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MINISTERIO DEL AMBIENTE Y DE LOS RECURSOS NATURALES RENOVABLES
THE REPUBLIC OF VENEZUELA

THE STUDY ON THE ENVIRONMENTAL IMPROVEMENT PROGRAM OF THE UPPER AND MIDDLE STREAM OF THE TUY RIVER BASIN

FINAL REPORT

VOLUME 4

SUPPORTING REPORT (I)
(SECTOR A TO E)

AUGUST 1997

CTI ENGINEERING CO., LTD.
KOKUSAI KOGYO CO., LTD.

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COMPOSITION OF FINAL REPORT

Volume 1:	Executive Summary
Volume 2:	Main Report (Master Plan Study)
Volume 3:	Main Report (Feasibility and Pre-Feasibility Study)
Volume 4:	Supporting Report (I) (Sector A to E)
Sector A:	Water Quality Condition and Monitoring
Sector B:	Existing Water Supply System
Sector C:	Industrial and Piggery Wastewater Treatment
Sector D:	Sewage Treatment
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Volume 5:	Supporting Report (II) (Sector F to J)
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Sector I:	Socioeconomic Condition and Project Evaluation
Sector J:	Environmental Aspect
Volume 6:	Data Book
Volume 7:	Resumen (Summary in Spanish)
Volume 8:	Informe Principal: Estudio del Plan Maestro (Main Report for Master Plan Study in Spanish)
Volume 9:	Informe Principal: Estudio de Factibilidad y de Pre-Factibilidad (Main Report for Feasibility and Pre-Feasibility Study in Spanish)

SECTOR A

WATER QUALITY CONDITION AND MONITORING

THE STUDY ON
THE ENVIRONMENTAL IMPROVEMENT PROGRAM OF
THE UPPER AND MIDDLE STREAM OF THE TUY RIVER BASIN

SECTOR A: WATER QUANTITY CONDITION AND MONITORING

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SECTOR A: WATER QUALITY CONDITION AND MONITORING

1. PRESENT CONDITION

1.1 Pollution Source Inventory

1.1.1 Factories

(1) List of Factories

Although there are a large number of factories in the basin of various sizes, those likely to cause water pollution can be limited to a certain number. In this study, the following factories have been selected for the inventory survey:

- Large scale factories with more than ten employees, based on the 1990 OCEI (Central Office of Statistical Information) census and listed by the Tuy Agency
- Factories not included in the census, but considered to be significant pollution sources based on past study results and information through governmental offices.

Table 1.1-1 shows factory categories as well as the number of employees by administrative unit of city and town in the study area. One hundred and three (103) factories fall into the above categories. These factories employ a total of 13,028 employees.

(2) Location of Factories

Generally the factories are concentrated in the major cities of the basin, such as Las Tejerías, Cúa, Charallave, and San Francisco de Yare. In particular, in Las Tejerías and Charallave there are many factories. These factories also have the highest proportion of employees: there are 2,323 employees in 18 factories in Las Tejerías and 3,481 employees in 19 factories in Charallave. The number of factories and employees are compared by sub-basin as follows (also see Fig. 1.1-1).

Location of Factories

Sub Basin	Tributary	Name of City	No. of Factories	No. of Employees
Upper Basin	Tuy River	Colonia Tovar	1	54
	Can. Tiquirito	El Consejo	3	678
	Tuy River	Las Tejerias	18	2,323
	Qda. Guayas	Guayas	4	698
	Qda. Maitana	Paracotos	12	646
	Sub-total		38	4,394
Middle Basin	Tuy River	Cúa	19	1,293
	Qda. Maitana	San Diego de los Altos	1	212
	Qda. Maitana	San Jose de los Altos	1	49
	Qda. Charallave	Charallave	19	3,481
	Qda.Charallave	Pitahaya	4	943
	Tuy River	Ocumare del Tuy	9	758
	Tuy River	San Francisco de Yare	12	1,898
	Sub-total		65	8,634
Total			103	13,08

(3) Pollution Load

(a) Food Related Industries

Food related industries, possibly discharging organic pollution, are dominant in both total number of factories and employees; accounting for 20% of the total number of factories and 29% of employees. Of these alcohol manufacturers, chiefly rum, have the largest employees. One factory in El Consejo employs 573 and another in Ocumare del Tuy 440. In Charallave, a food and snack manufacturer employs 691 workers.

(b) Non-Food Related Industries

The textile, foundry, and car parts industries, which possibly discharge heavy metals, are second to the food related industries in numbers of factories and employees. One manufacturer of ceramic floor tiles in San Francisco de Yare has an exceptionally large number of employees, 1,039.

Other possible polluters include: tanneries which discharge large quantities of organic substances and probably cyanide, chromium and lead; paint factories; plastics and synthetic fiber manufactures; soap and cleaning chemical factories; other chemical manufactures; glass and fiberglass factories. These, however, are small in number compared with other industries mentioned above.

The table next is a list of industries whose factories possibly discharge toxicants, mainly heavy metals, cyanide and arsenic in their wastewater.

Factories Probably Discharge Toxicants

CIIU	Industrial Category	Toxicants	No. of factories (employees)
32311	Tannery and finishing of leather	CN, Pb, Cr^{6+}	1(14)
32321	Industry to prepare tanning leather	CN, Pb, Cr^{6+}	2(65)
35211	Manufacture of paint and varnishes	Cd, CN, Cr^{6+}, Pb, Acid	6(914)
35231	Manufacture of soaps and cleaning products	CN, Pb, Cr^{6+}, Alkali, Oil and grease	7(821)
36201	Production of fiberglass	CN, Pb, Cr^{6+}, As, Alkali	2(87)
37201	Production of non-ferrous metals and alloys	CN, Pb, Zn, Cr^{6+}	6(524)
38191	Manufacture of metallic products, excl. machinery	CN, Pb, Cr^{6+}	4(205)
38193	Metal plating	Cd, CN, Pb, Cr^{6+}, As, Hg, Zn, Phenol, Acid	9(911)
38431	Car parts factory	Cd, CN, Pb, Cr^{6+}, As, Hg	1(296)
38433	Automobile spare parts factory	CN, Pb, Cr^{6+}, As,	5(822)

(4) Treatment Condition

During the study period, it was decided to conduct interviews with 41 factories that were considered to be significant polluters according to past studies. Information gathered included details of their establishments and treatment facilities (see Table 1.1-2).

It was learned that many factories were founded over 25 years ago, in particular, two famous rum factories were founded nearly a half century ago; Ron Santa Teresa started operation 40 years ago, while Industrial Pampero 58 years ago.

Of the 41 factories selected, it was also found that a significant number lack proper wastewater treatment systems (refer to Table 1.1-2). This is of concern because of their large scale. Four of twelve food related factories surveyed have no treatment facilities. Of the other 29 factories, 14 which maybe discharging inorganic pollutants do not carry out any treatment.

1.1.2 Piggeries

(1) List of Piggeries

Many piggeries and poultry farms are scattered about the basin. These are possible pollution sources, however, all the waste from chicken farms is being recycled and used as agricultural fertilizer. Therefore, the piggeries are the main source of animal pollution in the upper and middle basins. A list of piggeries in the study area is shown in Table 1.1-3.

(2) Location of Piggeries

Piggeries are mostly concentrated around a few areas (see Fig. 1.1-2): Qda. Morocopo and Qda. Guayas in the upper basin, and Ocumare del Tuy and

Charallave in the middle basin. The 20 upper basin piggeries have a total of 48,413 pigs and, in size, are generally larger than those in the middle basin, where 13 piggeries contain 23,068 pigs. Of the upper basin the area around Qda. Morocopo has the greatest concentration, having 11 piggeries with the effluent from 33,500 pigs being discharged into the creek (see Table 1.1-4).

Compared to the condition in 1988, the number of piggeries in the upper basin decreased from 28 to 20, while stock numbers increased from 38,000 to 48,413 (Table 1.1-5). In the middle basin the numbers of piggeries and pigs decreased from 18 to 13 and 32,000 to 23,068 respectively. Meaning that over the whole study area the number of piggeries fell, while the number of pigs increased.

(3) Treatment Condition

Most piggeries treat wastewater using oxidation ponds or septic tanks, or both, functioning to various degrees of efficiency. However, one out of eighteen piggeries in the upper basin and three out of thirteen in the middle basin do not have any treatment facilities.

According to the information, however, several piggeries, including the piggeries without treatment facilities, are not pollution sources, because they do not directly discharge wastes into a water course, but discharge it to open fields or use it for irrigation - five piggeries (25 %) in the upper, and eight piggeries in the middle basins (60 %) (refer to Table 1.1-3).

1.1.3 Population and Households

(1) Population in the Study Area

Table 1.1-6 presents the following information: population, population density, number of households, and persons per household in major population centers in the study area, including the population of surrounding rural areas for some centers. This data was obtained from the by 1990 OCEI census.

The population is concentrated in the large centers: Las Tejerías (23,819), Charallave (59,939), Cúa and Las Mercedes (62,836), and Ocumare del Tuy and Colonia Mendoza (76,880). These cities are contain industrial areas and except for Las Tejerías, are located in the middle basin

Moreover, high population densities are also found in the cities located beside the Tuy River in Jose Felix Ribas Municipality: El Consejo (4,542/km²), Sabaneta (2,301/km²), and Santo Domingo and La Concepcion (1,214/km²). The total population of these area is not, however, high.

Persons per household in the larger cities and towns are roughly the same throughout the upper and middle basins, 3.6 to 4.6 with a mean of 4.2 persons per household.

(2) Spatial Distribution of Population

The population and area of each sub-basin was estimated using the populations in the towns, parroquias and rural districts in a tributary basin and their total areas (OCEI-1990). The 1990 population was multiplied by the standard population growth rate, obtained in this study, giving the 1995 population. (Table 1.1-7 and Fig. 1.1-3).

The sub-basins of Charallave (143,185), Ocumare del Tuy (95,399), and Las Tejerías (41,887) have the largest populations. Although the populations of large cities make up most of the sub-basin populations, the total population of each sub-basin should be considered to cause pollution, domestic waste. From this the total pollution load received by the Tuy River is estimated.

(3) Treatment Condition

In general, the following conditions were observed for the treatment of wastewater from households in the basin:

- Individual treatment by septic tanks and flush toilets, but direct discharge of other wastewater
- Sewer systems without treatment plants, of with outfalls flowing into tributaries of the Tuy or directly into the Tuy River
- others (cesspools, latrines, etc.)

The percentage of households connected to sewage systems is 78% in Miranda State and 75% in Aragua State. Sewer systems exist in the major cities of the basin, such as: La Mora, El Consejo, Las Tejerías in the upper basin, and Cúa, Charallave, Ocumare del Tuy, and San Francisco de Yare in the middle basin. (refer to Tables 1.1-8 and 1.1-9).

Moreover, there exists seven sewer systems with treatment plants for small local communities as shown in the table below:

Treatment System for Domestic Wastewater

No.	Location	Type of Treatment	Treatment capacity (m^3/day)	Water body (receiving)	Status
1	La Mora	Oxidation pond	800	C. Tiquirito	Not connected to sewer
2	El Consejo	Oxidation pond	600	C. Tiquirito	Not connected to sewer
3	Las Tejerías	Oxidation pond	800	Tuy River	Not connected to sewer
4	La Estrella (Charallave)	Biological Treatment	2,100	Qda.Charallave	Operating
5	Vallecito (Charallave)	Biological Treatment	500	Qda.Charallave	Operating
6	Ave María (S.F de Yare)	Biological Treatment	1,500	Tuy River	Stopped
7	Terraza de Cúa	Biological Treatment	800	Qda. Cúa	Operating

Among the seven treatment facilities, three are located in the upper basin and four in the middle basin. These systems consists of oxidation ponds to treat wastewater from neighboring residential areas. The collection rate of the wastewater is low due to damaged pipes, furthermore the ponds have been poorly maintained and are not functioning.

The remaining four areas are in the middle basin and are biological treatment plants. Of these only three are operating.

1.2 Water Quality Analysis

In this section, the water quality condition of the Tuy River is discussed in the following order: (1) the water quality standard applied to the Tuy River, (2) the results of water quality analyses conducted in this study and (3) the results of water quality investigations in the previous studies.

1.2.1 Water Quality Standard

According to the "Standard for Classification and Quality Control of Water Bodies and Liquid Residues or Effluents" in Decree No. 883 (December 18, 1995), the general classification of water is summarized in the table below:

Type	Description
Type 1	Water for domestic and industrial use which requires potable quality, whatever part of a product or sub-product for humans or in contact with.
Sub-Type 1A	Water that can be adapted for use with only the addition of disinfectants in terms of sanitation.
Sub-Type 1B	Water that can be adapted by means of conventional treatment such as coagulation, flocculation, filtration and chlorinating.
Sub-Type 1C	Water that can be adapted by non conventional potabilization processes.
Type 2	Water for agricultural and livestock use.
Type 3	Saline water or of marine related, destined to the growing and exploitation of mollusks to be consumed crude.
Type 4	Water for bathing resorts; aquatic sports; sport, commercial or subsistence fishing.
Sub-Type 4A	Water for the total human contact
Sub-Type 4B	Water for the partial human contact
Type 5	Water for industrial use which do not require drinking water.
Type 6	Water for navigation and power generation.
Type 7	Water for transportation, dilution and dispersion of contaminants without causing interference with the adjacent environment.

The water type currently applied to the Tuy River is Sub-type 1B, whose precise qualities are listed in Table 1.2-1, comparing with those of Type 2 and the standard limitations for discharged water. Later in this section, "the standard" particularly means the water quality standard for the Sub-type 1B.

1.2.2 Results of Water Quality Analyses in This Study Period

(1) Condition of Water Quality Analysis

According to the previous study results, the water pollution in the Tuy River is chiefly due to (1) wastewater from factories, piggeries, residences and (2) sediment transport on the river basin. The pollutants are broadly classified into four; namely, organic substances, toxicants, solid particles (cause of high turbidity), and others.

To confirm the pollution condition of the Tuy River, a series of water quality analysis was conducted in the following manner:

(a) Parameters of Analysis

The specific parameters were selected for this study from those commonly applied in examining pollutants (see Table 1.2-1).

(b) Sampling Sites and Sampling Times

Sampling sites were selected from the following view points:

- To examine the pollution balance: Tuy River and tributaries,
- To confirm the serious sources: Wastewater discharged from factories, piggeries and residences .

Each sampling site was selected, corresponding to that of the previous studies in order to compare with past observation results and the key points to examine the pollution balance of the Tuy River. The number of sampling sites is listed in Table 1.2-2 and each site location is shown in Fig. 1.2-1.

The sampling and observation with the river flow measurement at each site were conducted once in the first study period.

(2) Results of Water Quality Analyses

(a) Water Quality of Tuy River

(i) Organic Pollution Condition

Organic pollution is basically identified by the indices of dissolved oxygen (DO), biochemical oxygen demand (BOD) and chemical oxygen demand (COD). The results of those are shown in Fig. 1.2-2 and Table 1.2-3.

In Fig. 1.2-2, organic pollution, BOD concentration of 720mg/ℓ, is apparent in the upper reaches and gradually improves to a BOD of 32mg/ℓ towards the lower reaches. The condition in the upper reaches is presumably owing to the wastewater from the factories on the upper reaches, especially in the Caño Tiquirito Basin and Qda. Guayas While, the improvement in the lower reaches is attributable to the discharge from the Ocumarito Reservoir and the river's purification effect observed in the stretch between the point R5 of the Tuy River called "Boca de Cagua" and the point R6 called "Tazón". The BOD at the water intake point becomes as low as 7 mg/ℓ after the balance between BOD pollution load and the purification effect in the lower reaches.

(ii) Heavy Metal Pollution Condition

Heavy metal pollution can be identified by the metals T-Cr, T-Pb, T-Cu, T-Zn, etc. The results of the analysis are shown in Fig. 1.2-3; The heavy metal pollution is generally not critical except three samples at R4, R5 and R8, which were detected to show higher values than the limitation for T-Cr.

(iii) Turbidity

The results of turbidity analysis are shown in Fig. 1.2-4; turbidity and suspended solids (SS) in the Tuy River are not serious by the standard except at one point, R8, which is attributable to the discharge from sand quarries along the river course.

The self-purification effect between R5 and R6 which is derived from the BOD analysis is not necessarily apparent in the results of turbidity and SS. This will be due to solid particles from the sand quarries in this stretch which overburdens the purification effect.

The sampling was done in the dry season and the seasonal difference in runoff condition suggests the different result may be observed in the rainy season.

(iv) Others

Among other indices, levels of fecal coliforms were analyzed and the results are shown in Fig. 1.2-5. The numbers of total coliforms are far higher than the standard limit and thus, such organic pollution is considered to be serious.

Nitrogen, which has a negative influence on the health of the inhabitants, was also analyzed and the results are shown in Fig. 1.2-5. According to the figure, multi-oxidized nitrogen (NO_3-N and NO_2-N) which is low in the upper reaches increases toward the lower reaches, while T-N (total nitrogen) which is high in the upper decreases towards the lower reaches. This is attributable to the chemical reaction that both organic and ammonium nitrogen in T-N are transformed into nitric acid.

(b) Water Quality of Tributaries

(i) Organic Pollution Condition

The tributaries which appear to have influence on the pollution balance of the Tuy River were selected for investigation sites. A set of results is shown in Fig. 1.2-6 and Table 1.2-4.

Judging from the results, the tributaries in the upper reaches are severely polluted as the BOD values of 840 mg/ℓ in Caño Tiquirito and 1,740 mg/ℓ in Qda. Guayas reveal, while those in the lower reaches whose BOD is in the range of 10 to 20 mg/ℓ is not regarded as severely polluted and some are clean enough to be used as a water supply source.

(ii) Heavy Metal Pollution Condition

All observed values of heavy metal pollution indices are within the allowable range of the standard, and thus, the heavy metal pollution in the tributaries is not serious.

(iii) Turbidity

The turbidity in the tributaries is not excessive by the standard (see Fig. 1.2-7) except in one tributary; Qda. Maitana where two sand quarries exist releasing highly muddy water. The turbidity of Qda. Maitana is 15,000NTU, though the limitation is not specified in the standard. However, the influence of a large amount of substances may be weakened by the purification effect in this stretch of the Tuy River as proven by the fact that the turbidity of the Tuy River after the confluence with Qda. Maitana does not significantly increase.

(iv) Others

Among other indices, total coliform numbers are high in most of the tributaries and all values exceed the limit of the standard (see Fig. 1.2-8.).

(c) Quality of Wastewater from Factories

The factories in the basin are broadly classified into two categories by their products: Food and non-food related factories. The wastewater released from these factories has the following qualities:

(i) Food related Factories

Among the food related factories, the main pollutants to the Tuy River are from an alcohol distillery, meat processing, and soft drink factories.

The figures for the quality of wastewater from these factories are in Fig. 1.2-9 and Table 1.2-5. The following remarks are derived from the results:

- Organic pollutants are dominant in the wastewater. BOD ranges from 5 mg/ℓ to 7,000 mg/ℓ. Six in ten factories released more highly polluted wastewater than the standard limit (60 mg/ℓ) for the effluent directly discharged into the river, and five factories also violated the standard limit (350 mg/ℓ) for those discharging into the sewer system. A similar condition can be observed for COD.
- The turbid condition, in general, is not high, judging from the observed values, although SS values of the samples from eight of ten factories were above the standard limit (80 mg/ℓ) for directly discharged effluent to river while the values of the other samples were higher than the standard limit (400 mg/ℓ) for discharged effluent to the sewer.
- pH values were within the allowable range of the standard. And values above the standard for nitrogen (T-N: 40 mg/ℓ, $NO_2 + NO_3$: 10 mg/ℓ) were detected in the effluent from three factories.

(ii) Non-food related Factories

Among the non-food related factories in the basin, the main pollution sources of the Tuy River are textiles, metal works, sand quarries, tanneries and car factories.

The qualities of wastewater from these factories are shown in Fig. 1.2-10 and Table 1.2-6 are explained as follows:

- Organic pollutants expressed by BOD released from some factories are over the standard limit, which is 350 mg/ℓ for effluent discharged into the sewer system and 60 mg/ℓ for the directly discharged effluent into the river. Among the samples from 17 factories, those from 5 factories, discharged directly into the river, were higher than 60 mg/ℓ, and from two factories discharged into sewer were higher than 350 mg/ℓ. For COD, samples from 9 factories had a higher value than the standard limit of 350 mg/ℓ for direct discharged effluent to the river while two others for the discharged effluent to the sewer system were higher than the limit of 900mg/l.

- Levels of heavy metals in the effluent from factories discharged to the Tuy River are high according to the results; three cases, two for T-Cr and one for T-Hg, were higher than the standard limit (2.0 mg/l for T-Cr and 0.01 mg/l for T-Hg, for both effluents discharged to the river and sewer system).
- In general, the turbidity is not high except the samples nearby the sand quarries. In contrast, SS values from 11 among 17 factories are above the standard limit of 80 mg/ℓ for direct discharged effluent to the river and effluent from two other factories were above the standard of 400 mg/ℓ for the effluent to the sewer system.
- The pH values of the effluents from five factories are out of the allowable range of the standard, while the nitrogen levels in the effluent from seven factories were above the standard.

(d) Quality of Wastewater from Piggeries

As in the case of the factories producing food related products, the quality of wastewater from piggeries is characterized by organic pollutants as summarized below (also see Fig. 1.2-11 and Table 1.2-7):

- Organic pollutants are dominant in the wastewater from the fact that the samples from seven of eight piggeries releasing wastewater into the river were above the standard limit for BOD (60 mg/ℓ) and that in the effluents from five piggeries releasing into the sewer were above 350 mg/ℓ. For COD values, all effluents from piggeries were higher than 350 mg/ℓ.
- Turbidity and SS were also high in the analyzed data. The samples from seven of eight piggeries releasing waste into the river were above the standard limit (80 mg/ℓ), and for and the samples from five piggeries releasing into sewers were above the limit of 400 mg/ℓ.
- The pH values are within the standard limit. Besides them, the condition of T-N pollution is severe because all piggeries are releasing more polluted wastewater, above the standard limit of 40 mg/ℓ.

(e) Quality of Domestic Wastewater

The domestic wastewater was investigated at the points where the raw sewage discharges into the rivers. It was also concluded that the standard for water discharging directly into rivers should be applied to the wastewater. The pollution condition is identified as follows (refer to Fig. 1.2-12 and Table 1.2-8):

- Organic pollution was dominant in the wastewater: The values of BOD at five out of eight points observed were above the standard limit, although those of COD at all points satisfy the standard.
- Turbidity is also high from the observed values of SS; four of nine points were above the standard limit of 80 mg/ℓ.
- Among the other indices, the values of pH were within the allowable range, but the values of T-N were above the limit at three points, while the value for NO_2 + NO_3 is under the limit at each point.

1.2.3 Water Quality Analysis Using the Previous Study Results

Water quality was investigated once at each point during the study period. Therefore, general characteristics and chronological difference cannot be concluded from this result. To identify some long term characteristics, past data were examined with focusing the historical and seasonal changes of pollution conditions.

(1) Historical and Seasonal Change at Toma de Agua

On the Tuy River and its tributaries, water quality investigations were carried out several times in the dry and rainy seasons. The BOD data at Toma de Agua are available for: 1968, 1985, 1990, 1992 and 1996. The data is shown from Figs. 1.2-13 and 1.2-14, which indicate the following pollution conditions.

- Annual change from 1968 to 1995: until 1985, the pollution condition had worsened due to increased pollution from the river basin. Then the improvement between 1985 and 1995 is observed (Fig. 1.2-14). Especially, remarkable improvement can be observed since December, 1995, when the inspection to control the illegal discharge of pollutants was strengthened. Thus, this improvement is presumably owing to the efforts for reduction of pollutant by the agencies concerned.
- There is no remarkable difference in the average BOD value between the dry and rainy seasons partly because of the limited data, although the high BOD value is observed in the rainy season ; A maximum value reaches.50 mg/ℓ in the rainy season, while that in the dry season is 35 mg/ℓ (Fig. 1.2-14).
- The fluctuation of the BOD values is detected relatively large even in a short period of the data. According to those in 1985, the values fluctuated between 15 mg/ℓ on August 14 and 50 mg/ℓ on August 28. This might have been caused by a flood that occurred at that time.
- Besides these comments, relatively stable pollution conditions were also observed in the rainy and dry seasons from the data of 1990 and 1995.

(2) Pollution Condition in Both Seasons in the Study Area

Water quality investigations covered many points on the Tuy River and its tributaries, though these investigations only irregularly undertaken (Tables 1.2-9 and 10).

Despite the limited data, it is noticed from the characteristics of the present pollution condition expressed by BOD and DO identified so far in this study that the conditions have not significantly changed. The general patterns in both seasons are that BOD in the Tuy River increases in the upper reaches and tends to decrease towards the lower reaches due to the high purification effect observed along the Tuy River. While, the general patterns of DO of both seasons show the opposite tendency to that found in BOD; DO at the uppermost part of the River is very high, but it drop until around 0 mg/l in El Consejo or Las Tejerías. Then it increase again towards the lower reaches of the River, though the values fluctuate (Fig. 1.2-15).

Though the data obtained from the tributaries are more limited than those from the Tuy River, BOD distribution patterns of the tributaries in dry season also show that the present pollution condition on the tributaries have not changed; BOD concentrations in the tributaries of upper reaches are higher than 100 mg/l, some of them as high as 4,000 mg/l. It, however, sharply decreases on the middle part of the water course in the upper basin until less than 10 mg/l. This level maintains until downstream of Ocumare del Tuy.

BOD in rainy season shows similar pattern as that in dry season (Fig. 1.2-16).

DO concentrations, as shown in BOD distributions, distribute with the opposite pattern to BOD pattern in both seasons (Fig. 1.2-16).

(3) Heavy Metals in the Tuy River

Heavy metals of Cadmium, Chromium, Lead, Zinc, Iron, Copper, Manganese and Nickel in the water of the Tuy River were measured several times in the last ten years..

Of these metals, Cadmium, Chromium and Lead tend to be accumulated in the human body and are toxicant to human health when the amounts exceed a certain level. The concentration of these metals should be taken into account as a source of potable water.

Table 1.2-11 shows the cases when the concentration of T-Cd, T-Cr, and T-Pb exceed the limit given in the standard, Decree Type 1-B, for the last ten years. The cause of the high concentration of heavy metals is considered to be effluents from factories.

1.3 Pollution Discharge and Flow Mechanism Study

1.3.1 Pollution Flowrate per Unit in Past Studies

(1) Industrial Wastewater

Past pollution flowrates per unit (i.e. pollution flowrate per employee for the case of industrial wastewater) differ according to category of industry (CIIU). Table 1.3-1 lists pollution flowrates per employee for industrial wastewater which were obtained in past studies. In this study the pollution flowrates per employee were determined using three different methods: (1) internationally recognized pollution flowrates per employee and population equivalents, (2) direct analysis of wastewater in Venezuela and (3) information gathered from interviews.

When calculating pollution flowrate per employee the relationship between employee numbers, pollution flowrate per employee and population equivalent is important. The employee numbers are periodically collected as mandatory submissions from factories registered with the ACRT. This data, thus, makes it possible to calculate the pollution flowrate per employee in order to estimate pollution load.

The pollution flowrates per employee listed in Table 1.3-2 (1/2) were estimated using the internationally recognized relationship between employee and population equivalents or, alternatively, using recognized SS pollution flowrates per employee.

In Table 1.3-2 (2/2), however, the pollution flowrates per employee were estimated using interview data and data from past studies. The discharged wastewater volume was collected from interviews. Then using the BOD flowrate per unit volume of wastewater the BOD flowrate per employee was calculated. BOD flowrate per unit volume of wastewater for each industry category was obtained from value used previously in a similar study carried out in another South American country.

(2) Livestock Wastewater (Piggeries)

Although lower than other countries the average pollution flowrate per pig is 162 g/pig/day (population equivalent of 3 people). This value was obtained from a past study carried out in Venezuela, PETA (Projecto de Estudio de Tratamiento de Agua).

Pigs are usually raised to between 140 to 200 kg. Each pig produces on average 10.8 liters of wastewater per day.

(3) Domestic Wastewater

Pollution flowrates per capita for Venezuela were obtained from past reports and are shown below:

Item	Pollution flowrate per unit (g/person/day)
BOD	54
SS	55
TS	120
TN	10
TP	2.6

In the case of Japan, many studies have applied similar value for pollution flowrate per capita for the domestic wastewater. For BOD 50 g/capita/day, 12 g/person/day for TN and 1.4 g/person/day for TP. In Germany the value usually applied is 60 g/person/day for BOD.

From this we assume that the values used in Venezuela are reasonable, and have therefore applied the pollution flowrate per capita to this study.

(4) Agricultural Fertilizers and Pesticides

Data from past studies showed that pollution resulting from the growing of crops was very small in comparison to other pollution sources and therefore has not been considered in this study.

(5) Runoff from Forests

Pollution from forest was not considered.

1.3.2 Water Pollution Load Balance

Water pollution load balance was examined at important points along the Tuy River and its tributaries together with water quality investigations and the river flow measurements.

Water pollution load is in diagrammatic form in Figs. 1.3-1 and 1.3-2. This was obtained by multiplying the concentration of the pollutants in the water by measured river flow. The loads for BOD and SS are observed at the following points:

(1) BOD Pollution Load

- At the uppermost point, R1, the pollution load is as small as 0.1 g/sec where water pollution is only slight.
- After the confluence with Caño Tiquirito, the BOD load of the Tuy River sharply increases to 113 g/s (9.8 ton/day) at point R2.
- The pollution load continues to increase from point R2 to 277.7 g/s (24.0 ton/day) at the point R5, just before the confluence point with the Cagua River, then sharply decreases to 29.0 g/s (2.5 ton/day) at R6. The river's self purification effect may contribute to this improvement of water quality.
- Below R6, the BOD load does not change significantly, fluctuating

between 29 g/s and 40 g/s (3.5 ton/day), finally the BOD load at the intake is 30.9 g/s (2.7 ton/day). This is because the released BOD load and self-purification effect in this stretch are balanced.

- Major BOD loads come from two tributaries: Caño Tiquirito and Qda. Guayas with the values of 90.7 g/s (7.8 ton/day) and 43.5 g/s (3.8 ton/day) flowing into the Tuy River near Las Tejerías. While BOD loads from other tributaries are less than 5 g/s (0.4 ton/day).

(2) SS Pollution Load

SS pollution load balance is slightly different from that of BOD:

- At the uppermost point, R1, the pollution load of 2.2 g/s (0.2 ton/day) is quite small and water is less polluted.
- After receiving SS load from Caño Tiquirito, the SS load of the Tuy River sharply increases to 125.6 g/s (10.9 ton/day) at point R2
- Then SS load increases towards the lower reaches, up to 326.0 g/s (28.2 ton/day) at point R5, a short distance upstream of the confluence point with the Cagua River, though the maximum value was detected at R4, 380.3 g/s (32.9 ton/day).
- There is no increase in SS load at R6 (286.0 g/s - 24.7 ton/day) in spite of receiving high polluted inflow from load Qda. Maitana, SS load of 1,728.3 g/l (149.3 ton/day). This reduction is attributable to the self-purification effect in this stretch of the Tuy River.
- The SS load in the lower reaches does not change in the stretch from R6 to R7 point, SS load of 277.1 g/s (23.9 ton/day).
- After R7 point, the SS load increases to 660.3 g/s (57 ton/day) because of the sand quarrying operations along this stretch.
- Finally, the pollution load at the intake point R10 is 494.1 g/s (42.7 ton/day).
- Major SS loads come from four tributaries, Caño Tiquirito, Qda. Guayas, Qda Maitana and Ocumarito River. Although the SS load of Ocumarito River is high, 70.4 g/s, due to a large amount of river flow, the SS concentration is not high. Moreover, another pollution source is the sand quarries along the stretch between points R7 and R8.

1.3.3 Pollution Analysis by Simulation Model

It is necessary to identify the pollution mechanism for the prediction of the pollution condition by changes of pollution loads from the basin, and to examine the effect of countermeasures in controlling the pollution. For that purpose, pollution analysis was conducted using a simulation model in accordance with the procedure in Fig. 1.3-3.

The pollution analysis is conducted under the following conditions:

- The RIOS model was chosen as the simulation model;

- For verifying this model, observed data was used as the present pollution condition in this study period;
- As the water quality index for simulation of organic pollution, BOD is used; and
- For the estimation of the BOD production pollution load, values of pollution flowrate per unit discussed in the section 1.3.1 were used.

These four points are explained in detail:

(1) Outline of the RIOS Model

The RIOS model which was developed in 1989 by Ing. Ivan Saavedra of SARETUY (UNDP VEN 87/004) is based on the following Streeter-Phelps equations, later modified to consider the effect of the consumption of carbon and nitrogen depending on the amount of dissolved oxygen (DO).

The basic equations are:

$$\frac{dL}{dt} = -K_r \cdot L + \frac{Wl}{A} \quad \cdots\cdots (1)$$

$$\frac{dN}{dt} = -K_{rn} \cdot N + \frac{Wn}{A} \quad \cdots\cdots (2)$$

$$\frac{dD}{dt} = u \cdot \frac{dD}{dx} = -K_a \cdot D + K_d \cdot L + K_n \cdot N + S_b - P \quad \cdots\cdots (3)$$

$$K_r = K_d + K_s \quad \cdots\cdots (4)$$

$$K_{rn} = K_n + K_{sn} \quad \cdots\cdots (5)$$

$D =$ Dissolved oxygen deficit
$L =$ Biochemical demand of carbonaceous oxygen
$N =$ Biochemical demand of nitrogenated oxygen
$S_b =$ Benetic demand of dissolved oxygen
$P =$ Net production of oxygen by photosynthesis less breathing of algae
$K_a =$ Re - aeration rate
$K_d =$ Oxygen removal rate of DBOC
$K_n =$ Oxygen removal rate of DBON
$K_s =$ Sedimentaiton rate of DBOC
$K_{sn} =$ Sedimentation rate of DBON
$K_r =$ Rate of total removal of DBOC
$K_{rn} =$ Rate of total removal of DBON
$W_l =$ Distributed discharge of DBOC
$W_n =$ Distributed discharge of DBON
$A =$ Cross - sectional area of flow

Although MARNR has verified the RIOS model to predict future pollution conditions, this was based on data observed at that time. Since more than five years has passed, it is thought necessary to re-examine the appropriateness of the model with new data.

(2) Calculation Condition to Verify the Model

The verification of the model is conducted on the basis of the following calculation conditions:

(a) Production Pollution Load

Production pollution loads are calculated for factories, piggeries, and domestic wastewater which are major pollution sources of the Tuy River. For the calculation, the study area is divided into ten areas, or sub-basins, as shown in Fig. 1:3-4..

Production pollution load is calculated in the following manner:

- Factories: Pollution flowrate per employee (specific to each industry category) multiplied by total number of employees each activity category
- Piggeries: Pollution flowrate per head of pig multiplied by head of pigs
- Domestic wastewater: Pollution flowrate per capita multiplied by population

With regard to the number of employees, OCEI data for 1990 is used as it is considered sufficiently similar to the condition that existed in 1995. Total head of pigs was surveyed in this study. Human population in 1995 has been estimated on the basis of the 1990 OCEI data, by the method presented in Chapter 3.

The results of production pollution load are shown in Fig 1.3-5 and Table 1.3-3 (also refer to Tables 1.3-4 to 6).

(b) Effluent Pollution Load

Effluent pollution load is calculated considering the reduction by treatment facilities of production load as follows:

(i) Factories related to Food Industry

According to the observed data, the removal rate of BOD by treatment facilities of food related factories is in the range between 40 % and 90 %. Maintenance of the treatment facilities in several factories is not good, while others do not have such facilities.

Considering such conditions, it is assumed that the effluent pollution load is 50% of production pollution load. Regardless of the factory in El Consejo, the value 85% was applied on the basis of the measured values.

(ii) Non-food Industry

In case of non-food related factories, the removal rates are in the range between 0 % and 80 % from the data. The percent of factories which have treatment facilities is about 50 % from the survey. In this study the effluent pollution load is assumed to be 80 % of production pollution load.

(iii) Piggeries

Effluent pollution load assumes the following three conditions depending on the treatment conditions:

- No discharge: those which do not discharge wastewater into open waterways. An effluent pollution coefficient of 0 % is used.
- Adequate treatment: those with properly functioning oxidation ponds. Effluent pollution coefficient of 30 % is used.
- Poor treatment: those with no facilities and discharging their pollutant directly into open waterways, Effluent pollution coefficient of 100 % is used.

(iv) Domestic Wastewater

After domestic wastewater is discharged into the sewer system, in most cases the wastewater flows directly into the Tuy River without treatment. Although the sewer is connected to a treatment system in several areas, the treatment is ineffective due to the negligence of maintenance. Therefore there is only a low removal rate of production pollution. The exception, however, is Colonia Tovar where many houses have a septic tanks.

Judging from these conditions, three effluent pollution coefficients are adopted:

- Where domestic waste is discharged into sewers without treatment. Effluent pollution coefficient of 100% is adopted.
- For residences in the middle basin where the removal rate is 40%. An effluent pollution coefficient of 60 % is adopted.
- For Colonia Tovar an effluent pollution coefficient of 50 % is adopted.

The results of effluent load is seen in Table 1.3-3 .

(c) Runoff Pollution Load

Runoff pollution load is defined as the percentage of effluent pollution load, which is discharged into the river through the process of sediment transport.

The runoff pollution load is calculated by multiplying the runoff coefficient by effluent pollution load. The runoff coefficient is decided in the following manner:

- For major pollutants from the areas of Las Tejerías, Qda. Guayas (Boca de Cagua), Rio Tarma including a part of Cúa and Ocumare, most of which are close to the Tuy River, the runoff coefficient of 0.9 is applied. For El Consejo, a runoff coefficient of 1.0 is applied because of the riparian nature of the town and because of actual measured values.
- For major pollutants from the areas of Colonia Tovar, Rio Guare (Tácata) and Charallave including Charallave city, which are farther from the river than other towns, the runoff coefficient of 0.2 is adopted based on results observed during this study period.

(d) RIOS MODEL Coefficients

The coefficients used in the RIOS model is obtained in the following manner:

- Re-aeration coefficient is calculated using the O'Connor-Dobbins equation.
- Deoxidization and removal rates of carbonates and nitrates are empirically calculated from the observed pollution load balance.

(3) Results

The BOD production load in the upper and middle basins of the Tuy River is 73 ton/day and 25 ton/day, respectively. The share of the production load in the upper basin is as high as 74%. While the total effluent load in the basin is almost the same at 20.9 ton/day in the upper and 20.6 ton/day in the middle basins. This is because the production load from an alcohol distillery in the upper basin contributes a large amount, though treatment at the same factory greatly reduces the production load the effluent load flowing into the river remains high level (Table 1.3-3).

Effluent load, in the middle basin is relatively high because of the high amount of domestic wastewater and the low removal rate by the treatment facilities (Table 1.3-3 and also refer to Fig. 1.3-6).

In the upper basin, the share of wastewater from factories is high. The discharge load from the alcohol distillery at El Consejo is high. An industrial area in Las Tejerías also discharges a large amount of pollution load. The share of the production load from factories is 80% while effluent load is 56%. Production load from piggeries is 12% and effluent load is 15%. The production load of domestic wastewater is only 8%, but accounts for 28% of the effluent load. This due to the low removal rate.

In the middle basin, the share of the domestic wastewater production load is as high as 54%, and the effluent load is 66%. Factories located in the cities of Cúa, Charallave, Ocumare del Tuy, and make up 31% of the production load and 25% of the effluent load. Piggeries make up only 9% of effluent load in the middle basin.

Over the whole upper and middle basins, the production load of factories is as high as 68%. The effluent load is lower, however, at 41% of the total effluent load. Domestic wastewater contributes 47% of the total effluent load. The ratio of wastewater from factories and piggeries in the upper and middle basin is 2:1, the ratio for domestic wastewater is 1:2 in contrast.

The rate of the load that flows into the Tuy River is compared: Many towns are not far from the Tuy River and most effluent load flows into the Tuy River. In contrast, on two tributaries, Qda. Maitana and Qda. Charallave, polluters are relatively far from the Tuy River and the runoff coefficient to the Tuy River is low.

Self-purification of the Tuy is high in some stretches. The stretch from Qda. Guayas to Tácata, receiving the water of Qda. Maitana, especially presents a high rate of self-purification. In this stretch, BOD concentration is reduced to one tenth. It should be noted that the self-purification is dissolved and/or the decomposition of organic substances and they are deposited on the riverbed, which is not an absolute improvement of the pollution. Such self-purification in the middle stream is also high.

Over the whole basin, the total production load is 99 ton/day, the effluent load is 41 ton/day. Due to natural purification effects the total pollution load flowing into the Tuy is 29 ton/day and the pollution load at Toma de Agua is 3 ton/day. This figure (29 ton/day) was calculated by summing the runoff pollution load at the observation points.

1.4 Monitoring System

1.4.1 Necessity of Monitoring

As mentioned in Section 1.2, the water quality of the Tuy River and its tributaries, in particular the upper basin, is seriously deteriorated due to human activities. The water quality problems are the result of the discharge of large amounts of organic pollution, high turbidity caused by suspended solids and existence of toxicants especially heavy metals, which are attributable to industrial effluent.

The future pollution condition was estimated (refer to Section 3) and it is forecast that organic pollution will be 2 to 3 times the present levels within five years in the upper basin, though in the middle basin the increase is not expected to be as high.

A crucial problem resulting from the environmental deterioration of the Tuy basin is the situation concerning the use of water from the Tuy as drinking water source for the Caracas Metropolitan Area (CMA). Any countermeasures taken to improve the environment of the Tuy should pay close attention to this situation.

Mentioned also in Section 1.2, several kinds of heavy metals were detected at higher than the acceptable limits for a potable water source even at the intake site.

During this survey period, 3 out of 10 cases of unacceptably high levels of T-Cr were found in the Tuy River. Moreover, 5 cases of factory effluent containing concentrations of heavy metals higher than the standard limit.

MARNR and ACRT are monitoring factories with the intention of undertaking legal proceedings against those illegally discharging pollutants in excess of the standards (refer to Sector G, Section 1). Presently 4 factories are being forced to close as a result of illegal discharges, 7 factories are being sued in the upper basin, while administrative proceedings have opened against 8 factories in the upper and 42 factories in the middle basin.

Hidrocapital started monitoring the river water near the intake from 1995, though on the advice of Hidrocapital only the data from 1996 should be used as early data is not thought to be reliable. Based on the results of the monitoring, the operating conditions of more than twenty factories were inspected. However, the analytical results of the monitoring take about one month to process, hence, it is impossible to take any immediate measures at the intake.

Therefore in regard to both environmental improvement and potable water source aspects it is necessary to continue and improve monitoring works.

1.4.2 History of Monitoring in the Tuy River Basin

In the Tuy River basin, monitoring studies on water pollution for the upper and middle Tuy started with the "Sanitary Study of the Tuy River", conducted by INOS in 1968. It included water samplings and tests at water intake points.

In 1974, a joint project between the United Kingdom and Venezuela (ESCOTUY-INOS) was carried out to identify the condition of water pollution including monitoring and its result was compiled in the report "Study on the Contamination and Treatment of Industrial Effluent of Tuy River" (1975).

Basically, since 1977, the year MARNR was founded, monitoring works in the Tuy River Basin have been the responsibility of the Directorate of Environmental Research, MARNR. It carried out the "Study of the Contamination of the Lower Tuy River and the Tributaries of the Guaire and Grande Rivers" in 1980, and has also been responsible for bacteriological analysis of all coastal areas since 1984.

As waterways in the Tuy River Basin have began to show signs of severe water pollution, a joint project between MARNR and the UNDP was initiated in 1987, "SARETUY" (Sanitation and Recuperation of the Tuy River Basin). A related water quality monitoring campaign was also started and continued until 1991.

This monitoring campaign was succeeded by a joint program between the Polar

Foundation and MARNR during 1991-1992 at 4 stations: Boca de Cagua, Los Cujies, Ocumare Bridge, and San Antonio de Yare.

In 1992, a joint project, "Sanitation of Tuy River", between MARNR (ACRT) and Germany (GTZ; the German Agency for Technical Cooperation) was started and the first phase of the project was continued until 1995. The second phase is currently in progress and will be continued until 1998. This joint project is supports the following program.

From November, 1995, the monitoring of the Tuy River has been carried out on a once and twice weekly basis, as well as on the industrial effluents in the upper and middle basins. This is part of the planned permanent program Systematic Control for the Quality and Quantity of the Surface Water Network in the Tuy River Basin.

1.4.3 Program of the Monitoring System by Tuy River Basin Agency Supported by GTZ for the First Stage

(1) The basic objective is sanitation of the Tuy River basin and it shall be archived by:

(a) Permanent operation of efficient surveillance of the water quality in the basin

(b) Permanent control of pollution sources discharging to water bodies

(2) Responsible Organization to Promote the Program

The program was signed and entered into by MARNR and GTZ. The central laboratory belonging to MARNR is responsible for all laboratory work and sample analyses.

MARNR is primarily responsible for the project, however, ACRT assist technically and participate in all activities. Almost all the counterparts are from the regional offices of Los Teques and Ocumare del Tuy.

(3) Participating Personnel

(a) Personnel in the Field

- Two technicians-in-training for the collection of samples and field measurements
- One chemical technician or chemist (in the laboratory) for maintenance of equipment

(b) Personnel in the Laboratory

- One chemist for the routine analysis
- One chemist for special analysis (heavy metals) and
- One biologist for bioassay for heavy metals

(4) Sampling Area and Sites

The target area of the investigation is from El Consejo in the upper basin to Santa Teresa in the middle Basin.

Nine sampling sites along the Tuy River were chosen and all recognized as the representative sites, where past data is available.

Sampling Sites on the Tuy River

No.	Name	Sub-basin	Location
1	Las Caballerizas	Upper	Upstream of El Consejo, Hydrometric station
2	Industrial Zone Bridge of Las Tejerías	Upper	Down stream of confluence with Qda. Morocopo
3	Boca de Cagua	Upper	Upstream of confluence with Cagua River
4	Los Cujíes Bridge	Upper	Upstream of Qda. Piedras Azules
5	Tazón Bridge	Middle	Under the bridge
6	Cúa Bridge	Middle	Under the bridge
7	Colonia Mendoza	Middle	In Colonia Mendoza
8	Ocumare Bridge	Middle	Hydrometric station
9	San Antonio de Yare	Middle	Upstream from intake

For investigation and examination of the wastewater from factories, 45 priority factories were selected based on past information. These factories are situated in El Consejo (1), Las Tejerías (16), Paracotos (1), Charallave (12), Cúa (5), Ocumare (7), and San Francisco de Yare (3).

(5) Frequency of Sampling

Sampling should be done regularly to detect variations in water quality as soon as possible.

For the first 3 months of the program it was planned to take at least 4 samples one time a week. The samples are then collected of the samples and the collection should be done once a week, although it must be a permanent program focused on water pollution control.

After 3 months, the sampling was planned to be done twice a week or whenever the laboratory can perform the analysis.

1.4.4 Present Situation of Monitoring System in the Tuy River Basin

Basically, the present monitoring system in the Tuy River basin was established through the above GTZ project started in 1992.

The present monitoring system in the Tuy River basin is outlined below:

(1) Monitoring Sites, Parameters for Water Quality Measurement and Frequency

Although monitoring was carried out at nine points at the beginning of the project, from November 1995 monitoring of the Tuy River is periodically carried out at only three points; Ocumare Bridge and Qda. Charallave, and at factories. The sampling and observations are conducted once a week. The parameters of water quality analyses are shown below.

Place of Test	Water Quality Parameter
Field Measurement	Temperature
	pH
	Dissolved Oxygen (DO)
	Conductivity
Laboratory Analysis	Solid s(seven types)
	COD
	BOD

Further, the monitoring of factory wastewater is conducted in the following manner:

Item	Description
Number of Factories	Two or Three
Time	Weekly
Place	
- Middle Tuy Basin	Ocumare del Tuy, Cúa and San Francisco de Yare
- Upper Tuy Basin	Las Tejerías industrial area, Paracotos
Water Quality Analysis	Solids(seven types), BOD, COD, Heavy metals*, Oil and grease*, MBAS*, TKN*

Note: *limited cases only

The water quality of samples are analyzed in the MARNR's central laboratory.

(2) Organization and Personnel

The middle Tuy operation unit (Ocumare del Tuy) and the upper Tuy operation unit (Los Teques) of the Agencia de la Cuenca del Rio Tuy handles the monitoring works. The number of staff engaged in the works is 5 in total: 1 engineer, 1 coordinator, 1 biologist and 3 technicians.

(3) Budget for Monitoring Works

Although there is no specific amount of annual budget for the monitoring works, the spending on personnel and transportation costs roughly Bs.1,000,000 (US$ 2,128) annually. This amount corresponds to 0.3% of the budget of the agency in 1996 which is Bs.326,720,000.

1.4.5 Present Situation of the Central Laboratory

All the samples are basically analyzed in the central laboratory. The laboratory belongs to Division of Research and Measuring, MARNR, "Environmental Laboratory Dr. Leopold Blumenkranz", founded in 1977, which is located outside of central Caracas, in El Hatillo.

(1) Laboratory Structure and Function

The structure of the laboratory is shown in the below.

Water Quality Section

(a) Function

Physical and chemical analyses of water and soil, support for water quality control program, direction of analytical techniques in other laboratories and taking part in COVENIN-No. 5.

(b) Parameters and Methods

In Table 1.4-1, the parameters of water quality which are capable of being analyzed at present in the central laboratory and the methods are listed.

The main analysis equipment housed in the laboratory are shown in the table below:

Analyzers in the Laboratory

Analyzer (number)
Gas Chromatography (2)
Atomic Absorption spectrometer (2)
Spectrophotometer (2)
UV-Visible Spectrophotometer
Turbidity meter (2)
Ion Analyzer
Sediment POC Analyzer
COD Analyzer
Ionic Chromatography
Chemical Balances, pH Meters, EC Meters, DO Meters

Some pieces of laboratory equipment are being repaired such as the atomic absorption equipment, gas chromatography and several incubators.

Also electrodes for ISE method, several lamps and gases for atomic absorption spectrometry are not available due to lack of additional supply.

Broken pieces of the equipment, planned for disposal, are the TOC analyzer, digester, muffle and chemical balance.

Air Quality Section

Tasks are: analysis of air pollution source, technical advice for other laboratories, taking part in COVENIN No.5, the Committee of Technology for the Environmental Protection

Biological Section

Tasks are: Microbiological examination of water from rivers, lakes, sewage and ground water, fresh and sea water plankton analyses, and bioassay of toxic substances using fish.

Waste Treatment Section

Tasks are: analysis of the waste, support for the waste control program, supervise, inspection of private laboratories, and taking part in COVENIN No.5

(2) Staff

Laboratory staff consists of six chemists, three biologists, one pharmacist, two technicians, five assistants or trainees, a librarian, and a few office workers at the time of this study.

The number of staff influences the way in which the laboratory treats and analyzes samples.

1.4.6 Problems of the Current Monitoring System

(1) No Program for the Emergency Situations

As mentioned in section 1.4.1, it is necessary to have some method of informing the intake operators of sudden changes of water quality and quantity.

There is no program to prevent the supply of unfavorable water containing toxicants, organic and turbid substances above the standard limits for drinking and domestic usage, which may occur suddenly. The water quality of the Tuy River, therefore, should be monitored continuously due to its function as a domestic water source.

(2) Insufficient Number of Sites, Frequency and Parameters to be Analyzed

Investigations should be done at more sites in order to conduct effective monitoring of the pollution condition of the Tuy River. The sites which receive a large amount of pollution load are located over the entire basin.

The measurement and collection of samples for monitoring is currently conducted twice a week, on the Tuy River and on a tributary. This frequency may be sufficient for some water quality parameters, however, in order to collect more information on the pollution condition from factory effluent, more frequent sampling is necessary.

Moreover, number of parameters analyzed is insufficient to cover those stipulated in the standard. In particular, the monitoring of pollutants from factories is insufficient.

(3) Shortage of Qualified Staff

Shortage of qualified staff is due to the insufficient budget. Personnel who are frustrated with inadequate salary tend to leave their jobs for the more lucrative private sector.

(4) Inadequate Data Filing System

A functional data filing system is necessary in order to analyze the present pollution condition and to formulate proper countermeasures for the pollution. This problem is also due to the insufficient budget.

2. PROJECTION OF WATER QUALITY

2.1 General

Based on the present conditions of water quality and pollution discussed in Chapter 1, the baseline has been estimated to forecast future changes of water quality brought about by pollution sources without undertaking countermeasures. As identified in Chapter 1, the main pollution sources are the factories, piggeries, and households, as well as erosion and sediment transport within the Tuy River basin. The magnitude of pollution is closely related to the size of these pollution sources. Their relationships are summarized in Fig. 1.3-3.

As discussed later in Chapter 3, the chief pollutants affecting water quality in the Tuy River are identified as three, namely, organic substances, toxicants, and turbid substances, with which are dealt with in the baseline projection and referred to by the parameters: BOD for organic pollutants and SS for turbidity. For toxicants (heavy metals) a qualitative study has been conducted due to insufficient data for quantitative analysis.

The basis for calculation of BOD and SS is summarized as follows:

Item	Source	Parameter of pollution flowrate per unit	Related economical indicator
BOD	factory	employee number	industrial growth
	piggery	head of pig	considered to be constant *
	residence	population	population growth
SS	factory	employee number	industrial growth
	piggery	head of pig	considered to be constant *
	residence	population	population growth
	sand quarry	employee number	industrial growth
	basin's erosion	land use	population growth

*: Refer to Section 2.2.4

In order to estimate and forecast the condition of BOD and SS in the future, two economic indicators were selected; industrial growth and population growth.

Firstly, three basic patterns are considered for projection. In each pattern, in this study, it is practical to assume that the trends of the indicators is independent. Future trends are estimated according to three socioeconomic scenarios, which are underlain by the national target, past performance, and the relationship between the two. These have been combined into the patterns below:

(1) Pattern-1 Standard: Combination of median estimation.

(2) Pattern-2 High: Combination of highest estimation.

(3) Pattern-3 Low: Combination of lowest estimation.

2.2 Projection of Socioeconomic Conditions

2.2.1 Basic Pattern for Projection

The three patterns are discussed in more detail regarding future changes in industrial and population growth.

Pattern 1(Standard)

Pattern 1 is the combination of the median estimation. The following scenarios of industrial and population growth were considered for this pattern.

(1) Industrial Growth

Industrial growth closely corresponds with the growth of the economy (GDP). It is assumed that the economy of Caracas grows at the same pace as the national economy and that the economy of Caracas has direct effects on industries in the project area. In other words, the growth of industry in the project area is assumed to strongly correlate with that of the national economy.

In the Ninth National Plan of Venezuela published by CORDIPLAN in January, 1995 ("the Plan"), the following GDP growth rates up to the year 2010 are given:

GDP Growth	1990-1997	1997-1998	1999-2004	2005-2010
Annual	0.9%	6%	5.2%	6.2%
Periodic	6.5%	6%	35.5%	43.5%
Total (1990=1)	1.06.5	1.126	1.526	2.190
Avr. (1990-2010)	4.0%/year			

Taking the economic performance 1990 to 1997 into consideration, the average economic growth is projected to be 4.0 % per annum during the period between 1900 and 2010.

In projecting industrial growth in the project area, a regression relation between GDP (x) and industrial GDP (y) is established. Then, the future GDP projected by CORDIPLAN is substituted for x. As a result, future industrial GDP in the project area can be calculated.

(2) Population Growth

The existing study on population growth in the Tuy River basin, the "Scenarios of Land Occupation in the Tuy River Basin" ("Scenarios") prepared by the Ministry of Environment and Natural Renewable Resources in January, 1990 was used to make population projections.

The Pattern-1 (standard) projection is the trend analysis, where the OCEI Population Census data for 1961, 1971, 1981 and 1990, for the parroquias concerned were used for a time series regression analysis. The resultant regression equation has the form of either natural or exponential simple formula. The dependability of each equation is expressed and confirmed by the correlation coefficient and T value. As regards to the population of an individual town within a parroquia, it was projected based on the ratio of the population of the town to that of the parroquia.

Pattern 2 (High)

Pattern 2 is the combination of the highest estimation. The following scenarios of industrial and population growth have been considered for this pattern.

(1) Industrial Growth

In the Pattern 1 projection, the relationship between the economy and the economic activity of industry follow what they used to be. In the Pattern 2 (high) projection, their relationships follow what the Plan envisages.

Under the Plan the industrial sector of the country is forecast to grow at the average annual rate of 8.0% and 9.5% during the periods 1999 to 2004 and 2005 to 2010, respectively. Here new relationships between the economy and industry are aimed for. It is clear that the government wants to put this sector at the helm of economic progress. In this projection the growth of industry as a whole in the study area will follow the above rates with the relative position of each industry remaining as it is in the preceding projection.

Hence, in this projection the growth of the future industrial GDP projected by CORDIPLAN is adopted for the projection of industrial growth in the study area.

(2) Population Growth

The Pattern 2 (high) projection follows the Middle Tuy Scenario in "Scenarios", as proposed by ORCOPLAN (*Plan Regional de Ordenacion del Territorio para la Region Capital*). The scenario considers the fact that the migration around the Caracas Metropolitan Area (CMA) is increasing, moving from the center to the outer suburbs as well as the study area due to growing constraints: space, infrastructure, economic opportunities and environment in the CMA. This trend results in the increase of the population concentration in the Middle Tuy River basin.

Pattern 3 (Low)

Pattern 3 is the combination of the lowest estimation. The following scenarios of industrial and population growth have been considered for this pattern.

(1) Industrial Growth

In the Pattern 3 (low) projection, the time series regression equation of the economy was obtained using GDP from 1986 to 1994 to estimate the future economic growth. The average annual growth rate was around 3% during this period.

The regression relation between GDP (x) and industrial GDP (y) is established. Then, the future GDP projected by the time-series regression equation is substituted for x. As a result, future industrial GDP is obtained.

(2) Population Growth

The Pattern 3 (low) projection follows the Intermediate Cities' Scenario in "Scenarios". It is an interpretation of PNOT (*Plan Nacional de Ordenacion de Territorio*). The scenario aims at the strengthening of remote, first and the second order regional cities to alleviate the population concentration of the central northern coastal region, whereby advancing political and economic decentralization and effectuating environmental protection.

2.2.2 Industry

BOD from factories is calculated applying the flowrate per employee. The number of employees in the target years should be accordingly calculated. The trend of employee numbers is considered to have a close correlation with the gross product of industry, and, likewise, the gross industrial product with the economy, namely GDP. The relationship between the gross industrial product and GDP has been accordingly examined for each category of factory listed below.

There are 15 categories of industry in the Study Area:

No.	Industry	No.	Industry
1	Food	9	Glass and glass products
2	Beverage	10	Non-metallic minerals
3	Textiles	11	Basic industry of iron and steel
4	Leather and skin	12	Non-iron minerals
5	Plastic products	13	Metallic products
6	Chemical products	14	Machinery
7	Other chemical products	15	Transport materials
8	Objects of clay, crockery & porcelain		

Each industry consists of several kinds of manufacturing classified by CIIU numbers. Regression equations for the above industries are listed in Table 2.2-1, being generalized in the following form:

$y = ax + b$

where, y: the gross product of an industry,
x: GDP, and
a, b: constants.

In this study, the variable "x" represents the country's GDP (gross domestic product) at 1984 prices and the variable "y" signifies gross industrial product at 1984 prices.

Substituting the GDP data for 2000, 2005 and 2010 in the Plan for "x", and comparing the resultant gross industrial product of each industry in respective years with the product in 1990, a set of results is obtained (Table 2.2-2 (1/3)).

Then, using the difference between the industrial growth in the Plan and the average industrial growth in Pattern 1, and considering the relative position of each industry in Table 2.2-2(1/3) Pattern 2 is projected. The results are shown in Table 2.2-2(2/3).

In Pattern 3, the future GDP is determined by the time series regression equation using the GDP data from 1986 to 1994:

$$\log y = 12.9732 + 0.02949t - 0.08139$$

where y = GDP at 1984 prices, t = year (1985 as 1).

(Correlation coefficient = 0.8839, T value = 5.0007)

Substituting future GDP estimated by the above equation for "x" in Table 2.2-1, the projection is made. The results are shown in Table 2.2-2 (3/3).

The table below summarizes the scenarios and industrial growth rates of the three patterns.

Projection Pattern	Condition	GDP Growth 1990 to 2010	Industrial Growth 1990 to 2010
Pattern 1 (Standard)	Following target economic growth in the Ninth National Plan	4.0%/year	4.3%/year
Pattern 2 (High)	Following target industrial growth in the Ninth National Plan	not applied *	5.8%/year
Pattern 3 (Low)	Following economic performances during the period 1986 to 1994.	3.0%/year	2.5%/year

*: Industrial growth rate has been determined based on the target of growth in industrial sector in Ninth National Plan of Venezuela

2.2.3 Piggeries

The following government policy is in force at present: the establishment of new piggeries is not allowed, those existing ones which do not follow the wastewater quality standard shall be closed, and only those that follow the standard can continue their business. For this reason, it is assumed that the piggery industry will not grow, but maintain status quo in future. This assumption was applied to all three projections.

2.2.4 Population

The population in the study area was 309,463 in 1990 based on the OCEI Population Census. It grew at the average annual rate of 5.1% in the nine years, growing from 197,458 in 1981.

In the Pattern 1 (standard) projection, the growth trend of the population of the study area from 1961 to 1990 is analyzed by parroquia using the regression method.

Firstly, the population of parroquias inside the study area was expressed in the form of time series regression equations based on the data from 1961 to 1990 (Table 2.2-3). Using the equations in the Table 2.2-3, the future population of each parroquia is estimated (Table 2.2-4).

The projection is finally calculated for each town. The population of a town was projected based on the ratio of the population of the town to that of the parroquia it belongs. It should be noted that, the fact that the study area's boundary divides some of the parroquias and towns was considered as well.

The name of the towns concerned and their code numbers are given in Table 2.2-5.

The projected percentages of the population of each town to that of the parroquia it belongs to are shown in Table 2.2-6.

From these tables the future populations of the towns concerned were estimated for the three patterns by parroquia (Table 2.2-7). Then the growth rates of the population in 2000, 2005 and 2010 as compared to the population in 1990 were calculated (Table 2.2-8).

The population growth rate in 2010 relative to that in 1990 is 1.94 times for Aragua and 3.06 times for Miranda, according to the Middle Tuy Scenario in "Scenarios". In Pattern 1, the rate is 1.52 for Aragua and 2.80 for Miranda. In other words, the projected population for Aragua and Miranda in this scenario is 27.4% and 9.3% larger than that in Pattern 1. The Pattern 2 projection is worked out based on this information (Table 2.2-8 (2/3)).

The population growth rate in 2010 relative to that in 1990 is 1.19 times for Aragua and 1.99 times for Miranda, according to the Intermediate Cities Scenario. In Pattern 1, the rate is 1.52 for Aragua and 2.80 for Miranda. In other words, the projected population for Aragua and Miranda in this scenario is 21.8% and 29.0% smaller than that in Pattern 1. The Pattern 3 projection is worked out based on this information (Table 2.2-8 (3/3)).

The table below summarizes the scenarios and population growth rates of the three patterns.

Projection Pattern	Condition	Population Growth from 1990 to 2010
Pattern 1 (Standard)	Trend analysis based on 1961 to 1990 population	4.7%/year
Pattern 2 (High)	Projects an acceleration of population concentration in Middle Tuy	5.3%/year
Pattern 3 (Low)	Interspersing of Caracas' population to outlying intermediate cities	3.0%/year

2.2.5 Land Use

One of the main pollutants in the Tuy River is turbidity, and in this study SS has been selected as a parameter to express the degree of turbidity. Approximately 85% of the SS is from basin erosion, accordingly the volume of sediment production is closely related to land use conditions of the area. Thus, future land use in the study area has been studied for the baseline projection.

Current Situation

The following table is the land use situation for upper and lower basins in the study area in 1990.

Basin	Unit	Land use pattern						Total	Rate
		Forest	Bush	Savanna	Grass	Agri-culture	Urban		
Upper	km^2	201	404	110	136	110	35	996	53.7
	%	20.2	40.6	10.0	13.7	11.0	3.5	100	-
	%	71.8			28.2			100	-
Middle	km^2	85	338	43	51	294	49	860	46.3
	%	9.9	39.3	5.0	5.9	34.2	5.7	100	-
	%	54.2			45.8			100	-
Total	km^2	286	742	187	153	404	84	1,856	100
	%	15.4	40.0	10.1	8.2	21.8	4.5	100	-
	%	65.5			34.5			100	-

The Upper Tuy makes up 53.7% of the total area and the Middle Tuy the rest (46.3%).

The combined area of natural lands (forest, bush and savanna) makes up 75.2% of the Upper Tuy and 54.2% of the Middle Tuy, while the total area of cultivated or land used for human requirements (pasture, agriculture and urban areas) makes up 24.8% and 45.8% in the Upper Tuy basin and the Middle Tuy respectively.

Observation of Changing Land Use

Lack of past data makes it difficult to do a more detailed analysis of changing land use in the study area.

Phenomena like forest fires, natural deterioration of trees, and deforestation has led to the current degradation of vegetation in the study area. From the viewpoint of erosion control, the forests are indispensable for sustaining watersheds and careful consideration should be required before allowing the commercial exploitation. It is obvious that the establishment of national parks is the preferable option to save the water resources.

Based on sporadic data, in fact, the total agricultural area is estimated to be decreasing each year in Middle Tuy at around 3%. The area is either being urbanized (including industrial areas) or it is being used for dam sites or roads.

The production of cereals, beans, sugar, coffee and horticultural products are gradually declining while that of tuber vegetables and fruits is rising.

The livestock sector is not clearly defined but the numbers are tending to increase as a whole. The number of cows, pigs, and poultry are increasing. However, horses, mule, and donkey numbers are decreasing.

In contrast, in the Upper Tuy all agricultural sectors are increasing with the exception of pasture lands.

Future Trends in Land Use Conversion

Along with the population, which is forecast to double in the Upper Tuy and triple in the Middle Tuy by 2010, the expansion of urban areas is expected. Assuming the urban area increases at a rate two thirds of the population growth, it will be 58 km^2 and 114 km^2 in the Upper Tuy and the Middle Tuy, respectively, or 172 km^2 in total. In other words the urban area will make up 5.8% of the Upper Tuy, 13.3% of the Middle Tuy, and 9.3% of the whole study area.

Industrial production is forecast to grow by two to three times by 2010 in the Study Area. The industrial area now occupies 1.6 km^2 and 2.8 km^2 of the Upper Tuy and Middle Tuy, respectively, which is incorporated in the urban area and will expand to 3.2 km^2 and 5.6 km^2 in the two basins.

In conclusion, the agricultural area of the Middle Tuy is gradually decreasing while urban areas are increasing along with the growth of population and industry. As a result, erosion is expected to increase sediment production on watersheds. In the Upper Tuy, the pasture, agricultural and urban areas are forecast to expand thus reducing other areas, also leading to an undesirable increase on sediment production. The condition of the land use change is summarized as follows:

Basin	Population growth rate	Land use conversion	
Upper Tuy	Based on basic projection patterns (Patterns 1 to 3)	Increase in agricultural land	2/3 of population growth rate
		Decrease in bush land	2/3 of population growth rate
Middle Tuy	Based on basic projection patterns (Patterns 1 to 3)	Increase in urban land	100% of population growth rate
		Decrease in agriculture land	100% of population growth rate

2.2.6 Projection Results

The results of the socioeconomic growth projections are summarized in the table below.

Projection Pattern	Industry			Population		
Year	1990	2000	2010	1990	2000	2010
Pattern 1 (Standard)	1.000	1.275	2.309	1.000	1.568	2.524
Pattern 2 (High)	1.000	1.311	3.075	1.000	1.634	2.819
Pattern 3 (Low)	1.000	1.193	1.634	1.000	1.381	1.815

Note: The growth of industry is finally indicated as the growth of the employment in factories (the subsection 2.2.2).

This table is observed as follows:

As for the growth of industry, the number of employees increases 2.3 times by the target year 2010 compared with 1990 at the average annual rate of 4.2% in Pattern 1. Similarly, in Patterns 2 and 3, the number rises 3.1 and 1.6 times at the annual rates of 5.8% and 2.5% respectively. The number of employees in Pattern 1 is 35% larger than in Pattern 2 and 30% smaller than in Pattern 3 in 2010.

As for the population, it grows 2.5 times from 1990 to 2010 at the average annual rate of 4.7% in Pattern 2; in patterns 2 and 3 it grows 2.8 and 1.8 times at the annual rates of 5.3% and 3.0% respectively. The population of Pattern 1 is 12% larger than in Pattern 2 and 28% smaller than in Pattern 3.

These industrial and population estimations are applied to water quality projection.

2.3 Baseline Pollution Projection

Baseline pollution projection has been conducted by indices, i.e., organic pollution (BOD) and turbidity (SS) as follows:

2.3.1 Organic Pollution

Calculation Method of Production and Effluent Load

BOD is selected as the indicator of organic pollution. Application of the pollution flowrate per unit has been common for the calculation of BOD production load. The specific pollution flowrates per unit in the previous studies in Venezuela as discussed in Section 1.3 are deemed appropriate thus are used for the present study.

(1) Production Pollution Flowrate per Unit

Industrial Wastewater

The BOD production flowrate per employee determined by the category of industry (CIIU code) is applied. The applied value is as presented in Section 1.3.

Wastewater from Piggeries

The BOD production flowrate per pig of 162 g/pig/day is applied.

Domestic Wastewater

The BOD production flowrate per capita of 54 g/person/day is applied.

(2) Effluent Load

The effluent pollution load is calculated through that the production pollution load at each pollution source minus the load removed by treatment plant e.g. the production pollution load is multiplied by effluent coefficient that is (1-removal rate). The removal rate obtained by the water quality test before and after the treatment plant is applied.

The coefficient for the total effluent load in each sub-basin is the weighed average value of those of wastewater from industries, piggeries and residences.

(3) Pollution Discharge into the River

The Streeter and Phelps's modified formula is applied. This formula is used in the RIOS model (see section 1.2). Pollution reduction factor of "K" is considered for reduction in BOD.

Baseline Pollution Projection

Projected BOD effluent load by sub-basin and projected BOD concentrations at major points in the year 2000, 2005 and 2010 are presented in Table 2.3-1 (also see

Fig 2.3-1 and Tables 2.3-2 to 5).

2.3.2 Toxicants

Pollutants of toxicants in the Tuy River are mainly heavy metals. However, only qualitative results were obtained in this study, then pollution projection is not conducted.

2.3.3 Turbidity

Calculation Method

Suspended solids (SS) have been regarded as the index for turbidity. Production of SS is broadly divided into three causes of sediment production: erosion of land, riparian sand quarries, and organic substances from factories, farms and households within the river basin.

The production of SS by the basin's erosion is calculated by the USLE method as discussed in Sector E: 1. In this method, land coverage is one of the factors that affects the volume of sediment production. For the baseline projection, the land coverage factor is selected as a parameter to express future conditions.

The projection of the future SS from sand quarries and of organic substances is conducted based on the industrial and population projections.

Baseline Pollution Projection

Projected SS concentrations at major points along the Tuy River in the year 2010 are as presented in Fig. 2.3-1.

3. Identification of key issues

Summary of key issues and problems for water quality is presented in Table 3.1-1 on the basis of the discussions presented in the following sub-sections.

3.1 Identification of Key Issues and Problems

Parameters for Water Quality Study

On the basis of the present conditions as discussed in Chapter I, it has been concluded that the issues of water quality in the study area can be represented by the following three factors:

- Organic Pollution
- Toxicants
- Turbidity

Key issues and problems for water quality have been identified by the three factors as follows:

Organic Pollution

Organic pollution is an important factor influencing water quality in the Tuy River. The function of the river is originally to provide a place of livelihood for aquatic life. On the basis of the baseline projection of water quality as discussed in Chapter 2 the BOD concentration, indicator of organic pollution, of the Tuy River in the year 2010 is projected as follows: (refer to Fig. 2.3-1, standard)

Projected Baseline BOD in Year 2010

Point	BOD (mg/ℓ)
Boca de Cagua (downstream of Las Tejerías)	2,440
Toma de Agua (water intake site)	14

The level of BOD is 2,440 mg/ℓ, 2010, at Boca de Cagua on the Tuy River. If such a high value occurs the Tuy will cease supporting the existence of aquatic life. This is an abnormal condition for a river.

The pollution of the Tuy River as a water supply source is also a serious problem. The BOD concentration at the intake in the year 2010 is projected at 14 mg/ℓ as shown in the above table. Unacceptable high organic pollution results:

- Suspension of water intake;
- Increased use of chlorine having potential creation of organic chloride and resultant adverse effects on human health; and,
- Increased operation costs for treatment.

Suspension of water intake at Toma de Agua occurred 36 times a year on average for the three years from 1993-95. Of these,18 stoppages were the result of organic pollution, namely, odor, color, and high chlorine demand.

Toxicants

Toxicants as a pollution source in the study area are mainly heavy metals. Through water quality analysis was conducted during the study period, heavy metals concentrations exceeding the Type 1B standard were detected at three out of ten sampling points along the Tuy River. Based on this, the occurrence probability of toxicant pollution is estimated at 30%. Their control in environmental improvement is important because toxicants have the potential of causing serious damage to human health for generations to come. In addition to the damage toxicants may have on the upper and middle stream of the Tuy River, there exists the possibility of wide ranging effects such as the effect on fisheries near the mouth of the Tuy where coastal fishing is presently conducted.

The control of toxicants is a very important matter when it is considered that the Tuy River supplies water for domestic use in Caracas. At the water intake site, toxicants are not checked daily at present, and hence are not included in the causes of the suspension of intake. Toxicants are, however, possibly reach the water intake site and if no measures are taken a very serious situation could arise.

Turbidity

Turbidity is also an important factor of water pollution in the Tuy River. Turbidity in the Tuy River creates aesthetically unfavorable environmental conditions. The high turbidity in the Tuy occurs mainly during the rainy seasons when the total load of suspended solids becomes high. The concentration of suspended solids in the year 2010 at Toma de Agua is projected from the baseline projection as follows (refer to Fig. 2.3-1);

Projected SS in Year 2010

Point	SS (mg/ℓ)
Toma de Agua (water intake site)	1,080

Note: SS is approximately three times Turbidity in NTU, according to test results of the study. SS is of the value for the discharge of 95-day discharge

High turbidity causes trouble at the intake. High turbidity caused suspension of water intake occurred, on average, 11 times (31%) of a total suspension. The number of times that high turbidity caused operation suspension of the intake is the highest of the causes. It also causes higher annual operation costs of the pre-treatment facility.

3.2 Pollution Source and Spatial Distribution

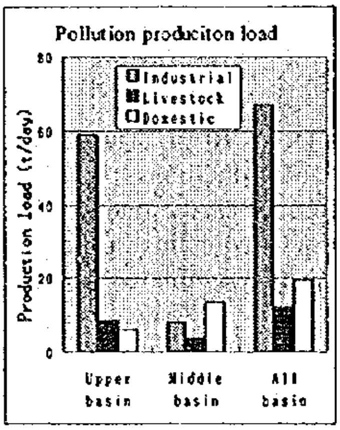
Pollution sources and their spatial distribution have been identified as follows:

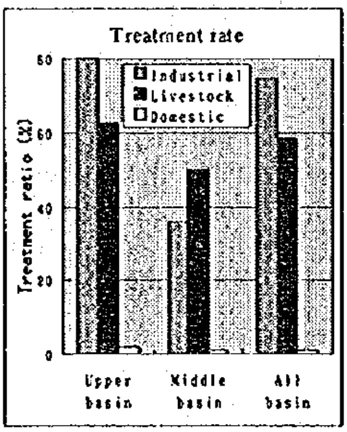
(1) Organic Pollution

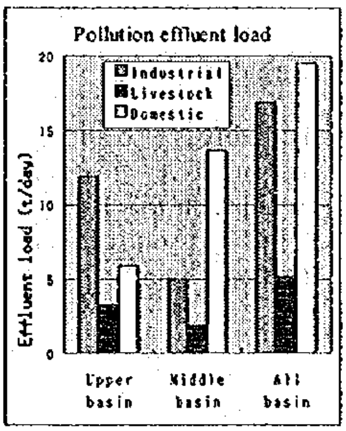
Pollution Source

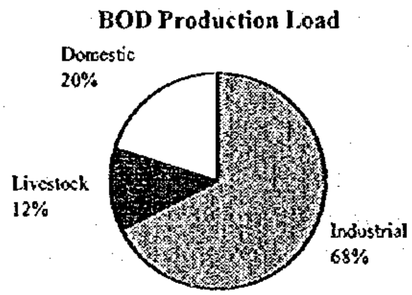
The source of organic pollution in the study area is broadly divided into three; namely, industrial wastewater, piggery wastewater and domestic wastewater. The share of BOD production and effluent loads from each pollution source in the study area is summarized as follows (see Tables 1.3-3):

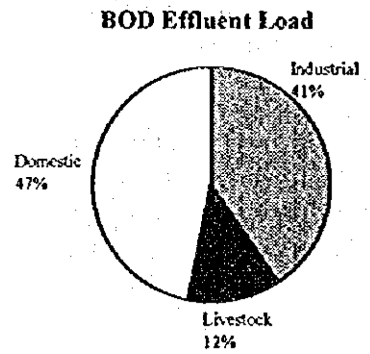
Production pollution load, removal rate by treatment facilities, and effluent load are plotted for pollution from the upper, middle, and overall basin. It is apparent from the charts below that the removal rate of domestic wastewater pollution is very low and thus there are high effluent loads in spite of its moderate pollution production load. Resultantly, effluent pollution loads due to industrial and domestic wastewater are at similarly high levels. The domestic wastewater would warrant closer attention in addition to the industrial pollution.











For the entire study area, 68% of the total BOD production load originates from industry. That of domestic and piggeries origin are comparatively less at 20% and 12%, respectively.

When the BOD effluent loads are compared, the share of domestic wastewater becomes higher to 47% and that of industrial wastewater decreases to 41%. This is because the present pollution removal rate of industrial wastewater is relatively high at 75% compared to the low pollution removal rate of domestic wastewater of 1%.

Organic pollution of factory origin is mainly from food producers, and some other from non-food industries, e.g., chemical and textile producers. According to an interview survey, 67% of the food-factories have treatment plants. Of these, the percentage of factories using biological treatment plants (this seems effective from the results of water quality analysis) is 63%. Others have physical-chemical treatment plants.

Both BOD production and effluent load of wastewater from piggeries share 12% of a total load. Piggeries are discharging wastewater in a variety of ways. Some piggeries have adequate treatment facilities and do not discharge any wastewater. While some others, however, especially those located near rivers discharge highly contaminated wastewater, sometimes of over 10,000 mg of BOD/ℓ into the river. The effect of the piggeries on the water quality of the Tuy River is thus high though the share is comparatively low.

The BOD effluent load of domestic wastewater in the study area is high at 47%. Sewer networks exist in the major urban areas, however, no treatment is conducted and the sewage discharges directly into the rivers.

Spatial Distribution

Spatial distribution of the organic pollution sources in the study area is illustrated in Fig. 3.1-1 by the parameter of BOD effluent load by sub-basin and by pollutant (see Table 3.1-2). The total BOD effluent load of each sub-basin is as follows:

Sub-basin	Total BOD effluent load (kg/day)
El Consejo	9,275
Las Tejerías	7,496
Qda. Guayas	1,800
Paracotos	2,027
Guare River	96
Tazón	1,158
Tarma River	947
Charallave	11,518
Ocumare del Tuy	6,970

The following can be deduced from Fig. 3.1-1:

- The BOD effluent load from factories and piggeries is relatively high in the upper basin, El Consejo and Las Tejerías;
- Domestic wastewater is a major source of pollution in the Qda. Maitana basin and the middle basin; and,
- The total BOD effluent load is high in the El Consejo, Las Tejerías, Charallave and Ocumare del Tuy areas.

(2) Toxicants

Pollution Source

Toxicants in the Study Area are heavy metals from factories, especially those from non-food factories. In the study area, textiles and chemical producers, mechanical parts manufacturers, tanneries, etc. are potential polluters.

Water quality investigations carried out during this study period revealed the following results: in the study area, pollutants in the wastewater from industries that exceeded the effluent standard limit are lead, chromium, copper, and zinc. These metals are found in the effluent from the following factories:

Heavy metal	Kind of factory
Pb	car parts
Cr	tannery, faucet factory, car parts,
Cu	faucet factory, car parts
Zn	textiles

The condition of pollution by heavy metals in the main stream of the Tuy River is as follows: Samples at R-4 (Las Tejerías), R-5 (Qda. Guayas) and R-8 (Cúa) have values of T-Cr (total chromium) above the standard limit of Sub-type 1B for river water. The fact that T-Cr was found at 3 locations out of the 10 sampling points, at the one time measurement, an occurrence probability of 30% implies that there is possibly a high discharge of heavy metals.

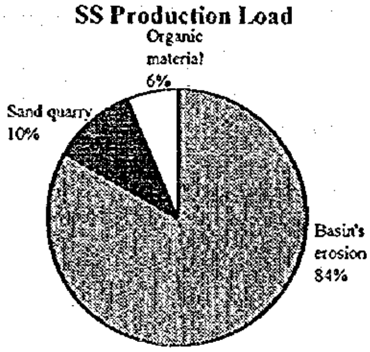
Spatial Distribution

The distribution of the projected numbers of non-food factories in 2010 is illustrated in Fig. 3.1-2. Much of them are located in the middle basin, namely in Charallave and Ocumare del Tuy; a few are also located in Las Tejerías and Paracotos in the upper basin.

(3) Turbidity

Production Source

Turbidity of the Tuy River originates from sand quarries, sheet erosion in all areas of the catchment basin, bank erosion of rivers, and from human related activities in the basin, e.g., land reclamation, road construction, as well as from organic pollution. Turbidity is discussed here using suspended solids. The source of SS production load is broadly divided into three; erosion, sand quarries, and organic pollution. Erosion includes sheet erosion in all the areas of the catchment basin, bank erosion of rivers, and from human related activities in the basin, e.g., land reclamation, road construction. The projected composition in the year 2000 is as follows:



Of the annual amount of production of total suspended solids, those from basin's erosion, make up 84%; sand quarries contribute 10%; and the share of organic material in the composition of SS is comparatively low at 6%.

Spatial Distribution

The sediment production volume is calculated using a 1×1-km grid. As seen in the illustration (Fig. 3.1-3), the production is comparatively low in the moderately undulating areas of Charallave, Cúa, San Francisco de Yare and in the catchment area of the Guare River. In other mountainous areas, no distinguishable differences were identified: the production occurs throughout the basin.

Major sand quarries are located in the Qda. Maitana basin. One quarry is equipped with a settling basin and the other without. In the Qda. Maitana, turbidity is very high during the dry season when river flow is low. The turbidity of Qda. Maitana in February, 1996, according to the results of water quality test, was extremely high at 14,800 NTU (SS of approx. 32,000 mg/ℓ).

3.3 Technical Measures Adopted and Their Status

To the pollution sources identified above, some measures have already been applied. In this section, technical measures already adopted are identified and the status of these measures are confirmed for planning. Table 3.1-1 summarizes the results of the study.

(1) Organic Pollution

The major sources of organic pollution are factories, piggeries and domestic wastewater. Status of measures is described below:

Factories

An alcohol distillery located in the upper basin is the factory having the greatest impact on the water quality of the Tuy River. A biological treatment plant has been introduced and the present BOD removal rate is around 95%; COD and SS are 89% and 83%, respectively (see Table 3.1-3). Attention should be paid to the fact that even after treatment the concentration of BOD exceeds 2,000 mg/ℓ. This level is well above acceptable limits for effluent being discharged into the river.

The fact that the concentration of the wastewater even after the treatment is at such a high level implies the necessity of overall measures for pollution load reduction including those in the production process, for example, reducing the total volume of material by recycling, and so on. The introduction of an oxidation pond by the year 1997 has been agreed upon between the factory and the Tuy River Basin Agency. Considering the fact that the effect of the factory on the Tuy River is very large, continued reduction of the pollution load is essential.

Although the removal rate of BOD with biological treatment plants by factories is generally high, at above 95% for food factories e.g. chicken meet processing, flour milling, dairy produce processing. Furthermore the removal rates of other parameters range widely, from 60-90% for COD, and 10-90% for SS. With regard to the installation of treatment plants, one third of the total number of the factories remain without any form of treatment. Improvement of the food factories is thus important for the reduction of the pollution load.

The percentage of non-food factories without treatment plants is 50 %. Improvement in BOD is not good in these factories as is easily imagined from the treatment method. Some of non-food factories, e.g. chemicals and textile producers, discharge high concentrations of organic pollution. Biological treatment is basically preferable for these factories. If biological treatment is not applicable as in the case of some chemical producers, the most appropriate method should be selected.

Piggeries

The effect of the piggeries on the river water pollution is significantly different between piggeries with oxidation ponds and without any treatment facilities. For example in the case of a piggery located along Qda. Morocopo, pre-treatment is conducted to remove solid wastes for compost, and water is treated with three oxidation ponds. Another example is to utilize water from the oxidation ponds for irrigation of adjacent upland crops. In these cases, more than 90% of pollution load could be removed. However in the case where there is no treatment, 100% of wastewater is discharged into the river. The Tuy River Agency plans to order piggeries not yet facilitated with treatment plants to totally shut down operations.

In Table 3.1-3, the water qualities are compared before and after treatment. As shown in the table, more than 90% of BOD and SS and 80-90% of COD are removed. Attention should be paid, however, to the fact that the wastewater from piggeries even after treatment contains high BOD concentrations, 1,000 mg/ℓ. Table 3.1-4 shows the effect of the removal of solid wastes from piggeries in the value of BOD. Utilization of solid wastes for fertilizer should be promoted as part of a biological recycling system for environmental improvement.

Domestic Wastewater

Pollutant removal rate from domestic wastewater is presently very low in the study area. Although sewer networks exist in many urban centers, treatment plants are not installed or are not operating. In the upper basin, oxidation lagoons have been constructed at three locations, but these are not utilized due to poor facility operation and maintenance.

Installation of treatment plants are deemed necessary to reduce BOD load of the domestic wastewater.

(2) Toxicants

In accordance with interview survey results, 54% of non-food factories have treatment plants. Of the factories with treatment plant, 53% are equipped with physical-chemical treatments, 13% with separators (including those of removal of solid particles), 7% are with biological treatment, and the remaining 27% have other treatment facilities that include effluent storage.

The results of water quality tests, before and after removing heavy metals, are discussed below (see Table 3.1-5):

With regard to Pb, one factory achieved a 53% removal rate and effluent from other factories is below the measurable limit. The effluent from the factory with the removal rate of 53%, however, still exceeds the discharge standard limit to the river and implies that there is a problem in the plant itself or in operation. The wastewater from this factory is discharged to a tributary of the Tuy River, and the concentrations of Cr and Cu also exceed the standard limits.

The Cu removal rates vary widely between 20 and 78%. At two factories, the concentration after the treatment is higher than before, indicating a possibility of inadequate operation and maintenance.

Also for Zn, the removal rates vary from 0 to 95%. At two factories, high concentrations were found in the wastewater after treatment. The removal rates for Hg and Ni also have a wide range and high concentrations were found in the effluent even after treatment.

(3) Turbid Water

As discussed before, turbid water originates, chiefly, from erosion over the entire basin and sand quarries. Of these, sand quarries are considered as industrial wastewater and the other is a natural condition (though the destruction of the basin is due to human activities).

Sand Quarries

Wastewater from sand quarries is from flushing water. In the case of sand quarries along the Qda. Maitana, 20 to 25 ℓ/sec of water is used. One site is equipped with two sand settling ponds and these are used alternatively. Overflow water from the settling ponds flows to the river. In the other case, there are no sand settling ponds and high concentrations of suspended solids flow into the Tuy River.

Erosion in the Basin

Regarding erosion in the basin, no measure has been implemented so far. Some river bank protection works have been conducted along the Tuy River, but these are mainly for the protection of bridges and not to protect the river from bank erosion.

Measure at Utilization Site

At Hidrocapital's water intake, a pre-treatment facility has been introduced and is presently operated.

4. MASTER PLAN STUDY ON MONITORING SYSTEM

4.1 Necessity of Monitoring

The Tuy River Basin is a precious source of domestic water supply to the Caracas Metropolitan Area (CMA). Environmental problems concerning water quality and quantity problems can be attributed to human activities. These problems have arisen due to various causes which include land development of forested areas, industrial and human activities. These activities result in the deterioration of water quality and the difficulty of securing sufficient water quantity with acceptable water quality. To cope with this environmental problems, it is necessary to carry out the collection of basic information indicating the environmental conditions and put into action the necessary countermeasures.

For the collection of the basic information, it is essential to monitor the factors that show the condition of: (1) land development and land utilization including shrub and forest fires, (2) industrial activities, and (3) daily activities of inhabitants. Among these, the monitoring of (1) is only needed occasionally and the monitoring operations can be performed by a few staff and at a small cost. Hence, it is not necessary to provide additional or new staff and facilities for the purpose.

On the other hand, items (2) and (3) need frequent monitoring, because their activities could potentially damage the environment in only a short time. In particular, industrial activities can bring about sudden changes to environmental conditions, as shown by the accidental or deliberate water pollution with toxicants, organic and turbid substances discharged into the river resulting in the suspension of water intake.

Under these circumstances, the required monitoring system is discussed, putting emphasis on the monitoring of water pollution caused by industrial and human activities.

4.2 Outline of the Monitoring System

In general, the proposed monitoring system is discussed regarding the:

- Objectives
- Operations (monitoring sites, parameters and frequency)
- Organization including personnel
- Necessary facilities and equipment
- Cost required

4.2.1 Objectives

The main objective of monitoring is to collect basic information for the prevention of the deterioration of water quality in the Tuy River from two aspects:

(1) environmental aspect, to preserve the water of the Tuy River complying with the water quality standard, and (2) water supply source aspect, to prevent water with unfavorable quality from being utilized as domestic water.

Moreover, the problems indicated in section 1.4 should be resolved by this monitoring work.

4.2.2 Operation of Monitoring

To fulfill the above objectives, the monitoring operation is broadly divided into two types: (1) monitoring at fixed sites and (2) monitoring at non-fixed sites. The former is adopted to monitor the river, while the latter is adopted to monitor industrial and human activities over the entire basin. In the case of industrial activities, it is the duty of owners of factories and piggeries to report the water quality of their effluent four times a year in order to confirm the effectiveness of treatment.

The two types of monitoring are discussed below:

(1) Fixed Site Monitoring

(a) Monitoring Sites

As mentioned in section 1.2.3, water quality investigations on the Tuy River and its tributaries have been carried out over the past thirty years. Though these investigations were irregularly undertaken these previously obtained results were used as reference material for the selection of fixed monitoring sites (Fig. 4.2-1).

From the nine points from which monitoring has been carried out the six most frequently monitored sites were selected. It is thought that these sites are sufficient to establish the monitoring system in this study from the environmental aspect.

Although these sites are sufficient to monitor the environmental condition of the Tuy River, it is desirable to designate at least two sites to monitor the water quality from the water supply source aspect, because there may be differences in monitoring parameters and frequencies depending on objectives.

Therefore, two cases for monitoring sites have been proposed:

Case 1	Nine monitoring sites (from environmental aspect).
Case 2	Two monitoring sites from the above nine monitoring sites (from water supply source aspect).

The monitoring sites are as tabulated below (refer to Fig. 4.2-1).

No.	Tuy River
1	Las Caballerizas
2	Las Tejerías
3	Boca de Cagua*
4	Tazón Bridge
5	Ocumare Bridge*
6	San Antonio de Yare

No.	Tributaries
1	Caño Tiquirito
2	Qda. Maitana
3	Qda. Charallave

* Designated sites

(b) Monitoring Frequency

From the environmental viewpoint, it is not necessary to frequently monitor water quality. Practically, a monitoring frequency of once a month in the dry season and twice a month during the rainy seasons is sufficient to grasp the water quality conditions from the environmental aspect. From the water supply aspect, however, it is necessary to continuously monitor the water quality conditions at several points to identify any sudden change of water quality so that measures can be implemented to prevent the transmission of unfavorable pollutants into the water supply system, and to detect polluters.

In this connection, two monitoring frequency plans have been proposed:

Case 1	Once a month in the dry season and twice a month in the rainy season (from environmental aspect)
Case 2	Continuous monitoring (from water supply source aspect)

(c) Monitoring Parameters

Basically, monitoring parameters also depend on the objective and frequency. From the environmental viewpoint, it is necessary to cover all parameters stipulated in the water quality standards to confirm the environmental condition of the Tuy River, although monitoring all of parameters every time and at every point may not be necessary.

In the case of monitoring for the water supply aspect, it may be difficult to continuously monitor many parameters of water quality physically and economically, while it is desirable to cover those parameters that indicate sudden changes in water quality due to the inflow of organic, toxicant and turbid polluting substances. In general practice, parameters most often used for continuously monitoring include pH, EC, turbidity, and DO. These factors can be observed through automatic monitoring equipment and, generally, any sudden change of water quality can be observed through the monitoring of these parameters.

Therefore, the following parameters have been proposed:

Case 1	Monitoring of all parameters stipulated in the water quality standards for the nine monitoring sites, though not every time and at every site (environmental aspect).
Case 2	Continuous monitoring of pH, EC, turbidity and DO plus water level and temperature at two monitoring sites (water supply source aspect).

(2) Monitoring at Non-Fixed Sites

(a) Monitoring Sites

As the objective monitoring sites for factories and piggeries, of which effluents have a large impact on water quality of the Tuy River, are in principle nominated as non-fixed monitoring sites. In addition, the monitoring sites for effluent from urban centers are also nominated.

(b) Monitoring Frequency

In the Tuy River basin, there are 95 large scale factories and 8 sand quarries, and 33 piggeries which discharge a large amount of effluent, and it is desirable to monitor these polluters at least twice a year. For this purpose, 8 factories and 2 piggeries are required to be monitored once a month.

(c) Monitoring Parameters

As the monitoring parameters, the major parameters stipulated in the water quality standards should be covered considering the extent of activities of factories, piggeries and urban centers.

4.2.3 Organization

In principle, the monitoring work shall be undertaken by the Tuy River Basin Agency (Agencia de la Cuenca del Rio Tuy, ACRT) which has the full responsibility for monitoring the environmental condition of the Tuy river basin. Although the agency is currently operating the monitoring system, the number of staff, equipment and facilities is insufficient considering the monitoring work volume to be covered. Therefore, it is necessary to strengthen the present organizational setup.

To cover the above monitoring operations, the organization should be strengthened in terms of staff, that is, engineers, technicians, and support staff. The engineers should be well qualified and have experience in chemical and environmental sciences.

4.2.4 Necessary Facilities and Equipment

To operate the monitoring system, the following facilities have been proposed:

- Fully equipped continuous monitoring stations.
- Office space for data filing staff and facilities.
- Laboratory facilities to conduct water quality analyses.
- Storage facilities for collected samples.
- Storage facilities for equipment.
- Transportation to conduct the monitoring works.

The necessary equipment shall include those for laboratory tests, field investigations and continuous monitoring. The major equipment required is as given below.

Laboratory Equipment	Refrigerator, Incubator, Chemical balance, etc.
Equipment for Field Measurement	Current meter, EC meter, DO meter, Turbidity meter, etc.
Equipment for Continuous Monitoring	Sensor, Gauge, Recorder, Accessories, etc.

At present, these facilities and equipment are provided at the Tuy River Basin Agency and the central laboratory, also a project is ongoing to strengthen the laboratory's function. Therefore, to finally establish the necessary facilities and equipment, it is necessary to modify the ongoing improvement project taking into account the above objectives. In this study, the necessary facilities and equipment are proposed for the monitoring works.

5. FEASIBILITY STUDY ON ESTABLISHMENT OF MONITORING SYSTEM

5.1 General

The objectives of monitoring system follow those made in the master plan to collect basic information for the prevention of deterioration of water quality in the Tuy River from two aspects: (1) environmental aspect, to preserve the water of the Tuy River complying with the water quality standard, and (2) water supply source aspect, to prevent water with unfavorable quality from domestic utilization.

A structure of the monitoring system, to achieve the above objectives, was proposed in the Master Plan. In this study, the following points proposed in the Master Plan were confirmed in order to establish the plan of the system: (1) monitoring conditions including sites, parameters and frequency, (2) organization and additional personnel, additional equipment and facilities, (3) comparison between the utilization of a new laboratory belonging to ACRT and the present Central Laboratory, and (4) necessary cost estimation.

5.2 Monitoring Conditions

5.2.1 Monitoring Conditions at Fixed Site

(1) Case 1 (Ordinary Monitoring)

(a) Site Condition

The Master Plan selected six sites on the Tuy River and three sites on the tributaries. The more information and data that can be collected at a point the more appropriate that point will. The table next lists the conditions of the selected sites: (refer to Fig. 5.2-1, and refer to Fig. 4.2-1).

Conditions of Monitoring Site

Site	Accessibility	Point of flow measurement and water sampling
Las Caballerizas	About. 1 km from major road, easy to pass a private yard	Measurement in the middle of the river may be possible
Las Tejerías	On a main road	Center of river possible from bridge
Boca de Cagua*	About 0.5 km from the main road and easy to approach by a little wild road	Center of river possible from bridge
Cua Bridge#	On a main road	Center of river possible from bridge
Ocumare Bridge*	On a main road	Center of river possible from bridge
S. A. de Yare	On a main road	Center of river possible from bridge
Caño Tiquirito	Across a passable private yard	Possible in the river
Qda. Maitana	About. 1 km from major road by a wild road	Possible in the river or from the pedestrian bridge
Qda. Charallave	On a main road	Possible in the river

Although Tazón Bridge was proposed in the Master Plan Study, it was not found accessible so Cua Bridge replaces it.

(b) Frequency

Field work and sampling should be monthly in the dry season (6 times) and fortnightly in the rainy season (12 times) by the conventional sampling methods. According to past data in the Tuy River basin, flow and water quality in the dry season do not tend to vary while in the rainy season they are sensitive to precipitation.

(c) Parameters

In addition to the monitoring parameters in the water quality standard Sub Type-1B, many others are to be analyzed to evaluate the level of pollution. This Study especially recommends the following parameters: Biological Oxygen Demand (BOD), Chemical Oxygen Demand (COD), Total Organic Carbon (TOC), Dissolved Organic Carbon (DOC), and Suspended Solid (SS), Total Nitrogen (TN) and Total Phosphorus (TP).

(2) Case 2 (Continuous Monitoring)

(a) Site Condition

Boca de Cagua and Ocumare Bridge, selected for the continuous monitoring stations are proved to be appropriate for this purpose. It will, moreover, be necessary to assure the following points for installation of the continuous monitoring system (Fig. 5.2-2):

- Building foundation of the monitoring station should be resistant to subsiding or damaged.
- Telephone lines should be facilitated at site.
- Person responsible for the monitoring station should be stationed near by.

(b) Frequency

Hourly measurement is principally required by automatic measurement equipment.

(c) Parameters

Monitoring parameters are water temperature, electric conductivity, pH, dissolved oxygen, turbidity and water level.

(d) Monitoring Station Equipment

The system has a water test tank with a sampling pump, sensors and stations with a gauge and recorder. A public telephone line sends observation data to a computer (Fig. 5.2-1).

(e) Response to Emergency

Whenever a parameter shows abnormality or hazardous state, the same water sample should spontaneously be analyzed by manually to check heavy metals or cyanide. When heavy metals or cyanide are detected in river water, Toma de Agua station should be informed of this for purpose of taking precautionary step.

5.2.2 Monitoring Conditions at Non-Fixed Site

(a) Site Condition

As in the Master Plan, pollution condition due to factories and piggeries, or urban centers should be monitored. Thus, non-fixed monitoring sites are to be at factories, piggeries and urban center.

Special site condition is generally not required for monitoring. Attention should rather be paid to site selection; Wastewater highly in organic pollutant and/or hazardous compounds should frequently be monitored.

(b) Frequency

Weekly monitoring is recommended. Two teams are to carry out monitoring activities at four sites each day. Factories discharging major pollutants should be the primary target of the monitoring.

(c) Parameters

In addition to the parameters in the standard list, the characteristic parameters detected in the wastewater from industries, urban centers and piggeries should be monitored.

Some wastewater from factories, in particular, may contain heavy metals and other toxic compounds, and thus large scale factories and others heavy metal polluters should firstly be monitored. The table next is the list of recommended parameters from such factories.

Recommended Parameters to be Monitored

Industrial category	Parameters to be monitored
Food related industry	Parameters relating to organic pollution including TOC and DOC
Tannery and leather factory	CN, Pb, Cr^{6+}
Manufacture of paint and vanishes	Cd, CN, Cr^{6+}, Hg
Manufacture of soaps and cleaning products	CN, Pb, Cr^{6+}, Oil and grease
Production of fiberglass	CN, Pb, Cr^{6+}, As
Production of non-ferrous metals and alloys	CN, Pb, Cr^{6+}, Zn
Manufacture of metallic products	CN, Pb, Cr^{6+}
Metal plating	Cd, CN, Pb, Cr^{6+}, Hg, As, Zn
Car part factory	Cd, CN, Pb, Cr^{6+}, Hg, As
Automobile factory	CN, Pb, Cr^{6+}, As

5.3 Laboratory

There need to be a laboratory capable of carrying out analysis on up to 300 water samples to be taken from. The central laboratory in Caracas carries out all analyses and laboratory works of water samples of the Tuy River as well as those of other areas. It currently analyzes more than 3,000 samples and has the capacity to cover the proposed monitoring work, provided staff members and equipment are increased.

A disadvantage is that it is not convenient to carry out daily monitoring works due to the location of the central laboratory being far from the monitoring sites of the Tuy River. An alternative is to build a new laboratory at a monitoring site, for instance, Ocumare del Tuy because of its general convenience.

This section compares the central laboratory and a new laboratory for the purpose of planned monitoring activities. The table below lists their features according to the required conditions for the water analysis laboratory.

Comparison between Two Laboratories

Item	Central Laboratory	New Laboratory
Driving time form the monitoring sites	1.5 - 2.0 hours	0.5 - 1.0 hours
Numbers of personnel	At present, 17 professionals are engaged; 2 professionals to be added	6 professionals are planned
Building	Existing with a capacity to accept the work	New building with a floor space of about 300 m^2
Laboratory facilities	Additions needed	New installation needed
Equipment	Additions needed (ca. 250000 US$)	New installation needed (ca. 550000 US$)
O/M cost for the monitoring work	Same as new laboratory	Same as existing laboratory
Work volume	Based on the sample numbers last 3 years, 10 to 16 times than proposed monitoring work volume (3,300 - 4,900)	300 samples in the proposed monitoring work

Even if a new laboratory can be conveniently located, it will demand a huge investment for building and maintenance relative to a limited amount of work. In an environmental improvement project for Lake Valencia, for instance, a new laboratory was built. To justify its cost the laboratory has to receive samples of other projects to. To avoid a repeat of the Valencia case the study does not recommend a new laboratory.

5.4 Personnel for the Monitoring

The Tuy River Agency (ACRT) should be responsible the monitoring, of the Tuy River basin. It was already found it necessary to strengthen the present organization by increasing personnel and adding equipment and facilities for the monitoring work.

Staff members have to be increased at particularly ACRT's regional office and at the central laboratory in order to carry out the monitoring activities efficiently.

Specific requirements are listed below:

Work	Necessary Personnel for the Monitoring System	Existing and Available Personnel	Additional Personnel
Supervising	1	0	1 in the main Office, ACRT
Field measurement and collecting samples	6 personnel for 2 teams	4 technicians including engineers from Los Teques Office, 2 engineers and 1 technician from Ocumare Office 1 chemist from the Central Laboratory (*)	Not necessary (1 technician for the continuous monitoring work shall also join the field work and collecting samples).
Continuous monitoring	1 technician 1 operator for data storage	1 secretary among 4 in Ocumare Office	1 technician in Ocumare Office
Laboratory work	3 chemists 1 biologist 3 technicians	1 chemists 1 pharmacologist instead of chemist 1 biologist 2 technicians	1 chemist in water quality section, Central Laboratory 1 technician in water quality section, Central Laboratory
Data arrangement	1 technician or engineer	1 technician	Not necessary

*: the personnel works for both in the field and the laboratory

One supervisor shall be added to the ACRT main office (Miranda Management Office) which directly controls the upper and middle Tuy basins.

Three of professionals or technicians are required for two field work teams, and three chemists, three technicians and one biologist are required for analyses in the laboratory. Considering an analyst's specialty and many parameters to be monitored, it is necessary to integrate a larger number of specialists.

Besides, continuous care and immediate analysis for fresh samples should be required for the continuous monitoring system; Ocumare Office needs 1 chemist technician.

5.5 Necessary Equipment

The central laboratory needs additional equipment for expanded monitored parameters, particularly heavy metals, cyanide or arsenic, along with upgrading existing equipment.

For field monitoring activities, besides another set of equipment for 2 teams, turbidity meters and current meters to measure flow are needed.

Also facilities and equipment for the continuous monitoring stations are newly required; those are cabinet for sensing equipment, sensors of pH, EC, DO and Temperature sensors, water level gauge and a recording device. A computer unit is also needed to store daily results.

See Table 5.5-1 for the list of recommended additions..

5.6 Operation and Maintenance Plan

Monitoring work will be carried out every week accordance with a schedule. Including 3 additional personnel, total 18 personnel are required for the monitoring work. For the field work and sampling, six out of eight members are sufficient. These people will each week carry out the monitoring system at fixed and non-fixed sites. One member should daily be in charge of the continuous monitoring system (Table 5.6-1).

The central laboratory needs to increase its staff due to the increase in the analysis of monitoring parameters.

For maintenance cost, different ratios to the original costs (3 - 10 %) are set according to the equipment type and estimated the annual maintenance cost (Table 5.6-2). Then, total operation and maintenance cost per year amounts to US$114,238 (Bs.53,691,860).

Replacement plan for each equipment was made and the cost was estimated as presented in Table 5.6-3).