REPUBLIC OF PARAGUAY
PRESIDENCIA DE LA REPUBLICA
SECRETARIA TECNICA DE PLANIFICACION

THE STUDY ON WATER POLLUTION CONTROL PLAN FOR THE LAKE YPACARAI AND ITS BASIN

VOLUME 1 SUMMARY

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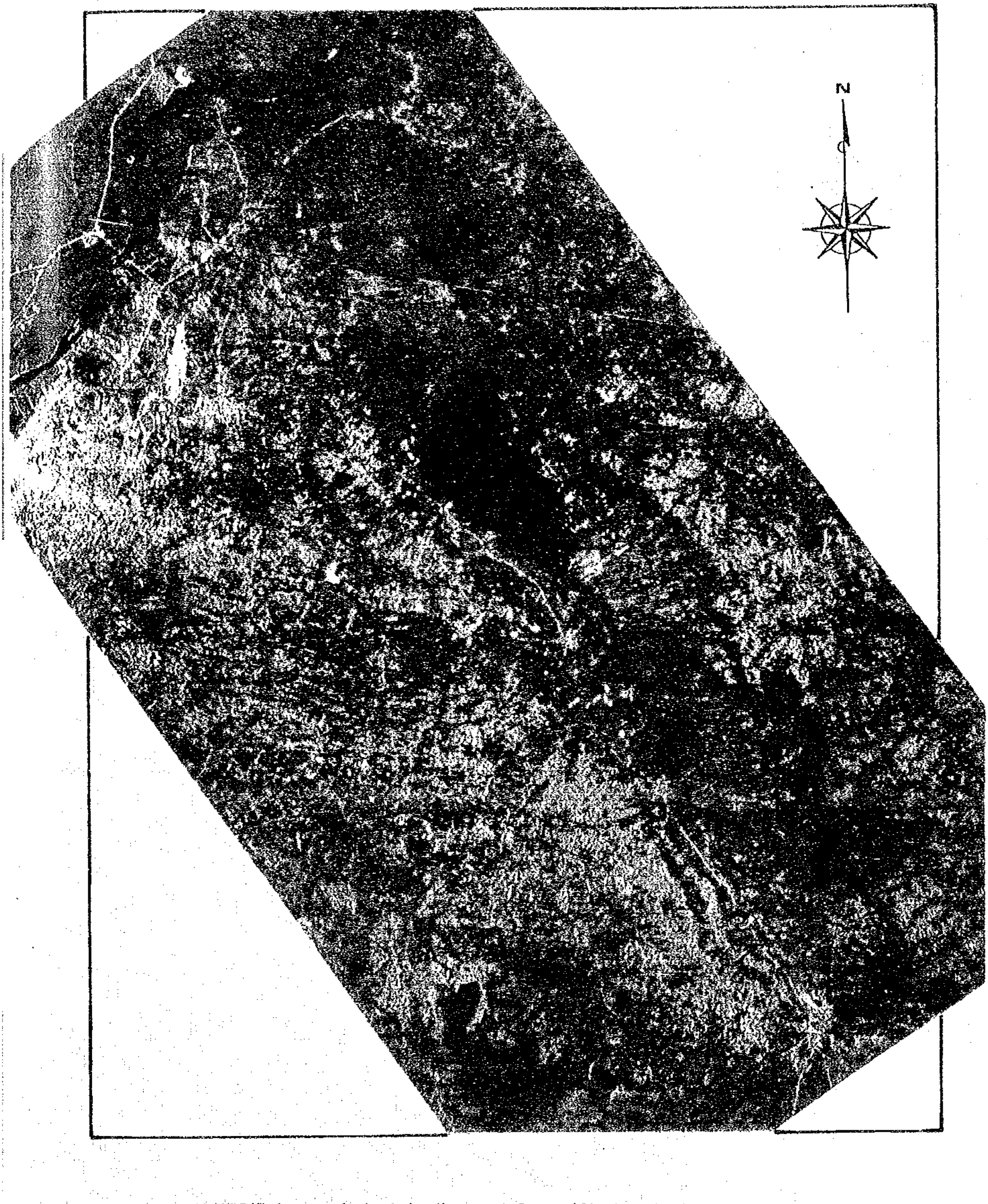

LANDSAT Image of the Lake Ypacarai Basin (Photo: NASA, April 5, 1981)

CONTENTS

I. INTRODUCTION

1. Purpose of the Study

Lake Ypacarai, located at about 30km east of Asuncion, is an important natural resource and a place for sightseeing/recreation for Paraguay, as an inland country. Unfortunately, its water quality is gradually deteriorating due to the limnological characteristics and surrounding development. If this trend is unchanged, the lake risks losing its value as a place for sightseeing/recreation and as a natural resource. With this consideration, this study was made for the purpose of formulating a water pollution control plan for the Lake Ypacarai and its basin, and then transferring the techniques to Paraguan counterpart personnel.

2. Outline of the Study

The study is composed of four parts: ① understanding the natural, socioeconomic environment of the basin as the background for water pollution, ② understanding the present state of pollution in the lake and rivers, and an analysis of the pollution mechanism, ③ selection and evaluation of water quality improvement techniques, ④ formulation of a complete water quality conservation plan. A flow chart is shown in Fig. 1.

3. Area of the Study

Lake Ypacarai and the rivers joining it were mainly studied, and the outflow rivers were also studied when necessary. The study area is shown in Fig. 2.

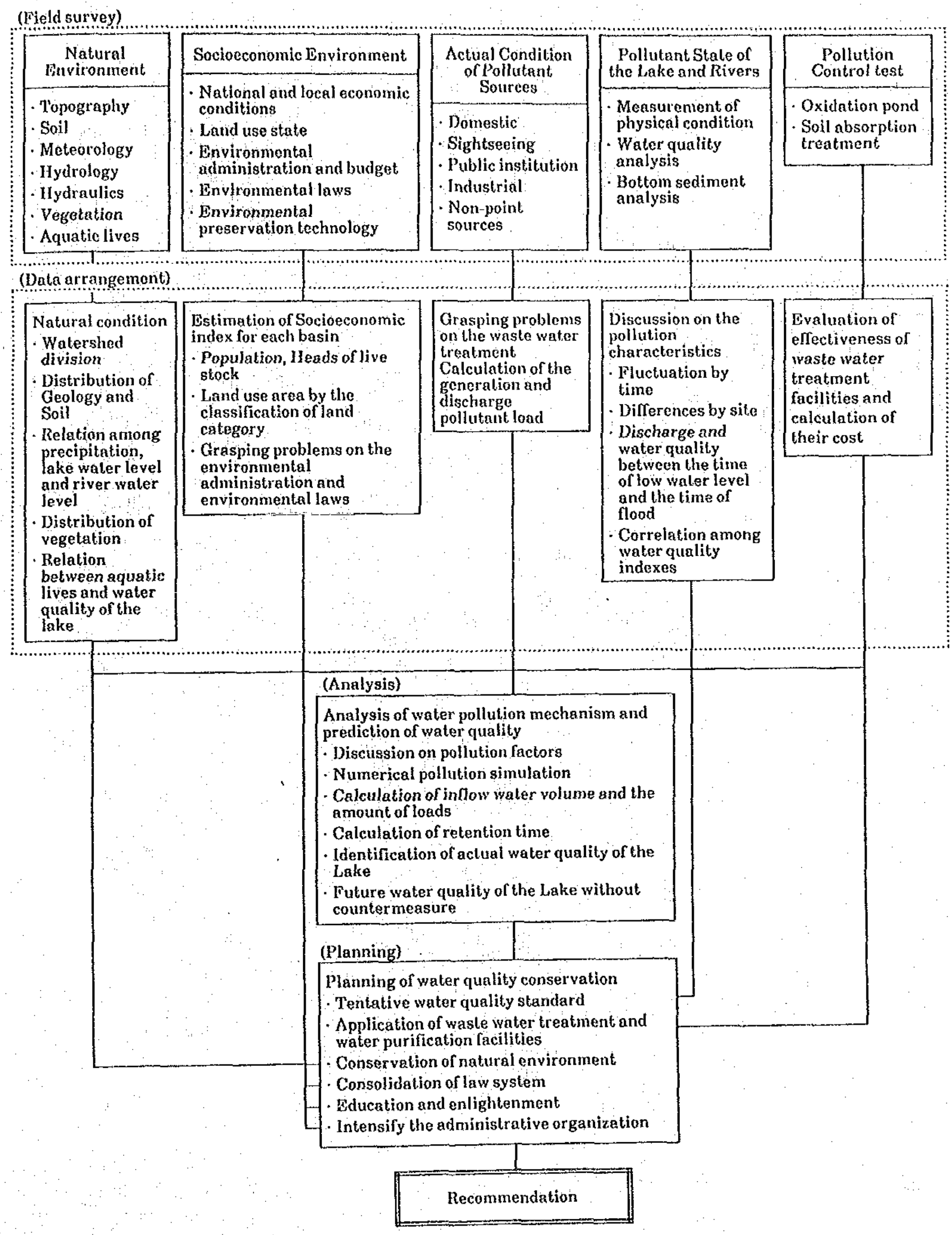

Fig. 1 Research Flow

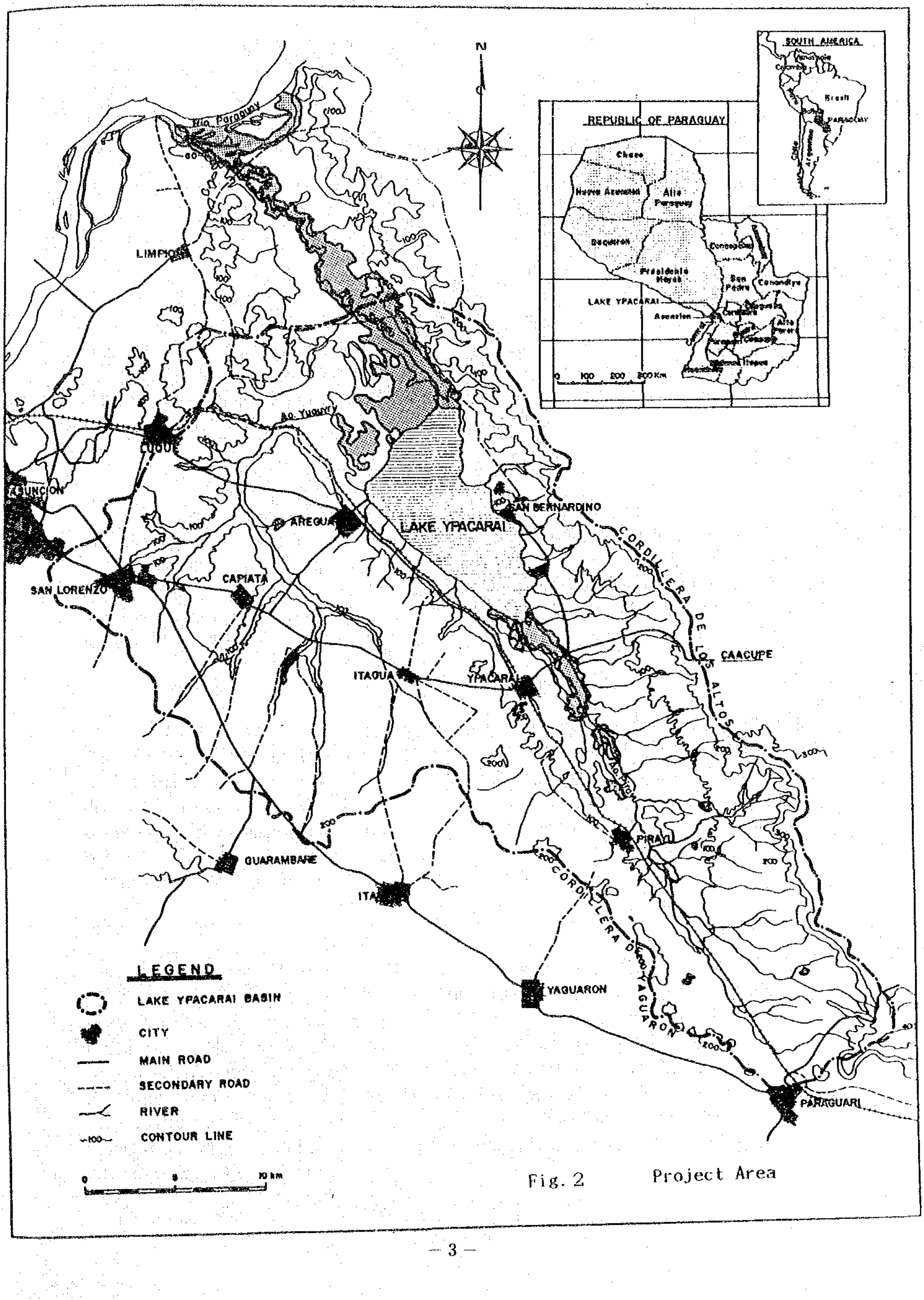

Fig. 2 Project Area

II. NATURAL ENVIRONMENT OF THE LAKE AND ITS BASIN

1. Relation between the Yuquyry River and the Lake

It can be judged from the results of various surveys that although the relationship between the Yuquyry River and the lake is not clear, most of the water from the former flows into the lake.

2. Basin Division

Therefore, the Lake Ypacarai basin is basically composed of four watersheds ; the Pirayu River (353.7km^2) system, the Yuquyry River (343.9km^2) system, the East shore river system (75.2km^2) and the West shore river system (60.2km^2), with a total area at 892.6km^2. There is only one river outflowing from the lake, the Salado.

3. Lake Bottom Topography and Bottom Materials

The area of the lake is 59.6km^2, with a maximum depth at 3m and a slight inclination to about 500m off the shore, however, most of the bottom is flat with no watercourse observed. The water depth at egress to the Salado, was 85cm below the datum level when measured. On the east and west lakeshores, quartz sand is distributed, but most of the lake bottom is uniformly covered with black mud.

4. Marsh

In the downstream of the Yuquyry River, a marsh of about 16km^2 in area exists which plays an important role in adjusting the lake water level and in maintaining the water quality, and therefore, is called humedales. In the downstream of the Pirayu River, a marsh of almost 2km^2 in area exists. These marshes and innumerable small scale shallow ponds distributed on the right bank of the Pirayu River main stream at 80 to 200m above sea level are considered remnants of the once-large former lake.

5. Geology

The lowest horizon of the strata distributed within the lake basin is granite of Cambrian period, with a small portion of outcropping. Most of the eastern mountains are composed of sandstone of Palaeozoic era, which is used as building stone in many places. On the other hand, most of the western hills are composed of conglomerate and red sandstone of Cretaceous to Tertiary period, and the conglomerate is excavated as material for gravel. In the central low lands, unconsolidated thin sand layer is distributed, and at the bottom of the Yuquyry River dark gray to dark brown, semi-consolidated clay is distributed, which is mined as ceramic material.

6. Soil

The soil distributed in the basin is basically classified into four kinds, lithosol, acrisol, regosol and planosol, and those without the last one are sandy and lacks in organic substances. They are distributed closely correlating with the topography. From this fact and from the results of grain size analysis, it can be said that the lithosol and the acrisol are the original soil formed on the parent rock, the regosol is sandy soil formed when they are transferred to low land and accumulated on grassland like wetland and the planosol is clayey soil formed when they are further worked by river water and only the fine particles are left. It seems that these soils were originally distributed thickly on gently undulated hills, but as a result of roads and residential lands development, large amount of them have been lost untill now. As to the cation exchange capacity (CEC) and the phosphoric acid absorption coefficient (PAC) of the soil, planosol was the largest (16.3me/100g, 500 mg/100g) and acrisol was the smallest (2.6me/100g, 100 mg/100g).

7. Weather

According to the meteorological observation result from March 1988 through February 1989, the yearly precipitation of the lake basin was 1,485mm, mean of the normal year. However, the April precipitation was 190 to 390mm, almost double of normal year, and on the contrary, the March and July precipitations were 20 to 55mm and 1 to 5mm respectively, considerably less than the normal year. And, the March average temperature (San Bernardino) was 28.2°C, the past highest record, and the May and July average temperatures were 16.2°C and 15.5°C respectively, the past lowest record. Besides, before the observation was started, from 13th to 16th January 1988, there was rainfall estimated as more than 180mm and the lake water level was remarkably rised. The season of the strongest wind during the observation was July to September, and the prominent wind direction was south-west-south.

8. Lake Water Level

The mean lake water level during 22 years from 1965 to 1987 was 1.20m above the datum level (62.29m above the sea level), and the highest level during this period was 2.20m above the datum level (Mar. 17, 1974). And, the correlation between the water level monthly average and the precipitation monthly average is low. This fact suggests that the lake water level is not decided only by the inflow amount, but is affected by the state of the egress to Salado River. Besides, the lake water level of 16th through 20th of January 1988 recorded the past highest of 2.60m, and the lake was cleared after that. The lake water level during this study was always 19 ~ 61cm higher than mean lake water level.

9. River Water Level

The Yuquyry River water level in floods reaches its highest at 0.5 to 1 day after the peak rainfall, and that of the Pirayu River , 1.5 to 2 days after the peak rainfall. It seems that this is due to the fact that the urbanization of the Yuquyry basin resulted in a runoff time decrease. Furthermore, in flood time the lake water level rises at almost the same time as when the river water level goes up, but does not fall easily after the river water level goes down. It seems that the outflow is controlled by the state of egress to the Salado River.

10. Vegetation in the Basin

The plant communities distributed in the basin are classified into four groups ; forest, palm community, grassland and hydrophyte. Within the forest group, mountain forests seem to be those secondary of the natural forest once spread in the basin but then transformed into bushes by selective felling and soil depletion. These mountain forests have almost vanished in the Yuquyry basin and are rapidly dwindling in other areas as well. As for the palm communities, there is the Karanday palm community which grows in low permeability clayey soil, and the coco palm community which grows in high permeability sandy soil. The latter is low density vegetation which developed after the mountain forest was felled.

11. Lakeside Vegetation

Various hygrophyte and hydrophyte is observed at the lakeside. Hygrophyte is mainly of *Cyperus* sp. group and widely distributed in the downstream marsh of the Yuquyry and the Pirayu Rivers and around the Salado River. Various hydrophytes grow together in the north inlet of the east lakeshore and in the south in the vicinity of the Pirayu estuary where the effects of wind and wave are not strong.

12. Aquatic Life

The phytoplankton of the Lake Ypacarai shows characteristics of a eutrophic lake, where the ratio of cyanophyta is large throughout the year. The cell number during the study period was at the order of $10^4/m\ell$, and in February and March of 1988, water bloom was observed. As for zooplankton, *rotifer*, *cladocera* and *copepoda* were abundant and the species composition was generally the same as for a eutrophic lake. However, the existence of benthos was less than that of an eutrophic lake in a temperate zone.

III. SOCIOECONOMIC ENVIRONMENT OF THE BASIN

1. Pressure from the Asuncion Metropolis

There are nine districts which belong to the basin. Among them, Luque and San Lorenzo have been completely included as part of the Asuncion metropolitan area, and Capiata and Aregua are playing role as its bedroom-community. Out of the population of 210 thousand in the basin, more than 160 thousand live in the Yuquyry basin. Route 2, connecting Asuncion and Brazil, crosses this basin, bordered by many factories and offices. Many of the visitors crowding the recreational facilities of the lakeshore also come from metropolitan area. Therefore, the water pollution problem of the Lake basin cannot be considered as apart from Asuncion metropolitan area.

2. Land Use

The ratio of the land use by land classification in the Lake basin is : forest 14.1%, waste (or dry grassland) 0.4%, marsh (or submerged zone) 3.8%, meadow 36.3%, farmland 28.9%, lake and swamp 0.3% and urban area 16.2%; however, the composition is quite different in the Yuquyry basin and in the Pirayu basin. In former case, the order is farmland > urban area > meadow, and the urban area occupies 71% of the total urban area within the Lake basin. On the other hand, in latter case, the order is meadow > farmland > urban area, and the meadow occupies 58% of the total meadow area within the Lake basin.

3. Expansion of the Urban Area

If land use of 1965 and 1988 are compared, the urban area has more than doubled within this 23-year period. This is mainly due to the population increase in the Yuquyry basin, which results in the conversion of farmlands into urban area. Such urban expansion shows that the Asuncion metropolitan area is expanding into the Lake basin. Furthermore, this trend is likely to continue, as long as no special measures are taken.

IV. POLLUTION SOURCES AND THE STATE OF THEIR GENERATION/DISCHARGE

1. Classification and Distribution of Pollution Sources

The pollution sources within the basin are classified as point sources and non-point sources, and for convenience, the point sources are classified as four types: domestic (households), tourism (hotels, clubs), public facility and industrial (mostly agricultural and livestock products processing industries). Almost 80% of the domestic pollution sources are located in the Yuquyry basin, and the tourism pollution sources are concentrated on the East shore basin. As for the public facility pollution sources, there is only one national hospital and one public sewage treatment plant. Among the industrial pollution sources, the largest in scale are four vegetable oil refineries, three of which are located in the Yuquyry basin. Many of the other industrial pollution sources are also located in the Yuquyry basin.

2. Domestic Pollution Source

As for the domestic water, only that of about 15,000 persons in San Lorenzo becomes sewage, and the rest are permeated into the soil through an infiltration tank (open shaft about 1m in diameter, and 2 to 6m in depth) installed at the house, or through the same to which a septic tank is attached. For this reason, health hazards often occur where the waterworks is not complete. The amount of discharge is estimated at 130 to 150ℓ/person/day in cities, and slightly less in rural areas.

3. Tourism Pollution Sources

At most of the tourism pollution sources, septic tanks and storage tanks are installed. However, many of these are not properly maintained and managed, and at some places the water directly flows into the lake. The amount of discharge increases in summer, at which time the number of guest still does not exceed 100person/day average.

4. Public Facilities Pollution Sources

As for public facilities pollution sources, the national hospital has 350 employees and 200 beds, and the waste water is passed through serial three stage septic tanks and then filtered by sand and pebbles. The sewage disposal plant consists of a serial three stage lagoon, and accepts the raw sewage and other waste water from about 15,000 persons from San Lorenzo.

5. Industrial Pollution Source

The discharge amount of four vegetable oil refineries, the large scale industrial pollution source, is estimated at 5,000m^3/day total, among which two refineries of large production have chemical treatment plants for high concentration waste water but which are now not in operation. The butchery is a semi-public facility and roughly one each is established at every city in the Lake basin, but many of them are disposing the blood and stomach contents from dissection into the river as is. In addition, there are middle to small-scale factories, such as, tanneries, breweries and sausage and starch factories, but only a few of them have lagoons and most of them are discharging into the river without processing.

6. Pollution Load Generation from Point Source

When the pollution load generation from point sources in the Lake basin was calculated based on the drain water quality survey data and existing data on the generation basic unit, the domestic origin occupied 52% of COD, 78% of TN, and 65% of TP. On the other hand, the industrial origin occupied 44% of COD, 15% of TN and 30% of TP. As for that of industrial origin, the rate for vegetable oil refineries was high and occupied 85% of COD, 64% of TN and 69% of TP.

7. Non-Point Sources

From meadows, which constitute a non-point source, there is run-off of a portion of livestock excretions. From dry fields, usually,a portion of fertilizer runs off, however the amount of fertilizer in the Lake basin is generally scant. The forest functions in purifying pollutions, however its presence in the Lake basin is decreasing. Much earth and sand are running off the Lake basin every year because the soil is sandy and lacks organic substances, and because of strong rainfall of 80 to 120mm lasting several hours which occurs several times a year. The originating places of gross sand and gravel are the mountain and hills not covered by forest, the Pirayu River left bank, roads and residential areas and stone/gravel/clay pits.

V. RIVER AND LAKE POLLUTION

1. Pollution in Rivers

In the Yuquyry water system, the DO saturation is low in many places, which shows that organic substances beyond the self-purification capacity are entering. On the contrary, in the Pirayu water system, in many places, the degree of organic contamination is low; in particular, the Yagua-Resa-u River is hardly contaminated. In every river, the BOD/COD are small at low water level, which shows that a large amount of organic substances are difficult-to-decompose. It is also common for 70% to 90% of the residue to be dissolvable (particle size less than 1 μm).

2. River Water Quality in Flooding

The pollutant concentration in flooding is 1.5 ~ 2 times more in the Yuquyry River but several times in the Pirayu River (Y-pucu and Yagua-Resa-u Rivers), and in both the pollution load becomes almost equal. It seems that this is due to the fact that, in the former, the ratio of load from the point source is large and, in the latter, the ratio of load from non-point source is large. Among the pollutants, the SS concentration increase is remarkable, which suggests that the earth and sand runoff increases in flood time.

3. River Bottom Materials

In spite of a large amount of organic substances flowing in from the basin, the organic substance content in river bottom materials is low. The reason seems to be because much inorganic SS originate from earth and sand deposit on the river bed.

4. Inflow Load

The yearly load into the lake obtained from the river water quality and flow rate, at low water level and in flooding of the Yuquyry and the Pirayu Rivers, calculated at the upstream side of marsh are: 9.8×10^6 kg of COD, 374×10^3 kg of TN, and 20.4×10^6 kg of SS. By basins, from the Yuquyry basin: 53% of COD, 48% of TN, 58% of TP and 39% of SS, and from the Pirayu basin: 27% of COD, 29% of TN, 20% of TP and 34% of SS, are inflowing.

5. Purification Capacity of Marshes

The pollutants are removed in the marshes by the large size particle settling caused by the reduction in flow speed, attachment onto the hydrophyte roots, decomposition by micro-organisms attached to hydrophytes and so on. However, the measuring method and frequency are not satisfactory. For the Yuquyry River, it is estimated that around 80% of SS, around 50% of COD,

around 75% of TN and around 70% of TP are removed by passing through the marsh at normal water level. As for the Pirayu River, it seems that the purification rate is extremely lower than this, as the area of its marsh is 1/8 to 1/9 of that in the downstream Yuquyry and the retention time is short.

6. Organic Substances in the Lake Water

With the increase of organic substances in the water, larger quantity of dissolved oxygen is consumed and selfpurifying capacity of the river and lake water decreases. Consequently both the water and the bottom materials become perishable and the ecosystem around the aquatic area changes. During the study period, COD concentration of the lake water was highest at 50mg/ℓ, and lowest at 20mg/ℓ, showing that organic pollution is advancing greatly in the lake. However, BOD concentration is 2.5-4.3mg/ℓ and BOD/COD is about 1/10, therefore most of the organic substances are believed difficult-to-decompose. There is little difference of DCOD concentration between the lake water and the inflowing river water.

7. Nutrient Salts in the Lake Water

With the increase of nutrient salts in the water, phytoplankton multiplies due to this nutrient source. This leads to trouble in the purifying process for potable water and to a cause of offensive odor of city water. Also, when plankton dies, it accelarates the organic contamination in that water area. The lake water TN concentration during the study period was 3.3mg/ℓ at maximum and 0.7mg/ℓ at minimum, and the TP concentration was low in 1988, but exceeded 0.2g/ℓ in 1989. The state of high nutrient salts is the same as in past data, and it can be said that the Lake Ypacarai reached a hypertrophic state long ago.

8. Causes of the Lake Turbidity

Turbidity reduces the aesthetic value of the water area as well as the comfortability of bathing. According to the existing data, transparency (SD) of the lake is normally less than 15 cm and seems very low, but during the study period, January through September of 1988, it was 60 to 80 cm. However, in 1989 the SD value decreased to around 25 cm, the water color turned to dark and TP concentration increased. The causes of the turbidity are ① dissolved substances within inflowing water (considered difficult-to-decompose substance), ② phytoplankton produced in the lake and its dead remains, ③ as for the bottom mud stirred up by waves and wind , the amount and ratio fluctuate greatly, depending on the weather and/or hydraulic conditions. It is not clear yet from this investigation what makes the water black and what decreases greatly the luminous intensity in the water.

9. Contamination by Bacteria and Toxic Substance

Both bacteria and toxic substances are the eventual causes of health damage for the people and the domestic animals. So far, the lake contamination level by bacteria and toxic substance is low. However, downstream in the Yuquyry River, fecal coliform groups are always at a level of 1,000 to dozens of thousands MPN/100 ml, which can be considered the effect of butchery and domestic waste water. Although few, there are factories which possibly discharge toxic substances, such as the pharmaceutical factory at San Lorenzo and the tanneries at Ypacarai.

10. Lake Bottom Materials

The lakeshore aside, the lake bottom materials are 99% clay and silt except for a small portion, and the natural water content is 150% to 400% with a small difference between points. IL is high at 15% to 20% and contains high levels of organic substances. The columnar samples show that the CN concentration, water contents and IL decrease remarkably between the bottom surface and 15 to 17.5 cm below it at the center of the lake. The bottom mud deposit rate obtained from the SS settling quantity is 5.3 mm/y when calculated from surface layer water content, and 2.1 mm/y when calculated from 20 cm below the surface layer water content. Therefore, the depth where the bottom materials change suddenly does not go back more than 80 years even taking into account the reduction by decomposition and consolidation.

VI. POLLUTION MECHANISM AND WATER QUALITY PREDICTION OF THE LAKE

1. Retention Time

The retention time obtained from the lake capacity and water balance is around 150 days, namely the turnover frequency is 2 to 3 times/year.

2. Water Quality Distribution Characteristics

The water quality difference at points in the lake is small, and advection and diffusion are always adequate. It seems that the horizontal mixing speed is very rapid, as the change in river water quality immediately affects the lake water quality change. The vertical water quality change is also scarcely observed, and DO saturation is always adequate at the bottom layer too. Therefore, the vertical mixing also seems to be active.

3. Regulation Factors of Water Quality

According to the investigation of water quality in relation to the weather and hydrological conditions and to the results on the existing water quality through simulation, the main factors which regulate the lake water quality are, ① residue of inflow load (which cannot be removed even by purification in the marshes nor by settling at estuaries), ② phytoplankton breeding in the lake, ③ elution from bottom mud and stir-up of bottom mud by wind and waves. The ratio of ① increases in flood time at a rate which is 15 to 20% that of the production in the lake. ② is controlled particularly by the thickness of the euphotic zone, however, the velocity of decomposition is high. For ③ the elution increases in summer when the water temperature is high and stir-up is remarkable in winter when the wind is strong.

4. Prediction on the Effects of Water Quality Conservation

The yearly change in lake water quality (COD and SS), when the load is reduced to half under the weather conditions of the survey period, was calculated by pollution simulation, and the results showed that it would be slightly improved but no significant effect. On the other hand, assuming the load will increase 2% each year from now, the lake water COD concentration in the year 2010 was calculated. The result was 1.5 to 2 times of the present value. This does not mean that water quality conservation measures have no effect, but rather it indicates that water quality improvement takes a long time in closed type water area where pollution progresses very rapidly when it is left to its own devices.

VII. WATER QUALITY IMPROVEMENT TECHNIQUES APPLICABLE TO THE LAKE BASIN

1. List of Water Quality Improvement Techniques

Among the water quality improvement techniques which are already used in Japan and/or other countries, those applicable to the basin were selected and listed in Table. 1 in order of priority. The order of priority was given taking account of the extent of water quality improvement effect, the degree of difficulty to provide funds and the necessity of new legislation, etc.

2. Measures for Industrial Sources

As measures for generating/discharging sources, the installation of water treatment/purification facilities is main issue in the case of point sources, and, due to their large share in the total load, it is an urgent matter to perfect industrial water treatment facilities. In particular, processing should be mandatory for vegetable oil refineries, as they discharge much waste water (total of four factories, over 5,000m^3/day) of high pollutant concentration. The recommendations are for : restarting the operation of chemical treatment plant for high concentration waste water at two factories where facilities exist but are not in operation ; and the immediate installation of a facility of similar capacity at two factories where none exists. Furthermore, it is desirable to install a lagoon besides the chemical treatment plant and increase the processing capacity. For other middle- and small-scale factories ,as well, guidance should be given so as to install lagoons, at least, and to discharge after the organic substances are decomposed to some extent. In addition, the pharmaceutical factories and tanneries which have possibility of discharging toxic substances must be constantly monitored.

3. Measures for Domestic Sources

The load originated from domestic waste water is far less than that from industry at present, but a large part of the pollution load generation is predicted to increase more and more in future due to the urbanization of the basin. In urban areas, people are running short of space for infiltration tank replacements, and health hazards by groundwater have generated where the city water is not yet supplied. Therefore, needless to say, to hasten the completion of sewarage and sewage treatment plant, it is necessary to transfer the domestic waste water from urban area where the completion of those facilities is retarded, to soil absorption treatment from disposal by infiltration tank. As to the area where the groundwater level is shallow or the soil is quite unsuitable for soil absorption treatment, the introduction of a raw sewage collection system by cesspit emptier is worthy of investigation. However, in this case, raw sewage and other waste

Table. 1 Water Quality Improvement Techniques Applicable to the Lake Ypacarai Basin

Application site	Contents of Load Reduction	Technology of Water Quality Improvement
Sources of load generation and discharge	Reduction of the quantity of generated load from point sources	· Regulation on the localization of industries and dwellings★ · Improvement in industrial production process (include recovery of valuable materials)
	Reduction of the quantity of discharge load from point sources	· Establishment of industrial waste water treatment system Big industry: High grade treatment (Chemical treatment plant)● Lagoon● Functional recovery of existing facilities● Small and average industries: Lagoon● · Right maintenance of waste water treatment system belonging to tourist installation● · Establishment of domestic waste water treatment system (urban area) Promotion of sewage work and sewage treatment plant★ Changing infiltration tank to soil absorption treatment system● Introduction of raw sewage collection system by cesspit emptier■ Function improvement of existing sewage treatment plant (San Lorenzo)◆ · Establishment of sludge treatment plant◆
	Reduction of the quantity of generated load from non-point sources	· Planned land use considering water quality conservation★ · Forest conservation (Regulation of deforestation, Forest management)◆ · Forest expansion★ · Prevention of the direct disposal of cattle evacuation into the rivers (Establishment of prohibited grazing zones, Reforestation of the river banks)★ · Prevention of soil erosion in cultivated land (Contour cultivation, Organic soil)★ · Prevention of erosion of residential zones and road (Construction chutes)◆ · Prevention of sediment discharge from quarries (Ditches for sedimentation, Containment wall)◆ · Prevention of river bank erosion◆
Inflowing rivers	Reduction of inflow load in flood time	· Establishment of flood control channel (waters below the Yuquyry)■
	Raise the purification effect in river beds	· Contact oxidation ditch (Rivers within urban zone)■
	Elimination of the accumulated load within river beds	· Elimination of sludge and garbage from river beds (urban zone)●
Within the lake	Reducdtion of load at the mouths of rivers	· Conservation of marshes (Yuquyry and Pirayu downstreams) · Widening of marshes (Pirayu mouth surroundings)★
	Reduction of direct inflow from the coast	· Elimination of garbage from the lake shores● · Conservation of lakeshore vegetation●
	Restrain internal production load	· Elimination of dead algae and dead aquatic plants ●
	Restrain ellution load from bottom materials	· Installation of a sluice at the mouth of Salado River ■

●: to execute as soon as possible ◆: better to execute within two to three years ★: better to execute within five to ten years ■: to judge its applicability after the feasibility study

water have to be separated, and a storage tank for raw sewage must be installed in addition to the infiltration tank.

4. Measures for Non-Point Sources

The basis of the measures for non-point pollution sources is to realize systematic land use, the nuclei of which is to conserve and expand forests which function in earth and sand runoff prevention and water purification, and to prevent the expansion of urban areas without complete basic living facilities. As for the forests, it is necessary, to prevent the reduction of mountain forests, particularly those at water supply sources and riverside forests alongside main rivers, and to urge afforestation on steep slopes. Also, it is desired to establish suitable prevention measures for earth and sand runoff for farmlands, roads, riversides, gravel/clay pits and quarries.

5. Measures in Inflow Rivers

The installation of drains (overflow type) which discharge the flood time load from the Yuquyry River to outside the basin, is the principal measure in inflow rivers, which is expected to have a large effect. However, in addition to the high cost (U.S.$5.4 million as a rough estimate), there is also a possibility of it having effects on the marshes around the Salado River. Therefore, it is necessary to assess the effects on the environment beforehand.

6. Measures within the Lake

As for the measures within the lake, the first priority should be for the conservation of the marshes downstream in the Yuquyry and Pirayu Rivers. For this, it is necessary to regulate developmental activity, such as residential land/road construction in the vicinity, and to reduce the inflow of earth and pollutants to a minimum. The dredge of bottom mud is effective from the view point of removing the cause of elution and stir up, but it is not practical, because the duration of its effect is supposed to be short compared with the cost. In addition, there are problems of contamination generated by work and disposal of removed bottom mud. Rather, if the bottom of the egress to the Salado River (at present the water depth is only 85cm) is dredged and a water gate is installed, so as the removal of bottom mud and adjustment of lake water level can be done freely, then there is a possibility to clarify the lake water. However, if the transparency is increased then, as from February to March 1988, there will be a possibility of generating water bloom and causing water utilization difficulties. Therefore, a detailed investigation is needed on the conditions controlling the inner production and so on.

7. Purification Effect Testing of the Oxidation Pond

An experimental oxidation pond was constructed at a butchery in Aregua, and the effects were tested. The experimental plant was designed so that the water of $6m^3$ per day could be processed and the BOD concentration could be

reduced to 5,000mg/ℓ from 10,000mg/ℓ. For that, about 1m-deep serial three stage lagoon (retention time 18 days) was installed, to which a sedimentation basin as pre-processing facility, and sprinkler piping and pump to retain aerobic conditions were attached. As a result, the removal ratio of both BOD and COD stayed around 30% because the original water concentration was very high and aerobic conditions could not been retained. From these results, it was understood in installing an oxidation pond at a butchery, it is necessary to remove blood and stomach contents in advance, and to treat the remaining waste water. What's more, the construction costs of such oxidation pond is estimated as 50U.S.$/$m^3$ roughly.

8. Purification Effect Testing of Soil Absorption Treatment

Experimental soil absorption treatment was conducted at the Aregua police station , and the effects were tested. The critical requirements were: number of person to be processed, 20; water quantity, 30 ℓ/day/person; permeable ratio, 7.8×10^{-3}cm/s; and, according to EPA specifications, a septic tank (retention time over 2 days) was attached to two 10m long trenches. The CEC of the soil at the location was 9.4 me/100g, and the PAC was 270 mg/100g. However the data reliability is low, as tests of planned frequency could not be realized due to various problems, thus it can be said that the organic substance removal ratio of this system is very high (around 90% both for BOD and COD.). It is desirable to promote the use of soil absorption treatment as a domestic waste water processing facility, because its organic substance removal ratio is high and groundwater contamination possibility is lower than with the infiltration tank, though it has a disadvantage as N and P are hardly removed. Moreover, the construction cost of such soil absorption treatment is estimated at 20 U.S.$/m.

VIII. WATER QUALITY CONSERVATION PLAN

1. Future Usage Demands for the Lake and its Vicinity

Potable water, originating from the lake, is supplied to only 1,095 houses in San Bernardino at present. However, SENASA and CORPOSANA intend to supply the lake water to Ypacarai and other areas where good quality ground water is difficult to obtain. On the other hand, the lake area is used for swimming and water sports in the summer at present, but it is expected that the demand of utilizing it for sightseeing/recreation will surely increase with the improvement in the standard of living. It seems also that there is a potential demand to use the river for recreation.

2. Water Quality Conservation Objectives

From the view point of future usage demands for the lake and surroundings, the water quality conservation objectives in the basin need to be established according to the following: ① use of lake for potable water supply, ② recreational use of lake and river surfaces, ③ maintenance of the aesthetic quality and ecosystem of the aquatic area and its surroundings. However, at this point, pollution mechanisms of the lake, the relationship between the water quality and health problems are not sufficiently understood, thus temporary water quality standards are suggested, as shown in Table 2, considering the water quality data obtained from this study and the water quality standards of Japanese public waters. In regards to these, it is hoped that they are improved within 2-3 years, according to future study results.

Table 2 Tentative Water Quality Standad for Lake Ypacarai

pH	COD	DO	Fecal col.	TN	TP
6.5~8.5	less than 20mg/ℓ	more than 7.5mg/ℓ	less than 1,000 MPN/100mℓ	less than 0.7mg/ℓ	less than 0.1mg/ℓ

3. Effluent Standards

The fundamental policy on preparation of waste water treatment/ purification facilities for point sources is described above, but it is necessary to establish effluent standards as a basis of preparation. The number of point sources which discharge large amount of waste water (factory, office) is yet small, and types also are limited. Therefore, it seems more effective to establish standards for every factory/office or for every type of industry, after the water

quality standards for the Lake and Rivers are established. However, as it is not desirable to leave the present state as it is, the control and guidance against factories and offices under the present law should be tightened, and, at the same time, to oblige them to monitor the waste water quality.

4. Framework of Water Quality Conservation Measures

It is necessary to conduct the water quality conservation measures in the Lake basin based on the following five items, ① basic investigation and research, ② application of water quality improvement techniques including natural environment conservation, ③ establishment of legislation on water quality conservation, ④ educational/instructional activities related to water quality conservation concept, ⑤ reinforcement of water quality administration. Of these five items, ② is already discussed in chapter Ⅶ and ③ through ⑤ will be discussed below.

5. Establishment of Legislation for Water Quality Conservation

Although Paraguay already has the law for environment conservation, these are not fully effective because within them, ① responsible supervisor of water quality (responsible environmental supervisor of public waters, responsible waste water superviser of factory/offices) and extent of his duty is not clear, ② water quality standards (water quality standards for public waters, effluent standards for factory/offices) are not indicated in reasonable figures, ③ systems for prior investigation (environmental effects assessment) and post inspection for pollutant discharge (development of residential area, pit etc., location of factory/offices) are not established, ④ incentives (tax exemption, grant for subsidies etc.) effective for promotion of systematic land use and/or water quality purification facilities installation are lacking. Therefore, legislation which supplements these points should be established.

6. Educational/Instructional Activities Related to Water Quality Conservation Concepts

To conduct water quality conservation measures smoothly, people at every level are required to understand that the environment itself, including water quality, is irreversible public property, that it is a common resource which has limits in use and, that to use this resource forever, the user must share its conservation costs proportional to its use. Therefore, it is necessary to start as soon as possible educational/instructional activities on such water quality conservation concepts by a variety of means, such as: mass media, lecture and/or training seminars and through school education.

7. Establishment of Basin Management Authority

Moreover, an independent administrative organization, with the capacity of planning the comprehensive measure by basin and the competence of promoting the countermeasure operations, is necessary to push the

aforementioned various kinds of water quality conservation measures steadily. However, as it seems difficult to establish in a short time such an organization which would constitute the whole country's water quality conservation administration, from the view point of all aspects, such as, funding, talent and adjustment with other existing organizations, it is desirable to establish at first the "Lake Ypacarai Basin Management Authority" which would plan water quality conservation measures and conduct projects only for the Lake basin, and then gradually expand the staff and the capacity.

8. Socioeconomic Benefits of Water Quality Conservation Measures

The expected socio-economic benefits from the execution of water quality conservation measures (including external effects) are ① cost reduction of water purification/waste water treatment, ② reduction of medical expenses of inhabitant, ③ reduction of veterinary expenses and increase in the market value of livestock, ④ increase of farmer's income by river water irrigation, ⑤ income increase at sightseeing/recreation areas, ⑥ land price increases around the water area, ⑦ stabilize and/or increase agricultural production, ⑧ increase of fuel resources. If it is proved that such benefits exceed the costs needed for execution of the measures, then support from the people may easily be obtained, but this work is left for future.

9. Procedure of Water Quality Conservation Plan

The water quality conservation plan should be proceeded with without loss of time and carefully considering the order of priority. It seems reasonable to settle the time of final goal achievement at 20 years hence, considering the object is a closed type water area. Under such circumstances, assuming that the water quality conservation target will be achieved in the year 2011, the bicentenary of Paraguay independence, the annual plan shown in Fig. 3 is prepared.

10. Funding for Water Quality Conservation Plan

Several ideas can be recalled to provide necessary funding to conduct the water quality conservation plan, but the tax collection is the most reliable, as it is certain for a long period. This tax should be collected in proportion to the drainage amount and/or product output, based on the principle that polluter will pay taxes according to the degree of pollution (Polluter Pays Principle).

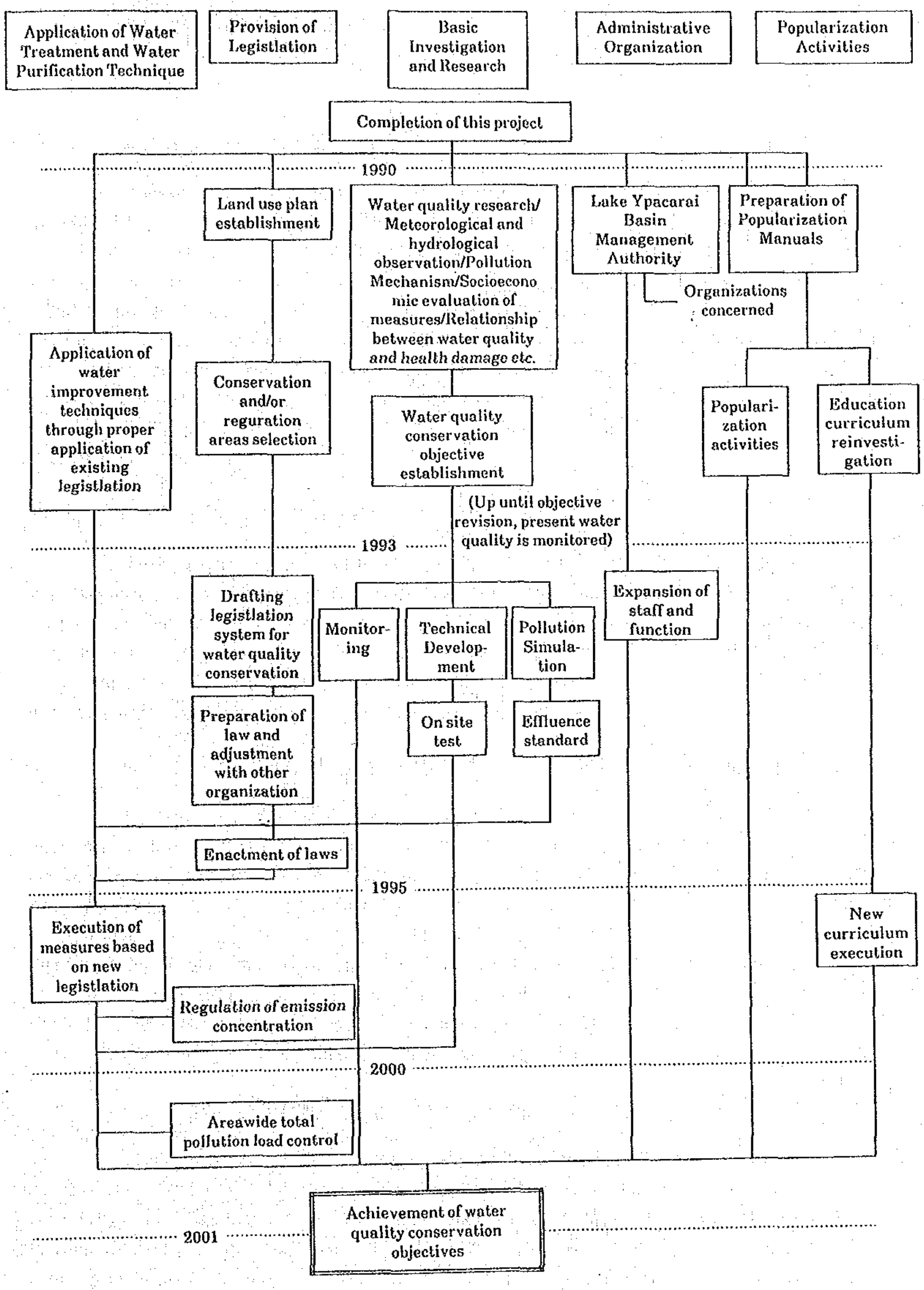

Fig. 3 Yearly Plan for the Water Quality Conservation

IX. RECOMMENDATION

1. Strategy for Water Quality Conservation

Keeping in mind the future usage demands of Lake Ypacarai and its basin, the present pollution status, water improvement techniques applicable to the Lake basin, and the present system and organization concerning the environmental conservation, it is desirable to base the promotion of the water quality conservation plan on the following five items : ① basic investigation and research, ② application of water quality improvement techniques including natural environmental conservation, ③ establishment of legislation on water quality conservation, ④ educational/instructional activities related to water quality conservation concept, ⑤ reinforcement of the water quality administration.

2. Basic Policy of Strategy

Judging from the results of pollution simulation and the effects of water quality conservation measures executed for other lakes, establishment of a long-range plan will be necessary for the Lake Ypacarai Basin. There is some hope for temporary improvement in the lake water quality itself, however, permanent improvement can only come about if measures are carried out for pollution sources within the Lake basin based on the water quality conservation plan.

3. Countermeasures for Pollution Sources related to Industry and Tourism

In light of the fact that a large share of the pollution load discharge originates from industrial sources, measure priority should be given to the completion of the waste water treatment facilities at these factories. It is hoped that lagoons as well as chemical treatment facilities for high pollutant concentration waste water will be installed at the vegetable oil refineries, and that at least lagoons will be installed at middle- and small-scale factories. As for the factories where treatment facilities exist but are not in operation or are not maintained sufficiently, an administrative authority should intervene to ensure the resumption of their functioning as soon as possible.

4. Countermeasures for Domestic Pollution Sources

The completion of a sewerage and sewage treatment plant is the most desirable countermeasure for domestic pollution sources in the urban area, however, it is necessary to introduce temporary measures for those districts where sewerage construction will be retarded. (It has been ascertained by on-site testing that soil absorption treatment shows a low removal rate for nutrient salts, whereas a very high one for organic substances.). In addition to this fact, this method has a lower possibility of contaminating the underground water as compared to that employing infiltration tank. Therefore, the soil absorption

treatment is a suitable temporary countermeasure in the urban ara. In those districts where the soil conditions do not allow for this method, the possibility of using cesspit emptiers to collect raw sewage should be further studied.

5. Countermeasures for Non-point Pollution Sources

The basis of the measures for non-point pollution sources is the execution of planned land use, the nuclei of which is to conserve and expand forests and to prevent the expansion of urban areas lacking in complete basic living facilities. It is hoped that the prevention operations are executed for those areas where sand and soil run-off is remarkable.

6. Countermeasures for Inflowing Rivers

One method of preventing the inflow load from large rivers entering the lake would be to build a diversion dam-type drainage canal between the Yuquyry River and the Salado River so as to divert the excess water in flood time. However, a possible drawback to this is the detrimental effect on the ecosystem of the downstream marsh around the Salado River. Thus, before such a project be carried out, adequate research should be undertaken.

7. Countermeasures for the Lake

As a measure to directly purify the lake water, the installation of a water gate at the egress to the Salado is considered. If the lake water is flushed out following the controlled rise in water level by manual periodical closing of the gate, it would be possible to render the water to its lucid state at the beginning of 1988. However, the suitability of this measure should be determined only following sufficient basic research on the phytoplankton increase conditions.

8. Utilization of the Purification Potential of the Natural Environment

Although development progresses, there is still a flourishing natural environment in the basin, consequently, along with the implementation of the above-mentioned water quality improvement techniques concerning the facility establishment, adequate consideration must be given to the conservation and the purification potential of the natural environment. The conservation of the Yuquyry and Pirayu downstream marshes, and the conservation and expansion of the stream source and riverside forests are important here.

9. Establishment of New Legislation

In order to promote water quality conservation measures, new legislation incorporating the following should be provided: ①water quality monitoring officials and their related duties, ②well-grounded numerical values for water quality standards concerning public waters and various kinds of effluents, ③systems for prior investigation and post inspection for pollutant

dischange, ④various proposals effective to promote the systematic land use and water purification facilities establishment.

10. <u>Early Initiation of Educational and Instructional Activities</u>

In order to smoothly execute water quality conservation measures, it is necessary that the significance of water quality conservation penetrate the public strata at every level. Therefore, with this objective, education and instruction by various means should be initiated as early as possible.

11. <u>Establishment of Lake Ypacarai Basin Management Authority</u>

In order to promote the above-mentioned general plan for water quality conservation, "Lake Ypacarai Basin Management Authority" requires to be established. This organization would concern itself initially, for the first 2-3 years, with planning and coordination, however, the ultimate goal would be, with a continuous increase in staff and function, the realization of an agency with the capacity of planning the comprehensive measure by basin, and having the competence of promoting the countermeasure operations.

12. <u>Responsibilities of the Lake Ypacarai Basin Management Authority</u>

The responsibilities of Lake Ypacarai Basin Management Authority will be promotion of: ①basic survey and research necessary for the drafting of water quality conservation plan, ②educational/instructional activities related to water quality conservation concepts, ③establishment of laws and regulations necessary for the execution of the water quality conservation plan, ④water quality conservation measure operations, ⑤developoment and guidance of water treatment and purification techniques, ⑥guidance and training for water quality control specialists, ⑦water quality monitoring at public waters and pollution sources, ⑧securiting funds and personnel necessary for the realization of these operations.

TERMINOLOGY

This word list includes the principal terminology employed in the abridged report along with a simplified explanation of each term.

Advection

The horizontal flow of the water. Besides advection, the other ways in which matter in the water is transported are via diffusion and settling.

Bacteria

Simple cellular matter which can only be seen if magnified 100 times. "Bacterial pollution" refers to water pollution in the form of bacteria causing water-related infectious diseases. The level is usually estimated by the number of fecal coliform group. Bacteria decomposes the organic matter in the water, and also contributes to the purification of water.

BOD (Boichemical Oxygen Demand)

In the index showing the level of organic pollution, this shows the amount of organic matter which can be decomposed by microorganisms. Generally, when the BOD increases, the dissolved oxygen decreases, which poses an obstacle for the development of aquatic vegetation.

CEC (Cation Exchange Capacity)

This is the index showing the cation adsorption capacity in the soil. In contaminated water, it exists in the form of inorganic nitrogen NH_4^+, NO_2^- and NO_3^-, however, only NH_4^+ is preserved in the soil by cation adsorption capacity. Consequently, if contaminated water is passed through soil with a high capacity for cation adsorption, ammoniac nitrogen can effectively be excluded.

Closed-type Water Area

This is a water body presenting a long retention time, similar to lakes and reservoir. Not only water, but also matter can easily be retained. Therefore, when there is a large inflow of nutrients salts, eutrophication is advanced, along with an increase in biological production in the water body, which contributes, in turn, to an easy increase in organic pollution.

COD (Chemical Oxygen Demand)

One index for the water quality pollution level wich indicates the standard for the existing amount of organic matters in the water. Differing from BOD, this includes organic materials which is difficult-to-decompose by microorganisms. Thus, generally the value is higher than that of BOD.

Difficult-to-decompose Organic Substance

As with compounds and humic acid, organic matter that for microorganisms, is either difficult to decompose or only decompose over a long

period of time. When this type of organic matter is abundant, even if the COD value is high that of BOD becomes low.

Diffusion

When the density of gaseous and liquid substances within a space is not uniform, diffusion is the movement of the gaseous and liquid particles which attempts to create uniformity.

Dissolved Residual Solids

Dense floating solids in the water of a diameter under 1 μm. Joined by SS results in total residual solids (TR). They cannot be eliminated by normal filtration.

DO (Dissolved Oxygen)

The amount of dissolved oxygen in the water, when the organic matters increase in the water, the microorganisms in the water consume this oxygen and perform organic matter decomposition, thus DO grows smaller. As DO changes depending on the water temperature and other factors, in order to understand the level of pollution, it is best to study the degree of saturation.

Euphotic Zone

The layer to which sunlight can penetrate and phytoplankton production takes place. This is also called "the production layer". This is usually thought to be up to a depth of 2 times that of the Secchi Disk reading value.

Eutrophic Lake

A lake in which nitrogen and phosphorous and nutrient salts abundantly exist, and plankton, aquatic plant, benthos and species of fish are produced abundantly. In particular, a lake with an abundance in nutrient salts is called a hypertrophic lake and one with a low salt amount and week production activity is called an oligotrophic lake. In general, over a long period of time, an oligotrophic lake converts to a hypertrophic lake due to a supply of nutrient salts from the basin, this phenomenon is called "eutrophication".

Fecal Coliform Group

A coliform group includes not only intestinal bacteria but microorganisms existing in the soil and in nature, in general. Consequently, in order to indicate the level of contamination by human and animal excrement, the number of fecal coliforms is used.

Toxic Substance

These are matters that, if contained in water, pose grave life-threatening health hazards. Cyanogen, organic phosphorous and arsenic are toxic substances of acute toxicity, whereas cadmium, lead and mercury are toxic substances of accumulative toxicity.

Infiltration Tank

A type of drainage treatment facility which infiltrates polluted water through soil. In the Lake Ypacarai basin, a well 1-2m in diameter and 2-6m in depth is widely used as a facility to purify domestic waste water. In areas where the ground water level is high, polluted water presents the possible hazard of leaking out and contaminating the ground water.

IL (Ignition Loss)

The difference between the weight of solid matter remaining after evaporation of water and bottom mud at 105-110° and that of ashes after being heated to $600 \pm 25°$ for 30 minutes. This is yardstick for the amount of organic material in water and bottom mud.

Lagoon

A shallow pond built for the purpose of water purification. It is also called a stabilization pond. An aerobic lagoon or oxidation pond is where organic matter in water is decomposed by use of aerobic bacteria and an anaerobic lagoon is where the same is done by use of anaerobic bacteria. The latter is geared for the treatment of food processing waste water with a high BOD density such as in meats, starch and fat.

Natural Water Content

The amount of water contained in soil and rocks in their natural state. This is presented by comparing the solid weight to the liquid weight.

Non-point Source

Pollution generation/discharge sources which are represented by wide area zones such as urban zones, cultivated land and pastures.

Nutrient Salt

Inorganic elements necessary for the growth and proliferation of microorganisms. The most important are considered nitrogen compounds and phosphates.

Organic Substance

Carbonaceous compounds that compose living organisms such as proteins, fats and carbohydrates.

Oxidation Pond

A lagoon using aerobic bacteria. With a water depth of about 1m, it accelerates the activity of aerobic microorganisms by oxygen discharged from proliferating algae. A large land space is necessary, however, as maintenance management is easy it is applied for purification of domestic sewage and low-concentration industrial sewage.

PAC (Phosphoric Acid Absorption Coefficient)

The index shows the absorption potential of phosphoric acid in soil. Phosphorous produces salts which do not easily dissolve in water adsorbed by Al, Fe, Ca in the soil. If polluted water is passed through soil with an abundance of these elements (especially active aluminum), phosphorous is effectively removed.

Point Source

Pollution generation/discharge sources which exist as in the point form such as factories, offices and homes. They are also called fixed pollution sources.

Pollution Load

The amount of polluted matters necessitating treatment in drainage water and greatly affecting irrigation. As an index, it estimates water quality per item ; for organic matters, BOD and COD, for turbidity; SS and for nutrient salts, N&P.

Raw Sewage

Human and animal excrement. It differs from other waste water in that it contains many solids, thus the treatment methods differ.

Retention Time

The average time it takes for water or matter to exit the waterbody. The retained water amount is divided by the average annual inflow amount. The divided number for a one-year retention period is called the turnover frequency.

Runoff Time

The time lag between the rainfall peak and the river flow amount peak. In a basin, when forest is widely distributed, the ronoff time generally

is longer and, on the contrary, where there is a widely distributed urban zone, it generally is shorter.

SD (Secchi Disk reading value)

The depth at which it is no longer possible to identify the white plate upon submerging the plate slowly into the water gave. It is an indicator of the degree of transparency of water.

Self-purification

The purification of waters and polluted air by the natural environment which is done by rivers, soils, swamps and forested zones. For example, the rivers purify contaminated emissions as much through the physical-chemical effect of dilution and aeration as through the biological effect by the decomposition of micro-organisms.

Septic Tank

It is an installation that sediments materials floating in the water and conducts the anaerobic decomposition of settled sludge.

Soil Absorption Treatment

This is a water pollution treatment technique which, through self-purification (by the use of soils), is employed to treat used domestic waters. There are two techniques: one is the irrigation of polluted water over the surface of the soil and another, by the irrigation of the same water inside the soil through the use of ditches. In both cases, the irrigation is not done directly but only after pre-treatments like settling, screening and certain anaerobic treatments are performed.

SS (Suspended Solids)

These are floating materials, existing inside large areas of water, whose grain size is 1 μm in diameter including organic and inorganic materials. It is an indicator of turbidity and transparency. The minor materials of 1 μm in diameter are called dissolved materials.

TN (Total Nitrogen)

This is the total of inorganic nitrogens (ammoniac nitrogen, nitrite nitrogen, etc.) and organic nitrogens (protein, urea, amino acid, etc.).

TP (Total Phosphorous)

The sum of inorganic phosphorous (phosphoric acid) and organic phosphorous.

Waste Water

These include polluted waters discharged from the kitchen, the shower and the sink. The difference here is that unlike raw sewage these waters do not contain a large amount of solids. As regards Paraguay, it is estimated that the quantity of waste water used per person in urban zones would be on the order of 130 to 150 liters per day.

Water Bloom

This is a phenomenom in which the color of water becomes green through the massive proliferation of phytoplankton (principally cyanophytes). By looking at this phenomenon, it is understandable why eutrophication is so far advanced.

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