been decreasing. And TP (especially PO_4P) has increased. This signifies that the amount of inflowing phosphorous from the area increased as well as the amount of PO_4P eluted from the bottom mud increased as a result of the rise in water temperature.

Table. M5341 is a comparison of analytical results on the specimens sampled offshore Aregua in summer (February and March) in 1982, 1984, 1988 and 1989. In any case, the water was at a temperature of approximately 30°C while a significant difference could be observed in SD, DO, pH, TP and $PO^-{}_4P$ for 1988 from the data for any of the other three years.

These facts will allow us to assume that the 1988's clarification of the lake was an exceptional phenomenon taking place as a result of the localized torrential downpour from Jan. 13 to 16 in 1988 and of an eventual remarkable rise of the lake water level. Thus, the water quality changes subsequent thereto may be interpreted showing the process of returning to the normal condition. Nevertheless, data has been still insufficient for us to reach a definitive conclusion concerning the normal water quality conditions of Lake Ypacarai and a water clarification mechanism such as that seen in 1988.

Table M5341 Water Quality of the Lake in Summer

Samping Site	AREGUA	AREGUA	St. 30	St. 30
Institution	*1 SENASA	*2 ICB	*3 JICA	*3 JICA
Date	May 9, 1982	Feb. 28, 1984	Feb. 16, 1988	Feb. 15, 1989
Air Temp.	-	-	-	29.4°C
SD (cm)	-	10	50	25
Water Temp.	30.0°C	29.5°C	31.0°C	29.8°C
DO (%)	112	134	199	86
pH	7.7	7.9	9.6	6.9
EC (μs/cm)	-	-	120	176
Color	-	-	brown	grey
TP (μg/ℓ)	-	293	132	210
PP (μg/ℓ)	-	-	61	38
DOP (μg/ℓ)	-	-	38	52
PO_4P (μg/ℓ)	0	121	23	120
TN (μg/ℓ)	-	-	-	1,605
PON (μg/ℓ)	-	-	-	83
DON (μg/ℓ)	-	-	-	865
NH_4-N (μg/ℓ)	16	29	53	166
NO_3-N (μg/ℓ)	43	-	330	490
TN / TP	-	-	-	7.6
TCOD (mg/ℓ)	11	18	-	23
DCOD (mg/ℓ)	-	-	-	22
BOD (mg/ℓ)	-	-	-	-
RS (mg/ℓ)	-	-	-	214
I L_{RS} (mg/ℓ)	-	-	-	34
SS (mg/ℓ)	302	-	-	31.7
I L_{SS} (mg/ℓ)	-	-	-	-
Cl^- (mg/ℓ)	-	-	-	42
Alkalinity	-	-	14	47
Chl-a (μg/ℓ)	-	-	24	15

*1 MSPBS (1984) Classificacion de Aguas Superficiales
*2 ICB (1985) Estudio Limnologico del Lago Ypacarai
*3 This Study

5.4 River Bottom Materials

At a total of five points, including three water level observatories, bottom materials were sampled by the use of an Eckman-Birge mud sampler to determine the particle size composition, density, water content, ignition loss and contents of organic N and C.

Out of five specimens, four were sandy. The specimens sampled only in the Pirayu River contained more silt and clayey matter, with its N and C contents reaching about 20 times those of the other four specimens.

Even in the Yuquyry River into which lots of organic substances inflow from the basin, bottom material has a low organic content. This is presumed due to the sedimentation of soil and sand.