JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)

STATE SECRETARIAT OF PLANNING AND GENERAL COORDINATION,
PARANÁ STATE, THE FEDERATIVE REPUBLIC OF BRAZIL

THE MASTER PLAN STUDY ON THE UTILIZATION OF WATER RESOURCES IN PARANÁ STATE IN THE FEDERATIVE REPUBLIC OF BRAZIL

FINAL REPORT

EXECUTIVE SUMMARY

December, 1995

Yachiyo Engineering Co., Ltd,
Tokyo, Japan

and

Nippon Koei Co., Ltd.
Tokyo, Japan

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Cost Estimate is Based
on The Price Level of August, 1994,
According to The Following Exchange Rate.

US$ 1.00 = ¥ 98.87
(as of August, 1994)

PREFACE

In response to a request from the Government of the Federative Republic of Brazil, the Government of Japan decided to conduct a study on the Master Plan for the Utilization of Water Resources in Paraná State and entrusted the study to the Japan International Cooperation Agency (JICA).

JICA sent to Brazil a study team headed by Mr. Yoshio Nakagawa, Yachiyo Engineering Co., Ltd., and composed of staff members of Yachiyo Engineering Co., Ltd. and Nippon Koei Co., Ltd. (5 times between March 1994 and October 1995).

The team held discussions with the officials concerned of the Government of Brazil, and conducted field surveys at the study area. After the team returned to Japan, further studies were made and the present report was prepared.

I hope that this report will contribute to the promotion of the project and to the enhancement of friendly relations between our two countries.

I wish to express my sincere appreciation to the officials concerned of the Government of the Federative Republic of Brazil for their close cooperation extended to the team.

December, 1995

Kimio Fujita
President
Japan International Cooperation Agency

December, 1995

Mr. Kimio Fujita
President
Japan International Cooperation Agency
Tokyo, Japan

Letter of Transmittal

Dear Mr. Fujita,

We are pleased to submit to you the Master Plan report on the Utilization of Water Resources in Paraná State in the Federative Republic of Brazil. This report presents a strategy over the state on water environment, which includes not only comprehensive surface and underground resources development for various types of water use but also environmental facets of water, such as flood, quality of river water, soil erosion, eco-system, forest, etc., as well as a Master Plan for improvement of water environment in selected two pilot river basins.

In the Master Plan for the pilot river basins, projects and recommendations are embodied towards the year of 2015 for sectors of water supply, hydro-electric generation, flood control, water quality control and sewerage development, soil erosion control, eco-system conservation, forest preservation, water environment management, and institutional improvement. Urgent implementation of studies to follow this Master Plan Study is also proposed in the report.

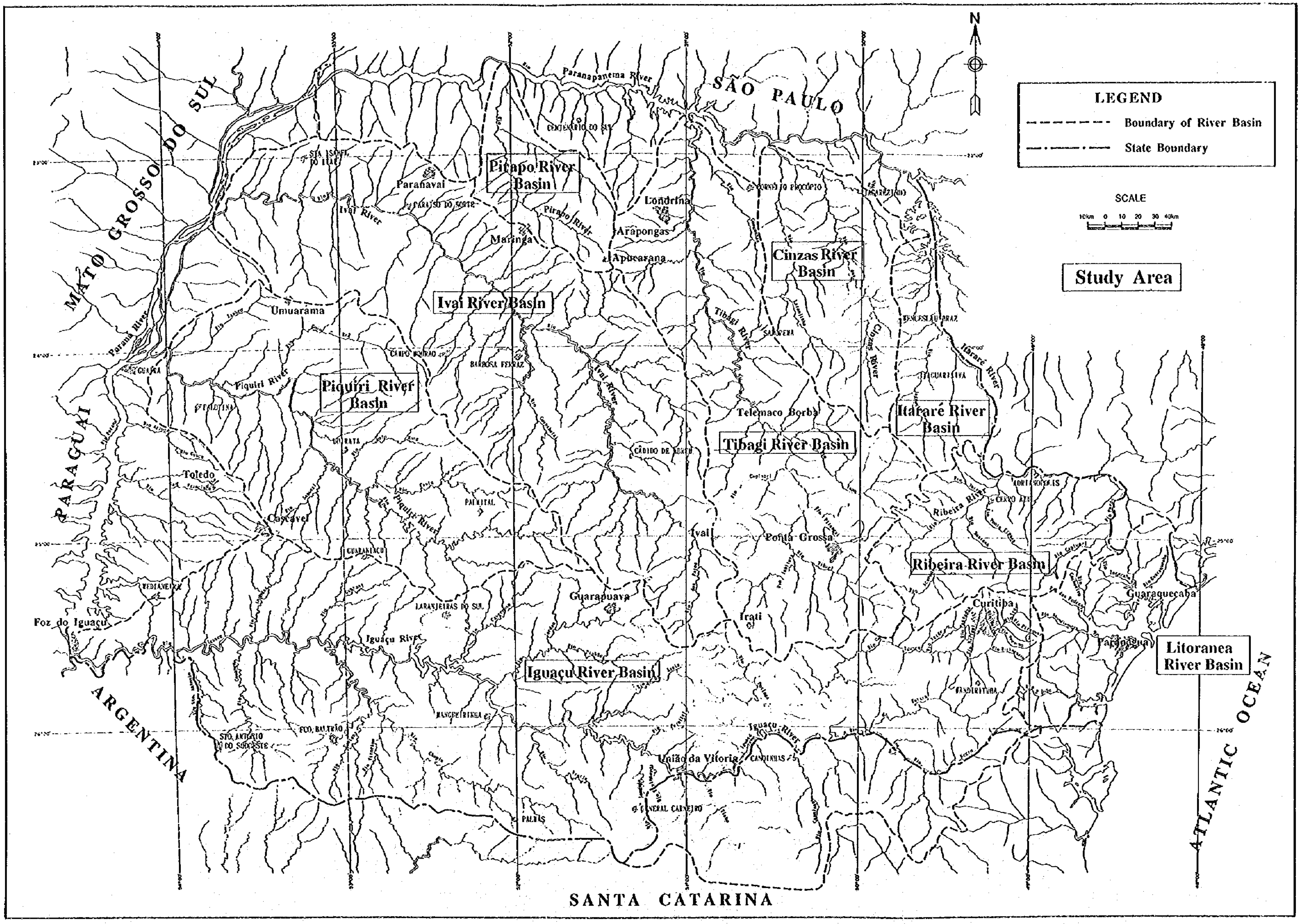
It would be a great honor for us that the result of the study would contribute to socio-economic development of Paraná State and to closer friendship between Japan and the Federative Republic of Brazil.

We wish to take this opportunity to express our sincerest gratitude to your Agency, the Ministry of Foreign Affairs, the Ministry of Construction, the Hokkaido Development Agency, the Embassy of Japan in Brazil and the General Consulate of Japan at Curitiba. We also wish to express our deepest gratitude to the State Secretariat of Planning and General Coordination and other authorities concerned of Paraná State as well as those of the Federative Republic of Brazil for close cooperation and assistance extended to us.

Very truly yours,

Y. Nakagawa

Yoshio Nakagawa
Team Leader
The Master Plan Study on
the Utilization of Water Resources in
Paraná State in the Federative Republic of Brazil


LEGEND
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State Boundary
SCALE
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PARAGUAI
ARGENTINA
SANTA CATARINA
ATLANTIC OCEAN
Paranapanema River
Pirapo River Basin
Ivai River Basin
Cinzas River Basin
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SYNOPSIS

THE MASTER PLAN STUDY ON THE UTILIZATION OF WATER RESOURCES IN PARANÁ STATE IN THE FEDERATIVE REPUBLIC OF BRAZIL

Study Period: March, 1994 - December, 1995
Recipient Agency : The State Secretariat of Planning and General Coordination of the State of Paraná

1. Background

Although agriculture was the main economic sector of the State, industrial development has been expanding around urban areas. The industrialization has resulted in concentration of the population to large cities, causing shortages in domestic and industrial water supply. In addition, water contamination due to domestic and industrial effluent, and the turbidity of river water caused by soil erosion on the large plateau have become critical issues. Further deforestation and decrease in riparian vegetation have resulted in destruction of eco-system including reduced numbers of endemic fish. In some parts of the State, floods have threatened lives and properties of the people.

2. Objectives

The objective of the Study is to formulate long term plans with target year of 2015, not only on comprehensive water resources development, but also on sectors regarding floods, river water quality, soil erosion, forests, and eco-system (in this Study these are included in the generic term of "water environment", together with water resources utilization), including recommendations on water environment management and institutions.

3. Study Area

The Study covers the whole State of Paraná - land area of 200 thousand km^2 with population of 8.5 million. There are eleven river basins in the Study area, comprising nine rivers flowing in the State - the Cinzas, the Iguaçu, the Itarare, the Ivai, the Litoranea, the Piquiri, the Pirapo, the Ribeira and the Tibagi Rivers - and two rivers forming boundaries with neighboring states or countries - the Paranapanema and the Paraná Rivers.

4. Outline of the Study

4.1. Frame of the Study

(1) Phases of the Study

The Study consists of the following three phases:

- Phase I: To determine the methodology for the Study on water environment improvement
- Phase II: To formulate the Strategy regarding water environment improvement in the whole Paraná State and to select Pilot River Basin(s).
- Phase III: To formulate the Master Plan regarding water environment improvement for the selected Pilot River Basin(s).

Master Plans for river basins other than the Pilot River Basins are expected to be formulated by the engineers and the staff of the State from now on.

(2) Socio-economic Framework

For the basis of the Study, a socio-economic framework was estimated as follows, assuming future rates of population increase and economic growth as 1.2 %/year and 5 %/year, respectively.

Table-1 Population and GDP Forecast

	1993	2005	2015
Population (thousand persons)	8,570 (=1.00)	9,910 (1.16)	11,130 (1.30)
GDP (US$ million)	27,811 (=1.00)	49,945 (1.80)	81,354 (2.93)
- Primary Sector	3,149	3,831	4,874
- Secondary Sector	9,295	17,446	29,110
- Tertiary Sector	15,367	28,668	47,370
GDP per Capita (US$/person)	3,240 (=1.00)	5,040 (1.56)	7,310 (2.26)

(3) Water Demand Projection

According to the above population and GDP forecast, water demands were estimated as shown in Table-2. Unit consumption rates of domestic use in urban and rural areas in 2015 were assumed as 180 liter/person-day and 80 liter/person-day, respectively. Agricultural water uses consist of those for livestock breeding and fish culture because of low requirement for irrigation due to favorable rainfall.

Table-2 Estimated Water Demands

unit: upper line $10^3m^3/day$
lower line $m^3/second$

Target Year	Domestic Water	Industrial Water	Agricultural Water	Total
1993	899 (=1.00)	476 (=1.00)	158 (=1.00)	1,533 (=1.00)
	10.4	5.5	1.8	17.7
2005	1,338 (1.49)	724 (1.52)	198 (1.25)	2,260 (1.41)
	15.5	8.4	2.3	26.2
2015	1,902 (2.12)	935 (1.96)	229 (1.45)	3,066 (2.00)
	22.0	10.8	2.6	35.4
(share to the total)	(62 %)	(31 %)	(7 %)	(100 %)

(Note) figures in the parentheses shows ratio to 1993 or to the total

4.2 Strategy for the Whole Paraná State

The Strategy on water environment improvement for the whole State of Paraná with target year 2015 is summarized in Table-3.

4.3 Master Plan for the Pilot River Basins

The Master Plan formulated for water environment improvement in the Iguaçu and the Tibagi River Basins selected as Pilot River Basins are shown in Table-4 and 5, respectively.

Table-3 Strategy for Water Environment Improvement in Paraná State

Sector / Contents of Strategy	Project Cost* (US$ million)
1. Water Supply	
(1) Structural Measures	
1) Domestic and Industrial Water	
- A volume of 1,678,000 m^3/day is planned to be supplied for Curitiba Metropolitan, 6 large urban areas and other urban areas through development of dams, direct intakes and boreholes	1,796
- No major development is planned for rural areas because rural population will not increase.	---
2) Agricultural Water	
- A volume of 88,000 m^3/day is planned to be supplied for livestock and fish culture through direct intake from streams near the demand points.	12
(2) Non-structural Measures	
- Decrease in water demand by public awareness campaign for saving water and promotion of recycle use of industrial water	
2. Flood Control	
(1) non-structural measures: land use control with resettlement, flood forecasting and warning systems, evacuation and rescue, enhanced flood proofing, etc., for 8 flood prone areas	---
(2) structural measures: dike construction, channel improvement, etc., for 4 areas - União da Vitoria, Curitiba Metropolitan Region, São Mateus do Sul, Morretes	200
3. Water Quality Improvement and Sewerage Development	
(1) Structural Measures	
- sewerage development with a total capacity of 920,000 m^3/day along 6 river basins to meet the water quality standards established by CONAMA throughout the State	704
(2) Non-structural Measures	
- optimum distribution of collective sewerage system and individual wastewater treatment units, such as septic tanks	
- introduction of cleaner production to industries	
4. Soil Erosion Control	
- terracing - 60,200 km^2 and applying non tillage cultivation 31,500 km^2 to reduce soil erosion, currently 28 ton/ha·year, to lower than 11 ton/ha•year	443
5. Eco-system Conservation	
(1) structural measures; solid waste management, establishment of urban green areas, establishment of a aquatic ecology laboratory	---
(2) non structural measures; monitoring water quality through benthic community monitoring, ecotoxicological study of agrochemicals, survey and research on fish, enhanced environmental education program, mangrove protection, legislation for restriction of the import of wood and reforestation, centralization of information to ecological database center, monitoring and preservation programs	---
6. Forest Preservation	
- preservation of natural forest and afforestation of 8,860 km^2	---
7. Water Environment Management	
- establishment of Water Environment Management Center and an integrated monitoring system	---
8. Institution	
i) strengthening organizations through current re-organization	---
ii) strengthened control/management of groundwater development/use	
iii) enhanced enforcement of environmental regulations	
iv) legal control of sand, soil and stone taking in river areas	
v) cost recovery in water environment management	
vi) encouraged residents' participation through information publication	
Sub-total	3,155
9. Hydropower Development	
- construction of 13 power stations with total capacity of 3,095 MW	3,381
Total	6,536

(Note) * estimated at prices in August, 1994 with an exchange rate of US$ 1 = R$ 0.89

Table-4 Master Plan for Water Environment Improvement in the Iguaçu River Basin

Sector Contents of Master Plan	Project Cost*1 (US$ million)
1. Water Supply	
1) Domestic and Industrial Water	
- Curitiba Metropolitan; amount 625,000 m^3/day ; 5 dams, 56 boreholes	760.0
- 3 large urban areas; amount 167,000 m^3/day ; 3 direct intakes, 10 boreholes	59.1
- 6 medium urban areas; amount 62,000 m^3/day ; 5 direct intakes, 1 borehole	35.8
- other 76 urban areas; amount 72,000 m^3/day ; direct intakes, boreholes	102.9
2) Agricultural Water; amount 33,000 m^3/day ; direct intakes	4.6
2. Flood Control	
- non-structural measures for 7 flood prone areas as shown in Table-3	
- structural measures for the following 3 areas	
· Curitiba Metropolitan; continuation of PROSAM (channel, landscape, park, resettlement, etc.), *2	(34.3)
extension of PROSAM (channel excavation, flood control dams)	---
· São Mateus do Sul; construction of dike and sluice	11.1
· União da Vitoria; construction of dike (L=17 km, H=5 m) and 8 sluices	85.9
3. Water Quality Improvement and Sewerage Development	
- Curitiba Metropolitan; treated amount 420,000 m^3/day	294.0
- Cascavel; treated amount 45,000 m^3/day	50.0
4. Soil Erosion Control	
- terracing; 10,781 km^2	43.1
- non tillage 7,520 km^2	35.5
- improvement of farm road 21,560 km	32.3
- maintenance of terrace and farm road	33.0
- agronomic measures and soil management	---
5. Eco-system Conservation	
- conservation programs (surveys on fish population, reproduction of endemic species, etc., conservation unit management, Serra Baitaca and Eng. Bley conservation, Biodiversity Institutes, etc.)	5.3
- education programs on water environment	0.9
- monitoring (bioindicator, river margin vegetation, sandfly)	2.4
6. Forest Preservation	
- river side afforestation for water environment conservation; 900 km^2	33.0
- commercial afforestation; 1,900 km^2	135.0
7. Water Environment Management	
- improvement of monitoring system (weather, hydrological measurement, sediment, groundwater level, aquatic ecology)	2.1
8. Institution	
Subsequent 6 programs are recommended after the 6 programs in Table-3.	---
vii) to introduce of river basin management and to establish competent entity	
viii) to promote coordinated and comprehensive management	
ix) to establish a Public Hearing System in water right allocation	
x) to enforce comprehensive water quality management by river basin	
xi) to enhance administration of water resources development	
xii) to enhance water pricing and charging for the optimal use and allocation	
Sub-total	1,726.0
9. Hydropower Development	
- construction of 3 power stations with total capacity of 1,400 MW	1,193.9
Total	2,919.9

(Note) *1 estimated with same assumption as Table-3.

*2 PROSAM: the Program of Environmental Sanitation in Metropolitan Region of Curitiba (currently in progress)

Table-5 Master Plan for Water Environment Improvement in the Tibagi River Basin

Sector Contents of Master Plan	Project Cost*1 (US$ million)
1. Water Supply	
1) Domestic and Industrial Water	
- 3 large urban areas; amount 188,000 m^3/day ; 2 direct intakes, 8 boreholes	74.9
- 6 medium urban areas; amount 81,000 m^3/day ; 6 direct intakes, 1 borehole	52.0
- other 26 urban areas; amount 30,000 m^3/day ; direct intakes, boreholes	32.9
2) Agricultural Water; amount 8,000 m^3/day ; direct intakes	1.0
2. Flood Control	
- non-structural measures as shown in Table-3 for 2 flood prone areas (Irati, Ipiranga)	---
3. Water Quality Improvement and Sewerage Development	
- Ponta Grossa; treated amount 30,000 m^3/day	29.2
- Londrina; treated amount 70,000 m^3/day	59.4
4. Soil Erosion Control	
- terracing; 3,344 km^2	13.4
- non tillage 2,530 km^2	18.7
- improvement of farm road 6,690 km	10.0
- maintenance of terrace and farm road	10.7
- agronomic measures and soil management	---
5. Eco-system Conservation	
- conservation programs (surveys on fish population, reproduction of endemic species, etc., conservation unit management, inundated lowland study)	1.9
- monitoring (bioindicator, river margin vegetation)	1.8
6. Forest Preservation	
- river side afforestation for water environment conservation; 400 km^2	15.0
- commercial afforestation; 2,000 km^2	142.0
7. Water Environment Management	
- improvement of monitoring system (weather, hydrological measurement, sediment, groundwater level, aquatic ecology)	0.7
8. Institution	
Subsequent 6 programs are recommended after the 6 programs in Table-3.	---
vii) to introduce of river basin management and to establish competent entity	
viii) to promote coordinated and comprehensive management	
ix) to establish a Public Hearing System in water right allocation	
x) to enforce comprehensive water quality management by river basin	
xi) to enhance administration of water resources development	
xii) to enhance water pricing and charging for the optimal use and allocation	
Sub-total	463.6
9. Hydropower Development	
- construction of 5 power stations with total capacity of 1,096 MW	1,147.3
Total	1,610.9

(Note) *1 estimated with same assumption as Table-3.

5. Project Costs

The project costs required for the implementation of the Strategy and the Master Plan for the Iguaçu and the Tibagi River Basins are as shown in Table-3, 4 and 5, respectively.

6. Evaluation of the Plans

6.1 Economic and Financial Evaluation

(1) Magnitude of the Investment

Required investment for the implementation of the Strategy for water environment improvement in Paraná State by 2015 will reach US$ 3,155 million, excluding that for hydropower development sector, where investment is covered through different channels. At the same time, the cumulative amount of public investment by the State Government will reach US$ 4,400 million by 2015. The total cost corresponds to 72 % of the cumulative public investment. The comparison of the total cost with projected cumulative public investment might show some financial feasibility of the magnitude of the total cost, even though the public investment includes those for development for housing establishments, transportation and telecommunication networks, etc., and substantial parts of the total cost except those for flood control or ecology conservation, will be invested by relevant State or private companies or entities.

(2) Economic Evaluation

Results of the economic analysis of the projects proposed in the Master Plan are shown Table-6.

EIRR's of the projects for most of the water supply in large and medium urban areas, flood control, sewerage development, and hydropower development surpass 10 %, a benchmark for economic feasibility. EIRR of water supply projects in other urban areas in the Iguaçu river basin is derived under 10 %. The reason can be that unit prices of water supplied in these area are high due to small scale of the development. Water supply projects generate various types of benefits other than economic ones, such as better public health with improved sanitation level, stable livelihood of the people and enhanced welfare, which cannot be quantified and taken into account in the economic evaluation. The water supply projects should not be judged only from the economic evaluation. The projects of soil erosion control have also lower EIRR's than 10 %. Benefits of these projects include not only savings in fertilizing as accounted in the evaluation, but also increased agricultural productivity, saving in purification for water supply, or other benefits resulted from better water quality or less sediment, which are difficult to quantify.

(3) Financial Evaluation

Of the projects analyzed in the above economic evaluation, water supply and sewerage projects and hydropower projects will generate revenue to the managing entity, such as SANEPAR and COPEL. A financial evaluation is carried out for water supply and sewerage sector, whose services are limited to the people of the State. The results are shown in Table-7. Water supply projects in other urban areas in the Iguaçu River Basin have considerably low FIRR as 4.8 %, while other projects show higher FIRR's at around 10 % or more.

Table-6 Result of Economic Evaluation

Sector	Project Scale	EIRR (%)	Net Present Value (US$ million)	Cost Benefit Ratio (B/C)
<Iguaçu River Basin>				
1. Water Supply				
- Curitiba Metropolitan Region	625,000 m^3/day	10.29	14.9	1.02
- 3 large urban areas	167,000 m^3/day	40.79	197.1	3.86
- 6 medium urban areas	62,000 m^3/day	25.92	50.1	2.20
- other 76 urban areas	72,000 m^3/day	8.20	-11.7	0.90
2. Flood Control				
- União da Vitoria	dike (L=17 km, H=5 m)	14.65	52.2	1.91
3. Sewerage Development				
- Curitiba Metropolitan Region	420,000 m^3/day	24.27	359.2	2.65
- Cascavel	45,000 m^3/day	16.57	24.6	1.66
4. Soil Erosion Control	18,300 km^2	8.63	-7.7	0.93
6. Hydropower Development	Fundao, 154 MW*	19.70	188.4	2.31
<Tibagi River Basin>				
1. Water Supply				
- 3 large urban areas	188,000 m^3/day	35.98	197.5	3.26
- 6 medium urban areas	81,000 m^3/day	22.82	55.9	1.92
- other 26 urban areas	30,000 m^3/day	12.90	6.7	1.18
2. Sewerage Development				
- Ponta Grossa	30,000 m^3/day	18.56	19.6	1.90
- Londrina	70,000 m^3/day	20.56	50.7	2.12
3. Soil Erosion Control	5,874 km^2	8.36	-2.0	0.92
4. Hydropower Development	5 stations, 1,096 MW	25.90	1,853.8	3.41

(Note) * excluding two hydropower stations (Jordão Diversion and Salto Caxias) in the Iguaçu River Basin, of which construction has already started.

Table-7 Result of Financial Evaluation

Sector	Construction Cost (US$ million)	Annual O&M Cost (US$ million)	Annual Revenue (US$ million)	FIRR (%)
<Iguaçu River Basin>				
1. Water Supply				
- Curitiba Metropolitan Region	760.0	68.4	157.5	9.5
- 3 large urban areas	59.1	5.3	31.3	28.9
- 6 medium urban areas	35.8	3.2	14.6	22.7
- other 76 urban areas	102.9	9.3	16.2	4.8
2. Sewerage Development				
- Curitiba Metropolitan Region	293.6	3.6	89.6	21.3
- Cascavel	49.5	0.7	9.6	14.3
<Tibagi River Basin>				
1. Water Supply				
- 3 large urban areas	74.9	6.7	40.7	29.5
- 6 medium urban areas	52.0	4.7	20.5	22.0
- other 26 urban areas	32.9	3.0	6.8	9.4
2. Sewerage Development				
- Ponta Grossa	29.2	0.4	6.3	16.0
- Londrina	59.4	1.0	14.8	17.7

6.2 Social and Environmental Assessment

The projects included in the Master Plan are 1) surface water use for water supply and power generation by dam development, 2) water supply by direct intake of surface water, 3) groundwater development by borehole drilling, 4) flood control by dike construction or channel improvement, 5) sewerage development, 6) soil erosion control by terracing or non tillage cultivation, 7) eco-system conservation, and 8) afforestation, aiming at improvement of water environment. The positive impacts will be much larger than the negative impacts on the society and the environment.

Since this Study is at a Master Plan level, detailed examinations of the negative impacts would be difficult at the moment. According to a preview of the negative impacts, the following issues should be examined in detail in feasibility studies.

1) lands acquisition, compensation or resettlement
2) water allocation between existing water right holders and prospective users
3) sedimentation in reservoirs and degradation of downstream river beds by dam construction
4) changes in reservoir water quality and effects on downstream river channel by dam construction
5) change in landscape and submergence of historical ruins, cultural heritage or conservation areas by reservoir development
6) groundwater level lowering or effects on water quality or discharge of surface water by groundwater development
7) affects on surrounding habitats of fauna or on aquatic or terrestrial flora by construction of dams or dikes, or channel excavation
8) effects on downstream river due to intake or discharge of water

7. Recommendations

(1) Studies to be Urgently Implemented

1) Study on Comprehensive Regional Plan on Water Environment for the Curitiba Metropolitan Region (regional planning and feasibility studies)
2) Feasibility Study on Flood Control in União da Vitoria
3) Feasibility Study on Water Supply and Sanitation in Londrina
4) Feasibility Study on Water Supply and Sanitation in Cascavel
5) Feasibility Study on Water Supply and Sanitation in Ponta Grossa

(2) Master Plan Study for Other River Basins than the Pilot River Basins of the Study

(3) Review of Development Plans of Other Sectors based on the proposed programs

(4) Implementation and Review of the Proposed Programs

THE MASTER PLAN STUDY ON
THE UTILIZATION OF WATER RESOURCES IN PARANA STATE
IN THE FEDERATIVE REPUBLIC OF BRAZIL
EXECUTIVE SUMMARY

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List of Abbreviation

CEPA : State Commission for Agricultural Planning
Comissão Estadual de Planejamento Agrícola

COMEC : Coordination of the Metropolitan Area of Curitiba
Coordenação da Região Metropolitana de Curitiba

CONAMA : National Council of Environment
Conselho Nacional do Meio Ambiente

COPATI : Inter Municipal Concessionaire for the Environmental Protection of the Tibagi River Basin
Consórcio Intermunicipal para a Proteção Ambiental de Bacia do Rio Tibagi

COPEL : Energy Company of the State of Paraná
Companhia Pananaense de Energia

CORPRERI : Permanent Regional Commission Against Floods in the Iguaçu River
Comissão Regional Permanente Contra as Cheias do Rio Iguaçu

DAGRI : Agricultural Operation Department
Departamento Operacional da Agricultura

DEPEC : Livestock Department
Departamento de Pecuária

DERAL : Economy Department
Departamento de Economia

DNAEE : National Department of Water and Electric Energy
Departamento Nacional de Águas e Energia Elétrica

ELETROBRAS : Brazilian Central Electric Joint-stock Company
Centrais Elétricas Brasileiras S.A.

ELETROSUL : Electric Center of the South
Centrais Elétricas do Sul do Brasil S.A.

EMATER : Paraná State Technical Assistance and Rural Extension Company
Empresa Paranaense de Assistência Técnica e Extensão Rural

EMBRAPA : Brazilian Agriculture and Livestock Research Company
Empresa Brasileira de Pesquisa Agropecuária

FAMEPAR	:	Institute for Municipal Assistance of Paraná State *Instituto de Assistência aos Municípios do Estado do Paraná*
FAO	:	Food and Agriculture Organization *Fundo das Nações Unidas para Alimentação e Agricultura*
IAP	:	Environmental Institute of Paraná *Instituto Ambiental do Paraná*
IAPAR	:	Agricultural Research Institute of Paraná *Instituto Agronômico do Paraná*
IBAMA	:	Brazilian Institute of Environment and Renewable Natural Resources *Instituto Brasileiro do Meio Ambiente e de Recursos Naturais Renováveis*
IBDF	:	Brazilian Forest Development Institute (current IBAMA) *Instituto Brasileiro de Desenvolvimento Florestal*
IBGE	:	Brazilian Institute of Geography and Statistic *Instituto Brasileiro de Geografia e Estatística*
IPARDES	:	Economic and Social Development Institute of the State of Paraná *Instituto Paranaense de Desenvolvimento Econômico Social*
JICA	:	Japan International Cooperation Agency *Agência de Cooperação Internacional do Japão*
MERCOSUL	:	South Common Market in Brazil, Argentina, Uruguay and Paraguay *Merca do Cone Sul*
MINEROPAR	:	Paraná State Mineral Company *Minerais do Paraná S/A*
PROSAM	:	Environmental Sanitation Program for Curitiba Metropolitan Region *Programa de Saneamento de Região Metropolitan de Curitiba*
SANEPAR	:	Sanitation Company of the State of Paraná *Companhia de Saneamento do Paraná*
SEAB	:	State Secretariat of Agriculture and Supply *Secretaria de Estado da Agricultura e do Abastecimento*
SEDU	:	State Secretariat of Urban Development *Secretaria de Estado do Desenvolvimento Urbano*

SEFA	:	State Secretariat for Treasury Secretaria de Estado da Fazenda
SEID	:	State Secretariat for Industry, Commerce and Economic Development *Secretaria de Estado da Indústria, Comércio e do Desenvolvimento Econômico*
SEMA	:	State Secretariat of Environment *Secretaria de Estado do Meio Ambiente*
SEPL	:	State Secretariat of Planning and General Coordination *Secretaria de Estado do Planejamento e Coordenação Geral*
SETR	:	State Secretariat of Transport *Secretaria de Estado dos Transportes*
SIMEPAR	:	Meteorological System of Paraná *Sistema Meteorológico do Paraná*
SETI	:	State Secretariat of Science, Technology and Higher Education *Secretaria de Estado da Ciência, Technologia e Ensino Superior*
SUCEAM	:	Superintendency of Erosion Control and Environmental Sanitation *Superintendência do Controle de Erosão e Saneamento Ambiental*
SUREHMA	:	Superintendency of Water Resources and Environment *Superintendência dos Recursos Hidricos e Méio Ambriente*
UEL	:	State University of Londrina *Universidade Estadual de Londrina*
UNDP	:	United Nation Development Program *Programa das Nações Unidas para o Desenvolvimento*

CHAPTER 1 INTRODUCTION

The State of Paraná is located in the south of Brazil, having a land area of around 200 thousand km^2 with population of about 8.5 million. Although agriculture is still the main sector of the State economy, agro-industry, chemical and paper industries, etc., have been expanding around urban areas under the industrialization policy of the State Government. Industrialization has resulted in concentration of population to large cities, such as Curitiba, the capital city of the State, Londrina, Maringa, Cascavel, Ponta Grossa, etc., causing shortages in domestic and industrial water supply. In addition, water contamination due to domestic and industrial effluent, and the turbidity of river water caused by soil erosion on the large plateau has become a critical issue. Furthermore, due to decrease of forest and river margin vegetation, the ecological system mainly in fish population has been devastated and large scale flood disasters have occurred in some particular river basins.

The topography of Panará is mainly plateau, and the rivers are eroding the plateau. Since most cities and agricultural lands are located on the plateau, the sources of water supply have to be waters in tributaries of upper stream of major rivers or groundwater. Despite comparatively favorable rainfall, conflicts have started to occur among the water uses of various sectors.

The situation mentioned above necessitated the State of Paraná to formulate a comprehensive Master Plan for the utilization of water resources, as well as long term plans for flood control, water quality improvement, soil erosion control and eco-system conservation with a target year of 2015.

With the circumstances as a background, the Government of the Federative Republic of Brazil requested technical cooperation related to the Master Plan Study on the Utilization of Water Resources in Paraná State from the Government of Japan in August, 1993. In compliance with the request, the Japan International Cooperation Agency dispatched a Preparatory Study Team in October, 1993, and the present Study has been conducted since March 1994.

The objective of the Study is to formulate long term plans regarding not only utilization of water resources but also sectors related to water environment, such as flood, river water quality, soil erosion and eco-system, etc. In the Study, the word "water environment" means these environmental sectors as well as water utilization.

The area covered by the Study is the whole of the state of Paraná. The Study was divided into three phases as follows:

- Phase I: To determine the methodology for the Study on water environment improvement
- Phase II: To formulate the Strategy regarding water environment improvement in the whole Paraná State and to select Pilot River Basin(s).
- Phase III: To formulate the Master Plan regarding water environment improvement for the selected Pilot River Basin(s).

Technology transfer to the Brazilian counterparts has been carried out in various forms throughout the Study.

CHAPTER 2 CONCEPTS OF WATER ENVIRONMENT MANAGEMENT

2.1 Framework of Water Environment Management

The concepts employed in the framework of water environment management are illustrated in Figure-2.1.

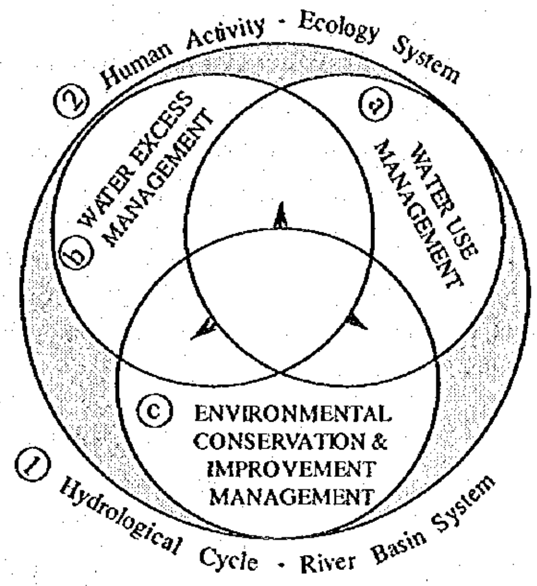


Figure-2.1 Framework of Water Environment Management

As shown in the above figure, water environment is composed of two folds of interactive systems;

1) hydrological cycle - river basin system, and
2) human activity - ecology system related to water.

The former system is an integrated surface and sub-surface system with basic dimensions of quantity, quality, time and space. The latter is an interactive biosphere between human activity and ecosystem relating to water.

Water environment in this Study covers such elements as;

a) use of surface and underground water for the purposes of domestic, industrial and agricultural water supply, hydro-power generation, navigation and aqua-culture,
b) flood control and urban drainage, and
c) environment conservation, such as water quality control, soil erosion control and eco-system preservation.

These elements form a circle, and are inter-related to each other. The magnitude of inter-relation among the elements will grow corresponding to the evolution of social and economic activities.

Although the following chapters describe the contents of the studies for the respective sectors, these sectors, in fact, have a close and complicated inter-relation to one another.

2.2 Water Environment Management

Water environment management is a comprehensive management system, comprising of the following components. The interactions among the components are illustrated in Figure-2.2.

1) Global Hydrological Cycle Model
2) Standards, Guidelines and Models for Planning and Management
3) Project Management for Water Use and Environmental Considerations
4) Integrated Institutional Framework
5) Operation of Surface and Sub-surface Water System
6) Monitoring of Surface-Subsurface Water System

In order to achieve the integrated water environment management, the existing institutional framework is necessary to be strengthened. At the same time, setting up a feed-back system of data acquired through monitoring to water environment management is necessary to attain comprehensive management.

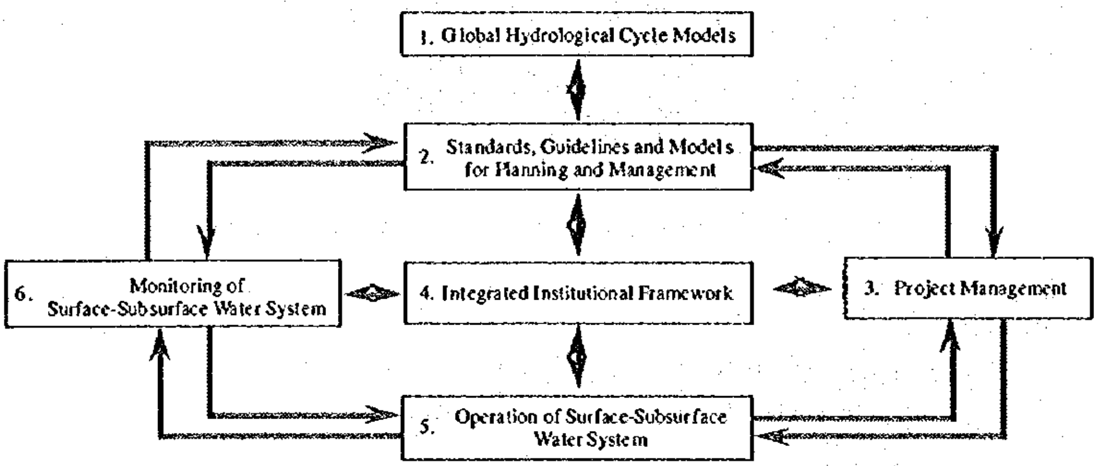


Figure-2.2 Concept of Integrated Water Environment Management

CHAPTER 3 NATURAL CONDITIONS

3.1 Location

Paraná State is located in southern Brazil, between latitude of 22° 31' to 26° 43' south and longitude of 48° 05' to 54° 37' east. The total land area of the State is 199,554 km^2 with length of 647 km from east to west and 486 km from north to south. The State borders with the States of Sao Paulo in the north, Mato Grosso do Sul in the north-west and Santa Catarina in the south, the countries of Paraguay and Argentina in the west and the Atlantic Ocean in the east. The Paranapanema river is the northern border and the Paraná river is the western border. The Atlantic Ocean coastline, 98 km in length and the eastern border of the State, forms the Parana bay, one of the most important bays in Brazil, where the ports of Paranagua and Antonia are located (refer to Study Area Map).

3.2 Topography and Geology

The topographic features of Paraná State consist of a narrow coastal plain in the eastern part, coastal mountain ranges (the Serra do Mar, dividing the coastal plain from the inland plateau) and three successive plateau (elevation ranging from 1,000 m to 300 m, with gentle topographic slope) stretching from east to west. The highest point of altitude is Paraná Peak, with a height of 1,922 m (refer to Figure-3.1).

Most parts of the narrow coastal plain are alluvial. The coastal mountain ranges are composed of crystalline rocks. The first plateau, the Curitiba region, is composed of the eroded crystalline rock formation. The second plateau, the Ponta Grossa region, is composed of sedimentary rock, stratified rock and limestone. The third plateau, the Guarapuava region and two thirds (2/3) of the State area, is covered by volcanic soils, so-called "purple soil" in the northern, western and southern regions, and covered by sandy soils of sedimentary rock origin in the northern region.

There are 11 major river basins in Paraná, most of which flow into the Paranapanema river formulating state boundary in the north, or the Paraná river formulating partly national boundary with Paraguay in the west. And they are the Itarare, Cinzas, Tibagi, Pirapo, Ivai, Piquiri and Iguaçu rivers. Only two rivers, and Litoranea in the east of coastal mountain range and the Rebeira rivers flow into the Atlantic Ocean. The gradient of the most rivers is also very gentle.

3.3 Meteorology and Hydrology

The annual average temperature in the state is between 16-22 °C. The maximum monthly mean temperature (20 °C-25 °C) and the minimum monthly mean temperature (11 °C-18 °C) occurs in January to February and in June to July, respectively.

The monthly mean rainfall in summer (December to February) is higher than that in winter (June to August) in the Litoranea and northern regions. In southern regions, seasonal variation is not remarkable although May and October have slightly higher rainfall. The highest rainfall occurs in the coastal region with 1,500-2,500 mm/year. The west of the coastal mountain ranges, including Curitiba region, has lowest rainfall of 1,400 mm/year. In the western parts of plateau, rainfall is higher than that in the east. The south-west of the plateau also has relatively high rainfall of 2,000 mm/year, which decreases gradually toward the east and north and reaches to 1,400 mm/year and 1,500 mm/year respectively.

The annual runoff percentages and the monthly specific discharge of the main rivers, except the rivers in the Litoranea, range from 30 % to 50 % with an average of 41 % and from 1.5 $m^3/sec/100\ km^2$ to 3.0 $m^3/sec/100\ km^2$, respectively. Due to the steep topographic conditions and high rainfall of the Litoranea region, the annual runoff ratio and the monthly specific discharge are 70 % to 80 % and 2.6 $m^3/sec/100\ km^2$ to 12.3 $m^3/sec/100\ km^2$, respectively.

3.4 Land Use

Land use distribution of the Parana state is obtained as below through the Satellite Imagery Analysis carried out by the IAP and the SANEPAR.

1)	Agricultural Lands	:	37.6 %
2)	Secondary Vegetation Lands	:	26.0 %
3)	Pasture Lands	:	23.1 %
4)	Forest Lands	:	9.0 %
5)	Reforest Lands	:	3.2 %

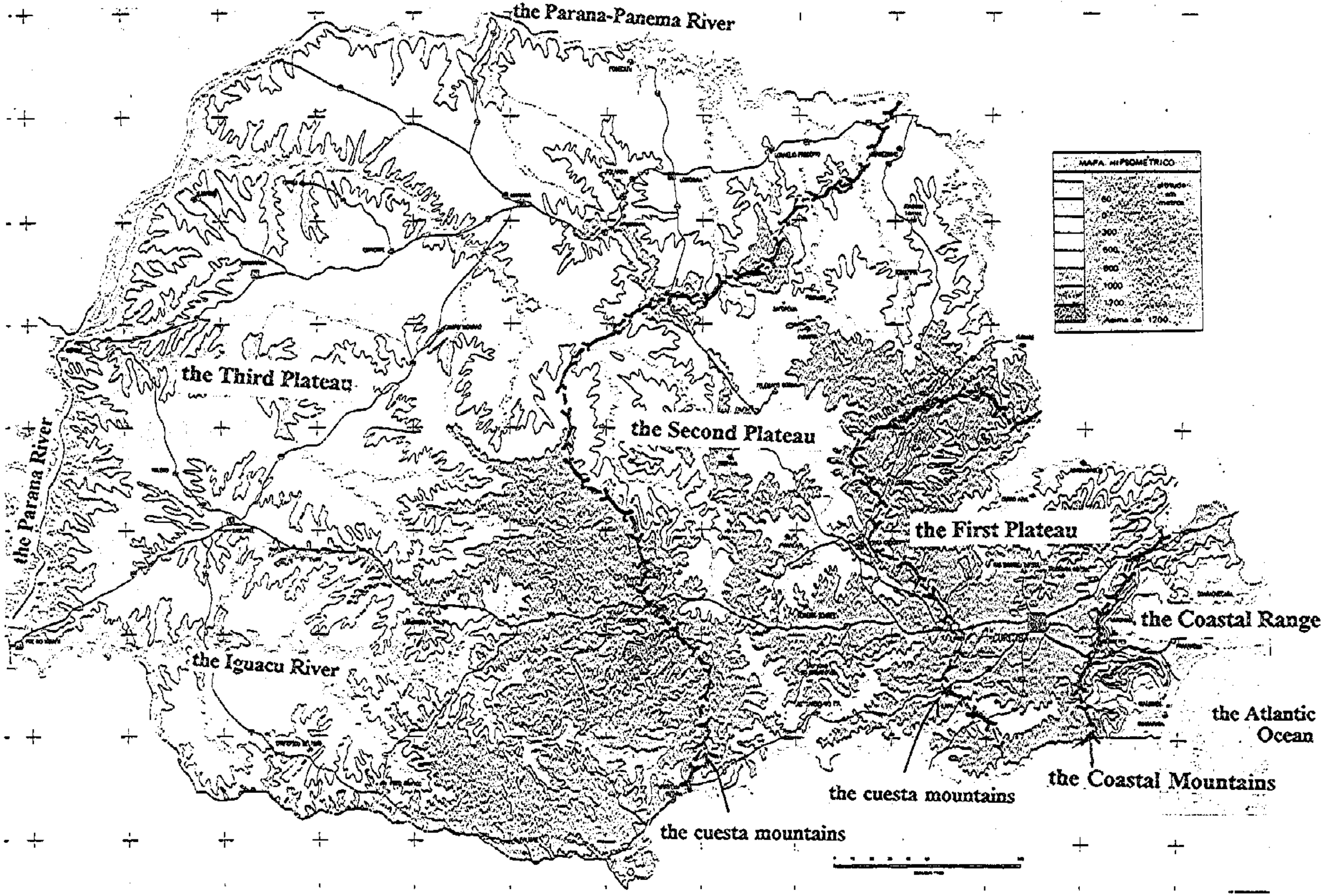


Figure-3.1 Topography Map of Paraná State

CHAPTER 4 PRESENT AND FUTURE SOCIO-ECONOMIC CONDITIONS

4.1 Administrative Features

The Federative Republic of Brazil consists of 26 states and one federal district, and the State of Paraná is one of them. Each state has state government and is substantially independent from the Federal Government and the administration is considerably decentralized. The executive branch of the State Government of Paraná headed by the Governor has 20 state secretariats. In the State of Paraná, there were 371 municipalities as in 1993. Each of the municipalities has a local government headed by the mayor. And each municipality is divided into urban area and rural area in accordance with urban perimeter determined by the municipality. Other than jurisdictional division, municipalities within the State are grouped into 24 socio-economic division, called as homogeneous micro region, for statistical and planning purposes, according to the social and economic characteristics of the municipalities.

4.2 Population

The census data of 1991 shows that the State of Paraná had a population of 8.45 million. The average rate of population increase during the period from 1970 to 1991 was 0.95 %/year, and had remained almost constant. This increase rate was considerably lower than that of the whole Brazil (2.12 %). The population increase during the same period in urban areas, however, reached 4.41 %/year, while the rate of population decrease in rural areas was -3.17 %. These figures show clear trends of population concentration in urban areas. Population increase in urban has kept high since 1970's, and the distribution of population to urban and rural areas in 1991 was 73 % and 27 %, respectively.

Estimation of future population has been carried out by the IPARDES and conducted in the Study as shown in the Table-4.1 and 4.2. The Study applies the figures as shown the tables.

Table-4.1 Estimate of Future Population for the Whole State

(unit: thousand persons)

	1993 (A)	2005 (B)	2015 (C)	Increase Ratio (B/C)	Increase Ratio (C/B)
Population					
- Urban	6,430 (75 %)	8,350 (84 %)	9,970 (90 %)	1.29	1.55
- Rural	2,150 (25 %)	1,560 (16 %)	1,160 (10 %)	0.73	0.54
Total	8,570 (100 %)	9,910 (100 %)	11,130 (100 %)	1.15	1.29

Annual Increase Rate		
- Urban	2.6 %	1.8 %
- Rural	- 3.2 %	- 2.9 %
Total	1.2 %	1.2 %

Table-4.2 Estimate of Future Population for Major Cities

(unit: thousand persons)

Name of City	1993 (A)	2005 (B)	2015 (C)	Increase Ratio (B/C)	Increase Ratio (C/B)
Curitiba	1,338	1,546	1,717	1.16	1.28
Londrina	381	488	580	1.28	1.52
Ponta Grossa	227	270	307	1.19	1.35
Foz do Iguaçu	186	250	303	1.34	1.63
Cascavel	204	354	479	1.74	2.35

4.3 Economy

(1) Industry

The share of the primary sector (agriculture, livestock breeding, fishery, etc.), the secondary sector (manufacturing), and the tertiary sector (commerce and other services) of the State in 1989 are 14 %, 26 % and 60 %, respectively. Paraná State has the major share of Brazil's Agricultural production. Value added (VA) by the agricultural sector of the State accounts 20 % of the total VA by agricultural sector of the whole Brazil. The productions of cotton, soybean, maize and wheat are ranked as first in Brazil. Agriculture is still a main industry in the State. Major manufacturing products are food, textile, pulp and paper, furniture and non-metallic minerals. The industrial sector is expected to grow in the future as well.

(2) Gross Domestic Products

Gross domestic products (GDP) and GDP per capita of Paraná State grew at the annual rate of 4.7 % and 3.7 %, respectively, during the period from 1980 and 1991 on average. GDP per capita has reached around US$ 3,000. Annual growth rates of the primary, secondary, and tertiary sectors were 2.1 %, 4.8 % and 7.6 % respectively, on average of 1980's. Future annual growth rate was estimated as 5 % according to the past trends as well as estimates studied by the ELETROBÁS/COPEL. Future annual growth rates of VA of the primary, secondary, and tertiary sectors were assumed to be 1.7 %, 5.4 % and 5.3 %, respectively. GDP per capita will grow at an annual rate of 3.8 % according to the above estimation. Estimates of the GDP, the VA and the GDP per capita are summarized in Table-4.3.

Table-4.3 Estimated GDP-Paraná by Sector - 1993, 2005 and 2015

Year	Primary Sector Million US$	Primary Sector %	Secondary Sector Million US$	Secondary Sector %	Tertiary Sector Million US$	Tertiary Sector %	GDP - Paraná Million US$	GDP - Paraná %	GDP per capita US$
1993	3,149	11	9,295	33	15,367	56	27,811	100	3,240
2005	3,831	8	17,446	35	28,668	57	49,945	100	5,040
2015	4,874	6	29,110	36	47,370	58	81,354	100	7,310

4.4 Public Investment

The amount of the recent GDP, government's revenue and expenditure of the State as well as public investment are shown in Table-4.4. Public investments are estimated with the assumption that the ratio of the Government's expenditure to the GDP and the ratio of the public investment to the expenditure will remain 6 % and 7 %, respectively in the future. Cumulative public investment from 1995 to 2015 will amount to US$ 4.4 billion based on to the estimate shown below.

Table-4.4 GDP, Government's Revenue and Expenditure, and Pubic Investment of the State

(unit: US$ million)

	1988	1989	1990	1991	1992	1993	2005	2015
GDP··········A	25,352	25,619	24,286	25,225	26,486	27,811	49,945	81,354
Revenue·······B	1,625	1,533	1,859	1,637	1,609	1,744	2,997	4,881
Expenditure··C	1,991	2,079	1,787	1,637	1,566	1,586	2,997	4,881
Investment···D	28.7	27.2	38.8	128.8	117.2	92.5	209.8	341.7
C/A (%)	7.9	8.1	7.4	6.5	5.9	5.7	6.0	6.0
D/A (%)	1.4	1.3	2.2	7.9	7.5	5.8	7.0	7.0

CHAPTER 5 PRESENT AND FUTURE WATER ENVIRONMENT

5.1 Domestic Water Use

The SANEPAR covers dominant share in water supply: 85 % of the municipalities and 92 % of the population in the Sate. Domestic water consists of residential water, consumed by individual households, and non-residential water, consumed in commercial and public establishments. Estimated consumption per person according to the data from SANEPAR is shown in Table-5.1. Unit consumption rates vary by urban and rural areas, as well as by income level within urban areas. The unit consumption rates in the target years were estimated taking into account raised income level. Water demand for domestic use was estimated by multiplying the unit consumption rate as estimated above by the projected population growth in the target years.

Table-5.1 Unit Consumption Rate for Domestic Use

(unit: liter/person·day)

	1993		2005		2015	
Classification	Urban	Rural	Urban	Rural	Urban	Rural
Residential Water	90	70	115	75	140	80
Non-residential Water	25	25	30	0	40	0
Total	115	70	145	75	180	80

(note) unit consumption rate in rural area is assumed as the minimum figure of urban areas

5.2 Industrial Water Use

There are around 26,000 factories in the State at present. Water used in some factories is supplied through SANEPAR distribution network, while other factories have developed water facilities, such as boreholes, of their own. Total consumption of water for industrial use is estimated at 474,000 m^3/day. Out of the total, 400,000 m^3/day is consumed by 900 large consumers.

Unit consumption rate per VA (US$ 1,000) in 1993 was estimated, putting all accounts of available data provided by SANEPAR, the IAP and the SEID, even though reliable data available for the estimation of industrial water use are quite limited. Future unit consumption rate was estimated taking account of increase in recycle use, as shown in Table-5.2. Industrial water demands in target years were calculated by multiplying the estimated unit consumption rate and projected VA in the secondary sector (manufacturing).

Table-5.2 Unit Consumption Rate of Industrial Water Use

	1993	2005	2015
Increase in Recycle Ratio (%)	---	19	37.5
Unit Consumption Rate (m^3/day·US$1000VA)	0.059	0.048	0.037

5.3 Agricultural Water Use

Agricultural water uses include those for irrigation, livestock breeding and inland fish culture. Due to favorable rainfall, rainfed agriculture is practically adequate in the State for eleven primary crops; cotton, rice (paddy and upland), potato, coffee, sugarcane, beans, cassava, maize, soybean and wheat. There is little water consumption to be accounted in terms of irrigation.

Cattle, pig and chicken are the primary livestock in the State, whose population in 1993 was 2,815,000, 9,736,000 and 60,744,000, respectively. Unit consumption rate was estimated for the primary livestock as shown in Table-5.3. Actual water supply for cattle was estimated as one third (1/3) of the total requirement, deducting the moisture content of forage. And thus water demand for livestock was estimated by multiplying the population projected by the trend analysis of IBGE data in the last twenty years, with the unit consumption rate.

Table-5.3 Water Requirement of Livestock

Livestock	Average Live Weight (kg)	Total Water Requirement (liter/head-day)	Actual Water Supply (liter/head-day)
Pig	40	4.0	4.0
Cattle	300	30.0	10.0
Chicken	2	0.2	0.2

Note: Total water requirement includes water intake by forage.

Main species of fish raising in Paraná are carp and tilapia. There were approximately 3,800 ha of fish ponds in 1993 with an average water depth of 1 m, according to DEPEC. The productivity is approximately 1.5 ton/ha/year. Water consumption in fish ponds was assumed as 1 mm/day, taking account of rainfall and evaporation data. Annual growth rate of fish pond area was assumed as 2 %, almost same as the growth rate of VA of the primary sector (agriculture). And thus water demand for fish culture was estimated by multiplying projected fish pond area with the water consumption rate.

5.4 Water Demand

Water demands for domestic, industrial and agricultural use in the target years are summarized in Table-5.4.

Table-5.4 Estimated Water Demands

unit: upper line 10^3m^3/day
lower line m^3/second

Target Year	Domestic Water	Industrial Water	Agricultural Water	Total
1993	899 (1.00) 10.4	476 (1.00) 5.5	158 (1.00) 1.8	1,533 (1.00) 17.7
2005	1,338 (1.49) 15.5	724 (1.52) 8.4	198 (1.25) 2.3	2,260 (1.41) 26.2
2015 (share to the total)	1,902 (2.12) 22.0 (62 %)	935 (1.96) 10.8 (31 %)	229 (1.45) 2.6 (7 %)	3,066 (2.00) 35.4 (100 %)

Note: figures in the parentheses shows ratio to 1993 or to the total

5.5 Hydropower

Power system in Brazil is composed of four major regional systems; north, northeast, southeast and south systems. ELETROBRÁS, a government owned corporation, manages the national systems. ELETROSUL is one of the four regional subsidiary companies, and in charge of operation of the south system, covering the States of Paraná, Santa Catarina, Rio Grande do Sul and Mato Grosso do Sul. The power supply and distribution in the State are managed by COPEL, a public corporation. Since the power system in the State is connected to the south and southeast systems, energy production is not determined from the power demand in the State, but from the whole demand of the regions covered by the two systems.

There are 13 hydropower stations operated by COPEL and ELETROSUL. The total generation capacity in the State reaches 5,773 MW. Power demand in the south and the southeast systems and in the whole Brazil projected in the long term plan of ELETROBRÁS is shown in Table-5.5.

Table-5.5 Power Demand Projection

	Energy Demand (TWh)			Peak Demand (GW)		
	Actual	Projected		Actual	Projected	
	1992	2005	2015	1992	2005	2015
South/Southeast system	176.5	319.0	444.3	28.8	48.6	67.6
Whole Brazil	224.0	430.6	631.3	36.6	65.5	96.1

Water demand for power generation is estimated as shown in Table-5.6. The water demand for hydropower plants has different characteristics to the other water demands such as domestic water, industrial water and agricultural water. The water used for hydropower plants only passes through water turbine for generation and is not consumed. Therefore, the water demand for hydropower plants does not affect downstream water consumption significantly.

Table-5.6 Water Demand for Hydropower Generation (2015)

	Installed Capacity (MW)	Firm Energy (GWh)	Water Demand (m^3/sec)
Existing Power Station	5,773	22,900	3,190
Planned Power Station*	3,095	13,627	N.A.
Total	8,868	36,527	N.A.

* Excluding Ilha Grande on the Paraná river

N.A.: not available

5.6 Inland Navigation

Although there were about 30 inland navigation companies during the golden age, the number of companies has decreased with the expansion of other transportation methods such as railway and trucking. Currently, only a few navigation companies are operating to convey agricultural products and vehicles. The STER carried out studies on the following commercial waterways for both the Ivai River and Tibagi River in 1985 and 1991 respectively, as shown in Figure-5.1.

1) Paraná River-Ivai River Waterway (between Doutor Camargo and the Paraná River)

This waterway system combines the new waterway in the Ivai river (from its mouth to Doutor Camargo Municipality, about 237 km) and existing rail-motorway (PR-323, from Cianorte to Maringa via Doutor Camargo). To increase sufficient water depth for navigability, Tres Figueiras dam (for hydroelectric power generation) with lock facility is assumed to be constructed in the Ivai River.

2) Tibagi River-Paranapanema River Waterway (between Jataizinho and the Parana River)

This waterway system starts from the confluence point of the Paraná and Paranapanema Rivers to Jataizinho or the planned Canoas Dam in the Tibagi River through the upper end of the Capivara Dam reservoir. This waterway passes the existing 3 dams: Rosana, Taquarucu and Capivara dams. New lock facilities are assumed to be installed at these 3 dams.

The estimated construction costs for Parana-Ivai and Tibagi-Paranapanema waterways are US$ 250 million at 1983 price level and US$ 250 million at 1991 price level, respectively. These waterway projects assume the construction of the Tres Figueiras dam with lock facilities and the additional installations of lock facilities to the existing 3 dams. The Tres Figueiras dam for hydroelectric power generation is scheduled to be constructed from 2005 to 2009 by COPEL. As it will take long time to start these projects, it seems that the requirement for transportation systems for inland navigation may drastically change. The feasibility study on these waterway projects has to be reviewed in future before the start of these projects.

Although these waterway projects do not consume water, new dam and reservoir including these projects may give such impacts to water environment as ecological issues, reservoir sedimentation, erosion, flood and others. Therefore, sufficient environmental assessment will be required.

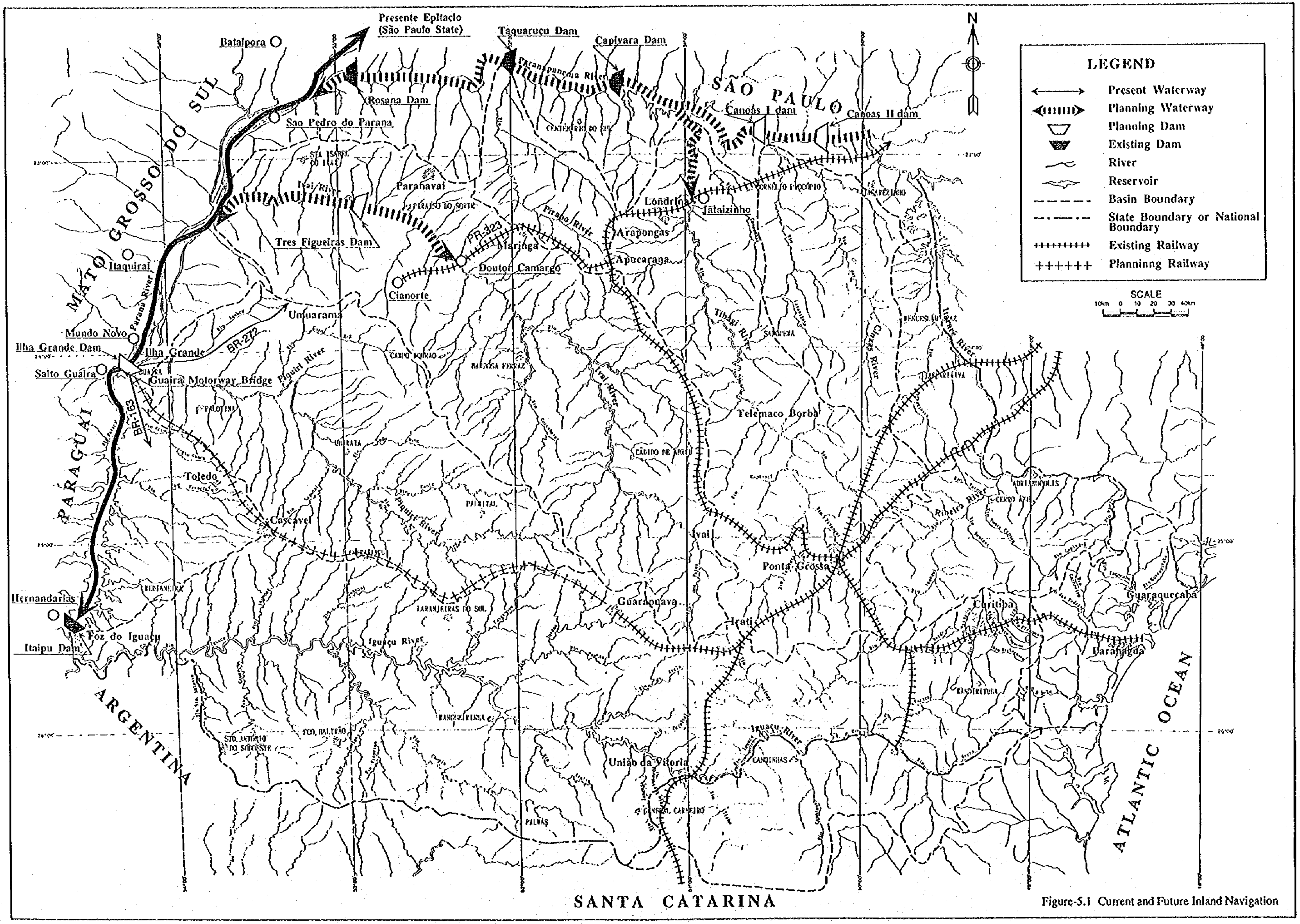


Figure-5.1 Current and Future Inland Navigation

5.7 Flood Control

Since 1931, large floods occurred in 1983, 1992 and 1995. The result of the investigation on the past floods (in 1983, 1992 and others) shows that the serious flood damages have occurred along the Iguaçu River as shown in Table-5.7. The most serious flood prone areas are the area around União da Vitoria in the Iguaçu River Basin (Region-4) and the Curitiba Metropolitan Area (Region-1). The estimated damages for both areas are US$ 10 million in 1982 flood and US$ 78 million in 1983 flood for the União da Vitoria area, and US$ 20 million in 1993 flood and US$ 44 million in 1995 flood for the Curitiba Metropolitan Region.

Table-5.7 Flood Disaster Area and Flood Damage Degree

River Basins	Areas		Damage Degree *1
Iguaçu River	Region-1:	Curitiba Metropolitan Area	4
	Region-2:	Porto Amazonas, São Mateus do Sul	4
	Region-3:	Reboucas, Guarapuava, Irati (Tibagi River Basin)	2
	Region-4:	União da Vitoria, Porto Vitoria, Porto União (Santa Catarina State)	5
	Region-5:	Rio Negro, Mafra (Santa Catarina State)	5
	Region-8:	Capanema	2
Paraná River	Region-6:	Foz do Iguaçu, Ciudad del Este (Paraguay)	3
		Upstream of Itaipu Dam	2
Coastal Basin	Region-7:	Morretes	3
Ivai River	All areas		1
Tibagi River	All areas		1
Other	All areas		1

(Note) Damage Degree: 5: Serious, 4: High, 3: Medium, 2: Low, 1: Negligible

5.8 Water Quality and Sewerage System

Water quality of main rivers had been observed by the SUREHMA since 1970 up to 1986. After the SUREHMA was abolished, the observation was succeeded by the IAP. The IAP has processed the observed data from 1982 to present. Observation items are the following 9 items; BOD (Biochemical Oxygen Demand), DO (Dissolved Oxygen), T-N (Total Nitrogen), T-P (Total Phosphate), Turbidity, Total Solid, pH, Fecal Coliform, Water Temperature.

The Brazil water quality standards issued by the CONAMA classifies water quality according to 8 items. Regarding BOD, the water quality classifications are; Class 1 < 3 mg/liter, Class 2 < 5 mg/liter, Class 3 < 10 mg/liter, Class 4 > 10 mg/liter.

Water quality target of each river or river basin has been classified, applying one of the above classes, by CONAMA or SUREHMA, according to their domain. Generally, Class 2 is adopted for water quality of rivers. Class 1 areas include the water sources for public water supply, park areas and particular rivers. Class 3 areas include parts of the large urban areas such as Curitiba, Londrina, Maringa, Ponta Grossa, etc., where water is particularly contaminated. For the rivers with good water quality in the coastal mountain range areas is classified into special class.

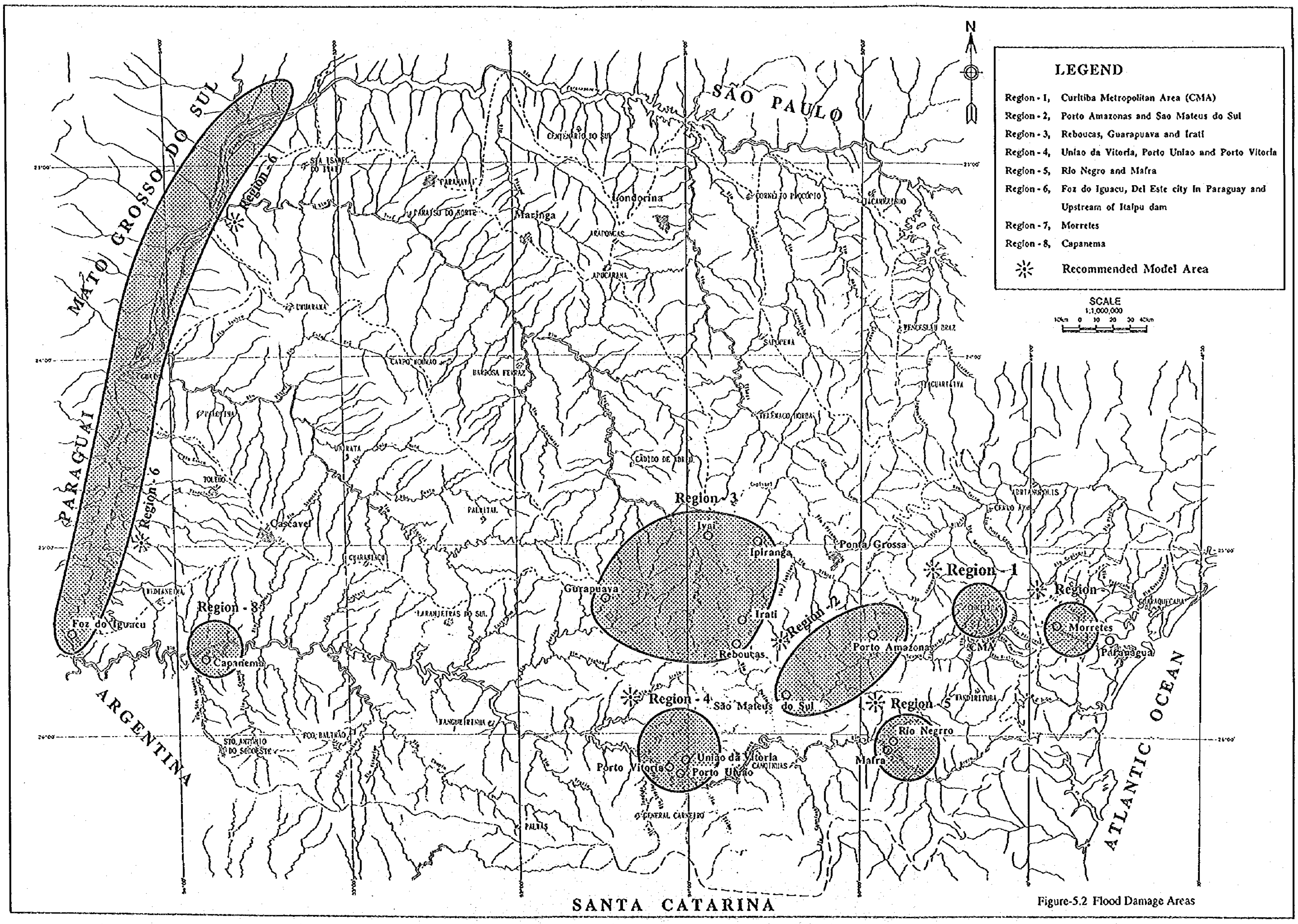


Figure-5.2 Flood Damage Areas

The current water quality of main rivers in the Paraná State belongs to Class 1 mainly, or Class 2 partly. Rivers in and near Curitiba, however, have been contaminated recently. The water of the Belém River, Bariguí River and the most upstream reach of Iguaçu River is contaminated at the level of Class 4 or worse.

According to the SANEPAR data in 1990, the coverage of sewer system to the total population of the State is 27.8 % and the coverage of the sewage treatment system is 12.4 %. In the case of Curitiba, the coverage of sewer system and treatment system are 41.7 % and 15.6 %, respectively.

The IAP has given licenses for discharging waste water into public water to 492 factories with instruction of the treatment level of waste water. The average BOD reduction rate of the effluent from these 492 factories is as high as 97 % in the State. However, the values of BOD discharged actually from these factories are rather high, ranging from 50 mg/liter to 850 mg/liter, compared to the Japanese standard (industrial waste water BOD to public water: 160 mg/liter).

The river water quality in 2015 has been forecast, covering estimation of future pollutant loads from domestic, industrial waste water and that of livestock breeding and natural pollutant under the future socio-economic conditions as estimated in previous chapter. In the estimation, the current capacity of the sewerage facilities was assumed, applying the estimated increase in population, industrial production and livestock population.

The result of the estimation revealed that the water quality of the rivers, whose current water quality is as good as Class 1 or Class 2 level, will be remarkably deteriorated and reach to Class 3 or Class 4 level in 2015. The rivers whose water quality will remain better than Class 2 level will be only the Itarare and Piquiri Rivers and those in Litoranea Basin. For the other 6 river basins, reduction of pollutant loads will be necessary through expansion of sewage treatment.

5.9 Soil Erosion

In Paraná State, the soil erosion is a serious issue. Soil erosion causes various problems such as low crop productivity induced by soil degradation, increase in fertilizer application, abandonment of agricultural lands by farmers due to the low productivity and migration to urban areas, as well as high sediment yield, degradation of ecosystem, water contamination and so on.

Gross soil loss was computed by river basin, as shown in Table-5.8, applying USLE equation. This equation estimates annual gross erosion per unit area analyzing various factors such as rainfall erosivity, soil erodibility, slope length and steepness, surface cover and conservation practices.

At the hydrological observation stations installed in each river, discharge and concentration of suspended sediment are observed. Based on the observed data, suspended sediment load of each river basin was calculated as shown in Table-5.8. Comparing the suspended sediment load and gross soil loss, sediment delivery ratio of each river basin was determined as shown in Table-5.8.

Remarkable soil erosion appears in Cinzas, Ivai and Ribeira River Basins, while soil erosion in the Itarare River Basin is relatively small. Since soil loss from the Litoranea River Basin was expected to the low due to large forest area and low agriculture practices, the Litoranea River Basin was excluded from soil loss computation. The permissible soil loss depends on the area of river basin ranging from 2 ton/ ha·year for an area more than 10 km^2 to 25 ton/ ha·year for field size. As the average soil loss is as high as 28 ton/ ha·year, remarkably larger than the permissible soil loss, some countermeasures should be taken.

Table-5.8 Soil Erosion and Suspended Sediment Load

Basin	Catchment Area (km^2)	Gross Soil Loss (1000ton/year) (A)	Gross Soil Loss (ton/ha·year)	Total Suspended Sediment (1000t/year) (B)	Unit Annual Suspended Sediment (ton/km^2·year)	Sediment Delivery Ratio (B/A)
Cinzas	9,291	33,066	36	780	84	0.024
Iguaçu	55,318	154,804	28	996	18	0.006
Itarare	5,198	2,439	5	504	97	0.207
Ivai	35,879	115,309	32	4,915	137	0.043
Piquiri	24,708	66,328	27	2,619	106	0.039
Pirapo	5,006	9,387	19	345	69	0.037
Ribeira	9,129	27,471	30	520	57	0.019
Tibagi	24,635	58,568	24	764	31	0.013
Total (Ave.)	169,164	467,372	(28)	11,439	(68)	(0.024)

5.10 Ecology

The ecological conditions of the following issues are studied with regard to the 11 main river basins:

1) Flora : forest cover, afforestation, native species in critical conditions and conservation units
2) Terrestrial Fauna : mammals, reptiles, birds and insects
3) Aquatic Fauna : fish, endemic species, exotic species and threatened or endangered species
4) Benthic Fauna : macro invertebrate communities
5) Aquatic Habitat : low land along watercources (varzeas), mangrove habitat cover, marsh vegetation cover

The above study reveals the following issues:

1) Before 1940, Paraná had 83 % of native forest cover. Today, only 5 % is left of the original forest cover, and by the year 2,000, if present conditions persist, it is estimated that only 2.5 % will remain.
2) Flora in the Iguaçu River Basin is in advanced state of devastation. In the Ivai River Basin most of forests have disappeared. In Tibagi River Basin, flora is absorbed by secondary vegetation. In Piquiri River Basin flora is very altered, and the original vegetation is difficult to reconstruct.
3) The basin where the terrestrial fauna is better preserved is the basin where the vegetation cover is also better preserved, such as the Coastal Basin.

4) Among the mammals reported in the State, 12.5 % are considered in the red list, also, 17 species of reptiles, 15 species of butterflies, and 117 species of birds are included in the red list.

5) The most comprehensive studies have been carried out for the Iguaçu, the Paraná and the Tibagi Rivers. Although the number of endemic species found in the Iguaçu river is very high, approximately 50 % of the river length has been modified by hydroelectric projects. Change in river flow, from a rapid one to a slow one interferes with the natural habitat of fish population. Dam construction blocks the access of migratory habitat to adjacent tributaries.

6) The low fisheries catch in the Paranapanema River is attributed to the disappearance of the river margin vegetation, agrochemical pollution and over fishing.

7) Bird fauna of fresh water aquatic habits in the state of Paraná is reported to have at least 156 species belonging to 28 families. The bird fauna is the most affected by human activities and environmental degradation. The reduced food supply and shelter due to deforestation, the agrochemical pollution and insect biodiversity reduction due to agriculture expansion are the main causes of depletion.

8) Lowlands along watercourses with some kind of restriction of use for agricultural purposes are reported to be incorporated into agricultural production. The mangrove habitat in the Guaratuba, Paranagua, Antonina, and Guaraquesaba bays, is threatened by the expansion of the port.

5.11 Forestry

According to the result of the satellite imagery analysis and GIS computation conducted by IAP and SANEPAR, the natural forest occupied only 9.0 % (17,800 km^2) of the state and reforestation covers 3.2 % (6,300 km^2) in 1990.

Until 1987 the federal government assisted to promote afforestation. The total area of afforestation during the registered period (1966 - 1987) extended to 9,600 km^2. Large scale reforestation was carried out in Ponta Grossa, Curitiba and Paranagua regions, accounting for 70 % of the total of the State.

The DAGRI/SEAB has started an afforestation program since January, 1994. The objective of this program is to encourage afforestation aiming at preservation and production of forest by offering loans of up to 50 % of the cost. Also, since 1991, the IAP has conducted a project for conservation and recuperation of riverian vegetation along rivers for the public water supply in association with SANEPAR. As of 1994, the implementation reached the planting of 2 million native forest seeding to cover the riverian vegetation of 1,300 km of river length.

Deforestation decreases water retention capacity of the land, inducing floods or reducing stable surface runoff, and increases rainfall impact on the surface, resulting in soil erosion. As a consequence, the water resources potential decreases and the water quality is degraded. As the large area of forest has been reduced so far, it is not possible to go back to 19th century when the forest area covered 84.8 % of the state. However, afforestation is essential to improve the water environment and is a part of the river basin management.

5.12 Environmental Sanitation Program for Curitiba Metropolitan Region (PROSAM)

PROSAM is an environmental sanitation project for Curitiba Metropolitan region including water supply, flood control and urban drainage, sewerage system, environment conservation etc. It includes construction of Irai dam for water supply of 1.8 m^3/sec, drainage channel excavation with a length of 15 km along left bank of the Iguaçu River, development river park, sewage collection pipe with a length of 1,300 km, 8 sewerage treatment plants, solid waste disposal, bridges, and environmental education, etc. The total project cost amounts to US$ 233x10^6, 52 % of which is to be financed by the World Bank. The project is scheduled to be implemented from 1992 to 1997. However, the progress rate as of June 1995 is estimated less than 20 %.

CHAPTER 6 WATER RESOURCES POTENTIAL

6.1 Surface Water

Paraná State has abundant surface water resources, being blessed with much rainfall. The surface water resources potential to be discussed in this section, is defined as direct intake water from river.

The regulation demands that the allowable direct intake volume should be less than 50 % of $Q_{10.7}$, or that the minimum discharge to flow downstream should be more than 50 % of $Q_{10.7}$. The discharge $Q_{10.7}$ is Q_7 discharge with recurrence of once in 10 years. Q_7 is annual minimum discharge of average discharge of continuous 7 days. This $Q_{10.7}$ is almost equal to Q_{355} (drought discharge defined in Japan, exceeded on more than 355 days in year).

The main river basins are divided into 30 blocks to assess the direct intake potential (50 % of $Q_{10.7}$) of each block as shown in Figure-6.1. The direct intake potential at the most downstream point of river is shown in Table-6.1. The total volume of direct intake potential amounts to 320 m^3/sec (or 27.7 million m^3/day). The water demand volume in 2015 (3.1 million m^3/day) projected in the section 5.5 only accounts of 11 % of the estimated total direct intake potential.

Table-6.1 Direct Intake Potential (Surface Water)

Name of River Basin	Catchment Area (km^2)	Direct Intake Potential (m^3/sec)	Annual Mean Discharge (m^3/sec)
Cinzas River Basin	9,291	4.95	141.6
Iguaçu River Basin	68,700	93.22	1,579.1
Itarare River Basin	5,198	7.64	104.2
Ivai River Basin	35,879	66.58	733.9
Litoranea River Basin	5,766	20.05	-
Paraná River Basin - 1	1,332	4.54	-
Paraná River Basin - 2	3,157	5.42	-
Paraná River Basin - 3	8,668	10.58	-
Paranapanema River Basin -1	1,246	1.30	-
Paranapanema River Basin -2	695	0.35	-
Paranapanema River Basin -3	3,712	4.17	-
Paranapanema River Basin -4	4,144	6.78	-
Piquiri River Basin	24,708	43.54	598.3
Pirapo River Basin	5,006	8.83	78.2
Ribeira River Basin	9,129	25.94	158.0
Tibagi River Basin	24,635	16.85	472.6
<<< Total >>>	211,266	320.74	3,865.9

Note: Annual mean discharge was calculated in proportion to the catchment area of the major observation at the most downstream of each river basin.
$Q_{10.7}$ value was calculated by the HG52.

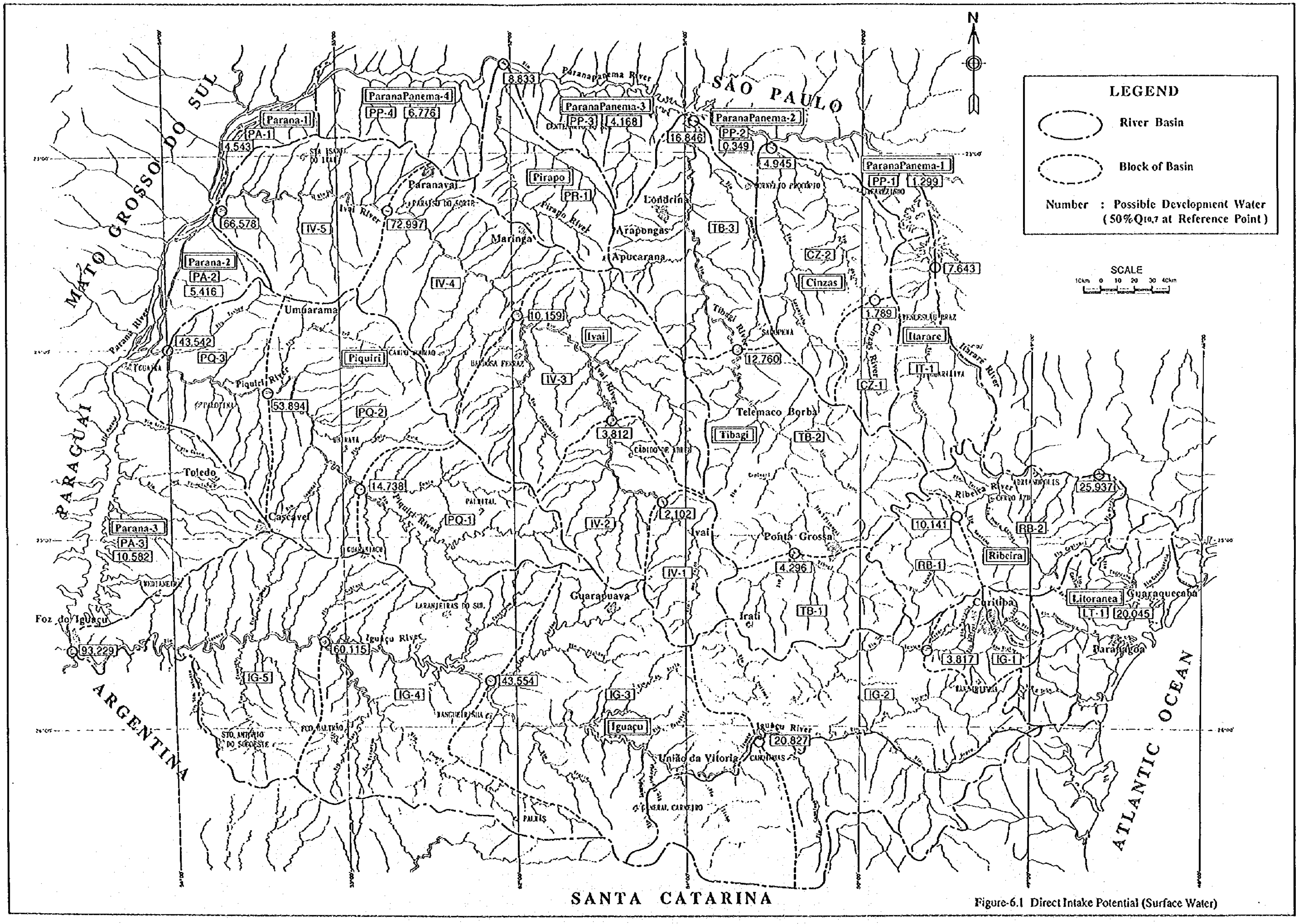


Figure-6.1 Direct Intake Potential (Surface Water)

6.2 Groundwater

To prepare plans of sustainable groundwater development, well productivity should be investigated considering not only the pumping test but also water balance analysis of groundwater.

Groundwater resources are composed of circulating resources and stored resources. The circulating groundwater level fluctuates according to recharge of rainfall and discharge to rivers. As the circulating groundwater discharge to rivers contributes to the river base flow in dry season and maintains natural water environment, the whole volume of circulating groundwater, therefore, cannot be developed. The ratio of permissive yield (permissive yield/circulating groundwater) is decided empirically considering the characteristics of aquifers and effect to river flow.

The permissive yield of each aquifer was estimated as shown in Table-6.2, through the analysis of the groundwater discharge to river base flow, using observed Q_7 and Q_{355}. The total permissive yield of groundwater amounts to 15.0 million m^3/day. The distribution of principal aquifers is as shown in Figure-6.2.

Table-6.2 Groundwater Potential

No	Aquifer Name	Area of Aquifer (km^2)	Circulating Groundwater (10^6 m^3/day)	Ratio of Permissive Yield (%)	Permissive Yield (10^6 m^3/day)	Well Productivity
1	Karst	5,740	4.5	30	1.4	AAA
2	Granite Rock in Pre-Oldvician	7,540	4.0	10	0.4	CC
3	Early Palaeozoic Castro/Prana G.	7,150	3.0	10	0.3	C
4	Middle-Late Palaeozoic Itarare/Guata G.	17,400	7.0	10	0.7	B
5	Late Palaeozoic Passa Dois G.	15,700	6.0	10	0.6	B
6	Botucatu & Serra Geral Formation (North)	59,050	40.0	20	8.0	AA
7	Botucatu & Serra Geral Formation (South)	42,060	20.0	15	3.0	BB
8	Caiua Formation	30,450	3.0	10	0.3	BB
9	Curitiba Metropolitan	1,130	0.34	10	0.03	-
14	Quaternary River Bed	380	1.11	30	0.3	A
	<< Total >>		88.95		15.03	

(Note) Well Productivity: AAA>AA>A>BB>B>CC>C

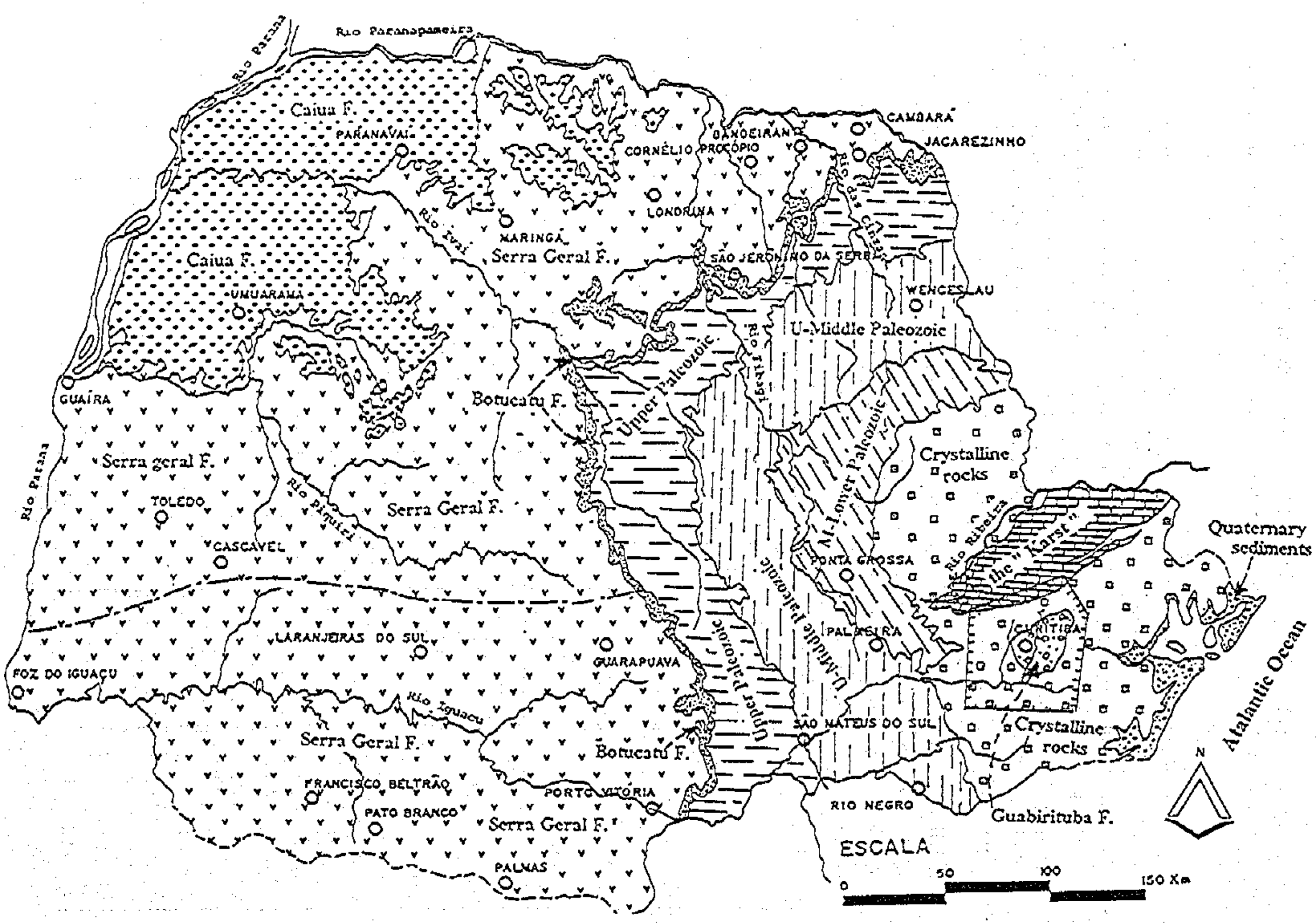


Figure-6.2 Distribution of Principal Aquifers in Paraná State

CHAPTER 7 WATER ENVIRONMENT STRATEGY FOR PARANÁ STATE

7.1 Water Supply

(1) Sources and Water Developed

To meet water demands for domestic, industrial and agricultural use, sources of supply can be surface and underground water. In principle, surface water is suitable for large demand, concentrated use and long term development, while groundwater is suitable for small demand, scattered use and short term development. Overall assessment is required to determine the source of supply taking account of the scale of the demand, time of the demand, and potential of surface and underground water, as well as geological, hydrogeological, technical and socio-economic conditions.

Water to be developed can be projected by adding the losses throughout the process of the supply, in conveyance, treatment and distribution to water demands estimated. In the Study, losses of 10 % to 25 % are applied for the calculation of water to be supplied. To meet the total demand of 3.07 million m^3/day, a volume of 3.84 million m^3/day of water should be developed, around 25 % more than the actual demands.

(2) Curitiba Metropolitan Region

Curitiba Metropolitan Region has the most concentrated population, and consequently, the largest water demand of the State. The population in 2015 will reach 3.1 million, and additional water supply is estimated at 613,000 m^3/day, or 7.1 m^3/second.

Since Curitiba is located at the most upstream of the Iguaçu and rivers there have small catchment areas, direct intake is very difficult, therefore, regulation of river flow by dam development is inevitable. Ten (10) dam sites have been studied by SANEPAR, whose development will add 6.6 m^3/second of water supply. Large potential of groundwater source lies in the Karst aquifer located 10 to 50 km north of the City.

Sources of water supply for domestic and industrial use in Curitiba Metropolitan Region will be obtained from dam development and groundwater development as described above. A portion of 70 % and 30 % is assumed for surface and underground water development respectively in the Strategy, while accurate proportion will be examined in detail in the Master Plan. Around 5.0 m^3/second (432,000 m^3/day) of water supplied by dam development and 2.1 m^3/second (181,000 m^3/day) by groundwater development were proposed in the Strategy.

(3) Large Urban Areas

Many large cities are located in the most upstream of mainstream or tributaries of rivers. Many problems lie in water resources development for these large urban areas. Measures to secure the sources of water supply are examined for major six cities of Cascavel, Ponta Grossa, Londrina, Apucarana, Maringa and Umuarama. Figure-7.1 shows the result of the comparison of possible measures, comprising of direct intake of river water, flow regulation by dam development. Although the figure shows surface water development only, groundwater development was also examined for the formulation of the Strategy. The Strategy proposed the least cost plan as shown in the Table-7.1, by selecting and allocating the possible measures.

(4) Other Urban Areas

There are 356 other municipalities than those covered in the above sections (1) and (2). The water required to be developed varies according to the municipality, from a minimum of 0.001 m^3/second to a maximum of 0.795 m^3/second, and the average is 0.024 m^3/second (2,100 m^3/day). In those urban areas, water sources can be secured generally by direct intake from rivers, as examined in the surface water potential. Water sources for these urban areas are planned as direct intake from rivers in or around the areas, unless groundwater development is more suitable due to some difficulties in direct intake.

(5) Rural Areas

Since the population in most rural areas will not increase due to movement to urban areas, water demands will not increase with a few exceptions. Groundwater development is to be planned for rural areas because of the scattered demands, if necessary. However, since there is no new demand, improvement and maintenance of existing facilities seem to be enough for the water demand.

(6) Agricultural Water

Water demand for livestock breeding and fish culture is comparatively small and scattered over the State. Sources for water supply can be secured by direct intake from small river streams near the points of the demand.

The Strategy for water supply described in the above sections are summarized in Table-7.1.

Table-7.1 Strategy for Water Development

	Volume (m^3/s)	Cost (10^6US$)	Unit Cost (10^6 US$/$m^3$/s)	Water Sources
(1) Domestic and Industrial Water Development (Urban Area)				
1) Curitiba	7.088(2.572)	759.7	107.2	dams & groundwater
2) Cascavel	0.611(0.145)	78.4	128.3	1 dam
3) Ponta Grossa	0.615(0.283)	20.0	32.5	direct intake
4) Londrina	1.045(0.300)	31.4	30.0	direct intake
5) Apucarana	0.202(0.058)	24.1	119.3	groundwater
6) Maringa	0.906(0.339)	24.1	26.6	direct intake
7) Umuarama	0.044(0.010)	30.5	693.2	1 dam
8) Other urban areas	8.497(1.603)	827.9	97.4	direct intake
Sub-total	19.008(5.310)	1,796.1	94.5	
(2) Agricultural Water Development (Rural Area)				
	1.018	12.2	12.0	direct intake
Total	20.026(5.310)	1,808.3	90.3	

Note: ( ) shows industrial water.

(7) Saving Water and Recycle Use

In the Study, future water demands were projected with current unit rate of consumption and estimate of raised living standards in the future. Future water demands, however, can be reduced through encouraged public awareness for saving water, and subsequently investment for water supply can be decreased. Industrial water demand projection in the Study was conducted with increased recycle water use in the future. Water demands can also be decreased through the promotion of recycle use further. To attain saving water and increased recycle use, the Government should take measures such as information dissemination and education, tariff revision, and financial support.

7.2 Hydropower Development

According to the long term plan by ELETROBRÁS/COPEL, 4 power stations (total installed capacity-1,559 MW) up to 2005 and 9 power stations (total installed capacity-1,536 MW) will be constructed successively in the State. The location of the projected sites are shown in Figure-7.2.

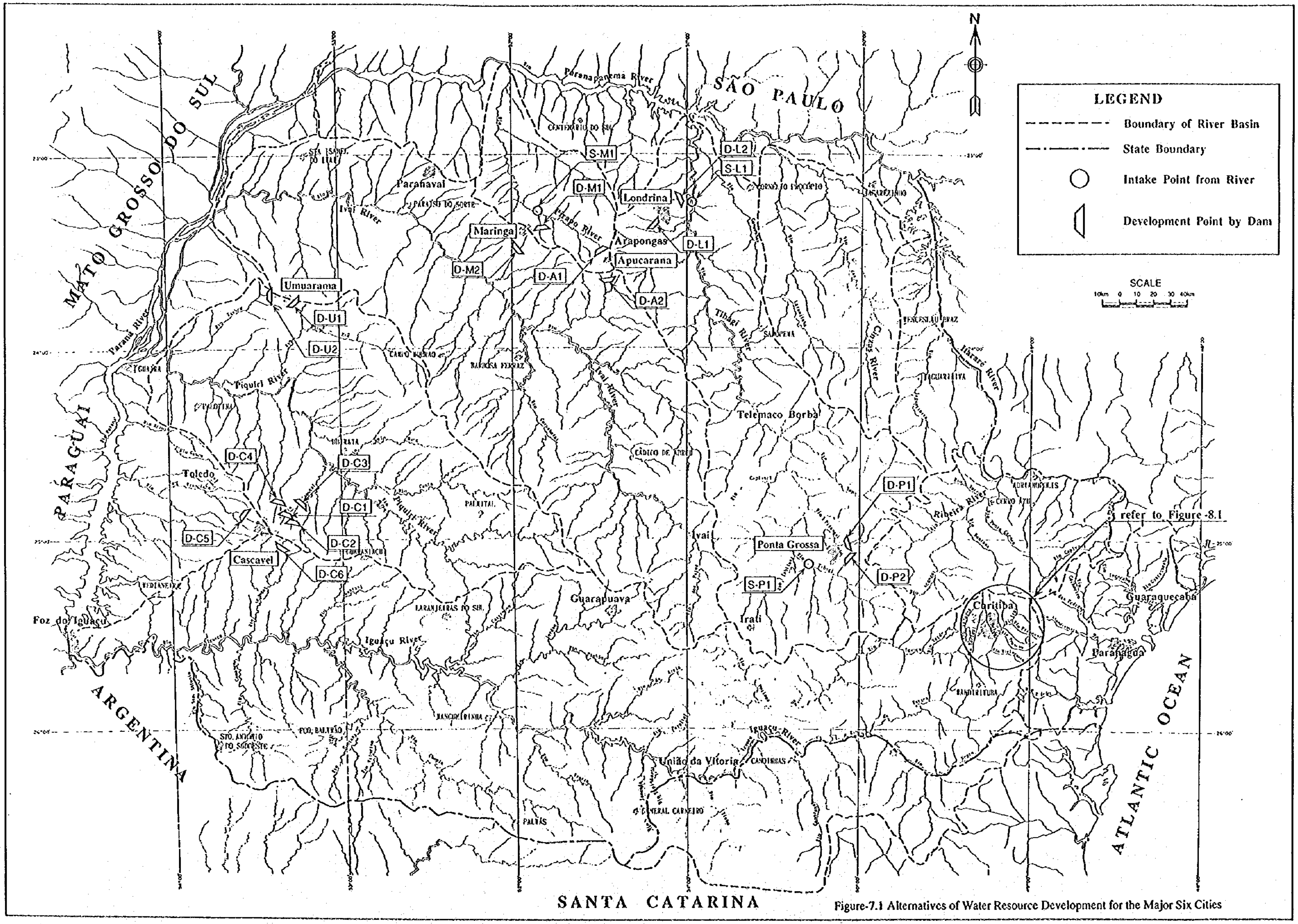
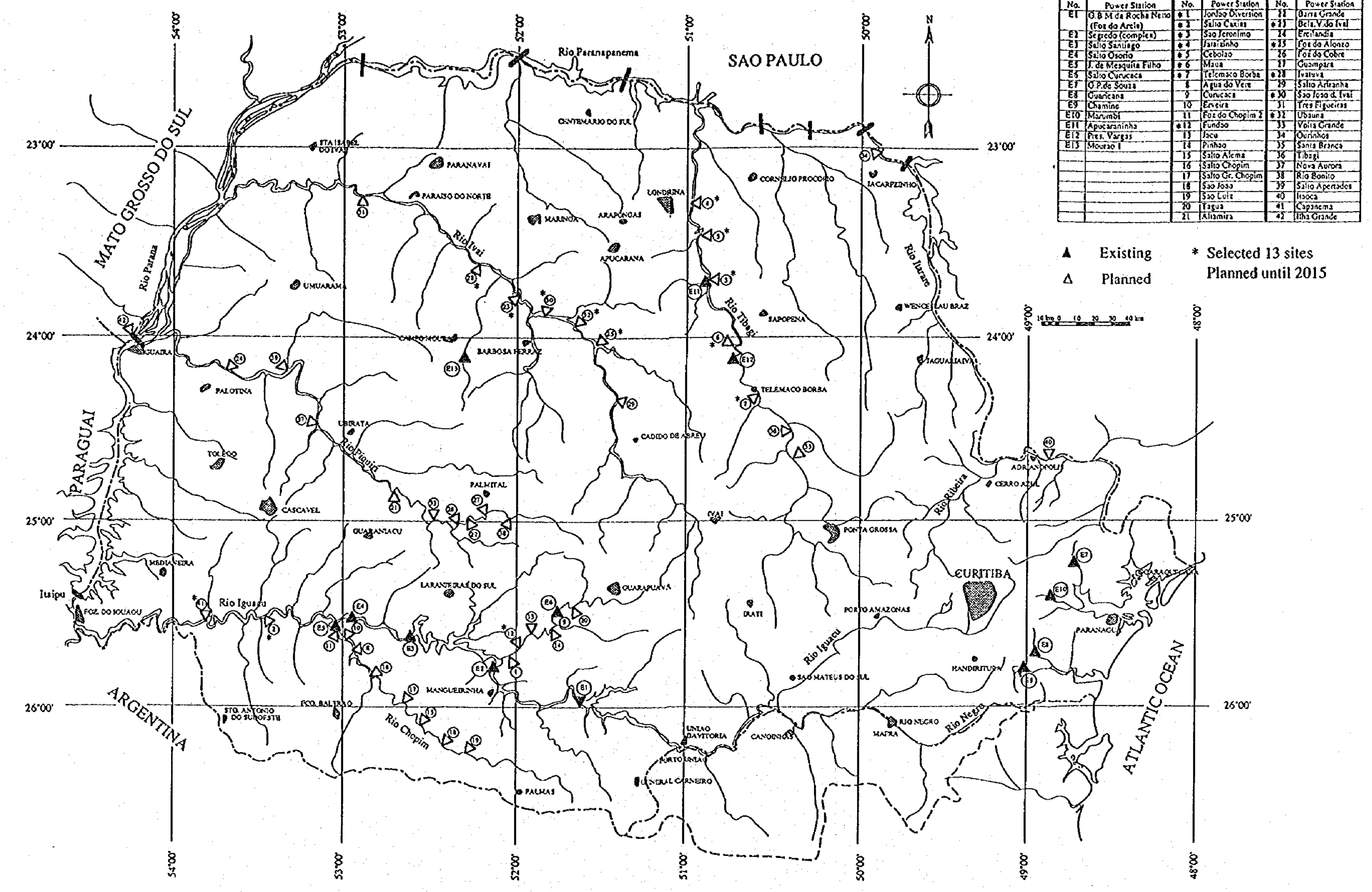


Figure-7.1 Alternatives of Water Resource Development for the Major Six Cities



List of Hydropower Stations

No.	Name of Power Station	No.	Name of Power Station	No.	Name of Power Station
E1	G.B M da Rocha Netto (Foz do Areia)	* 1	Jordao Diversion	22	Barra Grande
		* 2	Salto Caxias	* 23	Bela.V.do Ivai
E2	Segredo (complex)	* 3	Sao Jeronimo	24	Ercilandia
E3	Salto Santiago	* 4	Jataizinho	* 25	Foz do Alonzo
E4	Salto Osorio	* 5	Cebolao	26	Foz do Cobre
E5	J. de Mesquita Filho	* 6	Maua	27	Guampara
E6	Salto Cucucaca	* 7	Telemaco Borba	* 28	Ivaiuva
E7	G.P.de Souza	8	Agua do Vere	29	Salto Ariranha
E8	Guaricana	9	Curucaca	* 30	Sao Joao d. Ivai
E9	Chamine	10	Erveira	31	Tres Figueiras
E10	Marumbi	11	Foz do Chopim 2	* 32	Ubauna
E11	Apucaraninha	* 12	Fundao	33	Volta Grande
E12	Pres. Vargas	13	Jacu	34	Ourinhos
E13	Mourao I	14	Pinhao	35	Santa Branca
		15	Salto Alema	36	Tibagi
		16	Salto Chopim	37	Nova Aurora
		17	Salto Gr. Chopim	38	Rio Bonito
		18	Sao Joao	39	Salto Apertados
		19	Sao Luiz	40	Itaoca
		20	Tagua	41	Capanema
		21	Altamira	42	Ilha Grande

Source : COPEL

Figure-7.2 Existing and Inventoried Hydropower Stations in Paraná State

7.3 Flood Control

Measures for flood control include non-structural and structural measures. Non-structural measures include;

1) Land use control in flood prone areas,
2) Resettlement,
3) Improvement of flood forecasting and warning system,
4) Evacuation and rescue activities,
5) Flood proofing, such as elevating structures and rearrangement of structural working space,
6) Review of operation rules of dams and reservoir.

Structural measures are provision of dams, dikes, floodways, retarding basins and channel improvement. Proposed measures for the regions seriously affected by flooding (refer to the Section 5.7) are listed in Table-7.2

Table-7.2 Strategy for Flood Control

Region	Non-structural Measures						Structural Measures
	(1)	(2)	(3)	(4)	(5)	(6)	Type of Structure
Region 1 Curitiba Metropolitan Region	-	-	*	*	*	*	Continuation of PROSAM (dam, dike, park, channel) Expansion of PROSAM (Dams and channel)
Region 2 São Mateus do Sul	-	-	*	*	*	-	dike
Porto Amazonas	-	-	*	*	*	-	---
Region 3 Reboucas, Guarapuava, Irati	-	-	*	*	-	-	---
Region 4 União da Vitoria	*	*	*	*	*	*	dike
(Porto União: Santa Catarina)	*	*	*	*	*	*	---
Region 5 Rio Negro, Mafra	-	-	*	*	*	-	---
Region 6 Foz do Iguaçu	*	*	*	*	-	*	---
Region 7 Morretes	*	*	-	*	*	-	dike, channel improvement
Region 8 Capanema	-	-	-	*	-	-	---

(Note) 1. - shows continuation of the current measures, * shows expansion or introduction of new measure

2. figures numbering of non-structural measures: (1) land use control, (2) resettlement, (3) forecasting/warning, (4) evacuation/rescue, (5) flood proofing, (6) dam operation rules

3. Refer to section 5.12 for PROSAM.

7.4 Water Quality Improvement and Sewerage Development

As mentioned in Section 5.8, in the basins where water quality was estimated to deteriorate beyond the limits of Class-2 (BOD; 5 mg/liter) in the CONAMA classification, sewerage projects were planned in order to conserve water quality.

The process of pollution analysis is as shown below:

1) Divide each river basin into several blocks and select water quality control points.
2) Calculate discharge BOD load for domestic wastewater, industrial wastewater, livestock wastewater, and natural load and assume run-off ratio (inflow ratio to river, of discharged BOD load) of each BOD load.
3) Calculate discharge BOD load, and run-off BOD load applying run-off ratio assumed above in 1993. And estimate the purification residual ratio (the ratio of flow out BOD to run-off BOD: run-off BOD load is decreased to flow out BOD load due to purification process through flowing down along river), comparing calculated run-off BOD load with flow out BOD load estimated from actual BOD observation and discharge in 1993.
4) Estimate water quality in 2005 and 2015 at water quality control points, using the BOD run-off ratio assumed above and residual purification ratio obtained above and estimated discharged BOD.

Table-7.3 summarizes required BOD reduction for water quality conservation or improvement, targeted population of sewerage services and volume of treated sewage as well as the cost incurred for the sewerage development projects.

In addition to the structural measures mentioned above, the following non-structural measures are recommended.

1) Optimal Sewerage Development

In sewerage development, there are two types of systems; collective treatment system with construction of sewers and treatment plants, and individual treatment system with installation of sptic tanks at each outlet of wastewater. The former system incurs a large scale of investment and is uneconomical in areas with low population density. Optimal plan should be formulated by area, examining alternatives from technical and economic points of view.

2) Introduction of Cleaner Production

In conventional industrial technology, wastewater is controlled with treatment at the "end-of-pipes". On the contrary in "cleaner production", wastewater is controlled with "in-process-technology", combining qualitative and quantitative control of waste and wastewater within the process of production. Promotion of the cleaner production will be necessary through financial support and information dissemination, etc. by the State Government.

Table-7.3 Sewerage Development Plan

River Basin	Water Quality Control Point No.	Run-off BOD Load (kg/day) (A)	Residual Ratio (B)	Flow-out BOD Load (kg/day) (C)	Target Water Quality (BOD) (mg/l) (D)	Diluting Water ($Q_{10,7}$) (m^3/second) (E)	Permissible Flow-out BOD Load (kg/day) (F)	Required Reduction of BOD Loads (kg/day) (G)	Target Population of Sewerage Services (thousand persons) (H)	Target Treated Sewage (thousand m^3/day) (I)	Cost (US$million)
Cinzas	CZ-05	24,812	0.24	5,955	5	8.80	3,802	8,971	166	28	21.4
Tibagi	TI-06	58,679	0.52	30,513	5	25.60	11,059	37,412	693	118	90.3
Pirapo	PI-13	65,555	0.23	15,078	5	15.00	6,480	21,495	398	68	52.0
Ivai	IV-12	131,302	0.23	30,199	5	14.00	6,048	48,302	894	152	116.2
Iguaçu	IG-36	250439	0.52	130,228	5	120.20	51,926	150,581	2,789	474	362.5
Ribeira	RB-03	57,000	1.00	57,000	5	72.80	31,450	25,550	473	80	61.2
Total									5,413	920	703.6

(Note) 1) Water quality in the Itarare, the Piquiri and the Litoranea Basins is estimated to remain under the limit of the Class-2 even in 2015.

2) C = A x B, F= D x E x 86.4, G = (C - F) / B, H = G / 0.054, I = H x 170 liter/person·day

3) Water quality control point was the point where the water quality is worst in the basin.

7.5 Soil Erosion Control

The maximum permissible soil loss vary according to the target land area. The permissible soil loss from an area more than 10 km^2 is 2 ton/ha·year and that from medium scale and field size is 11 and 25 ton/ha·year, respectively. Since the areas of subjected river basins range from 5,000 to 55,000 km^2, 2 ton/ha·year is the threshold. However, this value is considered as too strict to be implemented in next twenty years, taking into account the current soil loss (28 ton/ha·year). Therefore, 11 ton/ha·year was adopted as the threshold of soil loss to propose the Strategy by the year 2015 and 2 ton/ha·year is assumed to be achieved thereafter.

Mechanical soil conservation measures considered comprise;

1) terracing,
2) contour bunds and buffer strips,
3) contouring,
4) road improvement with proper surface cover and drainage system,
5) gully erosion control with proper drainage system,
6) sediment settlement pond.

Common agronomic measures and soil management include;

1) non tillage,
2) proper spacing of crop strips,
3) proper crop calendar,
4) maintenance of soil fertility with application of fertilizers and green manure,
5) intercropping,
6) mulching and crop residue cover,
7) permanent vegetation cover,
8) stabilization of aggregate.

Among the countermeasures, terracing and non tillage are the most effective measures to suppress soil erosion. Therefore, these two were applied to assess the gross erosion in 2015 quantitatively and examine the cost and benefit of measures. The result is shown in Table-7.4. The gross erosion from each river basin is drastically reduced to 32 %-19 % of the current gross erosion, and an average soil loss is reduced from 28 ton/ha·year to 8 ton/ha·year.

Costs for terracing and non tillage, and their benefits which is the saving cost in fertilizer application (nitrogen and potassium) and water purification, were estimated as shown in Table-7.4. The results show that these soil conservation measures are feasible from an economical point of view.

Table-7.4 Effect of Countermeasures on Soil Erosion

Basin	Gross Soil Loss 1994 (ton/ha·year)	Countermeasure (1000ha)		Gross Soil Loss 2015 (ton/ha·year)	Cost (US$million)		Benefit (US$million)		
							Fertilizer Saved		Water Purification
		Terrace	Non Tillage		Terrace	Non Tillage	N	K	
Cinzas	36	384	233	7	15.4	15.0	49.5	4.1	0.13
Iguaçu	28	1,935	1,063	8	77.4	69.0	201.7	16.8	0.54
Itarare	5	176	97	1	7.0	6.0	3.3	0.3	0.01
Ivai	32	1,334	565	8	53.4	36.0	159.5	13.3	0.42
Piquiri	27	964	514	7	38.6	33.0	89.7	7.5	0.24
Pirapo	19	184	80	6	7.4	5.0	12.1	1.0	0.03
Ribeira	30	293	116	8	11.7	7.0	37.6	3.1	0.10
Tibagi	24	751	479	7	30.0	31.0	76.6	6.4	0.21
Average	28	-	-	8	-				
Total		6,021	3,147		241.0	202.0	630.0	53.0	2.0
Grand Total		9,168			443		685		

(Note) N: nitrogen, K: potassium

7.6 Ecological Conservation

For the ecological conservation and improvement, the following structural and non-structural measures are recommendable.

(1) Structural Measures

1) Implementation of municipal solid waste recycling, composting and landfilling projects
2) Establishment of urban green areas and parks, and introduction of fauna into the urban green belts as environmental education and recreation program.
3) Allocate resources, areas and laboratory equipment for a centralized aquatic ecology laboratory
4) Allocate resources area and laboratory equipment for an endemic fish reproduction facility

(2) Non-structural Measures

1) Monitoring and assessment of water quality through benthic community
2) Ecotoxicological study of agrochemicals
3) Survey and research on fish population and reproduction of endemic fishes
4) Enhanced environmental education program oriented to sustained development
5) Enforcement of mangrove protection legislation and avoiding destruction of mangrove ecosystem
6) Legislation for restriction of the import of wood and enhancement reforestation efforts
7) Centralization of information to ecological database center.
8) Encouraged ecological monitoring and preservation programs

7.7 Forest Preservation and Afforestation

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

Considering the past drastic decrease of forest area and the current conditions of shortage in budgetary support and insufficient public awareness, the expansion of forest for conservation and preservation purposes will remain gradual. Despite substantial regulations for forest preservation, deforestation has progressed rapidly.

The Strategy for afforestation should place emphasis on the promotion by means of commercial afforestation for timber production, material provision for paper mills, etc. Commercial afforestation should be implemented in where land is not suitable for agriculture and pasture. According to the agriculture aptness map drawn by Brazil Ministry of Agriculture (1981), there are approximately 886,000 ha of the land in Paraná suitable for afforestation but not for agriculture. Therefore, these areas should be shifted to forest for commercial use so as to generate more income by 2015.

Recommended forest species for afforestation are eucalyptus, araucaria and pine (exotic). If afforestation of 886,000 ha were implemented evenly over the next twenty years, the area of afforestation for each year would be 44,300 ha. During 1974 to 1985, when there was the government subsidy, the average annual area for afforestation was 48,000 ha. This figure verifies that annual afforestation of 44,300 ha is feasible. In case that the above Strategy is implemented, the forest cover expands up to 12 % of the land area of the State, as shown in Table-7.5.

Table-7.5 Future Projection of Afforestation

Kind of Forest	Year 1994		2015	
	Area (km^2)	area ratio to whole state (%)	Area (km^2)	area ratio to whole state (%)
Natural forest	10,200	5.1	10,200	5.1
Afforestation	5,000	2.5	13,860	6.9
Total	15,200	7.6	24,060	12.0

Note: Forest area in 1994 was computed by SANEPAR GIS.

7.8 Water Environment Management

(1) Framework of Strategy

A desirable framework of the strategy for water environment conservation, improvement, development and management is shown in Figure-7.3. The framework of the strategy is widely ranging and is composed of 1) Policy and 2) Implementation Strategy. The Policy includes objectives and principles for middle or long term, with the target year of 2015, and policies for the improvement of implementation measures and institutional arrangement (instruments). Implementation Strategy contains programs for water resources development, environment conservation and financial and cost recovery arrangement.

(2) Water Environment Management Center

A Water Environment Management Center was proposed in order to realize the concept and framework as described above. Water environment management is proposed to be handled by the State Center, covering the whole State, and the Regional Water Environment Center, covering the region and management by basin. Since the State Center is in charge of administration of and technical support to the Regional Centers, an information system with database and a network is necessary, connecting the State Center and Regional Centers. Regional Centers are in charge of not only monitoring of environmental conditions, and project management of relevant basins, but also daily practice at site providing information, and communication with residents for equitable implementation of water environment management.

(3) Integrated Monitoring System

Planning, project management, operation and monitoring is a process of cyclic, mutually interactive, and harmonized as a whole in close connection with this institutional framework. The water environment will be seriously affected by rapid urbanization and agricultural development towards the 21st century. Integrated monitoring provides basic data and management information required to attain a symbiosis of human beings and aquatic ecology, and forms a basis of water environment management. Proposed integrated monitoring system is composed of the following four sub-systems, and its operation requires integrated databases and information networks.

1) hydrological cycle monitoring with high density and multidimensional monitoring
2) monitoring of ecosystem library, in particular endemic or endangered species
3) flood forecasting and warning system
4) a bulletin system to the citizen

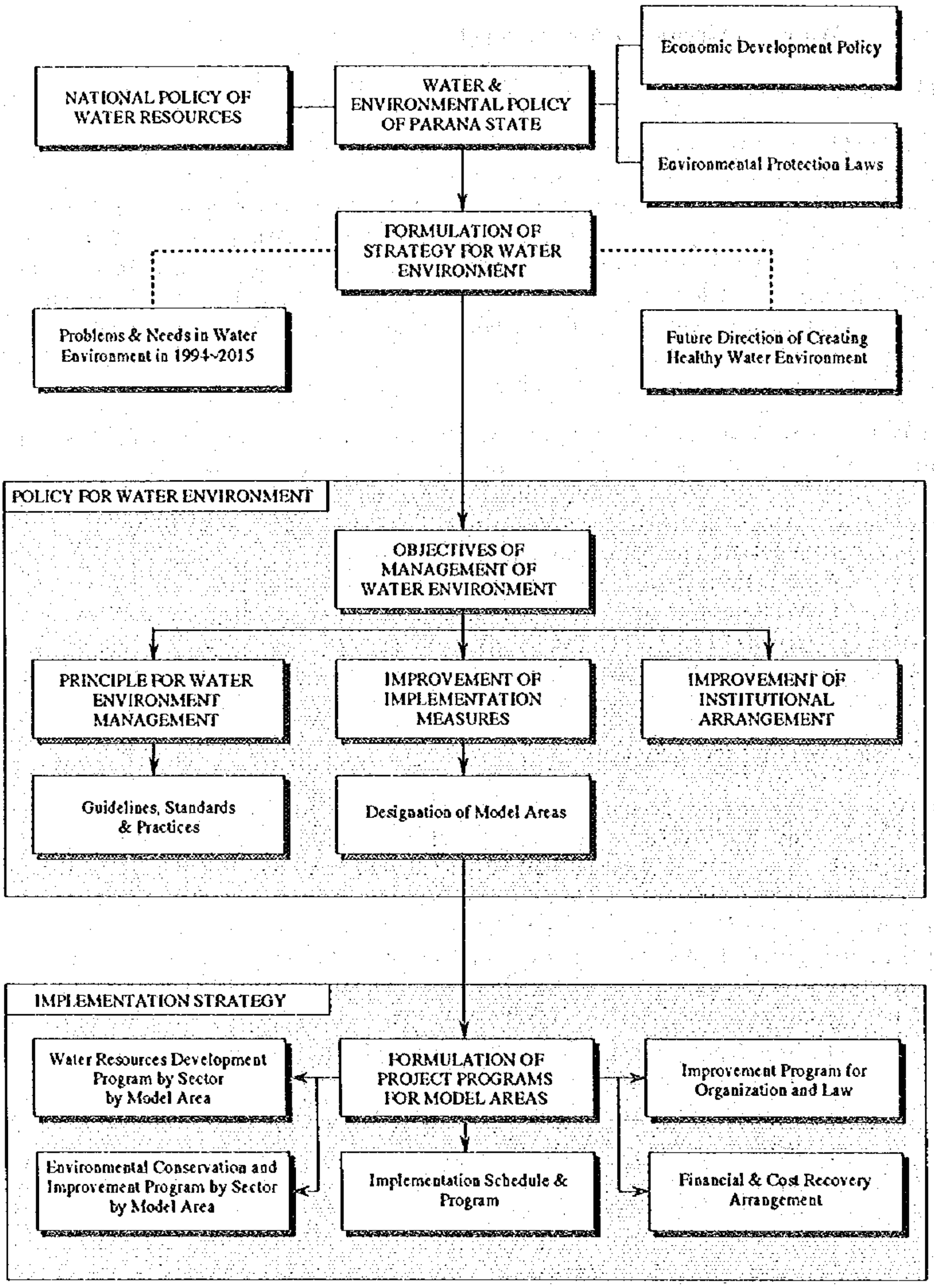


Figure-7.3 Framework of Strategy for Water Environment in Paranà State

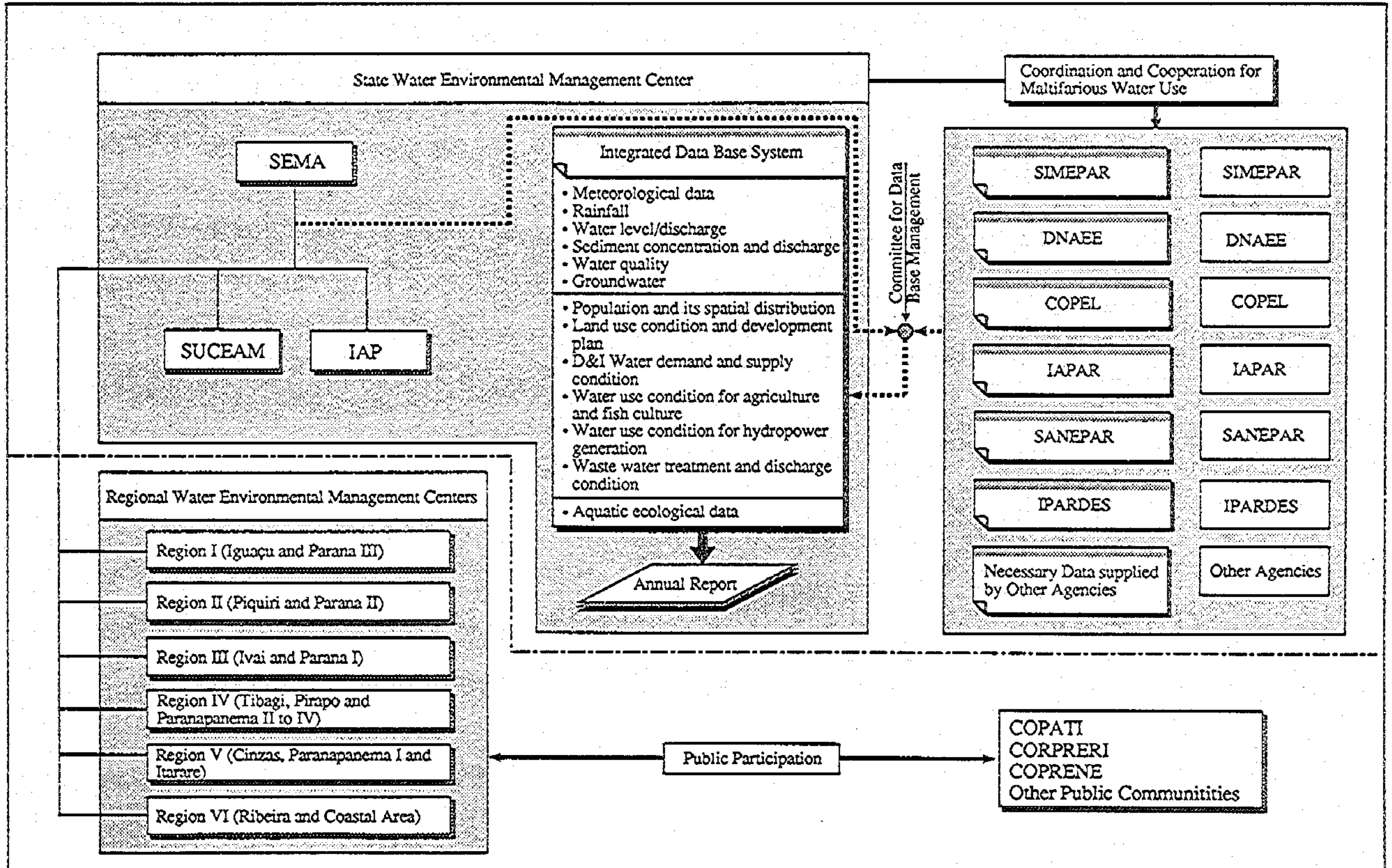


Figure-7.4 Water Environment Center, Integrated Database and Information Network