CHAPTER 7 ENVIRONMENTAL CONSERVATION AND IMPROVEMENT

7.1 Flood

7.1.1 Planning Criteria

Within the context of the goal and principle of water excess management of the Strategy the flood control model areas and design standard for the Master Plan are established as set out below.

(1) Model areas

Iguaçu River Basin
Region-1: Curitiba Metropolitan area
Region-2: Porto Amazonas, São Mateus do Sul
Region-4: União da Vitoria
Region-5: Rio Negro
Region-6: Foz do Iguaçu

(2) Flood Plain Management and Urban Storm Water Management

As a part of flood plain management, combination of structural and non-structural measures will be necessary for the Curitiba metropolitan area and municipalities of São Mateus do Sul and União da Vitoria/ Porto União. Non-structural measures are to be primarily employed for the flood prone areas in the other municipalities. Integrated view of urban sewage, flood protection, storm drainage and environmental protection is necessary for the Curitiba metropolitan area as urban storm water management. Environmental protection includes waste disposal control, water quality control, protection of aqua-ecosystem, and protection of riverine landscape.

(3) Design Standard

The flood control (or protection) level must be determined appropriately taking into consideration of social significance of damage level and efficiency of benefit and cost with the principle of risk and benefit. Appropriate combination of flood control level for zoning and structural measures must be also determined.

7.1.2 Master Plan for Iguaçu River Basin

(1) Non-structural Measures

Zoning for land use control is the most effective measures for all the flood prone areas in and around the urban areas in Paraná State (Region-1 to 8). Zoning for land use control includes restricted area, river regime, natural preservation and recreational park, and retarding basin area. Zoning and resettlement are a tandem for implementation and have been widely applied in the Curitiba metropolitan area (CMA), São Mateus do Sul, Porto Amazonas, Reboucas, Guarapuava, União da Vitoria, Rio Negro, etc. in the Iguaçu river basin. Resettlement includes relocation of illegal residents occupying the river regime and legal residents in the flood prone areas.

The existing flood forecasting and warning system (FFWS) is planned to be upgraded by the provision of the new lightening sensoring and rainfall monitoring system under SIMEPAR. This upgraded system will provide basic warning information required for rescue activities for the time being. This system will be necessary to be upgraded for a basinwide real time flood management and operation to avoid both natural and artificial flood disaster in the future when number of water rescues and flood control facilities is increased significantly.

Flood proofing such as elevating ground level and structures is effective for some locally inundated areas in CMA and other flood prone areas. Review of the operation rule of the existing and planned dams and reservoirs will be necessary taking flood control function into consideration for the integrated and effective operation.

The proposed non-structural measures and their implementation schedule are listed in Table-7.1.

(2) Structural Measures

The structural measures are proposed only for CMA, São Mateus do Sul and União da Vitoria - Porto União region.

The proposed structural measures and their implementation schedule are listed in Table-7.2.

(3) Description of Flood Control Measures and Projects

Curitiba Metropolitan Area

Non-structural measures are most effective in particular by zoning with resettlement and park in the Curitiba Metropolitan Area (CMA). Continuation and extension of the flood control and drainage improvement projects of PROSAM which is composed of structural and non-structural measures is the first priority. PROSAM is composed of the following components:

i) 15 km long flood channel excavation of the main stream of the Iguaçu river parallel to the existing channel (about 1.3 million m^3),

ii) Landscape restoration and park development of river bank area,

iii) Irai dam for flood control and to guarantee 1.8 m^3/s to Curitiba water supply,

iv) Relocation and resettlement of houses located in risky areas including occupying river flood plains, and

v) Expropriation of 7,000 plots of land and rights needed for environmental protection along rivers and environmentally sensitive areas.

Table-7.1 Proposed Non-structural Flood Control Measures and Implementation Schedule for Iguaçu River Basin

Region	Municipalities	Non-Structural Measures	1st Stage Present - 2005	2nd Stage 2006-2015 onward
1.	Curitiba Metropolitan Region	•Zoning	-	-
		•FFWS	Δ	O
		•Evacuation	Δ	Δ
		•Proofing	Δ	Δ
		•Operation Rule	Δ	O
2.	São Mateus do Sul	•Zoning	-	-
		•FFWS	Δ	O
		•Evacuation	-	Δ
		•Proofing	Δ	Δ
	Porto Amazonas	•Zoning	-	-
		•FFWS	Δ	O
		•Evacuation	-	Δ
		•Proofing	Δ	Δ
3.	Rebouças, Guarapuava Irati, Ipiranga	•Zoning	-	-
		•FFWS	Δ	Δ
		•Evacuation	-	Δ
4.	União da Vitória	•Zoning	Δ	Δ
		•FFWS	Δ	O
		•Evacuation	-	Δ
		•Proofing	Δ	Δ
		Operation Rule	Δ	O
5.	Rio Negro	•Zoning	-	-
		•FFWS	Δ	O
		•Evacuation	-	Δ
		•Proofing	Δ	Δ
6.	Foz do Iguaçu	•Zoning	Δ	Δ
		•FFWS	Δ	O
		•Evacuation	Δ	Δ
		•Proofing	Δ	Δ
		•Operation Rule	Δ	O
8.	Capanema	•Zoning	-	-
		•FFWS	-	-
		•Evacuation	-	Δ

Notes

(1) Zoning = zoning for land use control with resettlement and parks;
FFWS = Flood Forecasting and Warning Systems ; Evacuation = evacuation and rescue activities;
Proofing = raising of ground level and buildings, etc.; Operation Rule = operation rule for reservoirs, flood control facilities, etc.

(2) - = Extention of present method; Δ = Improvement of present method; O = Employment of new concept

Table-7.2 Proposed Structural Measures and Implementation Schedule for Iguaçu River

Region	Municipality	Structural Measures	Project Cost (US\$ 10^6)	Implementation Schedule			
				1st Stage		2nd Stage	
				1996 ~ 2000	2001 ~ 2005	2006 ~ 2010	2011 ~ 2015
1.	Curitiba Metropolitan Area	Continuation of PROSAM	Total 34.3 (1992 price)				
		Extension of PROSAM - channel excavation by Curitiba municipality - Piraquara II, Pequeno, Alto Miringuava dams with flood control function	Not Available				
2.	São Mateus do Sul	Dike system with a sluice	11.1				
4.	União da Vitoria	Dike system with sluices	85.9				

The total project cost was estimated to be 34.3 million US dollars in 1992 excluding the Irai dam. A part of the channel excavation (11 km) shown in Figure-7.1 is now under construction, and the resettlement and park plans are in progress.

The extension program of PROSAM will be composed of the following components:

i) Channel excavation and maintenance of the flood channel of the main stream of the Iguaçu river by Curitiba City Hall and COMEC, and

ii) Piraquara II, Pequeno, Alto Miringuava dams for water supply with flood control function.

In order to maintain the flood discharge capacity of the Iguaçu river a strong regulation to control extraction of sand and gravel in and around the water course of the Iguaçu river is necessary. Modification and maintenance of the two existing and on-going parallel flood channels will also be continuously necessary.

The dams which are newly planned as water supply projects are to be reviewed as multipurpose having flood control function. The Piraquara II, Pequeno, Alto Miringuava dams may have a function to mitigate floods in the flood prone areas in the municipalities of Curitiba, Pinhais, Piraquara and São Jose dos Pinhais. The location map of the planned dams is shown in Figure-7.1.

Integrated view of urban sewage, flood protection (including floodways, retarding basins and channel improvement), storm drainage, and environmental protection is now in practice in CMA, and it will be more significant in the 21 st century depending on the expansion of urban area and the deterioration of urban environment.

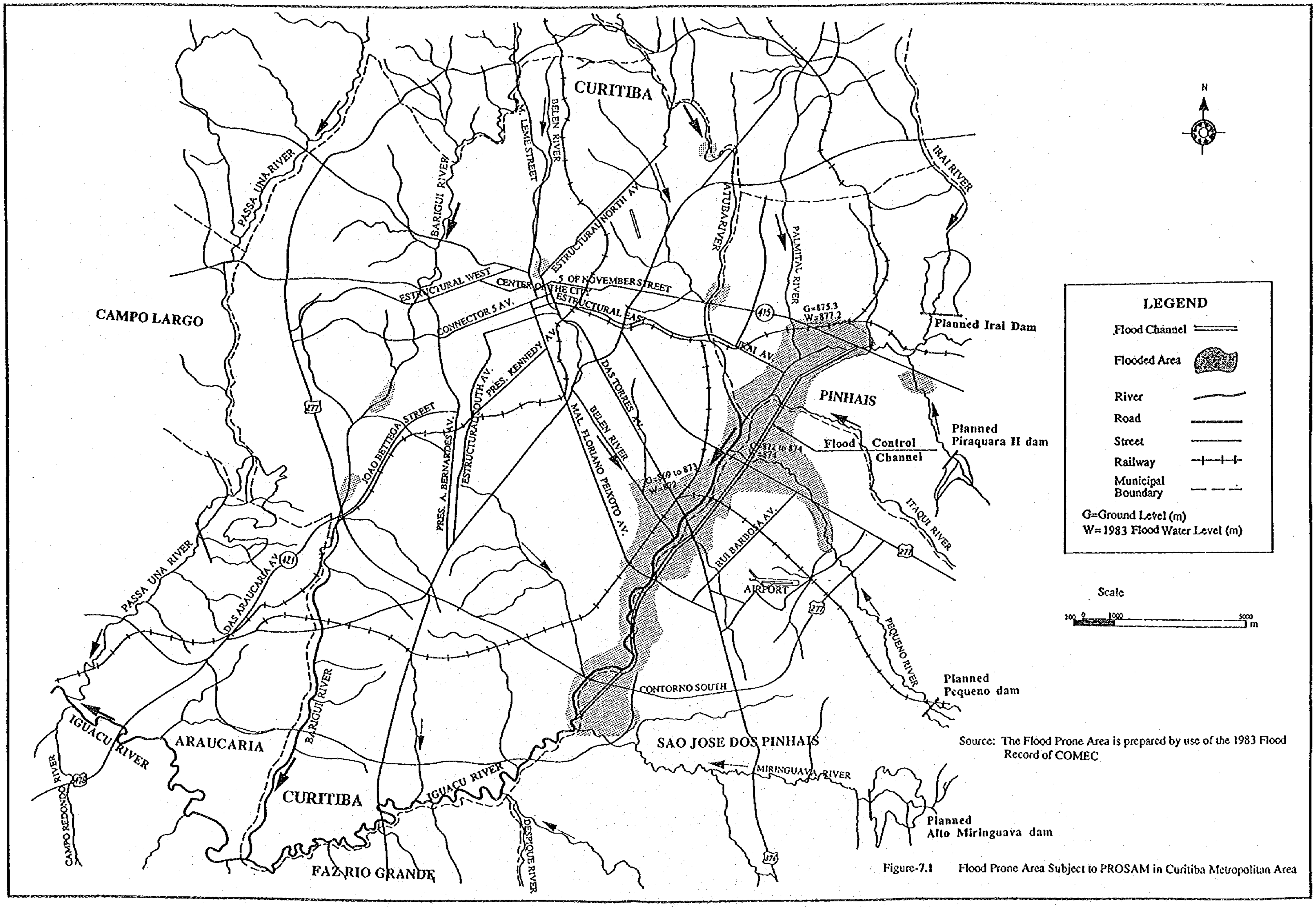
São Mateus do Sul

In the 1983 flood 5,800 people evacuated from houses and food of 22,858 tons was provided to the affected people in São Mateus do Sul. In the 1992 flood 970 people evacuated, 570 people lost houses and 1,200 houses were damaged.

Non-structural measures are most effective, and zoning with a combination of resettlement and park is first priority in São Mateus do Sul. However, a dike system on the right bank of the Iguaçu main stream may be effective in the future after the year 2006 for the flood prone area where demand of development of low cost housing for low income people are very high in spite of the city's zoning requirement. Channel improvement will not be financially feasible. A conceptual alignment of the dike system is illustrated in Figure-7.2. Feasibility study will be necessary for financial and technical evaluation.

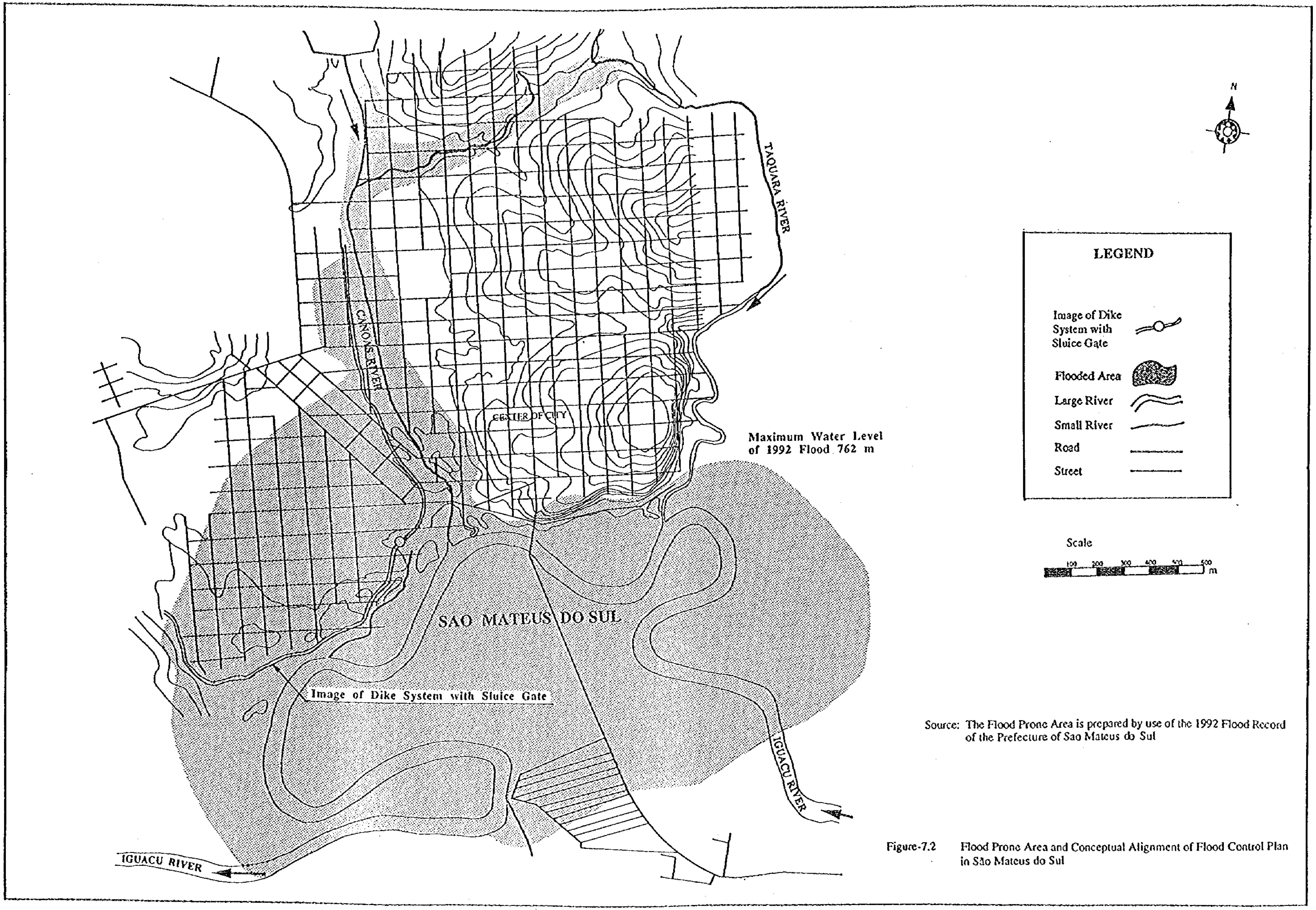
Porto Amazonas

Non-structural measures are most effective, and zoning with a combination of resettlement and park is first priority in Porto Amazonas. Excavation of a natural rock drop, which exists in the low water channel and interrupts the stream flow of the Iguaçu river, will improve flood discharge capacity, but it will not be financially viable.



Source: The Flood Prone Area is prepared by use of the 1983 Flood Record of COMEC

Figure-7.1 Flood Prone Area Subject to PROSAM in Curitiba Metropolitan Area



Source: The Flood Prone Area is prepared by use of the 1992 Flood Record of the Prefecture of Sao Mateus do Sul

Figure-7.2 Flood Prone Area and Conceptual Alignment of Flood Control Plan in São Mateus do Sul

Uniāo da Vitoria and Porto Uniāo

Uniāo da Vitoria in Paraná State and Porto Uniāo in Santa Catarina State experienced significant flood inundation in 1983 (flood water level of 750.03 m; DNAEE gauge water level 10.42 m), 1992 (flood water level of 748.51 m), 1993 (flood water level of 746.86 m) and 1995 (flood water level of 746.36 m). In the 1983 flood about 30,000 people evacuated from their houses and food of 122,673 tons were provided to the affected people in Uniāo da Vitoria accoding to the report from the Civil Defence of Paraná State. In the 1992 flood 14,129 people evacuated from their houses, 3,736 people lost houses and 4,500 houses were damaged in Uniāo da Vitoria only. The flood inundation area is shown in Figure-7.3 for 1983 and Figure-7.4 for 1992.

Flood protection for this region will not be materialized by the provision of non-structural measures only. It will be practically and financially not acceptable for these municipalities to apply zoning by resettlement to the elevation of 750 m (1983 flood water level) because the property value in the flood prone area is extremely high and the town function in this area is significant. The land value is shown in Figure-7.4.

At present the municipality of Uniāo da Vitoria restricts the land use below the elevation of 744.5 m in the urban area and 745.0 m in the rural area as the dispossessed area coordinated with COPEL. In Porto Uniāo (Santa Catarina State) construction of public buildings (schools, hospitals, etc.) are prohibited in the area below 750.0 m by law. The flood water level exceeded the elevation 744.5 m 36 times, 745.0 m 26 times in the period 1930 -1995 (66 years) as shown in Figure-7.5. If the elevation of restricted area is raised to 746.5 m the chance of exceedence of this level will be reduced to 5 times during 66 years.

An alternative study including a channel improvement plan, a dike system plan and a combined plan of channel improvement and dike assessed that only dike system plan would be financially feasible with combination of zoning with resettlement.

The Study Team recommends the following zoning and structural measures

<Zoning>

a) Restricted Area

No private and public buildings and houses are allowed to exist below the ground elevation 746.5 m. The existing houses and buildings are to be resettled to the designated safe areas.

b) Conditional Area

Construction of new private and public buildings and houses is not allowed in the ground elevation between 746.5 m and 748.5 m. Flood proofing such as elevating structures is to be enhanced as necessary.

<Structural Measures>

A dike system with sluice gates is to be provided to protect urban areas of both municipalities.

a) Design flood - the recorded maximum flood (1983 flood, return period of about 120 years, peak discharge of 4,980 m^3/s)

b) Design flood water level - 750.0 m

c) Design crest elevation - 751.2 m with freeboard of 1.2 m

d) the dike system is to be aligned at clebation 746.5 m to limit the maximum dike height less than 5 m.

e) Sluices with drainage pumps

The total length and volume of the dike system will be about 17 km and 1.4 milliom m^3 respectively. The channel improvement including excavation of a series of natural rock drops along the main stream of the Iguaçu river in the stretch upstream of the Foz do Areia dam just downstream of Porto Vitoria to União da Vitoria will not be financially feasible because of its extremely large excavation volume (over several million m^3).

It is recommended to conduct a feasibility study on provision of the dike system and sluice gates. The total project cost of the dike system plan is approximately estimated to be about 86 million US dollars. The conceptual alignment is illustrated in Figure-7.4.

<Flood Water Level at União da Vitoria>

Non-uniform flow calculation was conducted to estimate the flood water level in the stretch from Foz do Areia to São Mateus do Sul in the Iguaçu river during the 1983 and 1992 floods, and evaluate an effect of natural river bed elevation and the reservoir water level of Foz do Areia on the flood water level in the stretch from União da Vitoria to São Mateus do Sul.

The reservoir water level at Foz do Areia (Section D1) is assumed from 739 m to 744 m depending on case. The 117 river cross section survey data are combined and used for this calculation: 66 by COPEL and 51 by JICA.

The calculated flood water level is not real value but only notional due to insufficient topographic, hydrologic and hydraulic data and characteristics of the non-uniform flow model. However, the calculated results and their interpretation will indicate some tendency with some error range.

The result of flood water level of 1983 and 1992 with the existing natural river bed is summarized in Table-7.3. The 1983 flood water level (with 744 m reservoir water level), 1992 flood water level (with 742 m reservoir water level), and average river bed elevation of the stretch are shown in Figure-7.6. The result indicates that the effect of the reservoir water level in Foz do Areia does not reach Fluviopolis and São Mateus do Sul if the water level is kept at least lower than El. 744 m. The effect of reservoir water level to União da Vitoria seems to be little if the reservoir water level is kept lower than El. 744 m. It also seems to be that the key factor to cause increase of the flood water level at União da Vitoria is increase of flood discharge (size of flood) rather than the reservoir water level of Foz do Areia if the reservoir is operated within the calculated conditions. However the amount of contribution of the reservoir water level of Foz do Areia to the 1983 flood water level can not be quantified by this calculation model only.

However, the adopted non-uniform flow calculation model can not deal with the extent to which level the reservoir water level is to be lowered.

Table-7.3 Summary of Calculated Flood Water Level without Excavation

Case	Flood	Foz do Areia (DI-77) CN011	Porto Vitoria (BAT-1B) CN153	Uniao da Vitoria (14.GPF) JT141	Fluviopolis (FINFL-01) CF271	São Mateus do Sul (S-25.GPF) JS251
A1	1983	744.0	746.7	750.1	759.0	764.3
A2	1983	742.0	746.3	750.0	759.0	764.3
A3	1983	739.0	746.1	749.9	759.0	764.3
A4	1992	742.0	745.4	748.7	757.7	763.3
A5	1992	739.0	745.3	748.7	757.7	763.3

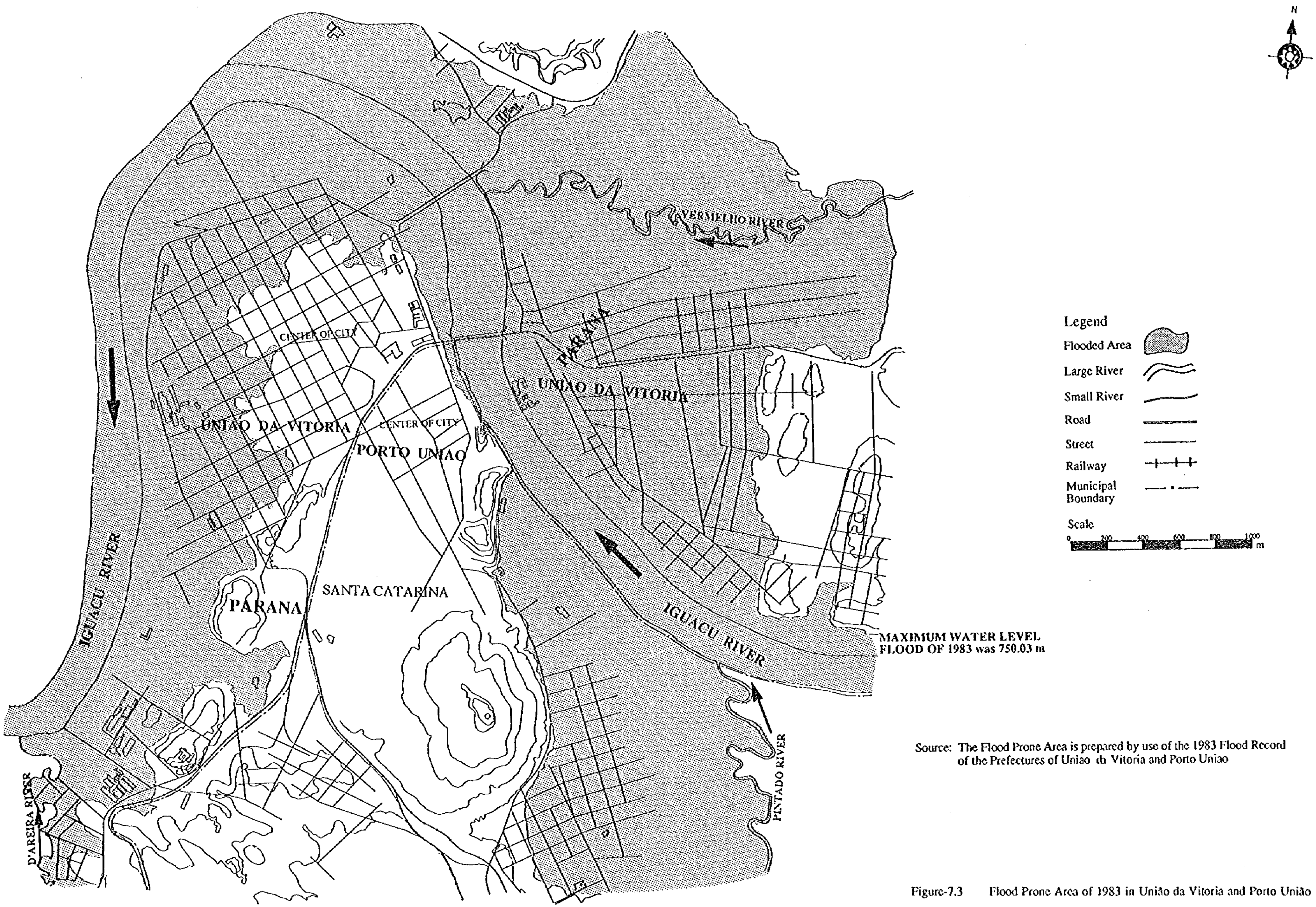
Note: (1)Flood discharges at União da Vitoria for 1983 flood and 1992 flood are 4,980 m^3/sec and 3,810 m^3/sec respectively.

(2)H.W.L of Foz do Areia reservoir is 742.0.

Rio Negro and Mafra

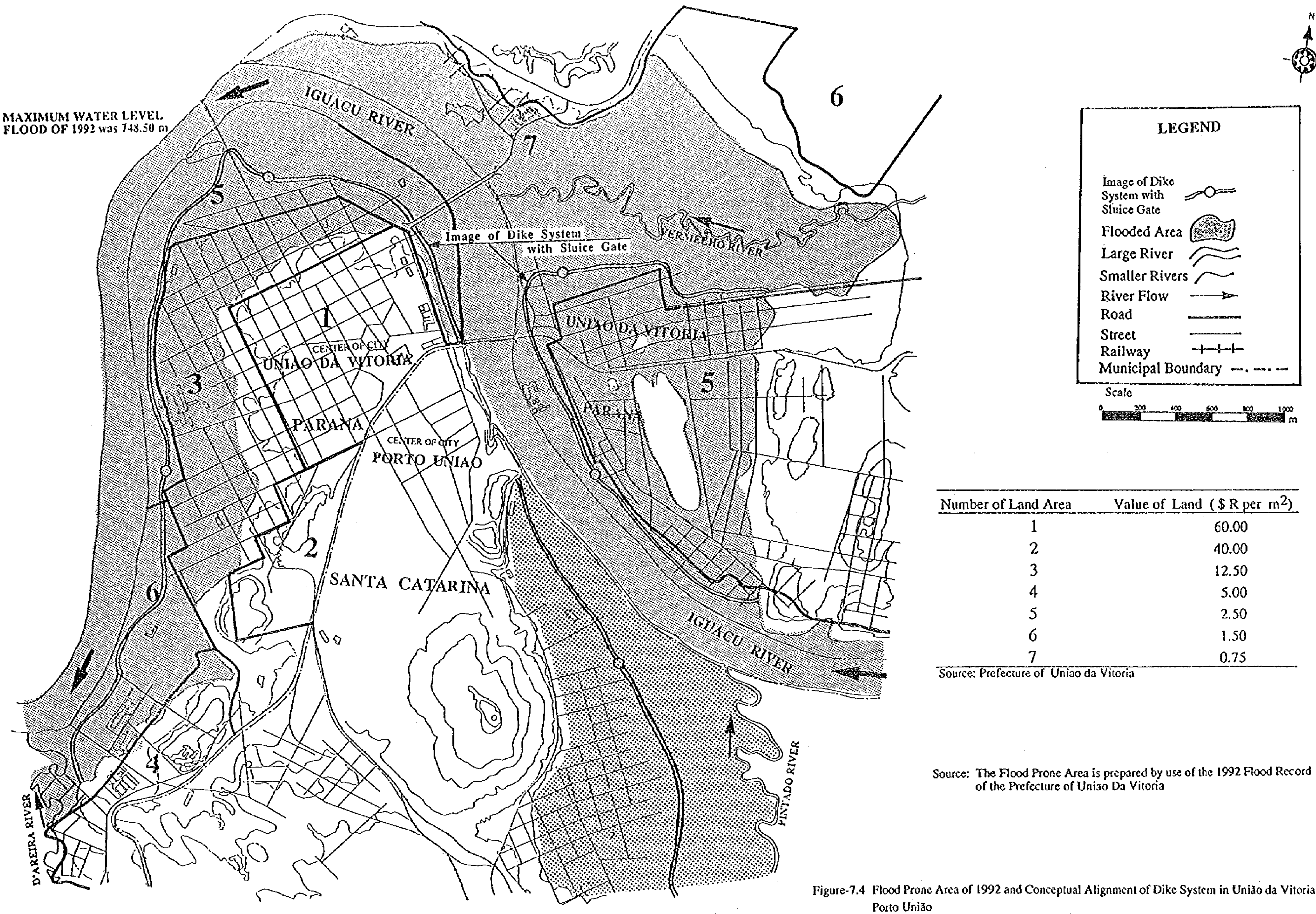
Rio Negro in Paraná State and Mafra in Santa Catarina State experienced severe flood inundation in 1983 and 1992. The recorded maximum gauge water level was 14.63 m at the DNAEE station in Rio Negro in 1983 which was higher than the normal water level by about 10 m. The peak flood water level of the 1992 flood was only 21 centimeters lower than that of 1983.

Non-structural measures by zoning are most effective in this region. Zoning with resettlement and park is in practice, but about 400 houses are still remained partly in the Negro river and partly in the Lança river the tributaries of the Negro river. A channel excavation of the Lança river in Mafra is in progress. Structural measures for the main stream of the Negro river will not be financially viable due to topographic constraints.



Source: The Flood Prone Area is prepared by use of the 1983 Flood Record of the Prefectures of Uniao da Vitoria and Porto Uniao

Figure-7.3 Flood Prone Area of 1983 in União da Vitoria and Porto União

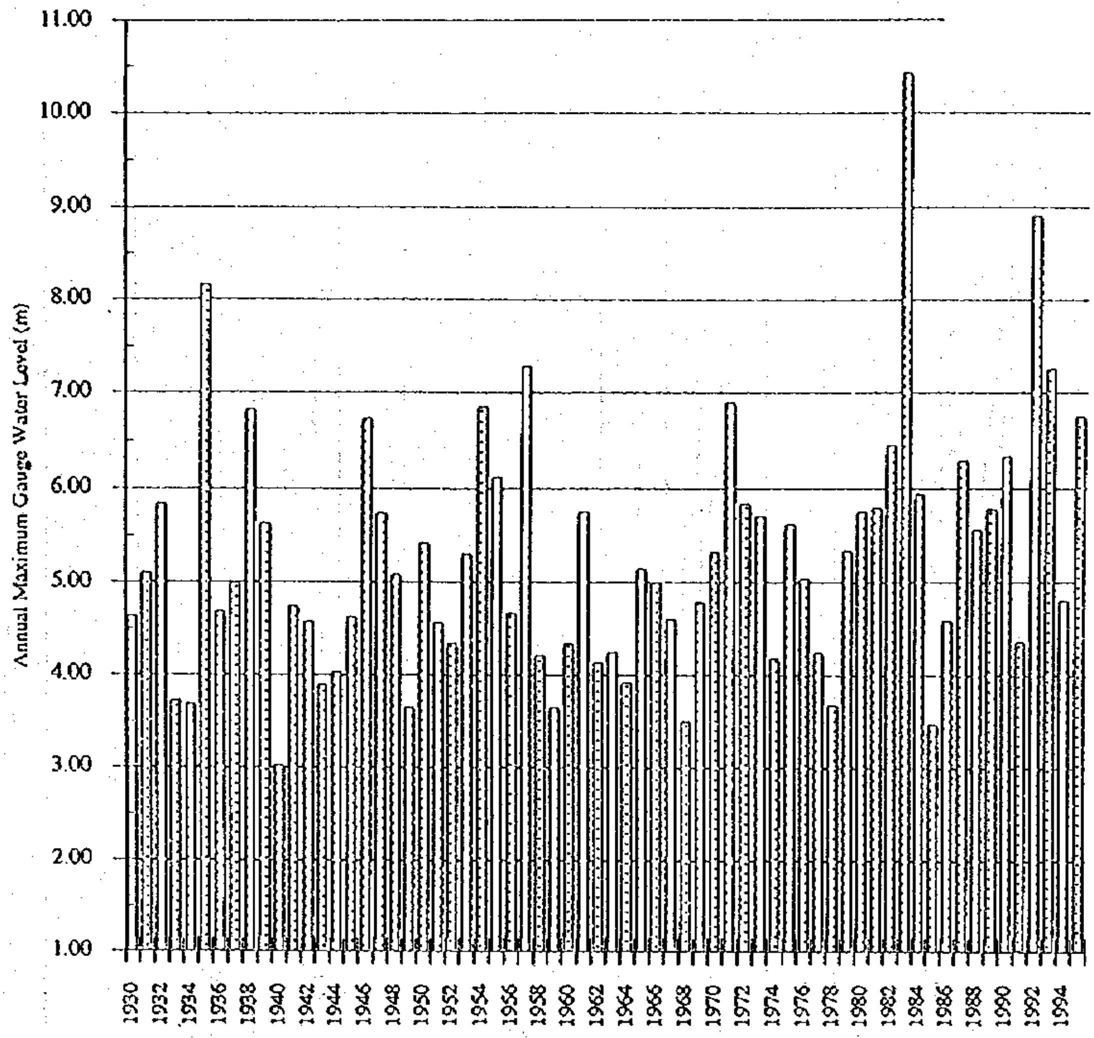


Number of Land Area	Value of Land ($ R per m^2)
1	60.00
2	40.00
3	12.50
4	5.00
5	2.50
6	1.50
7	0.75

Source: Prefecture of Uniao da Vitoria

Source: The Flood Prone Area is prepared by use of the 1992 Flood Record of the Prefecture of Uniao Da Vitoria

Figure-7.4 Flood Prone Area of 1992 and Conceptual Alignment of Dike System in União da Vitoria and Porto União



Year	Annual Maximum Gauge Water Level	Year	Annual Maximum Gauge Water Level	Year	Annual Maximum Gauge Water Level
1930	4.64	1952	4.34	1974	4.18
1931	5.10	1953	5.30	1975	5.62
1932	5.84	1954	6.85	1976	5.03
1933	3.73	1955	6.12	1977	4.24
1934	3.69	1956	4.66	1978	3.68
1935	8.16	1957	7.28	1979	5.33
1936	4.68	1958	4.20	1980	5.75
1937	4.99	1959	3.65	1981	5.79
1938	6.82	1960	4.34	1982	6.45
1939	5.63	1961	5.75	1983	10.42
1940	3.02	1962	4.13	1984	5.94
1941	4.74	1963	4.24	1985	3.47
1942	4.57	1964	3.92	1986	4.59
1943	3.89	1965	5.14	1987	6.28
1944	4.02	1966	4.99	1988	5.56
1945	4.62	1967	4.60	1989	5.78
1946	6.73	1968	3.50	1990	6.33
1947	5.74	1969	4.78	1991	4.36
1948	5.08	1970	5.32	1992	8.90
1949	3.65	1971	6.89	1993	7.25
1950	5.42	1972	5.84	1994	4.80
1951	4.56	1973	5.71	1995	6.75

Source: COPEL unit: meter

Figure-7.5 Annual Maximum Gauge Water Level at União da Vitoria

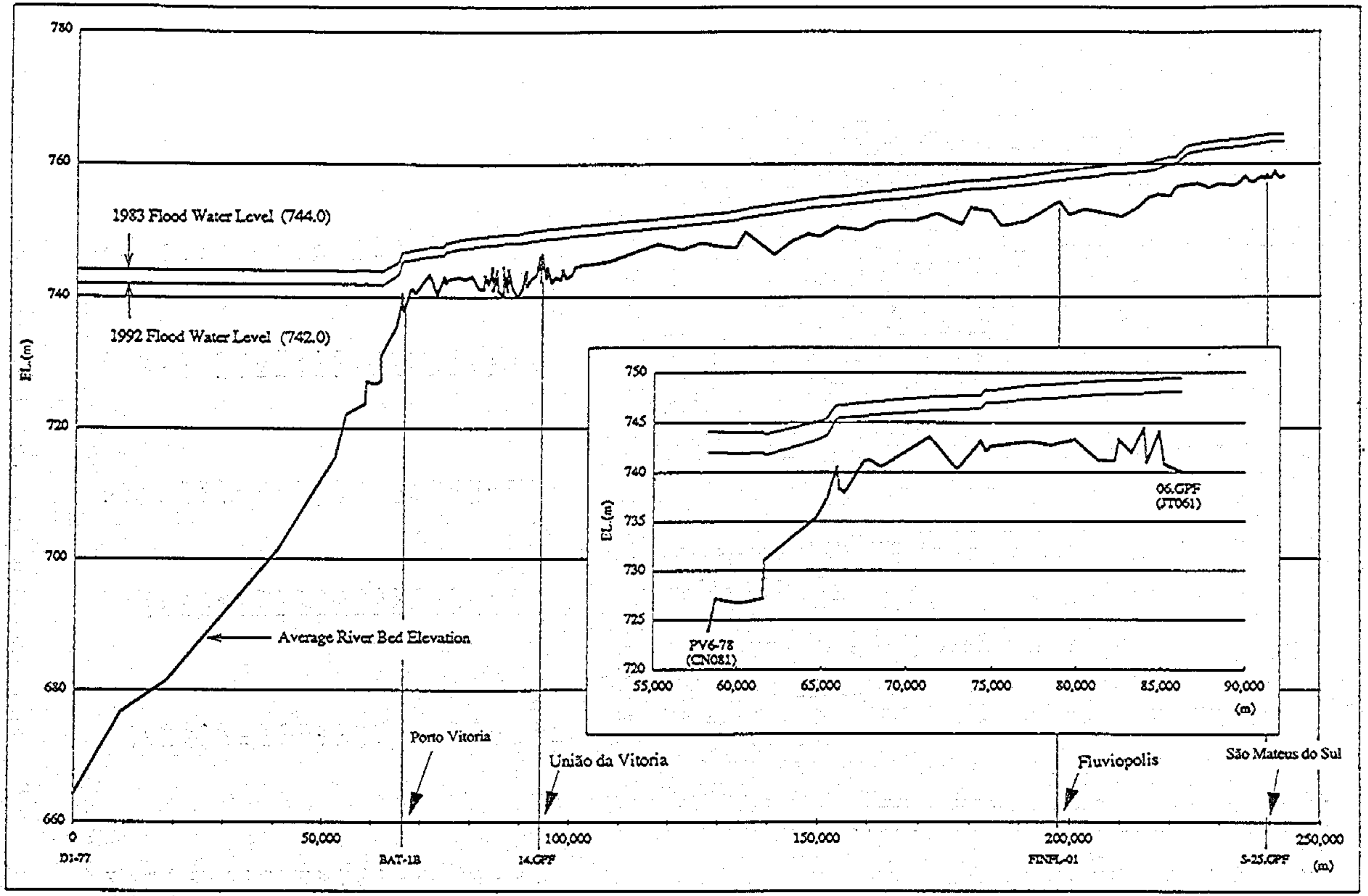


Figure-7.6 Flood Backwater from Foz do Areia Reservoir

7.2 Water Quality and Sewerage

7.2.1 Present Condition and Future Prediction of Pollutant Load of the Iguaçu River Basin

(1) Present Condition of Pollution Load and the River Water Quality

Judging from the present pollution level, the Iguaçu River basin can be divided into the upper river basin (Iguaçu ST.1 - ST.21) and the middle/lower river basin (Iguaçu ST.22 - ST.43) in order to make the analysis easier. Figure-7.7 illustrates the average BOD values for these two basins, based on the water quality data measured by SUREHAMA and IAP in the past 12 years from 1982 to 1993.

The BOD values in Figure-7.7 are the annual average values of all the water quality monitoring points in each basin. The difference between the two basins is clear. For the upper river basin, BOD exceeded 5 mg/l for most of the years with the highest value of 24 mg/l in 1986. The reason of river water pollution is due to the discharge of large quantity of domestic and industrial wastewater from the densely populated Curitiba M.A.

For the middle/lower Iguaçu river basin, the annual average BOD values were 2-3 mg/l through all these years. This is because of the lower pollutant load in this basin and the larger quantity of water flow where pollutants from the upper stream can be diluted.

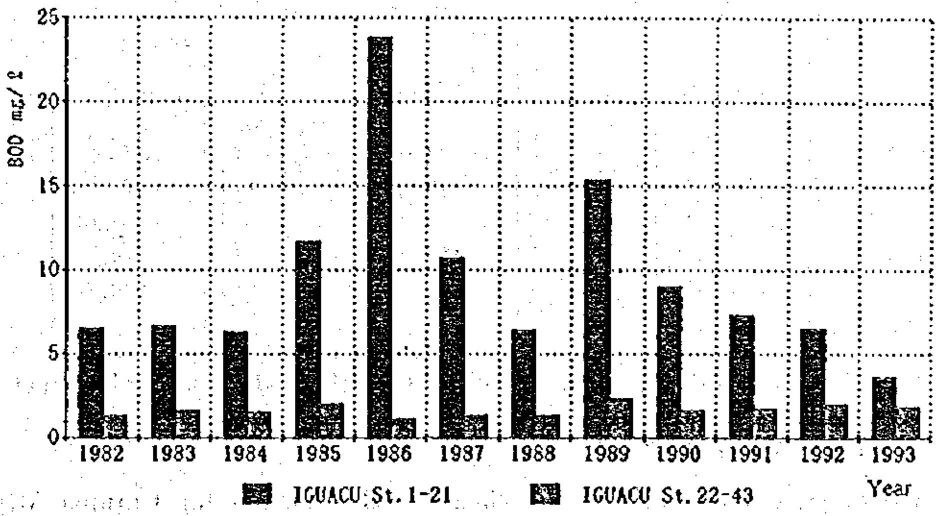


Figure-7.7 BOD Average of Iguaçu River Basin (1982 ~ 1993)

(2) Pollutant Load Prediction

Iguaçu basin is the most densely populated area in Paraná state. Domestic sewage and industrial wastewater are the main pollution sources to the river. Table-7.4 shows the predicted discharge BOD loads of these two kinds by the years of 2005 and 2015 with a comparison with those in 1993. It is understood from this table that besides an increase of the total BOD load in the whole basin, the percentage of domestic BOD load from the urban area will increase from 70% in 1993 to 74% in 2005 and 75% in 2015. This is due to the high rate increase in urban population. Therefore, pollutant load reduction should mainly be carried out in the urban area, especially in the large municipalities.

Table-7.4 Pollutant Load Prediction of Iguaçu Basin

Unit: KgBOD/day

Item	1993	2005	2015
Domestic (Urban Area)			
Population	2,837,310	3,831,190	4,671,360
BOD Load	153,215	206,884	252,253
Domestic (Rural Area)			
Population	925,830	835,160	734,240
BOD Load	49,995	45,099	39,649
Industrial BOD Load	18,630	29,017	43,573
Total BOD Load	221,840	281,000	335,475

(3) Target Cities for Pollutant Load Reduction

Table-7.5 shows the domestic BOD loads from several large cities in Iguaçu basin area and their populations. The largest BOD load is from Curitiba M.A. followed by Foz do Iguaçu and Cascavel. It is no doubt that Curitiba M.A should be given the top priority, and then Cascavel city which is situated at the upstream of a small tributary. As for Foz do Iguaçu city, since it is situated at the downstream of Iguaçu River where the run-off BOD load, although it is considerably high, can be diluted by the abundant river flow, pollutant load reduction is less emergent. Therefore Curitiba M.A. and Cascavel city were selected as the target cities in Iguaçu basin for pollutant load reduction.

Table-7.5 Pollutant Load from Large Cities

City	1993		2005		2015	
	Population	BOD (kg/day)	Population	BOD (kg/day)	Population	BOD (kg/day)
CURITIBA M.A.	1,908,360	103,051	2,524,380	136,317	3,040,510	164,188
FOZ do IGUAÇU	204,365	11,036	353,920	19,112	479,380	25,887
CASCAVEL	185,746	10,030	250,280	13,515	303,280	16,377
GUARA PUAVA	117,385	6,339	154,360	8,335	179,920	9,716
FRANCISCO BELTRAO	48,417	2,615	73,320	3,959	100,490	5,426

7.2.2 Pollutant Load Reduction Plan for Curitiba M.A. and Cascavel

1) Target Water Quality

The target water qualities for pollutant load reduction for Curitiba M.A. and Cascavel are set as follows considering present water quality and reasonably attainable water quality in future:

Curitiba M.A. BOD $\leq$ 10 mg/l (Class 3)

Cascavel BOD $\leq$ 5 mg/l (Class 2)

2) River Water Flow

The river flow (draught flow $Q_{10,7}$) was calculated from the specific flow rate and the city areas as follows:

Curitiba M.A. $Q_{10,7} = 0.231(m^3/s/100km^2) \times 2,800\ (km^2)$

$= 6.468\ m^3/sec = 558,835\ m^3/day$

Cascavel $Q_{10,7} = 0.420m^3/s/100km^2 \times 250\ km^2$

$= 1,050m^3/sec = 90,720m^3/day$

3) Quantity of Diluting Water

The quantity of water which dilutes the run-off BOD consists of the base flow in the river ($Q_{10,7}$) and the quantity of domestic sewage and industrial wastewater flowing into the river. Table-7.6 shows the calculated quantity of diluting water for the two cities.

Table-7.6 Quantity of Diluting Water

Unit: m^3/day

City	Year	$Q_{10,7}$	Domestic Sewage Discharge (1)	Industrial Wastewater Discharge (2)	Total
CURITIBA	2005	558,835	362,935	32,805	954,575
M.A.	2015	558,835	535,130	49,318	1,143,283
CASCAVEL	2005	90,720	31,035	3,189	124,944
	2015	90,720	48,525	4,783	144,028

Note: (1) = Population x Unit Water Consumption Rate x 80%
(2) = Actual discharge in 1993 x (1 + industrial sector growth rate)

(2) Pollution Analysis

1) Pollution Analysis of the Present Condition of Curitiba M.A.

a) Method of Analysis

Analysis of the present condition was conducted in order to determine the purification-residual ratio which is the fundamental parameter for the prediction of river water quality in future. The procedures of analysis are as follows:

(i) Calculate the discharge BOD load from each pollution source;

(ii) Calculate the run-off BOD load by taking into consideration the run-off ratio

(iii) Calculate the flow-out BOD load based on the current water quantity;

(iv) Evaluate the purification-residual ratio

b) Result of Analysis

The result of analysis is shown in Table-7.7. The purification-residual ratio was evaluated as 0.34. This value is used for future water quality prediction described in the following sections.

Table-7.7 Pollution Analysis of Present Conditionof Curitiba M.A.

	Item		Calculated Value
(1)	Population		
	Total	1)	1,908,860
	Sewage treatment served	2)	658,620
	No sewage treatment served	3)	1,249,740
(2)	Domestic Discharge Load BOD (kg/day)		
	Total	4)	103,051
	Treated by existing system	5)	35,565
	Untreated by existing system	6)	67,486
(3)	Run-off BOD Load (kg/day)		
	Total	7)	70,379
	From untreated domestic load	8)	53,989
	From treated domestic load	9)	5,335
	From industrial load	10)	11,055
(4)	Quantity of Diluting Water (m^3/sec)	11)	801,290
(5)	Measured Water Quality (BOD mg/l)	12)	30
(6)	Calculated Flow-out Load (BOD kg/day)	13)	24,040
(7)	Purification-residual Ratio	14)	0.34

Note: 2) = 1) x 0.345 (diffusion rate in 1994), 3) = 1) - 2), 4) = 5) + 6), 5) = 2) x 0.54, 6) = 3) x 0.54, 7) = 8) + 9) + 10), 8) = 6) x 0.8, 9) = 5 x 0.15, 10): based on actual data, 11) & 12): Assumed, 13) = 11) x 12) ÷ 1000, 14) = 13) ÷ 7)

2) Pollution Analysis for 2005 and 2015

a) Analysis methods

i) The domestic and industrial discharge BOD loads were calculated as follows:

– Domestic load : From the population predicted for the future.

– Industrial load : Directly proportional to GRDP growth.

ii) Target water qualities for the two cities were set as follows:

Curitiba M.A. : BOD < 10 mg/ l

Cascavat: BOD < 5 mg/l

iii) The permissible BOD load was calculated according to the target water quality.

iv) The quantity of pollution reduction was evaluated from the difference between the predicted run-off BOD load and the permissible run-off BOD load.

b) Calculation results

The calculation results are shown in Table-7.8.

Table-7.8 Pollution Analysis and Pollutant Reduction Plan for 2005 and 2015

Item		CURITIBA M.A.		CASCAVEL	
		2005	2015	2005	2015
Urban Population	1)	2,520,380	3,040,510	250,280	303,280
Discharge BOD Load					
From domestic sewage (kg/day)	2)	136,100	164,188	13,515	16,377
From industrial wastewater (kg/day)	3)	16,361	23,216	216	305
Permissible Flow-out Load					
Target Water Quality (BOD mg/l)	4)	10	10	5	5
Diluting Water (m^3/day)	5)	954,575	1,143,285	124,944	144,028
BOD Load (kg/day)	6)	9,546	11,432	625	720
Permissible Run-off Load (BOD kg/day)	7)	28,076	33,624	2,083	2,400
Run-off Load of the Permissible Domestic Wastewater (BOD kg/day)	8)	11,715	10,408	1,867	2,095
BOD Load Reduction for Domestic Wastewater					
Total BOD Load (kg/day)	9)	136,100	164,188	13,515	16,377
Treated BOD Load by existing system (kg/day)	10)	28,452	28,452	2,318	2,318
Reduction BOD Load (kg/day)	11)	93,004	122,726	8,864	11,440
Quantity of Sewage Treatment					
Method of Treatment		Standard Activated Sludge	Standard Activated Sludge	Anaerobic + Aerobic Treatment	Anaerobic + Aerobic Treatment
BOD Removal Efficiency (%)	12)	95	95	80	80
BOD Load Factor (g/person/day)	13)	54	54	54	54
Unit Discharge (lit./person/day)	14)	144	176	124	160
Treatment BOD Load (g/day)	15)	97,899	129,185	11,080	14,300
Population to be Served	16)	1,813,000	2,392,315	205,185	264,815
Quantity of Sewage Treatment (m^3/day)	17)	261,064	421,047	25,443	42,370

Note: 2) = 1) x 0.054, 3) = discharge in 1993 (1 + industrial sector growth rate), 5): refer to Table-7.6
6) = 4) x 5) ÷ 1000, 7) = 6) ÷ 0.34 (0.30), 8) = 7) - 3), 9) = 2), 10) = Treated BOD in 1993 x 0.8
11) = 9) - 8) ÷ 0.8 - 10), 15) = 11) ÷ 12) ÷ 100, 16) = 15) ÷ 0.054, 17) = 14) x 16) ÷ 1000

(3) Plans for the Reduction of Pollutant Load by the Year 2005 and 2015

Based on the result of calculation shown in Table-7.8, the BOD load to be reduced for Curitiba M.A. is 93,004 and 122,726 kg/day by the years of 2005 and 2015, respectively, and that for Cascavel is 8,864 and 11,440 kg/day. This needs implementation of sewage treatment facilities of capacities mentioned above to remove these amounts of pollutants.

Plans of sewage treatment are also shown in Table-7.8. For Curitiba M.A., the standard activated sludge process will be applied in consideration of its high treatment efficiency (95% BOD removal) for reduction of the great amount of pollutants. For Cascavel, the method of anaerobic digestion followed by aerobic treatment (80% BOD removal) will be applied.

7.2.3 Pollution Analysis of the Whole Iguaçu River Basin

(1) Objective and Methodology

1) Objective

The objective of pollution analysis is to investigate the water quality at each of the control points in the whole Iguaçu river basin in 2005 and 2015 on condition that pollutant reduction plans are implemented in Curitiba M.A. and Cascavel. If the target water quality cannot be met at some of the control points, additional plans will have to be worked out for pollutant reduction in the related areas.

2) Methodology

For the pollution analysis of the whole river basin, a water quality simulation model is formulated on the basis of Streeter-Phelps formula. This model can mainly simulate the self-purification process in a river course where organic pollutants are removed by biological degradation, sedimentation and absorption.

(2) Pollution Analysis

1) Water Quality Control Points

In order to select water quality control points for pollution analysis, Iguaçu river basin was divided into 20 sub-basins. Each sub-basin contains one or two water quality control points. The locations of the selected 22 water quality control points are shown in Figure-7.8.

2) Fundamental Parameters

(i) The parameters used for pollutant load calculation were assumed as shown in Table-7.9 referring to Japanese guideline.

Table-7.9 Parameters for Pollutant Load Calculation

Item	Pollutant Load Factor	Run-off Ratio
Domestic Sewage	54 gBOD/person/day	Urban area: 0.8 Rural area: 0.1
Industrial Wastewater		1.0
Livestock Wastewater	Cattle: 600 gBOD/head/day Pig: 200 gBOD/head/day	0.05 0.05

(ii) Self-purification Coefficient

By an analysis of the current condition of pollutant load and water quality in the river basin, the self-purification coefficient was evaluated as 1.5 for the main stream and 0.8 for the tributaries of Iguaçu river.

(iii) River Flow Velocity

Based on the collected information about the hydrological characteristics of Iguaçu river, the average flow rate was assumed as 0.4 m/sec in the river course and 0.01 m/sec in the dam area.

3) Analysis Results

Table-7.10 shows the results of water quality prediction for the 12 control points along Iguaçu river. The BOD concentrations at most of these points are lower than 1.0 mg/l by both the years of 2005 and 2015, except for No. 1 at the immediate downstream of Curitiba M.A. where the target water quality was set as 10 mg/l. The lowest BOD value appears at control points No. 6 to No. 9 as only 0.01 mg/l. This is because dams are built in the main river and these sub-basins where water flows very slowly and self-purification efficiency is very high. The results indicate that if pollutant load from Curitiba M.A. and Cascavel can be reduced as has been planned in the former section, the water quality in the whole river basin can be soundly improved. Therefore, sewage treatment implementation should mainly be planned for the two large municipalities.

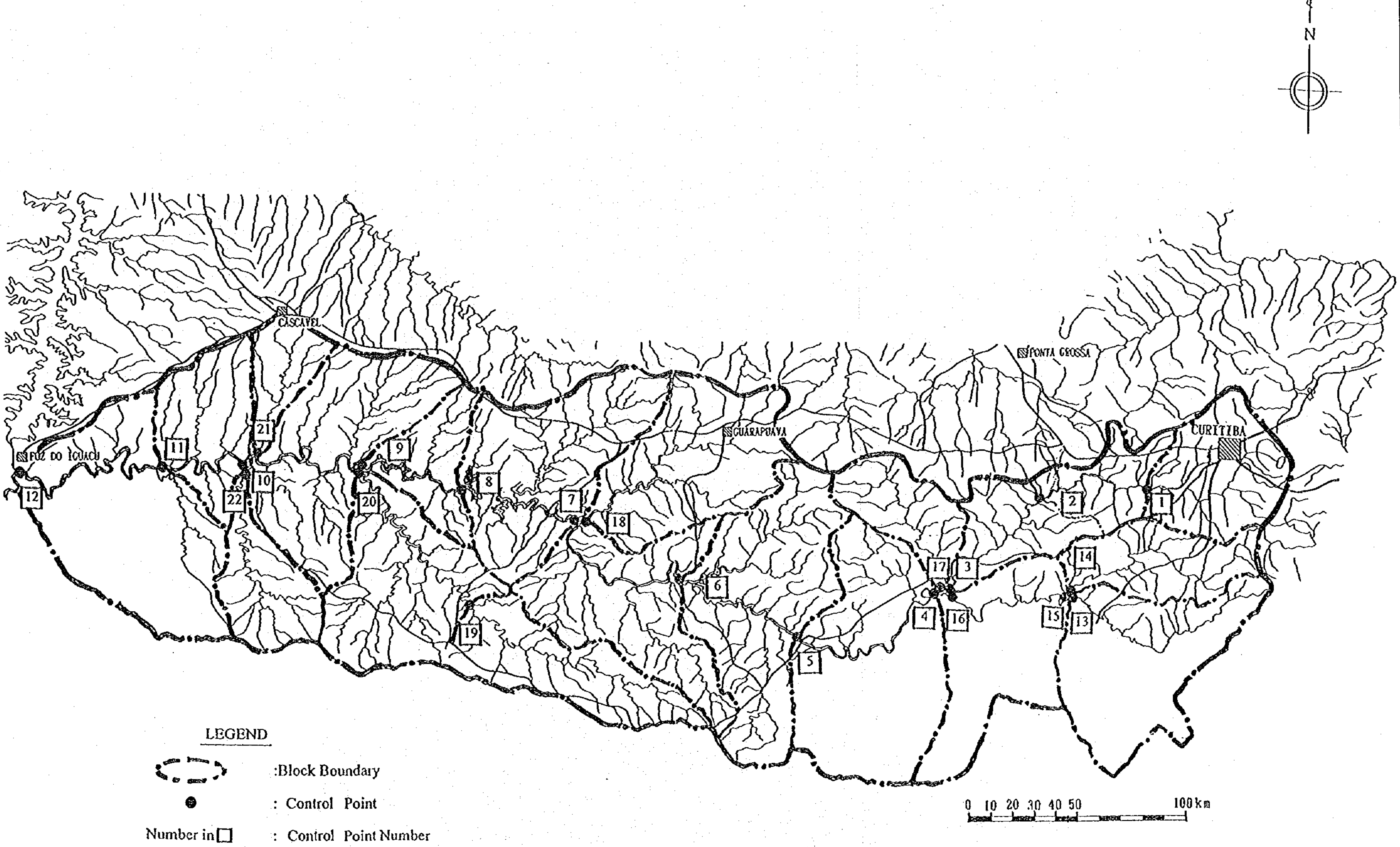


Figure-7.8 Water Quality Control Points in Iguaçu River Basin

Table-7.10 Water Quality Prediction of Iguaçu River

Unit: mgBOD/l

Water Quality Control Point	2005	2015
No.1	4.02	5.84
No.2	0.53	0.71
No.3	0.42	0.47
No.4	0.35	0.39
No.5	0.08	0.10
No.6	0.01	0.01
No.7	0.01	0.01
No.8	0.01	0.01
No.9	0.01	0.01
No.10	0.21	0.23
No.11	0.06	0.06
No.12	0.13	0.16

7.2.4 Sewage Treatment Plan

(1) Quantity of Sewage to be Treated

As has been discussed in the former sections, the target cities for pollutant reduction are Curitiba M.A. and Cascavel. Therefore, sewage treatment facilities have to be implemented in these two municipalities. Table-7.11 shows the quantity of sewage to be treated by the years of 2005 and 2015, based on the results of pollution analysis in 7.2.2.

Table-7.11 Quantity of Sewage to be Treated

Unit: m^3/day

Year	CURITIBA M.A.	CASCAVEL
2005	260,000	25,000
2015	420,000	45,000

(2) Project Implementation Plan

Table-7.12 shows the implementation plan of sewage treatment system for Curitiba M.A. and Cascavel. The plans will start in 1996 and be carried out through 4 stages to the target year of 2015.

Table-7.12 Project Implementation Plan

Unit: m^3/day

Implementation Period	CURITIBA M.A.		CASCAVEL	
	Treatment Capacity	Treatment Method	Treatment Capacity	Treatment Method
1996~2000	100,000	a	---	b
2001~2005	100,000	a	20,000	b
2006~2010	100,000	a	---	b
2011~2015	120,000	a	25,000	b
Total	420,000		45,000	

Note: The treatment methods and efficiencies corresponding to the symbols are as follows:

		BOD Removal (%)
a:	Standard Activated Sludge Process	95
b:	Anaerobic Digestion + Aerobic Treatment	80

(3) Project Cost Estimation

The project cost was estimated based on the SANEPAR's "Plano Director de Esgotamento Santario de Curitiba de Regao Metropolitana (Sept., 1993)" which provided the standard unit cost for sewerage system construction. Table-7.13 shows the costs for sewage treatment facility construction including the additional cost for the construction of sewer pipelines and other accessory facilities. For Curitiba M.A., the total cost will be about US$ 293.6 million, and for Cascavel, it will be about US$ 49.5 million.

Table-7.13 Total Construction Cost

(Unit: US$ x 1,000, Year 1994)

Period	CURITIBA M.A.	CASCAVEL
1996~2000	70,300	23,400
2001~2005	70,300	---
2006~2010	70,000	26,100
2011~2015	82,700	---
Total	293,600	49,500

Note) The cost includes those for sewage treatment facilities, sewer pipelines and other accessory facilities.

7.3 Soil Erosion

At the Strategy study, the current and future soil loss from Iguaçu river basin was roughly estimated with USLE, Universal Soil Loss Equation. Since the main objectives of USLE application at Strategy is to grasp the magnitude of soil loss, the data with a large division wise was used and analyzed.

USLE was applied to Iguaçu river basin again for the following objectives and Municipality wise data was used to determine each factor in USLE. The data regarding agriculture in 1994 was obtained from EMATER and GIS computation was conducted by SANEPAR based on the IAP satellite imagery analysis (1990 &1994).

1) To identify the location with high degree of soil erosion in order to formulate the soil conservation plan with location priority

2) To evaluate the effectiveness of the soil conservation plan proposed

7.3.1 Current Gross Soil Loss

(1) Determination of Factors in USLE

Compared to the simulation at the Strategy study, the simulation for Iguaçu river basin was involved in much detail analysis of the data with Municipality wise and some factors of USLE were estimated applying RUSLE, Revised Universal Soil Loss Equation. In the following sections, the determination of USLE factors is briefly explained and the result is discussed.

USLE is expressed in equation-1.

$$A = R \cdot K \cdot LS \cdot C \cdot P \qquad \cdots\cdots\cdots(1)$$

where A: annual gross erosion (ton/ha), R: rainfall factor (MJ·mm/ha·hr), K: soil erodibility (ton·ha·hr/ha·MJ·mm), LS: slope length and steepness factor (dimensionless), C: cover and management factor (dimensionless), P: support practice factor (dimensionless)

Since the above factors in USLE are local dependent variables, the improvement of model requires careful examinations of local data. Therefore, the model was applied close cooperation with Roloff, Federal University of Paraná, especially the determination of K and C factors.

1) R factor

Rufino et al. (1993) derived the following correlation equation of rainfall factor, R, with average monthly and annual rainfall. Their equation was applied to compute rainfall factor of each Municipality.

$$R = a + b \cdot Rc$$

$$Rc = p^2 / P$$

where R; rainfall factor, a and b: coefficient, Rc: rainfall coefficient, p: average monthly rainfall (mm), P: average annual rainfall (mm)

2) K factor

Roloff and Denardin (1994) derived the regression equation to estimate K with silt fraction, fractions of iron and aluminium oxides, amount of fine sand and permeability. Assuming no seasonal variation of K, their equation was adopted to determine K factor of soils in Iguaçu river basin.

3) LS factor

The following equations in RUSLE were applied.

$$L = (\lambda / 22.1)^m \qquad m = \beta / (1 + \beta)$$

$$S = 10.8 \sin(\theta) + 0.03 \qquad steepness < 9\%$$

$$S = 16.8 \sin(\theta) - 0.50 \qquad steepness \geq 9\%$$

where λ : slope length (m), β : a ratio of rill and interrill erosion, θ : slope angle

4) C factor

Compared to USLE, the major advantage of RUSLE is the determination of C for crop land as a function of the effect of prior land use, canopy cover, surface cover and surface roughness. Since C determination with RUSLE requires crop and tillage databases, agricultural data from EMATER and Roloff's database were used.

C factors for perennial crops, reforestation and fallow were estimated with the surface method developed by Dissmeyer and Foster (1981), while C factors for forest and permanent pasture were estimated with the original USLE, Agricultural handbook No. 537 (Wishmeier and Smith, 1978).

5) P factor

It was obtained from the original USLE, Agricultural handbook No. 537 (Wishmeier and Smith, 1978).

(2) Result of Simulation

Current gross soil loss estimated for each landuse classification is shown in Table-7.14 with Municipality wise. The soil loss from crop land ranges between 1.9 to 146.0 ton/ha·year depending on the spatial variation of cropping pattern, tillage, soil conservation and so on. The average soil loss from Iguaçu river basin is 28 ton/ha·year at the Strategy study, while one at the Master Plan study is 18 ton/ha·year. This discrepancy is mainly due to:

1) difference in scale of data

The Strategy study adopted agricultural data with EMATER division wise, which splits Paraná in 20 regions, while the Master Plan study adopted agricultural data with Municipality wise in order to specify the crop land (the land use classification) with cropping pattern, tillage and cultivation methods, extension of soil conservation and so on.

2) difference in scale of analysis

The data analysis for the determination of USLE factors was conducted by EMATER division wise at the Strategy study, while USLE factors were determined for the specific land use in each Municipality at the Master Plan study.

The accuracy of the model should be examined through the comparison between the result computed and real data; however, in Paraná neither USLE nor RUSLE has been tested enough. Since the USLE model at the Master Plan study was involved in the detail analysis of data to compute factors of USLE, the result in Table-7.14 was adopted to propose the Master Plan. The result of USLE at the Strategy study is considered to have at least enough accuracy to compare the magnitude of soil loss from river basins.

The average soil loss of Municipalities was classified from low to high. Low means soil loss less than 10 ton/ha·year, Medium is between 10 and 20 ton/ha·year and High is more than 20 ton/ha·year. As shown in Figure-7.9, The most of area with high soil erosion is located on the left side in the downstream of Iguaçu river basin due to high rainfall erosivity and large crop area, while soil loss on the right side in the downstream of Iguaçu is low because of the large area of forest preserved.

Table-7.14 Current Gross Soil Loss in Iguaçu River Basin

Unit: ton/ha/year

No.	Municipality	Area (km2)	1994 Forest	2nd Veg.	Ref.	Pasture	Crop	Average	No.	Municipality	Area (km2)	1994 Forest	2nd Veg.	Ref.	Pasture	Crop	Average
I-001	Campina Grande do Sul	79.2		3.2	1.3	1.6	19.0	4.6	I-052	Manopolis	232.1	0.3	2.9		3.4	2.8	2.9
I-002	Quatro Barras	99.5	0.1	4.6	1.5	6.0	14.3	6.6	I-053	Vitorino	326.1	0.1	1.4		4.1	53.7	29.7
I-003	Piraquara	171.9	0.2	4.7		11.4	24.3	10.7	I-054	Renascenca	434.7	0.3	7.1	3.2	4.0	18.1	11.2
I-004	Sao Jose dos Pinhais	674.2	0.1	3.7	1.3	7.4	19.9	11.8	I-055	Bom Sucesso do Sul	135.3		7.8		2.3	30.6	18.1
I-005	Colombo	127.6		1.5		1.5	18.5	4.0	I-056	Itapejara D'Oeste	246		9.5		2.4	102.3	57.2
I-006	Pinhais	98.2		0.5		1.6	18.6	10.7	I-057	Vere	345.6		9.5		24.2	51.2	36.9
I-007	Almirante Tamandare	189.3		4.0		5.8	19.2	7.7	I-058	Sao Joao	408.9	0.3	10.0		24.0	26.1	23.6
I-008	Curitiba	431.7		0.6		1.9	16.3	8.6	I-059	Sulina	158.5		10.1		26.3	79.8	53.3
I-009	Campo Largo	297.2		3.8	1.6	13.1	114.2	65.0	I-060	Saudade do Iguacu	147.8	0.3	7.8		20.6	27.3	21.8
I-010	Araucaria	503.7		1.7		1.5	22.9	13.8	I-061	Rio Bonito do Iguacu	459.3	0.2	0.8		7.0	45.8	6.8
I-011	Fazenda Rio Grande	110.9		0.5		1.7	19.1	10.8	I-062	Nova Laranjeiras	578.8	0.3	6.1	2.6	19.4	101.0	19.6
I-012	Mandirituba	392.3		3.3	1.1	10.2	16.5	11.3	I-063	Guaraniacu	495	0.3	10.1		28.2	82.7	32.4
I-013	Tijucas do Sul	422.6	0.2	3.1	1.5	4.0	18.4	5.8	I-064	Quedas do Iguacu	1192.9	0.2	0.7	0.2	5.4	28.1	7.0
I-014	Balsa Nova	319.7		2.2	1.1	2.0	29.7	8.3	I-065	Sao Jorge do Oeste	385.1	0.3	10.1		14.1	45.0	28.5
I-015	Contenda	222.2		3.3		4.2	30.2	18.7	I-066	Cruzeiro do Iguacu	96.6	0.3	9.1		11.4	55.4	34.1
I-016	Quitandinha	419.4	0.1	3.3	1.1	10.9	23.8	14.4	I-067	Boa Esperanca do Iguacu	249.4	0.3	10.1		33.7	120.9	77.1
I-017	Agudos do Sul	259.6	0.2	4.6	1.7	14.5	60.9	35.6	I-068	Dois Vizinhos	372.7		9.5		14.6	38.8	27.2
I-018	Pien	261.7	0.1	3.3	1.1	10.9	34.5	19.4	I-069	Eneas Marques	234.7		9.5		31.8	72.8	42.4
I-019	Rio Negro	603.2		4.3	1.7	12.4	33.1	11.0	I-070	Francisco Beltrao	696.7	0.3	9.5		7.3	52.9	31.5
I-020	Campo do Tenente	314	0.2	4.7	1.9	5.5	17.3	9.8	I-071	Marmeleiro	449.9	0.3	9.5	3.2	4.0	17.7	12.6
I-021	Lapa	2203.9	0.2	3.8	1.9	2.5	11.9	6.7	I-072	Flor da Serra do Sul	94.7		1.0		3.5	45.6	23.9
I-022	Porto Amazonas	153		1.5	0.5	5.1	19.2	8.1	I-073	Barracao	386.3		9.5		31.8	107.7	62.5
I-023	Palmeira	273.4	0.1	2.5	0.8	2.0	3.5	2.8	I-074	Salgado Filho	506.4		9.5		12.0	127.2	29.7
I-024	Sao Joao do Triunfo	708.1	0.1	2.6	0.5		17.8	4.9	I-075	Santo Antonio do Sudoeste	313.8		9.2		22.9	53.9	37.9
I-025	Antonio Olinto	482.5	0.2	2.7			29.6	12.0	I-076	Pranchita	297.1		8.6		10.5	37.3	23.8
I-026	Sao Mateus do Sul	1332.8	0.1	1.5	0.9		26.0	9.7	I-077	Pinhal de Sao Bento	107.6		7.8		9.1	46.6	14.0
I-027	Reboucas	498.9	0.1	4.0			44.5	27.5	I-078	Ampere	307.9		9.2		5.6	37.7	19.6
I-028	Ireti	408.1	0.1	4.2	0.9		56.7	32.2	I-079	Nova Esperanca do Sudoeste	176.9	0.3	9.5		31.8	141.4	86.2
I-029	Rio Azul	642.6	0.0	3.6		14.8	51.3	26.6	I-080	Salto do Lontra	336.9	0.3	9.5		14.6	45.6	28.6
I-030	Mallet	672.8	0.1	4.7			77.2	34.4	I-081	Santa Izabel do Oeste	330.5	0.3	9.7	3.2	27.1	65.8	41.9
I-031	Paulo Frontin	377.5	0.0	0.7	0.3		12.1	7.1	I-082	Nova Prata do Iguacu	333	0.3	10.1		31.6	36.3	31.2
I-032	Paula Freitas	417	0.0	0.8	0.3		19.9	9.1	I-083	Perola do Oeste	330.1	0.3	9.7		24.4	79.8	50.5
I-033	Uniao da Vitoria	773.9	0.1	5.7		2.9	17.1	6.2	I-084	Planalto	337.1	0.0	9.7		32.2	43.3	35.9
I-034	Porto Vitoria	220.2	0.2	6.9		0.0	8.2	6.2	I-085	Realeza	351.9	0.3	9.7		29.4	50.3	40.2
I-035	General Carneiro	1063.7	0.2	5.0		2.6	22.7	7.4	I-086	Capanema	403.9	0.3	9.7		32.2	73.0	56.2
I-036	Bituruna	1209.7	0.2	5.1		2.3	24.3	7.6	I-087	Tres Barras do Parana	521.7	0.3	10.1	3.4	3.3	14.7	10.4
I-037	Cruz Machado	1500.5	0.2	5.9		2.3	24.5	12.1	I-088	Catanduvas	593.9	0.3	2.2	3.4	10.4	28.3	14.7
I-038	Inacio Martins	879.9	0.2	1.4		2.6	27.5	7.5	I-089	Ibema	148.3	0.3	8.0	3.4	10.6	5.3	7.2
I-039	Guarapuava	3402.7	0.3	7.4	2.6	4.7	1.9	3.2	I-090	Cascavel	1198.9	0.3	7.1	3.4	2.8	12.5	8.7
I-040	Pinhao	2875.2	0.3	4.2		2.5	14.1	6.5	I-091	Boa Vista da Aparecida	232.2		10.0		11.5	26.2	19.2
I-041	Palmas	3125.5	0.3	7.7		4.3	9.7	5.1	I-092	Capitao Leonidas Marques	279.8	0.3	9.7		25.7	29.5	26.2
I-042	Clevelandia	708.4	0.3	3.9		2.8	34.6	18.1	I-093	Santa Lucia	137.1	0.3			32.2	137.3	99.6
I-043	Honorio-Serpa	806.6	0.3	8.0		9.6	110.8	53.3	I-094	Lindoeste	273.2	0.3	10.1		26.9	88.6	59.5
I-044	Mangueirinha	801.3	0.3	7.8		14.3	13.2	10.4	I-095	Santa Tereza do Oeste	235.5	0.3	10.1	3.4	10.8	11.6	10.4
I-045	Candoi	999.8	0.3	7.8		24.6	28.3	19.1	I-096	Ceu Azul	937.2	0.2	2.2		7.4	5.9	0.8
I-046	Cantagalo	774.1	0.3	3.5		18.5	146.0	62.5	I-097	Matelandia	601.4	0.2	2.3		6.7	5.9	2.2
I-047	Virmound	198.4	0.1	3.7		26.1	68.2	39.0	I-098	Medianeira	621.1	0.2	2.4		6.7	14.3	5.6
I-048	Laranjeiras do Sul	1052.7	0.2	5.4		20.2	83.3	38.6	I-099	Sao Miguel do Iguacu	455.7	0.3	8.2	0.0	9.6	32.0	17.3
I-049	Chopinzinho	992.5	0.1	7.4	0.7	19.5	22.5	16.8	I-100	Santa Terezinha de Itaipu	162.1	0.0	0.7		3.9	16.7	10.2
I-050	Coronel Vivida	681.5	0.3	9.9	3.3	15.2	66.5	35.7	I-101	Foz do Iguacu	312.2	0.1	3.1		8.6	32.9	13.2
I-051	Pato Branco	570.2	0.3	3.7		4.1	73.3	34.9		Total	55776					Average	17.8

Area: = Total Area of Municipality - Area of Others in Landuse Classification   2nd Veg.: Secondary Vegetation, Ref.: Reforestation

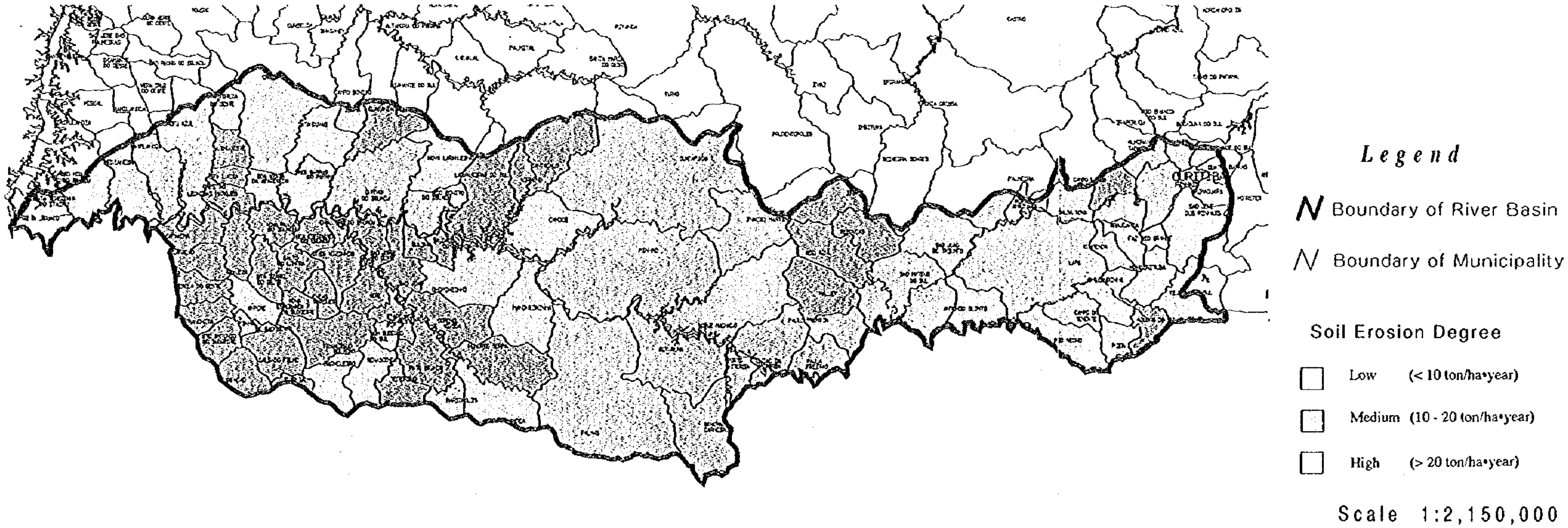


Figure-7.9 Local Variation of Soil Erosion in Iguaçu River Basin

7.3.2 Master Plan

The soil conservation is to control the erosion below a threshold level depending on a specific object. The theoretical threshold is a state of equilibrium between the amounts of erosion and soil formation. On the other hand, the practical threshold generally applied is a less severe level to maintain soil fertility in the medium term (20 and 25 years) allowing soil amendment with fertilizer, green manure, lime etc.

To determine criteria and threshold, the specific object is required. Since no criteria are available in Paraná to establish a threshold of erosion control for the water environment, the widely acceptable figures in terms of area of river basin were adopted at the Strategy. These figures were applied to Iguaçu river basin also as a goal of soil conservation. Therefore, the threshold of soil loss to propose a soil conservation plan (Master Plan) by the year of 2015, is 11 ton/ha·year. After the suppression of soil loss below the threshold, 2 ton/ha·year which is widely acceptable values for a large river basin will be achieved successively.

The soil conservation plan have to integrate the agronomic measures, soil management and mechanical measures because they have different effect on soil erosion and are the most effective when integrated rather than individual implementation.

Specific countermeasures depend on crop, size of farmers, farming system and so on. Considering the agricultural characteristics in Iguaçu river basin, the soil conservation plan was formulated as a Master Plan and shown in Table-7.15. For the application of the soil conservation plan at field, the suitable measures should be selected from the table examining local variation of agriculture.

The main target of the Master Plan in Iguaçu river basin is to suppress the soil loss from crop lands. Since terracing and non tillage are the most effective measures, their implementation is essential. Terracing with contouring should cover 100 % of the crop area and non tillage is expected to be practiced in 50 % of beans, maize and soybean fields by the year of 2015. Application of other measures depend on the local characteristics of agriculture.

The effectiveness of soil conservation plan was examined applying USLE. For the computation sake, the following assumptions were made.

1) 100 % implementation of terracing with contouring to crop land

2) 50 % implementation of non tillage to beans, maize and soybean field where the current application of non tillage is less than 50 %

3) no consideration of other measures , such as agronomic measures and soil management

As shown in Table-7.16, the average soil loss would be reduced to 4 ton/ha·year with the Master Plan. Since no other measures than terracing and non tillage are counted in estimation of future soil loss, the result is considered as underestimation. If the Master Plan was implemented fully, less soil loss would be expected.

Table-7.15 Soil Conservation Plan (Master Plan) in Iguaçu River Basin

Crop	ML	Essential TY	Essential Measures	Essential Effect	Ideal TY	Ideal Measures	Ideal Effect
all crop field and Pasture	—	M	improvement of farm road	2	M	diversion ditches	2
		M	drainage along road side	2	M	terrace channels	2
		A	proper spacing of crops	1 &2	M	grass water ways	2
		A	proper crop calendar	1 &2	M	energy dissipater at outlet of drainage	2
		S	maintenance of soil fertility	1 &2			
		A	proper plant selection	1 &2			
Soybean Wheat Maize Beans	I	M	terracing with contour cropping	2	M	contour stripcropping	2
		M	buffer stripcropping	2	A	non tillage	1&2
		S	avoid excess operation of machinery	2			
		S	subsoiling to stir hard pan of soil	2			
		S	proper plowing or harrowing	2			
		A	mulching by crop residue	1 &2			
		A	seeding of winter green manure crops	1 &2			
Maize Beans	II	M	terracing with contour cropping	2	A	non tillage with animal	1&2
		M	buffer strips with stones	2			
		M	buffer stripcropping	2			
		A	mulching by crop residue	1 &2			
		A	seeding of winter green manure crops	1 &2			
		M	contour stripcropping	2			
		A	intercropping with green manure crops	1&2			
		M	stripcropping with spring & summer crop	1			
Potato	I	M	terracing with contour cropping	2			
		S	proper plowing or horrowing	1			
		S	avoid excess operation of machinery	2			
Cotton Sugarcane Cassava	I	M	terracing with contour cropping	2	M	contour stripcropping	2
		M	buffer stripcropping	2			
		S	avoid excess operation of machinery	2			
		S	subsoiling to stir hard pan of soil	2			
		S	proper plowing or harrowing	2			
		S	seeding of winter green manure crops	1 &2			
Cotton Sugarcane Cassava	II	M	terracing with contour cropping	2	M	contour stripcropping	2
		M	buffer strips with stones	2			
		M	buffer stripcropping	2			
		A	seeding of winter green manure crops	1 &2			
Olericulture	I	M	terracing with contour cropping	2			
Pasture	I & II	M	terracing	2	A	crop rotation	1
		M	water supply system for cattle	1&2	A	perennial forage	2

Abbreviation: ML: Management Level, I: Mechanized Farming System, II: Farming System with Man or Animal Power
TY: Type of Measures, M: Mechanical Measures, A: Agronomic Measures, S: Soil Management
1: Effect on Rainsplash, 2: Runoff

Table-7.16 Soil Loss with Master Plan in 2015

Unit: ton/ha/year

No.	Municipality	Area (km2)	2015 Forest	2nd Veg.	Ref.	Pasture	Crop	Average
I-001	Campina Grande do Sul	79.2		3.2	1.3	1.6	0.2	2.1
I-002	Quatro Barras	99.5	0.1	4.6	1.5	6.0	0.2	2.7
I-003	Piraquara	171.9	0.2	4.7		11.4	0.6	2.8
I-004	Sao Jose dos Pinhais	674.2	0.1	3.7	1.3	7.4	0.3	2.5
I-005	Colombo	127.6		1.5		1.5	0.2	1.3
I-006	Pinhais	98.2		0.5		1.6	0.5	0.8
I-007	Almirante Tamandare	189.3		4.0		5.8	0.3	3.6
I-008	Curitiba	431.7		0.6		1.9	0.3	0.8
I-009	Campo Largo	297.2		3.8	1.6	13.1	1.9	3.7
I-010	Araucaria	503.7		1.7		1.5	0.4	0.9
I-011	Fazenda Rio Grande	110.9		0.5		1.7	0.3	0.7
I-012	Mandirituba	392.3		3.3	1.1	10.2	0.3	3.5
I-013	Tijucas do Sul	422.6	0.2	3.1	1.5	4.0	0.2	2.3
I-014	Balsa Nova	319.7		2.2	1.1	2.0	0.5	1.7
I-015	Contenda	222.2		3.3		4.2	0.5	1.9
I-016	Quitandinha	419.4	0.1	3.3	1.1	10.9	0.5	2.3
I-017	Agudos do Sul	259.6	0.2	4.6	1.7	14.5	1.7	2.9
I-018	Pien	261.7	0.1	3.3	1.1	10.9	0.8	1.8
I-019	Rio Negro	603.2		4.3	1.7	12.4	0.9	2.9
I-020	Campo do Tenente	314	0.2	4.7	1.9	5.5	0.4	2.7
I-021	Lapa	2203.9	0.2	3.8	1.9	2.5	0.4	2.1
I-022	Porto Amazonas	153		1.5	0.5	5.1	0.4	2.2
I-023	Palmeira	273.4	0.1	2.5	0.8	2.0	0.4	1.6
I-024	Sao Joao do Triunfo	708.1	0.1	2.6	0.5		0.3	1.4
I-025	Antonio Olinto	482.5	0.2	2.7			0.4	1.5
I-026	Sao Mateus do Sul	1332.8	0.1	1.5	0.9		0.4	0.9
I-027	Reboucas	498.9	0.1	4.0			0.9	2.0
I-028	Irati	408.1	0.1	4.2	0.9		1.2	2.1
I-029	Rio Azul	642.6	0.0	3.6		14.8	0.7	1.7
I-030	Mallet	672.8	0.1	4.7			2.1	2.6
I-031	Paulo Frontin	377.5	0.0	0.7	0.3		0.4	0.5
I-032	Paula Freitas	417	0.0	0.8	0.3		0.5	0.6
I-033	Uniao da Vitoria	773.9	0.1	5.7		2.9	0.3	2.5
I-034	Porto Vitoria	220.2	0.2	6.9		0.0	0.3	3.8
I-035	General Carneiro	1063.7	0.2	5.0		2.6	0.3	2.0
I-036	Bituruna	1209.7	0.2	5.1		2.3	0.3	2.1
I-037	Cruz Machado	1500.5	0.2	5.9		2.3	0.3	2.2
I-038	Inacio Martins	879.9	0.2	1.4		2.6	0.3	0.8
I-039	Guarapuava	3402.7	0.3	7.4	2.6	4.7	0.2	2.4
I-040	Pinhao	2875.2	0.3	4.2		2.5	0.9	1.8
I-041	Palmas	3125.5	0.3	7.7		4.3	0.7	3.6
I-042	Clevelandia	708.4	0.3	3.9		2.8	0.7	2.0
I-043	Honorio-Serpa	806.6	0.3	8.0		9.6	1.8	5.4
I-044	Mangueirinha	801.3	0.3	7.8		14.3	0.8	5.1
I-045	Candoi	999.8	0.3	7.8		24.6	1.0	7.8
I-046	Cantagalo	774.1	0.3	3.5		18.5	2.0	6.1
I-047	Virmound	198.4	0.1	3.7		26.1	1.0	8.1
I-048	Laranjeiras do Sul	1052.7	0.2	5.4		20.2	1.5	7.3
I-049	Chopinzinho	992.5	0.1	7.4	0.7	19.5	1.2	7.5
I-050	Coronel Vivida	681.5	0.3	9.9	3.3	15.2	2.0	7.7
I-051	Pato Branco	570.2	0.3	3.7		4.1	0.8	2.5

No.	Municipality	Area (km2)	2015 Forest	2nd Veg.	Ref.	Pasture	Crop	Average
I-052	Manopolis	232.1	0.3	2.9		3.4	0.5	1.6
I-053	Vitorino	326.1	0.1	1.4		4.1	1.5	1.8
I-054	Renascenca	434.7	0.3	7.1	3.2	4.0	0.7	3.4
I-055	Bom Sucesso do Sul	135.3		7.8		2.3	1.4	3.3
I-056	Itapejara D'Oeste	246.0		9.5		2.4	1.8	3.4
I-057	Vere	345.6		9.5		24.2	1.7	9.6
I-058	Sao Joao	408.9	0.3	10.0		24.0	1.8	9.6
I-059	Sulina	158.5		10.1		26.3	1.8	10.4
I-060	Saudade do Iguacu	147.8	0.3	7.8		20.6	0.9	7.4
I-061	Rio Bonito do Iguacu	459.3	0.2	0.8		7.0	1.4	0.8
I-062	Nova Laranjeiras	578.8	0.3	6.1	2.6	19.4	1.2	5.7
I-063	Guaraniacu	495.0	0.3	10.1		28.2	1.7	13.0
I-064	Quedas do Iguacu	1192.9	0.2	0.7	0.2	5.4	1.6	1.3
I-065	Sao Jorge do Oeste	385.1	0.3	10.1		14.1	1.2	6.8
I-066	Cruzeiro do Iguacu	96.6	0.3	9.1		11.4	2.0	5.7
I-067	Boa Esperanca do Iguacu	249.4	0.3	10.1		33.7	4.7	14.1
I-068	Dois Vizinhos	372.7		9.5		14.6	1.7	6.7
I-069	Eneas Marques	234.7		9.5		31.8	3.1	13.5
I-070	Francisco Beltrao	696.7	0.3	9.5		7.3	1.6	4.6
I-071	Marmeleiro	449.9	0.3	9.5	3.2	4.0	0.5	3.9
I-072	Flor da Serra do Sul	94.7		1.0		3.5	0.7	1.1
I-073	Barracao	386.3		9.5		31.8	2.6	12.7
I-074	Salgado Filho	506.4		9.5		12.0	1.5	8.9
I-075	Santo Antonio do Sudoeste	313.8		9.2		22.9	1.5	9.2
I-076	Pranchita	297.1		8.6		10.5	2.1	5.9
I-077	Pinhal de Sao Bento	107.6		7.8		9.1	1.5	7.2
I-078	Ampere	307.9		9.2		5.6	1.8	5.0
I-079	Nova Esperanca do Sudoeste	176.9	0.3	9.5		31.8	3.8	12.7
I-080	Salto do Lontra	336.9	0.3	9.5		14.6	1.3	6.9
I-081	Santa Izabel do Oeste	330.5	0.3	9.7	3.2	27.1	2.2	11.5
I-082	Nova Prata do Iguacu	333.0	0.3	10.1		31.6	2.0	12.5
I-083	Perola do Oeste	330.1	0.3	9.7		24.4	1.9	10.3
I-084	Planalto	337.1	0.0	9.7		32.2	3.0	13.6
I-085	Realeza	351.9	0.3	9.7		29.4	2.2	11.3
I-086	Capanema	403.9	0.3	9.7		32.2	3.0	13.2
I-087	Tres Barras do Parana	521.7	0.3	10.1	3.4	3.3	0.8	3.6
I-088	Catanduvas	593.9	0.3	2.2	3.4	10.4	1.8	3.7
I-089	Ibema	148.3	0.3	8.0	3.4	10.6	1.6	6.1
I-090	Cascavel	1198.9	0.3	7.1	3.4	2.8	1.7	3.4
I-091	Boa Vista da Aparecida	232.2		10.0		11.5	1.3	5.6
I-092	Capitao Leonidas Marques	279.8	0.3	9.7		25.7	1.5	9.4
I-093	Santa Lucia	137.1	0.3			32.2	3.0	13.1
I-094	Lindoeste	273.2	0.3	10.1		26.9	1.4	8.6
I-095	Santa Tereza do Oeste	235.5	0.3	10.1	3.4	10.8	1.7	4.8
I-096	Ceu Azul	937.2	0.2	2.2		7.4	1.3	0.6
I-097	Matelandia	601.4	0.2	2.3		6.7	1.1	1.7
I-098	Medianeira	621.1	0.2	2.4		6.7	1.3	1.9
I-099	Sao Miguel do Iguacu	455.7	0.3	8.2	0.0	9.6	1.5	4.5
I-100	Santa Terezinha de Itaipu	162.1	0.0	0.7		3.9	2.1	2.3
I-101	Foz do Iguacu	312.2	0.1	3.1		8.6	2.4	2.8
	Total	55776.0						4.0

Area: = Total Area of Municipality - Area of Others in Landuse Classification

2nd Veg.: Secondary Vegetation, Ref.: Reforestation

7.3.3 Implementation Schedule, Cost and Benefit

(1) Implementation Schedule

As current soil loss from the most of crop land exceeds the permissible level, 11 ton/ha·year, the implementation of soil conservation is urgently required. Thus, 100 % implementation of terracing inclusive of the improvement of farm roads should be achieved by the year of 2005. Since the total crop area which is not conserved currently is estimated 1,078 thousand ha, the implementation rate would be 110 thousand ha per year to achieve 100 % coverage of terracing.

The priority of location where terracing will be implemented depends on the magnitude of the current soil loss. The larger the soil loss is, the higher the priority is. In Table-7.17, the priority of Municipality is shown with the area to be terraced.

50 % implementation of non tillage is expected to be achieved by the year of 2015. Non tillage is currently practiced in 325 thousand ha of beans, maize and soybean field. With the Master Plan, it would increase evenly in the next twenty years to 1,077 thousand ha.

Other measures, such as agronomic measures and soil management would be practiced continuously in the next twenty years.

(2) Cost

Main measures which should be considered for the cost estimation are terracing, improvement of farm roads and non tillage. The costs of other measures are considered as small compared to ones of main measures. For the computation sake, the assumptions made are: 1) Cost of terracing is 40 US$/ha., 2) Cost of improvement of farm roads is 1,500 US$/km and average length of farm roads per ha is 0.02 km., 3) Maintenance costs of terraces and farm roads are 3 % of their construction costs., 4) The difference between machinery costs for non tillage and for traditional tillage is 4,000 US$. Thus, 4,000 US$ is the cost for application of non tillage and its maintenance cost is negligible., 5) Machinery for non-tillage lasts ten years., 6) One machinery for non tillage covers 200 ha., 7) The cost for herbicide for non tillage is not considered.

The result of cost estimation is shown in Table-7.18. The total cost would be 144 million US$.

(3) Benefit

Paraná Rural Program (SEAB, 1989) has estimated nutrient loss compensated by fertilizers assuming the average soil loss of 20 ton/ha·year and enrichment ratio of 1.0. Consequently, the fertilizer applications of nitrogen and potassium are 20 kg/ha and 2.3 kg/ha, respectively. The cost of fertilizer is approximately 200 US$/ton for calcium nitrate and 220 US$/ton for potassium chloride.

The reduction of fertilizer application with the Master Plan is considered as one of benefits. Assuming that terraces and farm roads last 30 years with the proper maintenance, above rate of nutrient loss and cost of fertilizer were applied to estimate the benefit by the year of 2025. The total cost would be 188 million US$, while the benefit would be 272.5 million US$.

Table-7.17 Priority of Municipality for Master Plan

			Terrace (1,000 ha)										
No	Municipality	Soil Loss from Municipality (ton/ha/year)	Area to be Terraced	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
I-93	Santa Lucia	89.8	4.60	4.60									
I-79	Nova Esperanca do Sudoeste	88.2	4.90	4.90									
I-87	Boa Esperanca do Iguacu	77.1	4.80	4.80									
I-9	Campo Largo	65.0	14.90	14.90									
I-73	Barracao	62.6	8.50	8.50									
I-46	Cantagalo	62.5	26.20	26.20									
I-84	Lindoeste	58.5	11.90	11.90									
I-56	Itapejara D'Oeste	57.2	8.00	8.00									
I-86	Capanema	56.2	8.10	8.10									
I-43	Honorio-Serpa	53.3	26.90	18.10	8.80								
I-58	Sulina	53.3	4.80		4.80								
I-83	Perola do Oeste	50.5	8.90		8.90								
I-69	Eneas Marques	42.4	3.40		3.40								
I-81	Santa Izabel do Oeste	41.8	6.50		6.50								
I-85	Realeza	40.2	6.80		6.80								
I-47	Vimound	39.0	7.40		7.40								
I-48	Laranjeiras do Sul	38.6	29.90		29.90								
I-75	Santo Antonio do Sudoeste	37.8	7.80		7.80								
I-57	Vere	36.8	7.40		7.40								
I-64	Planalto	35.8	4.00		4.00								
I-50	Coronel Vivida	35.7	15.10		13.50	1.60							
I-17	Agudos do Sul	35.6	7.80			7.80							
I-61	Pato Branco	34.9	25.10			25.10							
I-30	Mallet	34.4	17.10			17.10							
I-66	Cruzeiro do Iguacu	34.1	1.90			1.90							
I-63	Guaraniacu	32.4	7.50			7.50							
I-28	Irati	32.2	14.40			14.40							
I-70	Francisco Beltrao	31.5	18.20			18.20							
I-82	Nova Prata do Iguacu	31.2	4.80			4.80							
I-74	Salgado Filho	29.7	7.80			7.80							
I-53	Vitorino	28.7	6.70			5.80	0.90						
I-80	Salto do Lontra	28.8	8.00				8.00						
I-65	Sao Jorge do Oeste	28.5	7.80				7.80						
I-27	Reboucas	27.6	20.90				20.90						
I-68	Dois Vizinhos	27.2	6.50				6.50						
I-29	Rio Azul	26.6	29.30				29.30						
I-92	Capitao Leonidas Marques	26.2	4.20				4.20						
I-72	Flor da Serra do Sul	23.9	2.80				2.80						
I-76	Pranchita	23.8	3.60				3.60						
I-58	Sao Joao	23.6	8.50				8.50						
I-80	Saudade do Iguacu	21.8	3.80				3.80						
I-78	Ampere	19.6	3.60				3.60						
I-62	Nova Laranjeiras	19.6	6.50				6.50						
I-18	Pien	19.4	8.70				7.80	0.90					
I-91	Boa Vista da Aparecida	19.2	3.50					3.50					
I-45	Candoi	19.1	17.40					17.40					
I-15	Contenda	18.7	11.70					11.70					
I-55	Bom Sucesso do Sul	18.1	2.60					2.60					
I-42	Clevelandia	18.1	20.10					20.10					
I-99	Sao Miguel do Iguacu	17.3	6.40					6.40					
I-49	Chopinzinho	16.8	14.00					14.00					
I-88	Catanduvas	14.7	6.60					6.60					
I-16	Quitandinha	14.4	18.50					18.50					
I-77	Pinhal de Sao Bento	14.0	0.70					0.70					
I-10	Araucaria	13.8	21.90					10.60	11.30				
I-101	Foz do Iguacu	13.2	1.90						1.90				
I-71	Marmeleiro	12.6	11.40						11.40				
I-37	Cruz Machado	12.1	54.20						54.20				
I-25	Antonio Olinto	12.0	14.90						14.90				
I-4	Sao Jose dos Pinhais	11.8	27.90						16.30	11.60			
I-12	Mandirituba	11.3	14.20							14.20			
I-54	Renascenca	11.2	8.70							8.70			
I-19	Rio Negro	11.0	8.00							8.00			
I-11	Fazenda Rio Grande	10.8	5.20							5.20			
I-6	Pinhais	10.7	3.20							3.20			
I-3	Piraquara	10.7	4.30							4.30			
I-44	Mangueirinha	10.4	9.90							9.90			
I-95	Santa Tereza do Oeste	10.4	2.10							2.10			
I-97	Tres Barras do Parana	10.4	6.80							6.80			
I-100	Santa Terezinha de Itaipu	10.2	0.90							0.90			
I-20	Campo do Tenente	9.8	10.10							10.10			
I-26	Sao Mateus do Sul	9.7	35.00							27.00	8.00		
I-32	Paula Freitas	9.1	8.60								8.60		
I-90	Cascavel	8.7	9.10								9.10		
I-8	Curitiba	8.6	3.70								3.70		
I-14	Balsa Nova	8.3	6.80								6.80		
I-22	Porto Amazonas	8.1	4.60								4.60		
I-7	Almirante Tamandare	7.7	3.60								3.60		
I-36	Bituruna	7.6	25.90								25.90		
I-38	Inacio Martins	7.6	21.10								21.10		
I-35	General Carneiro	7.4	20.60								18.70	1.90	
I-89	Ibema	7.2	0.20									0.20	
I-31	Paulo Frontin	7.1	9.20									9.70	
I-64	Quedas do Iguacu	7.0	9.00									9.00	
I-81	Rio Bonito do Iguacu	6.8	3.30									3.30	
I-21	Lapa	6.7	42.90									42.90	
I-2	Quatro Barras	6.6	2.10									2.10	
I-40	Pinhao	6.5	39.60									39.60	
I-34	Porto Vitoria	6.2	2.30									1.80	0.50
I-33	Uniao da Vitoria	6.2	10.10										10.10
I-13	Tijucas do Sul	5.8	8.00										8.00
I-98	Medianeira	5.6	2.40										2.40
I-41	Palmas	5.1	17.90										17.90
I-24	Sao Jose do Triunfo	4.9	11.40										11.40
I-1	Campina Grande do Sul	4.6	0.90										0.90
I-5	Colombo	4.0	1.80										1.80
I-39	Guarapuava	3.2	30.60										30.60
I-52	Mariopolis	2.8	1.70										1.70
I-23	Palmeira	2.8	2.40										2.40
I-87	Matelandia	2.2	0.40										0.40
I-96	Ceu Azul	0.8	0.20										0.20
		Total	1,078.1	110.00	110.00	110.00	110.00	110.00	110.00	110.00	110.00	110.00	88.10

Table-7.18 Cost and Implementation Schedule of Soil Conservation

Soil Conservation Measures	Amount to be covered	Cost (million US$)	1990s 96	97	98	99	2000s 00	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15
Terrace for crop Land	10,781 km²	43.1																				
Improvement of Farm Road	21,560 km	32.3																				
Maintenance of Terrace and Farm Road	—	33.0																				
Non Tillage	7,520 km²	35.5																				
Agronomic Measures	30,700 km²	not estimated																				
Soil Management	30,700 km²	not estimated																				
5 Year Progress Rate		143.9	31 %					38 %					13 %					18 %				

Since the determination of agronomic measures and soil management involves the detail study, it was not estimated.

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7.4 Ecology

7.4.1 Biological Environment

(1) Flora

1) Terrestrial Flora

The total forest cover area as percentage of the basin area is estimated in 43.7%, most of this area (27.42%) is considered under brush coverage (Capoeira), followed by 14.56% of native forest coverage, and 1.72% of reforestation area. The total conservation area is estimated in 10.21% of the basin area.

Main problems associated with the existing conservation areas are related to the lack of implementation of management plans, deficient infrastructure and maintenance, and reduced number of personnel.

Areas which are not under a specific conservation criteria have been detected by IAP and the Botanical Museum in the localities of Serra da Baitaca and Corredeiras Eng. Bley. Main issues associated to these areas include endemic and endangered birds, orchids and other botanical species living in these habitats, as well as recreational, cultural and scenic values associated to these areas.

2) Aquatic Flora

Main issues related to aquatic microalgae are reported by the SANEPAR, where proliferation of undesirable species originates bad flavor, offensive odors and oxygen depletion in water supply reservoirs. Other problems associated to this condition are filter clogging and hampering of the flocculation process.

A reduction of the organic load in the water sources through the implementation of industrial water and sewerage treatment would alleviate this problems.

(2) Aquatic Fauna

The most detailed fish inventories in the state have been carried out for the Iguaçu river, approximately 70% of the species reported are found only in this river throughout the world. The distribution of endemic, introduced and rare species in the Iguaçu river are follows:

Species	47
Endemic	33
Introduced	4
Rare	4

Main impacts associated with this resource are related to hydroelectric dam construction and modification of the water environment, urban, industrial, agricultural and municipal pollution, sediment runoff through deforestation and sand extraction, and reduction of the river margin vegetation.

(3) Benthos

Sampling and biodiversity assessment by IAP has shown drastic diversity index reduction as consequence of pollution in the rivers associated with the Curitiba metropolitan and industrial area.

(4) Aquatic Birds

For the Iguaçu Environmental Protection Area (APA-Iguaçu) located adjacently to the Curitiba metropolitan area, an important community of aquatic birds, including temporary resting and migrant populations has been identified. The following table summarizes the reported bird groups in the area:

Table-7.19 Reported Bird Species for the APA-Iguaçu

CATEGORY	NUMBER REPORTED	PERCENTAGE (%)
Bird Species	117	100
Bird Families	36	
Aquatic Species	37	31.6
Migratory Species	10	8.5
Rare Species	6	5.1
Endangered Species	2	1.7

Source: SMMA, 1993, and Museum of Natural History

Among the migratory species, populations up to 600 individuals have been reported. Five species are known to depend on wetland vegetation for shelter, nesting, and food supply.

7.4.2 Socioeconomic Environment

(1) Rural Migrations Towards the Urban Areas

From the 1970's onward, the exodus of farmers to the metropolitan area became the origin of poverty belts. The settlement is more evident in the low lands along the river margins, where the value of the land is less. A model area for this condition can be appreciated at the Palmital river shown in Figure-7.10, where 3 sectors can be identified:

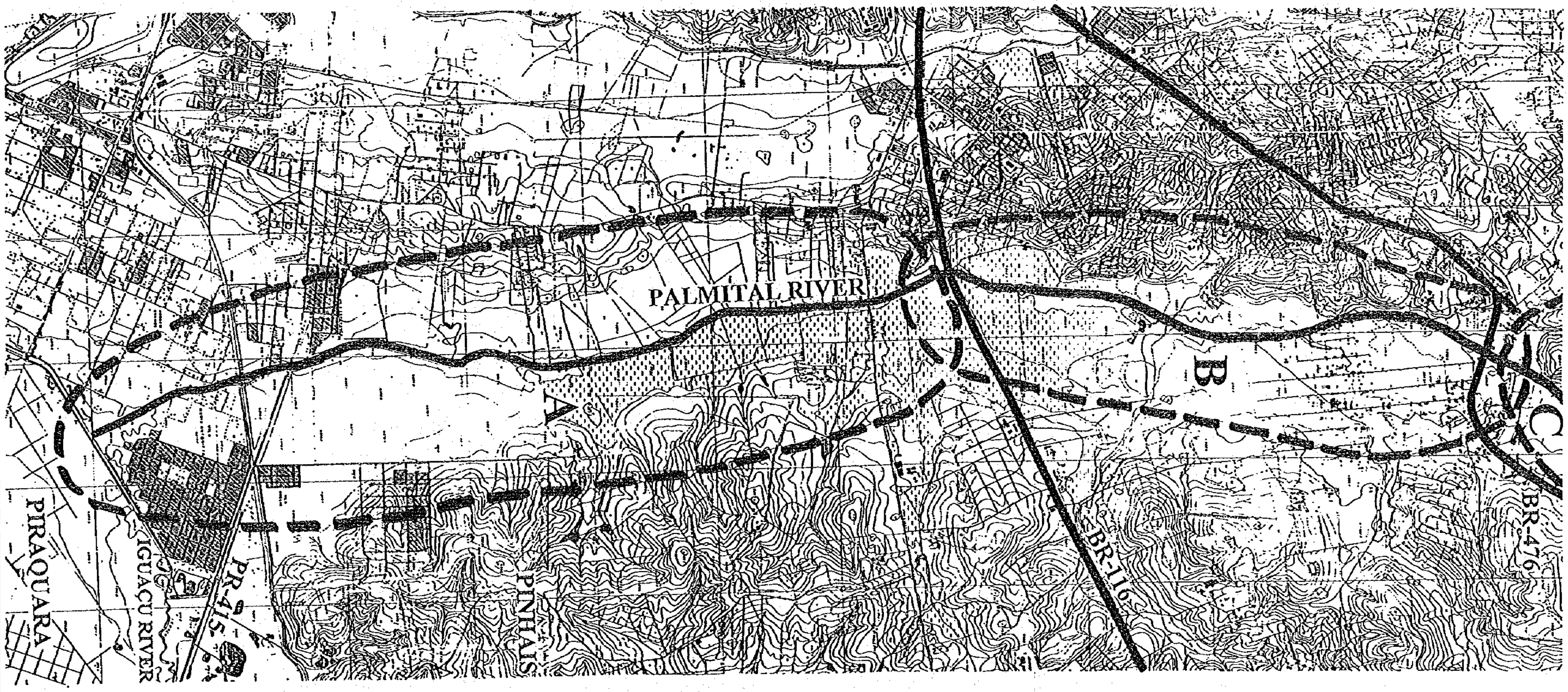
1) Upper Palmital

The area is considered rich in groundwater resources, and the river margin vegetation is still in a well preserved condition.

2) Middle Palmital

The populated areas are some 30 Km from Curitiba center, where most of the people work. Approximately 100,000-150,000 people are living in this area. Main problems associated with these settlements are raw sewerage and open air waste disposal, high criminal, low income and low educational status of the population.

Habitation of flood prone areas, deficient municipal services and deficient potable water availability further deteriorate the living conditions.



A = Lower Palmital
B = Upper Palmital
Source: COMEC

Figure-7.10 Detail of Palmital River

Raw sewerage disposal, and open solid waste disposal are polluting the Palmital river, and affecting water quality of SANEPAR water intake located at the BR-277 intersection with the Palmital river, and eventually deteriorating the water quality of the Iguaçu river.

3) Lower Palmital

Problems in this area are not so critical, sewerage treatment is planned to be done at the Atuba river sewerage treatment plant, and the area is closer to the Curitiba Metropolitan area for solid waste collection and disposal. Population density is considered low.

(2) Hydroelectric Projects

Five major hydroelectric projects operating and one under construction are the existing projects in the Iguaçu river. All of the projects are located in the main course of the Iguaçu river, damming approximately 50% of it's extension.

The main impacts associated with these projects besides modifying the river hydrology from a rapid to a slow flow are associated to psychological distress such as resettlement of about 300 families in Salto Segredo project, and disruption of fishing areas of the indigenous population in the Salto Santiago project.

The implementation cost for the environmental programs of Salto Caxias is estimated in 150 million US$ or 15% of the total value of the project. This cost reflects the concern and commitment of COPEL in the present EIA studies performed, where the learning experience of previous projects has generated a comprehensive approach to the environmental issues involved.

(3) Landfills

The total volume of solid waste per day generated in the Iguaçu river basin is estimated by IAP in 2,200 MT/day. Five urban centers generate 56% of the municipal solid waste of the basin, the other municipalities are estimated to generate some 970 MT (44%) of the total for the basin, the system used for disposal goes from open air disposal to municipal landfill.

Major problems associated with the municipal solid waste disposal are lack of equipment, improper disposal systems (open air), lack of environmental education in waste separation and recycling, and improper effluent treatment with consequent leaching of pollutants.

(4) Water Intake Locations

Main problems are associated with organic pollution originating microalgae growth and oxygen depletion cycles, agrochemical runoff from agricultural fields adjacent to the Passauna reservoir, leaching of the Lamenha Pequena abandoned landfill into the Passauna reservoir, domestic sewerage disposal in waterways, and industrial effluent disposal without proper treatment.

7.4.3 Master Plan for Iguaçu River Basin

The master plan is conceived as a series of specific programs to be implemented in the conservation, rehabilitation and monitoring context. Figure-7.11 shows the relationship between monitoring and preservation programs.

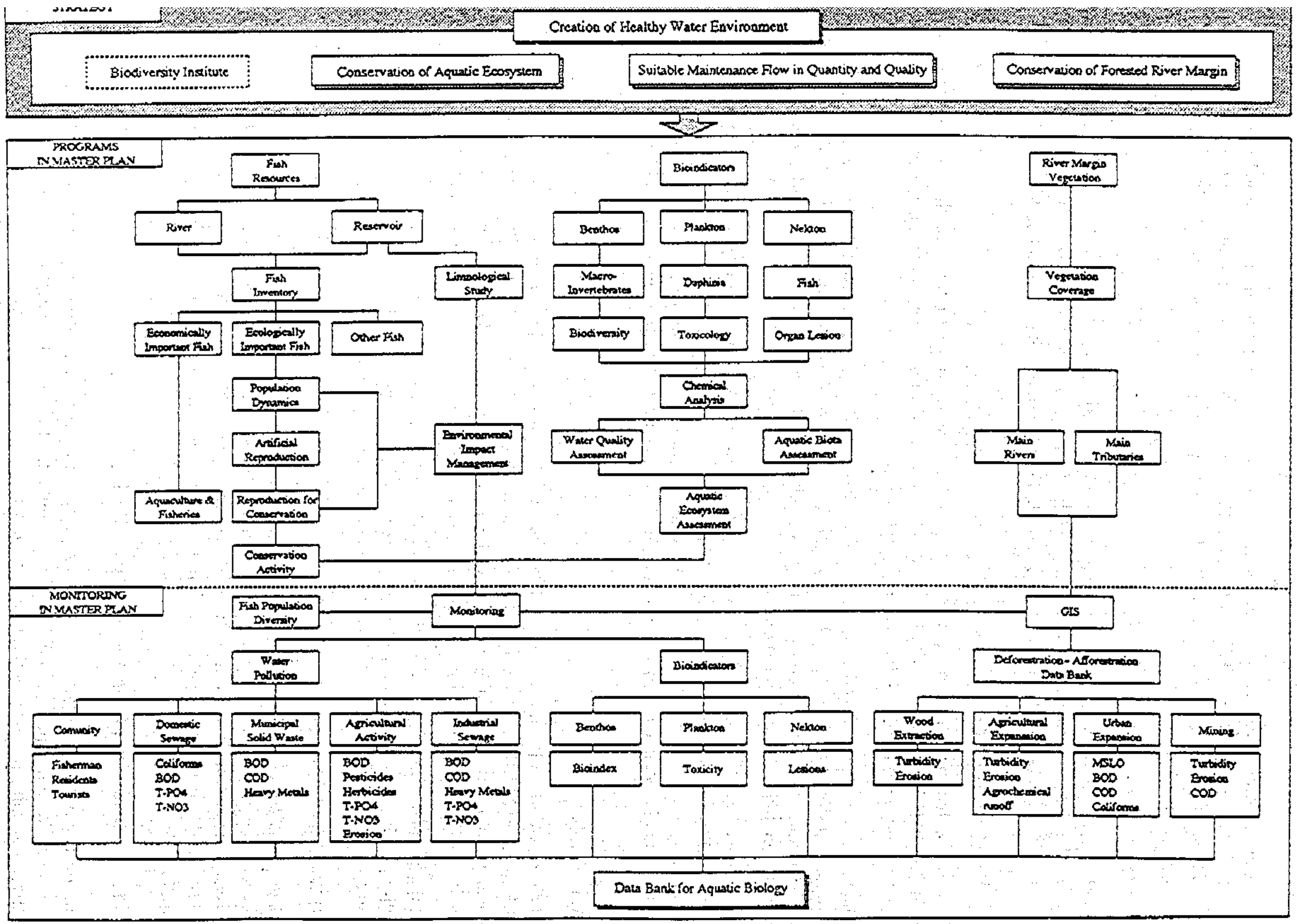


Figure-7.11 Interrelationship Between Monitoring and Preservation Program

(1) Program for the Inventory of Fish Populations.

Mainly oriented in the areas of the Iguaçu Park and tributaries of the Iguaçu river.

(2) Program for the Assessment of the Fish Population Dynamics.

Oriented to rare, endangered, migratory, and/or commercially important species, the purpose is to attain knowledge in the way these species eat, reproduce and about the habitat they occupy.

(3) Program for the Artificial Reproduction of Endemic Fish with Ecological and/or Economic Interest.

For the massive production and repopulation and/or production of endangered or commercially viable species.

(4) Program for the Assessment of the Fish Fauna and Experimental Aquaculture in the Iguaçu River Hydroelectric Reservoirs.

Oriented towards the inventory, population dynamics and limnology of the reservoirs, with the objective of conservation, mitigation, and eventually production of fish in the reservoirs.

(5) Program for the Assessment of the Aquatic Environment through the use of Bio-Indicators.

Integrated monitoring approach using benthic organisms, zooplankton toxicity tests, and correlation with chemical analysis is suggested to be implemented in water treatment plants, as well as in industrially and agriculturally polluted areas to monitor water environment quality. See Figure-7.12 and Figure-7.13.

(6) Program for the Upgrading of Management Plans for Existing Conservation Units.

To strengthen and improve the existing conservation areas, the program is geared towards eco-tourism and conservation.

(7) Program for the Identification and Monitoring of the River Margin Vegetation and Lowlands Along Water Courses.

To define the existing area, and regularly monitor the resource degradation or improvement.

(8) Program for the conservation of the Serra da Baitaca and the proposed Irai reservoir area.

Rare, endangered, and endemic species of plants and animals, genetic diversity typical and unique for the region, and scenic, recreational and landscape values, are reasons to consider the preservation of this area.

(9) Program for the Geographic Definition and establishment of the Corredeiras Eng. Bley as a conservation unit.

Area	Monitoring Stations	IAP Station #
A =	6 Benthos Stations	
	. Canguiri River (2x)	44
	. Passaúna River (2x)	16
	. Timbu River (2x)	02
	2 Daphnia Monitors	
	. Iraí Water Intake	
	. Iguaçu Water Intake	
B =	6 Benthos Stations	
	. Barigui River (2x)	10
	. Barigui River (2x)	60
	. Passaúna River (2x)	11
C =	Benthos Station	
	. Passaúna River (2x)	32
	. Barigui River (2x)	57
	1 Daphnia Monitor	
	. Passaúna Water Intake	
D =	4 Benthos Stations	
	. Cambui River (2x)	68
	. Cambui River (2x)	69

Area	Monitoring Stations	IAP Station #
E =	12 Benthos Stations to be allocated	Middle Iguaçu
F =	12 Benthos Stations to be allocated	Lower Iguaçu
	1 Daphnia Monitor	
	. Cascavel Water Intake	Cascavel River
G =	6 Benthos Stations to be allocated	Francisco Beltrão Area
	1 Daphnia Monitor	
	. Francisco Beltrão Water Intake	Marrecas River
LAB. 1	Integrated Regional Laboratory	Curitiba
LAB. 2	Integrated Regional Laboratory	Toledo

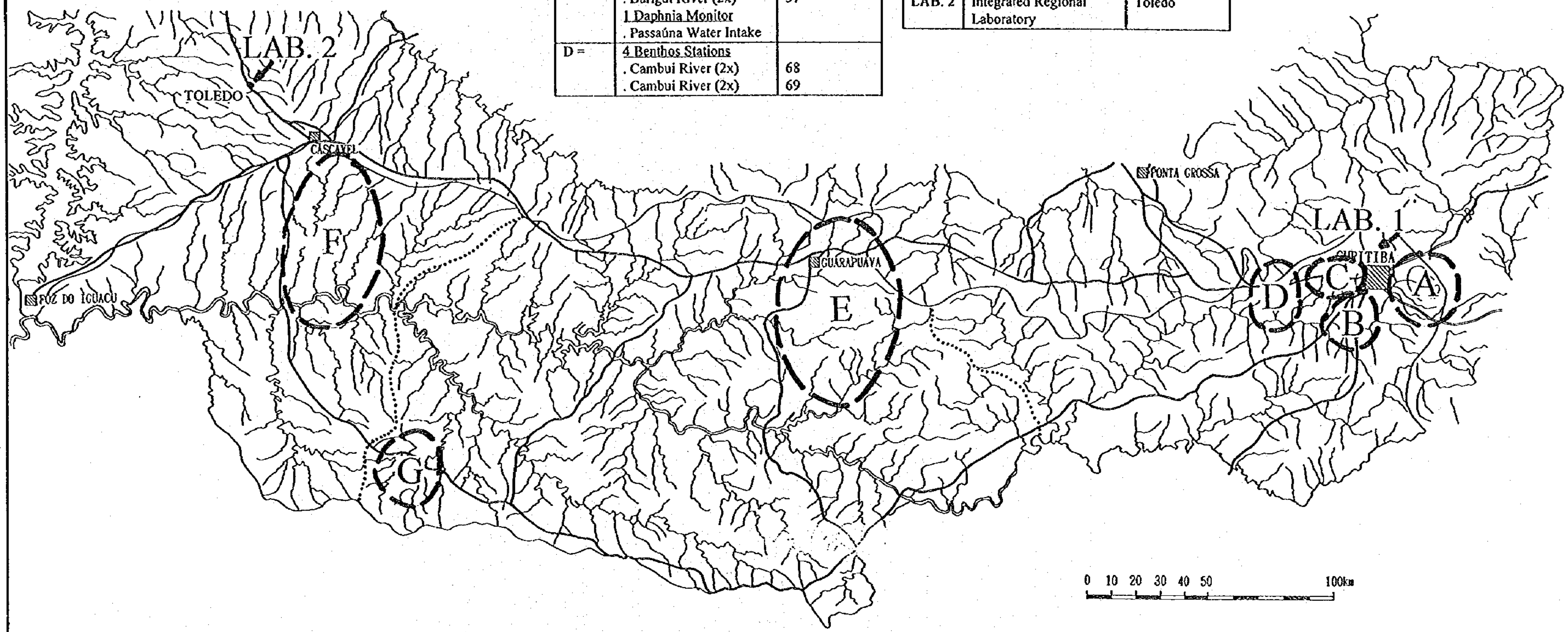


Figure-7.12 Indicative Location of Bioindicator Sampling Stations in the Iguaçu River Basin

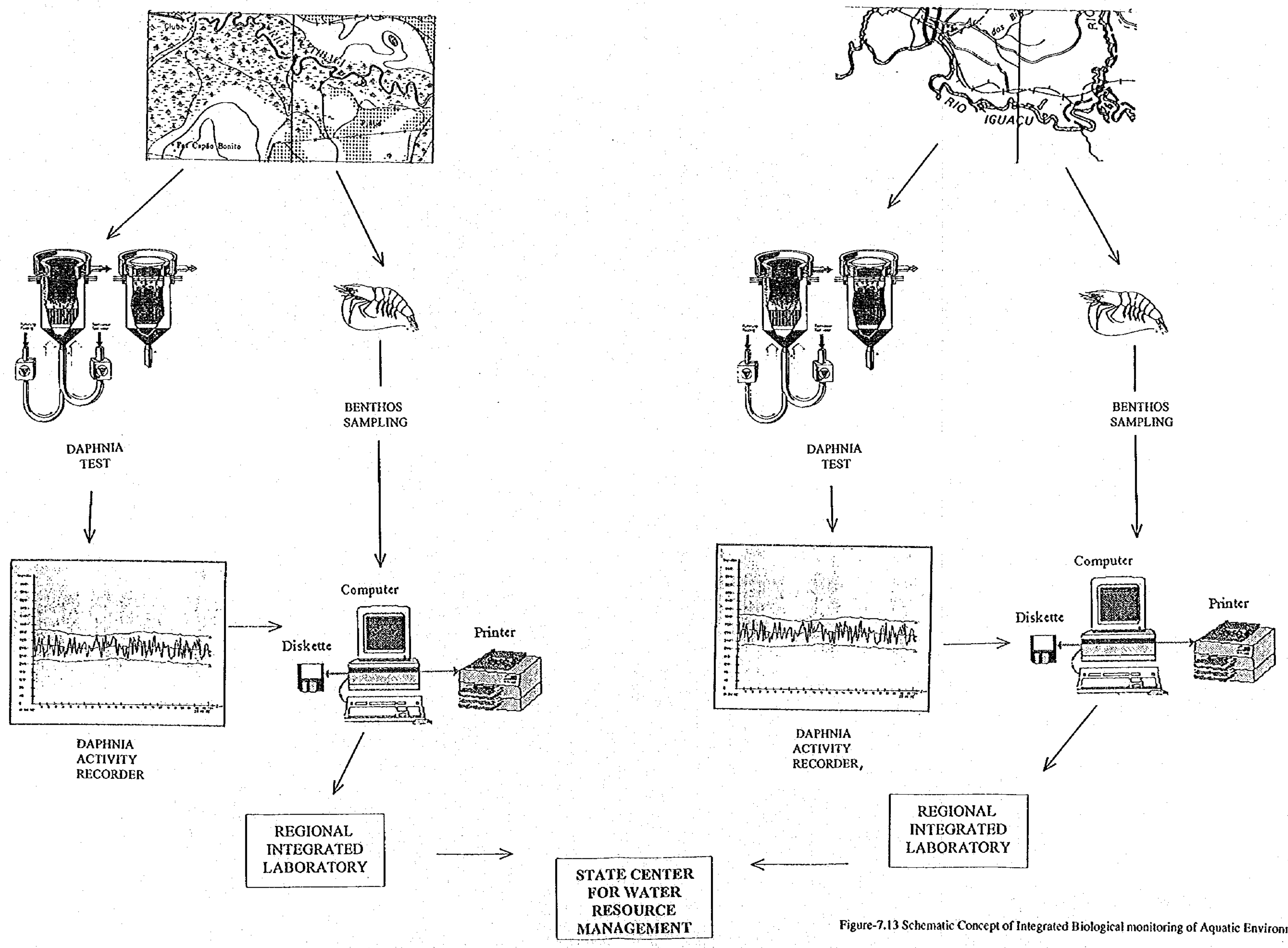


Figure-7.13 Schematic Concept of Integrated Biological monitoring of Aquatic Environment

Important scenic, touristic, and recreational values exist in this area. This river sector maybe the last one resembling the original Iguaçu river condition of rapids.

(10) Program for the Establishment of a Biodiversity Institute.

Resources available in the terrestrial vegetation, insects and other species not directly related with the aquatic environment could be a natural resource capital from which, significant developments in biotechnology and pharmaceutical can be developed generating income to support conservation projects related for the water and terrestrial environment.

(11) Program for the Control of blackfly (Simulium sp) in the Iguaçu River Basin.

Control of the fly population adjacent to the water environment, the vector inflicts bites, rashes and allergies to the adjacent populations, and it's considered a pest.

(12) Program for the Environmental Education of the Water Sources Development.

The present program is oriented towards the integration of cultural, architectonic, historic, sanitation, and water environment values and components for the education and training of the population in the context and processes of potable water source development.

7.4.4 Summary of Program Objectives and Indicative Costs

Table-7.20 summarizes the area of influence of each one of the proposed projects:

Table-7.20 Summary of Program Objectives for Iguaçu River Basin

PROGRAM NAME	COST US $ X 1000	OBJECTIVES (1)	(2)	(3)	(4)
Preservation Programs					
1) Fish Population Inventory	881	X			X
2) Fish Population Dynamics	487	X	X		
3) Endemic Fish Reproduction	493	X	X		
4) Reservoir Fish Assessment	2,620	X	X		X
6) Management Plans for Conservation Units	31	X	X		
8) Serra Baitaca Preservation	585	X	X	X	
9) Eng. Bley Preservation	241	X	X		
10) Biodiversity Institute	---	X	X		X
Environmental Education Program					
12) Water Environment Education	860	X		X	
Monitoring Programs					
5) Bioindicator Monitoring	1,286	X		X	X
7) River Margin Vegetation Monitoring	670	X		X	X
11) Blackfly Monitoring	414			X	X

NOTES : (1) CONSERVATION, (2) ECONOMIC, (3) SANITATION, (4) MONITORING

7.5 Forest

7.5.1 Existing Forest

As shown in Table-7.21, the natural forest and reforestation in Iguaçu river basin cover 14.3 % (7,900 km²) and 1.7 % (900 km²) of its area, respectively. The total area of natural forest in the sate is approximately 17,800 km² and 44.4 % of them belongs to Iguaçu river basin. The natural forest is well preserved in Iguaçu river basin compared to other river basins and it is mainly achieved by means of parks and indigenous preserves of state and federal as shown in Figure-7.14. In contrast to the preservation of natural forest, the implementation of reforestation is low.

Table-7.21 Forest and Reforestation Coverage in Paraná

		River Basin Area (km²)	Landuse (%)	
			Forest	Reforestation
State		197882.0	9.0	3.2
River Basin	Cinzas	9290.7	2.9	6.2
	Iguacu	55318.0	14.3	1.7
	Itarare	5197.7	1.3	21.7
	Ivai	35878.9	5.0	1.8
	Litoranea	5766.0	68.9	3.9
	Parana	13156.3	7.5	0.0
	Paranapanema	9797.0	4.9	0.0
	Piquiri	24707.9	2.1	0.3
	Pirapo	5005.9	2.5	0.0
	Ribeira	9129.3	5.7	5.3
	Tibagi	24634.7	3.8	9.4

Source: SANEPAR GIS Computation
IAP Satellite Imagery Analysis

7.5.2 Master Plan

Proper management of forest contributes to sustainable level of production of timber, preservation of environment, erosion control, flood control, maintenance of soil fertility and so on. Considering the development of society, it is not possible and not necessary to go back 19 century, when forest covered most of the land; however, afforestation is essential to improve the water environment and is a part of the river basin management.

Benefits of afforestation consist of direct and indirect ones. The former is an income from timber production, wood as fuel and perennial crops, such as fruit trees. The latter is the conservation of the water environment, such as erosion control, flood control, improvement of water quality in a river basin and so on.

The main concern to formulate the Master Plan is the proper landuse. In other words, the land not suitable to agriculture and pasture should be converted to forest for direct and indirect benefits. For the conservation and preservation purposes only, direct benefit is not expected; however, indirect benefit is much greater than income born from forest if the effect on the environment, such as suppression of soil erosion and flood, is counted.

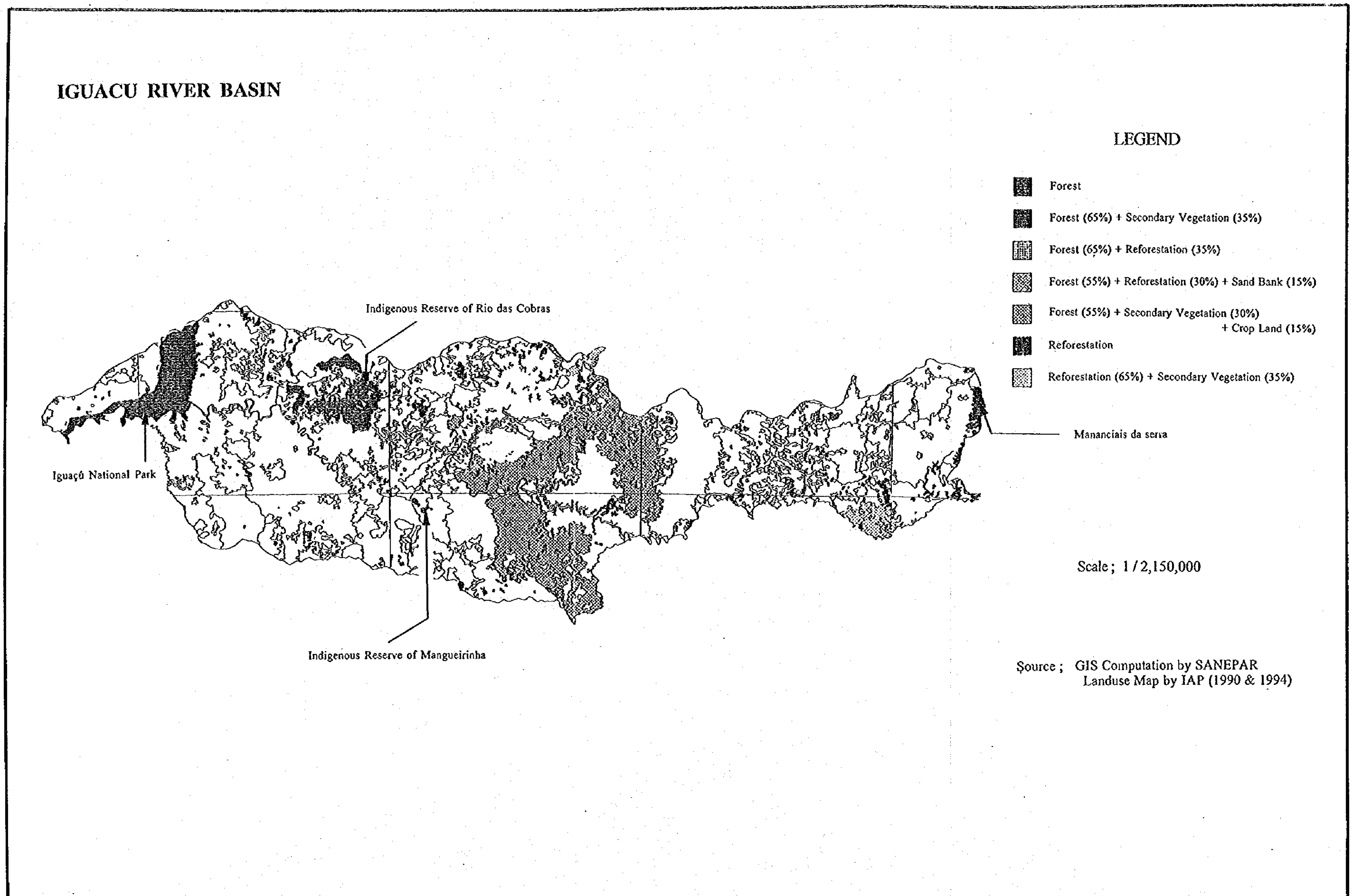


Figure-7.14 Location of Forest and Reforestation in Iguaçu River Basin

The Master Plan for forest consists of three purposes, preservation of natural forest, conservation of water environment and commercial afforestation. Recommended species and sites for each purpose are summarized in Table-7.22. The implementation of Master Plan will involve the detail study site by site, such as identification of soil and climate, selection of forest species, plan of thinning etc. For the selection of specific species, recommendations of native and exotic species dividing the sate in 7 bio-climatic regions are available from EMBRAPA (1985).

Table-7.22 Recommended Species and Sites

Purpose	Direct Benefit	Indirect Benefit	Site Recommended	Recommended Species
Preservation of natural forest	No	Yes	1) Current preservation area 2) Promotion of preservation area to protect ecosystem, landscape and so on	Native forest, Wild Fruits
Conservation of water environment	No	Yes	The area stipulated by law, such as along rivers or any water courses, steep land, etc.	Native Forest, Wild Fruits, Araucaria, Bracatinga
Agroforestry	Yes	Yes	Farm land	Bracatinga, Mate
Energy	Yes	Yes	The land whose slope steepness is less than 25 degree.	Bracatinga, Eucalyptus
Commercial use for timber &	Yes	Yes	1) Brush fields 2) The land not suitable for both crop and pasture cultivation	Eucalyptus, Araucaria, Pine

Direct Benefit: to generate income
Indirect Benefit: to conserve the water environment

Considering the current conditions, the area expansion of forest for preservation and conservation of the water environment purposes is expected to be gradual. Therefore, afforestation should be promoted by means of commercial afforestation. Each purpose of the Master Plan is described in the followings.

(1) Preservation of Natural Forest

Currently preserved areas must not be exploited as laws control (Forest Code, Law 4771/65). Besides, the promotion of preservation area should be continued not only to preserve the ecosystem and environment but also scenic and recreational purposes. In Iguaçu river basin, there are several plans of the establishment of new preservation areas, such as Irai reservoir area and Palmital river basin. For the implementation, the government assistance by means of finance, law enforcement and technical support is essential.

(2) Afforestation for Conservation of Water Environment

Currently degraded areas despite the fact that Forest Code defines the preservation areas have to be afforested for preservation of native flora and fauna, erosion control, stabilization of hydrologic cycle and so on. The recommended forest species for this purpose are native ones because exotic species often alter the endemic ecosystem.

(3) Afforestation for Direct Benefits

Land with no aptness for agriculture and pasture should be converted to forest to generate more income instead of bearing the low productivity. Besides, this afforestation contributes to conserve the water environment because the applicable land is steep and has a great potential of soil erosion and flood.

For the sustainable production of wood and conservation of the water environment, it requires the proper management system, such as space of seedlings, thinning plan and so on. The relative institutions, for example IAP and EMATER, should support the formulation of forest management system.

Since Iguaçu river basin belongs to 1, 2 and 3 bio-climatic regions (EMBRAPA, 1985), main species recommended for commercial afforestation are Araucaria, Mate, Bracatinga, Eucalyptus and Pinus. The use of recommended species is shown in Table-7.23.

Table-7.23 Use of Recommended Species for Commercial Afforestation

Species	Bio-climatic Region			Use					
	1	2	3	paper & cellulose	construction	timber	plywood	firewood & charcoal	nourishment
Araucaria angustifolia (Araucaria)	X	X	X	X	X	X			
Ilex paraguariensis (Mate)	X	X	X						X
Mimosa scabrella (Bracatinga)	X				X	X	X	X	
Eucalyptus	X	X	X	X	X			X	
Pinus (Pine)	X	X	X		X	X			

Souce: EMBRAPA (1985)

7.5.3 Implementation Schedule and Cost

The average cost and gross income from afforestation of main species suitable for Iguaçu river basin were estimated by Ferreira (1995) as shown in Table-7.24. Cost and income depend on the use of wood products. For example, the price of Eucalyptus for fuel is approximately 3.3 US$/m^3, while one for sawmill is 10 US$/m^3. Assuming the specific use of wood, cost and gross income were estimated.

Based on the agriculture aptness map (Ministry of Agriculture, 1981) and Landuse map (IAP, 1990 &1994), the area of existing secondary vegetation spreading over the land suitable for forest was estimated at approximately 1,900 km^2. This land should be afforested for commercial use to generate income. If Pinus was adopted, the total cost and net income would be US$ 135 million and US$ 1157 million, respectively. The implementation depends on ability of annual afforestation. Considering its annual average of the state, 9,500 ha/year of implantation is feasible. Therefore, 1,900 km^2 of the land should be afforested evenly in next twenty years.

Table-7.24 Cost and Gross Income of Afforestation

Species	Spacing (m x m)	Cost (US$/ha)			Yield		Rotation Year	Gross Income (US$/ha)	Net Income (US$/ha·year)
		Planting	Maintenance	Pruning	Product	Production			
General native species	4x4	270	100	–	–	–	–	non	non
angustifolia (Araucaria)	3x3	270	100	–	cellulose	400 m^3/ha	45	4,000	301
					saw-mill	30 m^3/ha		900	
					lamination	180 m^3/ha		9,000	
Ilex paraguariensis (Mate)	3x3	430	360	–	Mate Tea	17 ton/ha·harvest	30	34,500	1124
Mimosa scabrella (Bracatinga)	1 kg seed/ha	260	370	–	fuel wood	270 m^3/ha	6	900	267
					maize, beans			700	
Eucalyptus	2x2	470	100	–	fuel wood	670 m3/ha	21	2,240	80
Pinus (Pine)	2x2	460	150	100	cellulose	160 m^3/ha	25	800	244
					saw-mill	150 m^3/ha		1,500	
					lamination	150 m^3/ha		4,500	

Note 1) Harvest of Mate starts after 5 years of implantation and harvest rotation is every 20 months. Therefore, in 30 years, harvest is possible 15 times.

2) For Bracatinga, the intercropping with maize and beans is considered. Therefore, the income is a result of annual crop yields and Bracatinga felling which is once in 6 years.

3) For Eucalyptus, the natural regeneration method, which the stand regenerates by budding of the stumps, is considered. Three successive rotation is possible for one Eucalyptus.

4) Since the cost of felling and transportation depends on use of wood and location, their estimation requires the detail plan. Therefore, they are not included in the table.

5) Net Income = (Gross Income-Cost) / Rotation Year

Source: Ferreira (1995)

Net income of Mate is much greater than other species and the recent market seems to be favor to Mate. However, its internal and external market is still limited compared to one of Pinus or other species for timber. Since one of advantages of Mate is the harvest during the winter, when the source of farmers' income is limited. Therefore, Mate is recommended for agroforestry, intercropping with maize and beans. Its area expansion depends on the future market and to avoid the risk of market crush, agroforestry is practical for Mate.

In general, the lateral of each plot of agricultural land inclusive of pasture faces to the water course and is deforested for the maximum cultivation despite the fact that Forest Code defines the preserved area. Exact figures of these area is not countable at this study level; however, the approximate figures were estimated with the following assumptions.

1) The river margin protected by Forest Code occupies 3 % of each plot of agricultural land.

2) All river margins belonged to agricultural land are currently deforested.

Since the total area of agricultural land in Iguaçu river basin is approximately 30,000 km^2, the river margins deforested is 900 km^2. This land should be afforested with native forest species for conservation of the water environment. The total cost would be US$ 33 million. The implementation would be evenly in the next twenty years. Therefore, annual area of afforestation would be 4,500 ha.

Table-7.25 Implementation Schedule

	Area to be Afforested	Cost (million US$)	Year 1996		2005	2015
Afforestation for conservation of the Water Environment	900 km^2	33				
Commercial Afforestation	1,900 km^2	135				
5 Year Progress Rate		168	25 %	25 %	25 %	25 %

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