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

MAIN REPORT I

STRATEGY FOR PARANÁ STATE

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).

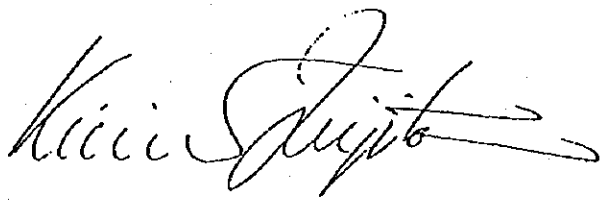
JICA sent to Brazil a study team headed by Mr. Yoshio Nakagawa, Yachiyo Engineering Co., Ltd., and composed of staff members of Yachiyo Engineering Co., Ltd. and Nippon Koei Co., Ltd. (5 times between March 1994 and October 1995).

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.

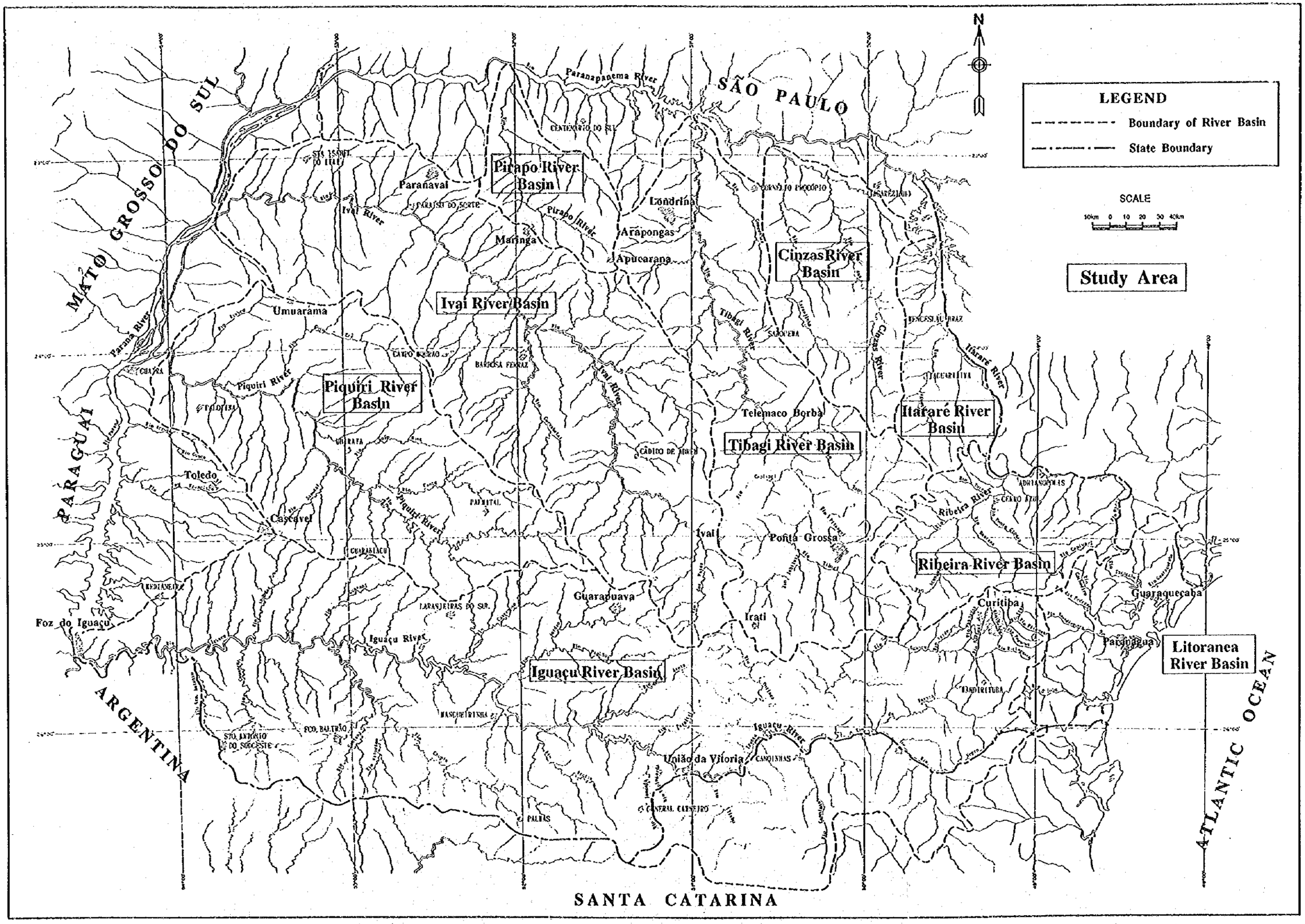
It would be a great honor for us that the result of the study would contribute to socio-economic development of Paraná State and to closer friendship between Japan and the Federative Republic of Brazil.

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


N
LEGEND
Boundary of River Basin
State Boundary
SCALE
10km 0 10 20 30 40km
Study Area
MATO GROSSO DO SUL
SÃO PAULO
PARAGUAI
ARGENTINA
SANTA CATARINA
ATLANTIC OCEAN
Paranapanema River
Pirapo River Basin
Paranavaí
Ivaí River
Pirapo River
Londrina
Maringá
Arapongas
Apucarana
Cinzas River Basin
Ivaí River Basin
Umuarama
Paraná River
Piquiri River
Piquiri River Basin
Tibagi River
Cinzas River
Itararé River
Itararé River Basin
Telemaco Borba
Tibagi River Basin
Toledo
Cascavel
Ivaí
Ponta Grossa
Ribeira River Basin
Guarapuava
Curitiba
Guaraqueçaba
Foz do Iguaçu
Iguaçu River
Irati
Paranaguá
Litoranea River Basin
Iguaçu River Basin
União da Vitoria

COMPOSITION OF FINAL REPORT

1. EXECUTIVE SUMMARY

2. MAIN REPORT
   - I. Strategy for Paraná State
   - II. Master Plan for Iguaçu River Basin
   - III. Master Plan for Tibagi River Basin

3. SECTORAL REPORT
   - A. Socio-economy
   - B. Meteorology, Hydrology and Surface Water Resources
   - C. Hydrogeology and Groundwater Resources
   - D. Domestic and Industrial Water
   - E. Agriculture
   - F. Hydroelectric Power Generation
   - G. Water Utilization Plan
   - H. Flood Control
   - I. Water Quality and Sewerage
   - J. Soil Erosion and Forest
   - K. Ecology
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4. DATA BOOK

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

1.1 Background of Study

The state of Paraná is located in the south of Brazil and has an area of approximately 200 thousand km^2 , equivalent to 87% of Japan's main island, Honshu, and a population of about 8.5 million inhabitants. Regarding economy, north and north-eastern Brazil are not well developed, while about 80% of the economy, including the agricultural and industrial sectors, is concentrated in eastern and southern Brazil. The state of Paraná is one of the wealthiest states in Brazil together with Rio De Janeiro and Sao Paulo.

Agriculture was the main sector in the state of Paraná; however, agro-industry, chemical industry, paper industry etc. have been expanding around urban areas in line with the industrialization policy of the state government. This expansion of industry has promoted a concentration of population around large cities, such as Curitiba, Londrina, Maringa, Cascavel and Ponta Grossa causing shortages of domestic and industrial water. In addition, water pollution due to sewage and waste water from factories has become an important issue and the turbidity of river water has been increased by soil erosion on the large plateau.

The topography of Paraná is mainly plateau and most cities and agricultural lands are located on the plateau. Since the major rivers flow in valleys eroding the plateau, it is popular to utilize the smaller tributary rivers which flow on the plateau, or groundwater, for city and agriculture use. As a result, it has tended to be difficult to distribute enough water to each sector, despite the fact that rainfall is quite plentiful.

To account for the situation described above, the state of Paraná urgently needs to formulate a Master Plan for the utilization of water resources with a target year of 2015, including countermeasures for environmental issues such as water pollution, soil erosion, flood mitigation, etc.

With this situations 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 (hereinafter referred to as the "Study") from the Government of Japan in August, 1993. The importance of the Study had been realized through the environmental Joint-Programming (JP) carried out as a part of JP between the two governments to find and establish a project which is necessary and worthwhile. In compliance with the request, the Japan International Cooperation Agency (hereinafter referred to as "JICA") dispatched a Preparatory Study Team headed by Mr. Koichi UZUKA in October, 1993, and the Scope of Work and Minutes of Meeting were agreed among the Governor of Paraná state, Secretary of State Secretariat of Urban Development (SEDU), Executive Director of Brazilian Cooperation Agency, Secretary of State Secretariat of Planning and General Coordination (SEPL), Secretary of State Secretariat of Environment (SEMA) and the leader of the Preparatory Study Team. With these agreements, a study team headed by Mr. Yoshio NAKAGAWA (Study Team) commenced the Study at the middle of March 1994.

1.2 Implementation of the Study

The objectives of the Study are as follows:

1) To formulate a Master Plan for the utilization of water resources, which contributes to urban, industrial, agricultural, hydropower development and environment conservation, in Paraná state aiming at the target year of 2015.

2) To promote technology transfer to the Brazilian counterparts during the Study.

The area covered by the Study is the whole of the state of Paraná as shown in Figure at frontispiece and consists of 11 main river basins.

The Study was divided into three phases as follows:

Phases I: To determine the methodology to formulate a Master Plan considering not only utilization of water resources but also environmental conservation in river basins, such as flood control, water quality improvement, ecosystem preservation, soil erosion control, etc.

Phase II: Based on the above mentioned methodology, to formulate the Strategy regarding utilization of water resources and environmental conservation in river basins in Paraná state and select pilot river basin(s) for the Master Plan considering importance and urgency of water utilization and environmental issues.

Phase III: To formulate the Master Plan for the selected pilot river basin(s).

The Study has been implemented for about 22 months from March 1994 to December 1995 by the Study Team under the close cooperation with the Brazilian counterparts. The members and the assignment schedule of the Study Team are shown in Appendix-1. The Government of Paraná State organized the Steering Committee and the Technical Committee for the purpose of over seeing the execution of the Study and providing technical guidance to the Study Team, respectively. In the same manner, JICA set up the Advisory Committee to manage the Study effectively. The members of the above committees are also shown in Appendix-2.

Technology transfer was achieved by joint working of the the Study Team and Brazilian counterparts in the course of the Study, by the first and second technical seminars hold jointly by the Study Team and Brazilian side, and by participation of three of Brazilian counterparts in JICA training course in Japan.

1.3 Contents of Report

The output of the Study was submitted as the Final Report to the counterpart agency, the State Secretariat of Planning and General Coordination (SEPL), which succeeded the former counterpart agency, State Secretariat of Urban Development (SEDU) in January 1995.

The Final Report comprises the Executive Summary, three volumes of Main Reports, fourteen volumes of the Sectoral Reports and one Data Book.

1.4 Acknowledgment

Throughout the duration of the Study, the JICA Study Team has been ably supported by the Steering Committee, the Technical Committee and the JICA Advisory Committee who have contributed a great deal of helpful assistance and advice. The Team wishes to express sincere gratitude to all the members of the Committees in both Brazil and Japan. The Team wishes to thank the Brazilian Counterparts who worked closely with the Team to ensure that collection of data, field surveys and study works were successful, and also the local consultants who undertook surveys on behalf of the Study Team. Finally, the Team wishes to acknowledge the cooperation and assistance of all who contributed to the Study in terms of data collection or provision of information. Such contributors are too numerous to list, but include many of the Government agencies, such as SEPL, SEMA, SEDU, SEAB, SETR, SITE, DNAEE, COMEC, IPARDES, IAP, SUCEAM, IAPAR, FAMEPAR etc. and semi-governmental and private organizations, such as COPEL, SANEPAR, EMATER, MINEROPAR, SIMEPAR, PROSAM, UEL, CORPRERI, COPATI etc. and many other individuals and organizations. The Team sincerely thanks all the above officials and individuals who helped to achieve the successful completion of this Master Plan Study on the Utilization of Water Resource in Paraná State in the Federative Republic of Brazil.

CHAPTER 2 SUMMARY OF STRATEGY

The proposed water environment improvement strategy for the Paraná state up to 2015 is summarized as shown in Table-2.1

Table-2.1 (1) Summary of Strategy

Sector	Description of Strategy			Cost (10^6US$)
Water Supply	•Domestic and Industrial Water Development for Urban Area			
	Area	Development Water	Development Method	
	- Curitiba Metropolitan Area :	: 7.1m³/sec :	dams and wells	759.7
	- 6 Large Urban Areas :	: 3.4m³/sec :	direct intake, dams, wells	208.5
	- Other Urban Areas :	: 8.5m³/sec :	direct intake	827.9
	•Agricultural Water :	: 1.0m³/sec :	direct intake	12.2
	Sub Total	20.0m³/sec		1,808.3
Flood Control	•Non-Structural Countermeasures such as Zoning, Resettlement, Flood Forecasting, Evacuation, Proofing and Operation Rule for 8 Regions suffering from flood damage			NA
	•Structural Measures			
	Areas	Structural Measure		
	- Curitiba Metropolitan Area	: Continuation of PROSAM		34.3
		: Extension of PROSAM		NA
	- Sao Mateus Do Sul	: Dikes		11.1
	- União da Vitoria	: Dikes		85.9
	- Morretes	: Channel Improvement and Dikes		NA
	Sub Total			200.0
Water Quality and Sewerage	•Development of Sewerage System			
	Area	Quantity of Sewerage Treatment		
	- Cinzas River Basin	: 28,000 m³/d		21.4
	- Tibagi River Basin	: 118,000 m³/d		90.3
	- Pirapo River Basin	: 68,000 m³/d		52.0
	- Ivai River Basin	: 152,000 m³/d		116.2
	- Iguaçu River Basin	: 474,000 m³/d		362.5
	- Ribeira River Basin	: 80,000 m³/d		61.2
	Sub Total	920,000		703.6
Soil Erosion Control	•Implementation of Countermeasures			
	Countermeasures	Implementation Area		
	- Terracing	: 60,200km²		241.0
	- Non Tillage	: 31,500km²		202.0
	- Sub Total	: 91,700km²		443.0

Note: (1) Sub total of flood control sector is estimated based on the cost for the Master Plan Study.
(2) For PROSAM refer to Section-6.7.
NA: not available

Table-2.1 (2) Summary of Strategy

Sector	Description of Strategy	Cost (10^6US$)
Ecological Concervation	•Structural Measures	NA
	- Implementation of municipal solid water recycling, composting and landfilling projects	
	- Establishment of urban green areas and parks, and introduction of fauna into the areas as environmental education and recreation program	
	- Establishment of Aquatic Ecology Laboratory and reproduction laboratory for endemic fish species	
	•Non Structural Measures	NA
	- Monitoring and assessment of water quality through benthic community	
	- Ecotxicological study of agrochemicals	
	- Fish population inventory	
	- Enhancement of mangrove protection legislation and avoidance of destruction of the existing mangrove ecosystem	
	- Promoting regulations and legislation to limit the importation of wood from other states and to promote incentive for reforestraction of endemic species	
	- Development of data base bank for ecological data base center	
Forest Preservation	•Preservation of natural forest	NA
	•Afforestration of 8,860 km^2 with annual rate of 443 km^2/year	NA
Water Environment Management	•Establishment of Water Environment Management Center	NA
	•Establishment of integrated monitoring system	NA
Institution	•Institutional Strategy	NA
	- Organizational strengthening through implementation of the current re-organization	
	- Strengthening groundwater management	
	- Enhancement in the enforcement of environmental regulations	
	- Legal arrangement for the control of soil, sand and stone taking in river areas	
	- Cost recovery of water environment	
	- Promotion of residents participation through information publication	
Total		3,155
	•Construction of 13-Hydropower Station (Total installed capacity; 3,095 MW.)	3,381
Ground Total		6,536

Note: Price levels in August 1994 is applied for cost estimation with exchange rate 1 US$ = 0.89 R$.

CHAPTER 3 APPROACHES TO THE STRATEGY FOR WATER ENVIRONMENT MANAGEMENT

3.1 Water Environmental Issues in Paraná State

The water environmental issues in Paraná State are classified into urban based and rural based ones. Shortage of domestic and industrial water supply, deterioration of surface water and groundwater resources due to increase of domestic sewage and industrial waste water and waste disposal, impact on aqua-ecology due to pollution loads and reduction of green coverage, variation of heat and evapotranspiration mechanism, increase of flood runoff, variation of base flow and groundwater recharge, deterioration of riverain landscape, and occupancy of illegal residents in the flood prone areas are common present and future problems in the growing municipalities in Paraná State.

These urban issues are impacts due to concentration of population and growing economic activities. Expansion of urban areas and increase of population density are consequence of migration from rural areas to urban areas rather than raise of birth rate in case of Paraná State. Enhancement of land use, increase of factories, and modernization of life style are product of concentration and growth of economy in urban areas.

Impact on aqua ecology due to increase of sediment, pesticide and fertilizer loads from agricultural land development, and change of food cycle in ecosystem due to deforestation and construction of hydropower dams are major environmental issues in the rural areas. Problems and needs relating to rural domestic water supply, industrial and agricultural water demand, and inland navigation are rather minor. Variation of temperature and weather due to change of evapotranspiration mechanism, and variation of runoff mechanism due to deforestation are not clear. These rural issues are impacts due to mainly development of agricultural land and water resources. Deforestation is consequence of mainly agricultural land development.

The relationship between the mentioned issues and management units of the multifarious water uses and improvement projects is defined in Figure-3.1. These progressive problems are predicted to cause significant deterioration of living environment and quality of life in both the urban and rural areas in Paraná state in future, while public interests in Paraná demand both creation of high quality of living environment and preservation of ecology.

In this circumstances, integrated view of water environment management will be urgent necessity for preservation and/or restoration of natural and living environment, i.e., symbiosis with natural environment.

3.2 Definition of Water Environment Management

In order to draw an ideal portrait of managing the water environment, the Study defines the framework of the water environment formed by two (2) fold 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 later ones is an interactive biosphere between human activity and ecosystem relating to water.

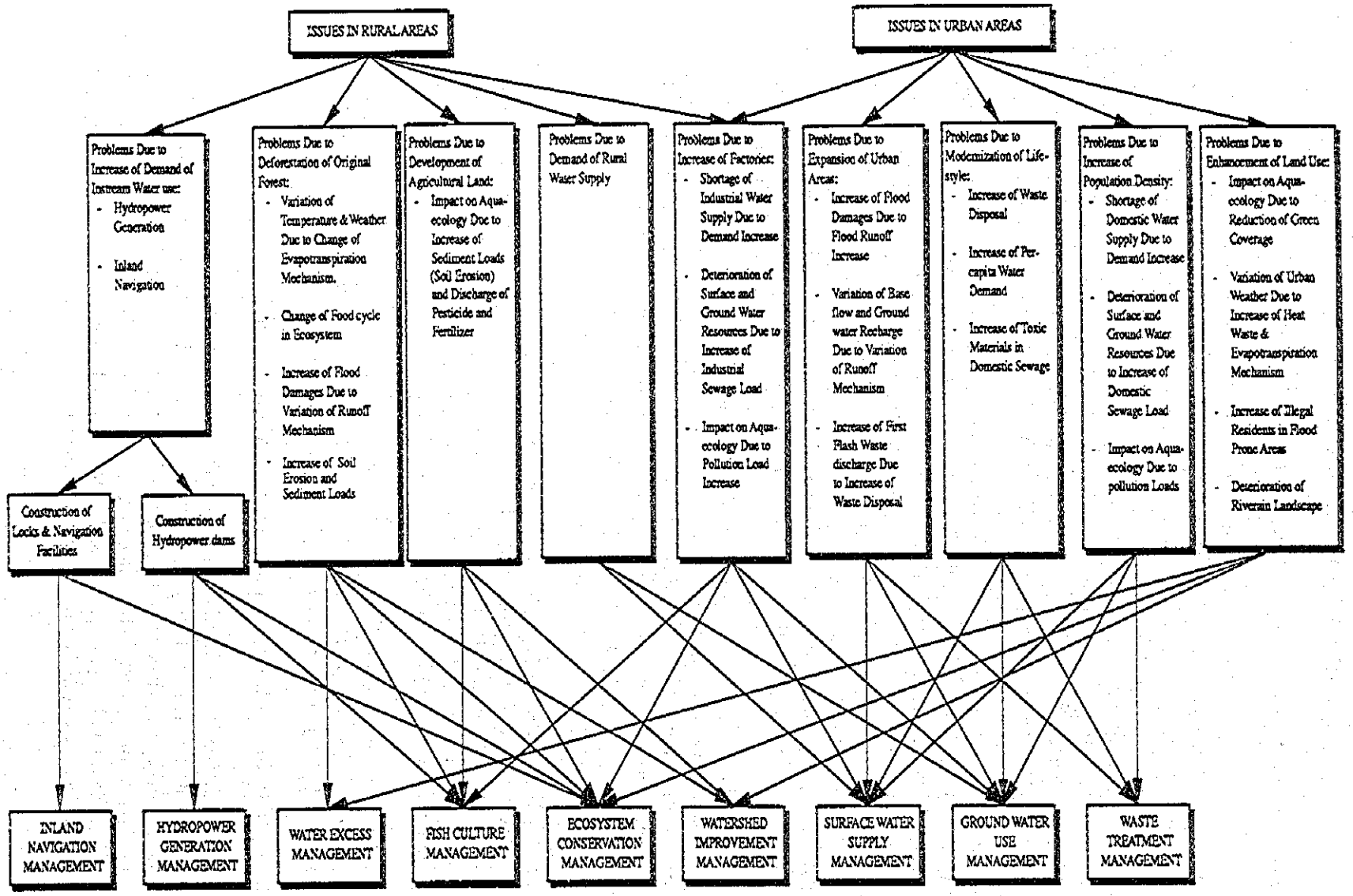

Figure - 3.1 Fundamental Issues in Water Environment in Parana State

The Study, also, defines a "Water Environment Management" as management of water resources consisting of surface and sub-surface water and excess water including flood and urban storm water, and environmental conservation and improvement of ecosystem, soil erosion, and water quality as illustrated as Figure-3.2:

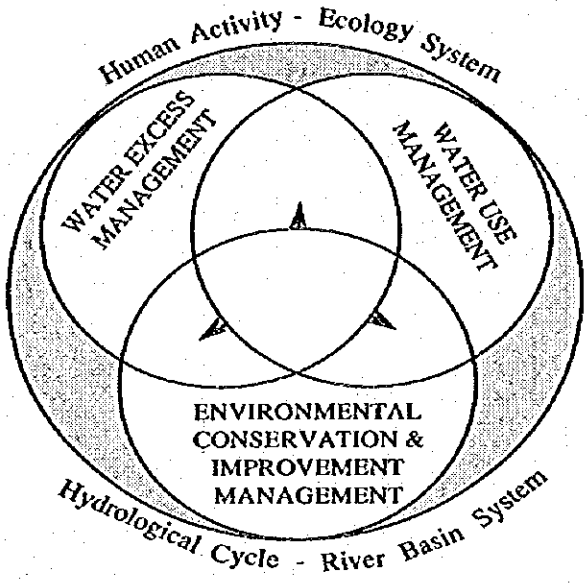

Figure-3.2 Framework of Water Environment Management

Water use management and water excess management (flood control) are major components aiming to achieve people's social well being in the sphere of water environment. The water use management consists of surface and sub-surface water supply and use, hydropower generation, inland navigation and fish culture. Environmental conservation and improvement management aims at symbiosis of human activities and natural environment such as waste water treatment, soil erosion control, and afforestation. Water excess management consists of flood plain and urban storm water control. The fringes of these management have a tendency to expand responding to development of region's economic as indicated in Figure-3.2.

3.3 Concept of Integrated Management of Water Environment

In order to establish a Strategy and Master Plan covering the aforesaid water environment, the Study applies the concept of an integrated management as illustrated in Figure-3.3, which is formed by the following components:

1) Global hydrological cycle models,
2) Standards, guidelines, and models for planning and management,
3) Project management for multifarious water use and environmental conservation and improvement
4) Integrated institutional framework, and
5) Operation and monitoring of surface and subsurface water resources.

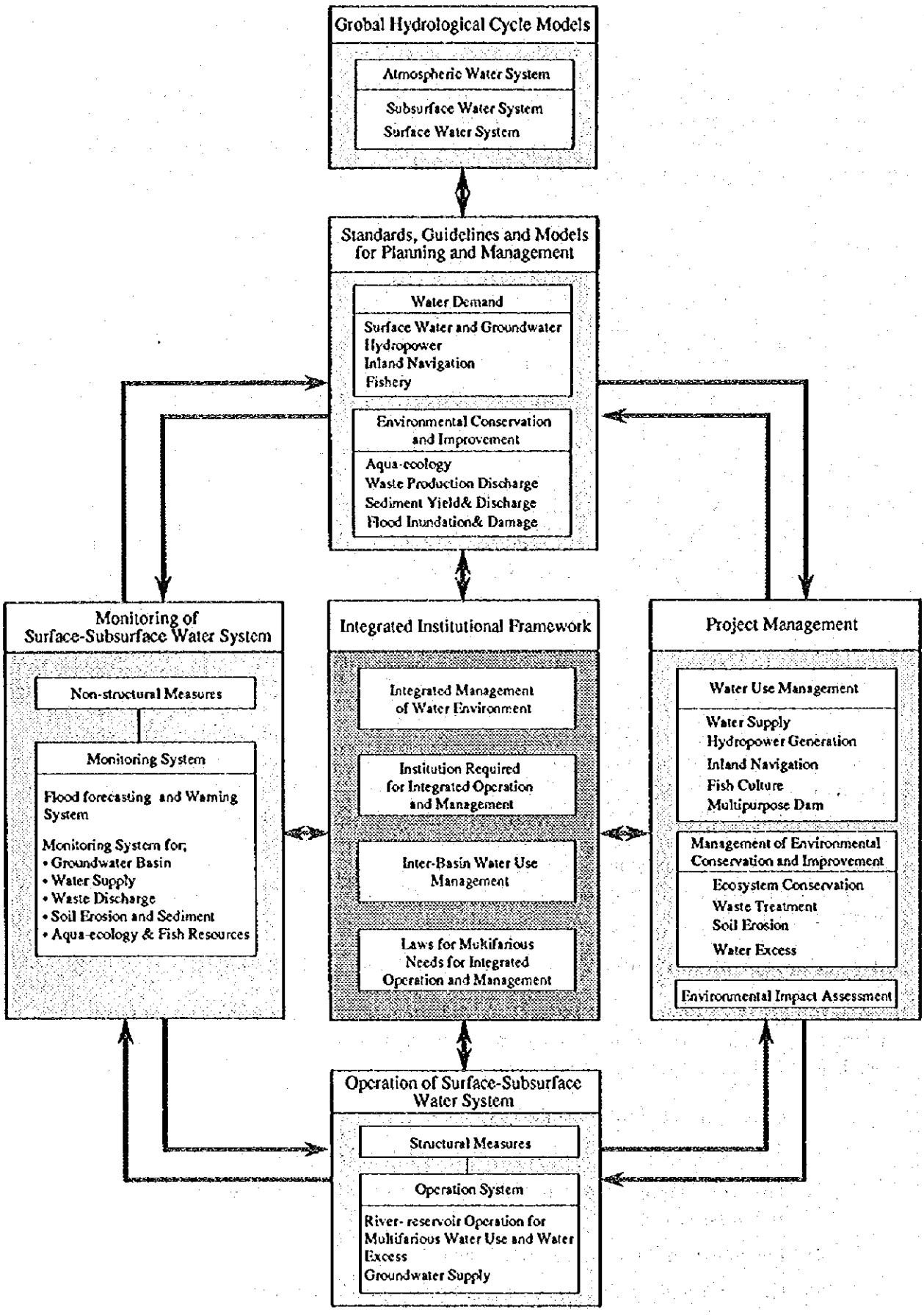

Figure-3.3 Conceptual Diagram for Integrated Management of Water Environment

These components are not only in cycle management process but also mutually interactive. In order to realize the integrated management system, institutional system have paramount importance for functioning the respective system effectively. Also, Figure-3.3 indicates significant role of monitoring in water environment management which provides data and information related to water environment to the management systems.

3.4 Framework of Strategy for Water Environment Management

The Strategy of the water environment management aims to provide a set of medium-term and long-term principles and broad action programs in order to support goals and key policies for protection, improvement, development and management of the water environment as a guideline as illustrated in Figure-3.4. As indicated in the figure, water environment management targets creation of healthy water environment and the Strategy comprises the sub-components of policy and implementation Strategy.

The policy is composed of core objectives and three (3) policy kits; principles, improvement of implementation measures and improvement of institutional arrangement. Objectives are to be established for achieving an ideal portrait of healthy water environment. Identification of problems and needs at present and in the future (2015) and image of future direction of creating healthy water environment becomes basis of objective formulation.

The principles define broad framework and basis for detailed guidelines, standards and practices. Designation of specific model areas will be required for actual implementation of improvement measures for problem areas.

The implementation measures are composed of three (3) sets of programs and an implementation schedule. These are project programs for model areas, improvement programs for organization and law, improvement programs for financing and cost recovery arrangement, and implementation schedule for these programs. Project programs are composed of water use programs and environmental conservation and improvement programs. Sector programs are formulated for identified specific model areas as described in the succeeding Chapters, based on the goal of water environment management, which aims to; 1) maintain sustainable development of reliable and safe water resources to achieve people's social well being, and symbiosis of human beings and natural environment; 2) minimize risk of encroachment of human life and ecosystem library due to human influence; 3) improve and/or reproduce the damaged water environment; and 4) coordinate smooth implementation and operation of multifarious water use and improvement projects among institutions.

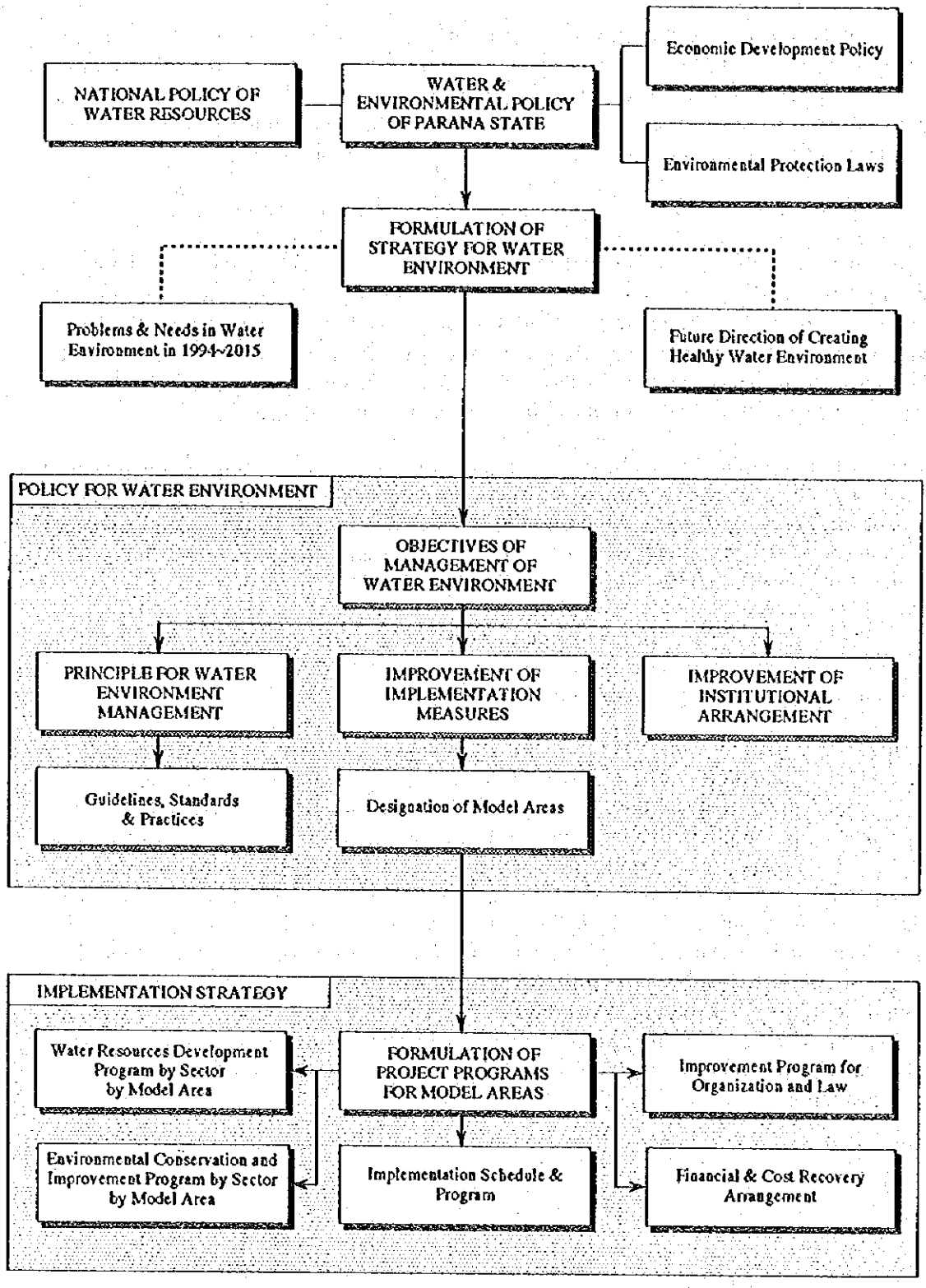

Figure-3.4 Framework of Strategy for Water Environment in Paraná State

CHAPTER 4 NATURAL AND SOCIO - ECONOMIC BACKGROUND

4.1 Topography

The state of Paraná is located in southern Brazil, between latitude 22° 31' to 26° 43' South and longitude 48° 05' to 54° 37' East. The total land area is 199,554 km^2 with length of 647 km from east to west and 486 km from north to south. The state borders on the states of São 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 north and west borders of the state are formed by the Paranapanema river and the Paraná river. Although only 98 km length, the Atlantic Ocean coastline in the east of Paraná state forms one of the most imporatant bays in Brazil, Paraná bay, of area 300 km^2 where the ports of Paranagua and Antonina are located.

The topographic features of Paraná State are generally characterized by the following four areas from east to northwest (Figure-4.1):

- the Coastal Range
- the First Plateau
- the Second Plateau
- the Third Plateau

The Coastal Range and the others are divided by the Coastal Mountains (named with "Serra Do Mar") composed of high mountains in altitude from 1,000 to 2,000 meters. The Coastal Range is classified into the mountain areas and the Coastal planes. The Coastal planes consist of the Coastal terraces and fans ranging in altitude from 0 to 25 meters. In the mountain areas, the rivers and tributaries have steep gradients and flow into the Atlantic Ocean.

The First Plateau consists of the upland planes such as Curitiba City and hills with gentle gradients, and it is restricted to the Coastal Mountains in the east and the cuesta mountains in the west and/or northwest. The upland planes are ranging in altitude from 800 to 1,000 meters and the cuesta mountains show the inclination of the geological formations trending to the west and/or the northwest. Some of the rivers and tributaries are flowing into the Paraná River and some of them are flowing into the Atlantic Ocean.

The Second Plateau consists of the planes and hills with gentle gradients ranging in altitude from 600 to 1,000 meters. It is restricted to two cuesta mountains in the east and the west. In this Plateau the rivers and tributaries are flowing into the Paraná River in final.

The Third Plateau consists of the planes and hills ranging in altitude from 300 to 800 meters. It is restricted to the cuesta mountains in the east and the Paraná River in the west. The hills in this Plateau are generally steeper than the hills of the other plateaus.

There are 9 major river basins within Paraná state. They are the Itarare, Cinzas, Tibagi, Pirapo, Ivai, Piquiri, Iguaçu, Ribeira and Litoranea rivers. Among them, the Itarare, Cinzas, Tibagi and Pirapo rivers flow into the Paranapanema river which is the state boundary with São Paulo and Mato Grosso do Sul states and successively flow into the Paraná river. And the Ivai, Piquiri and Iguaçu rivers flow into the Paraná river which is the state boundary with Mato Grosso do Sul and the national boundary with Paraguay and Argentina. The Ribeira and Litoranea rivers flow into the Atlantic Ocean.

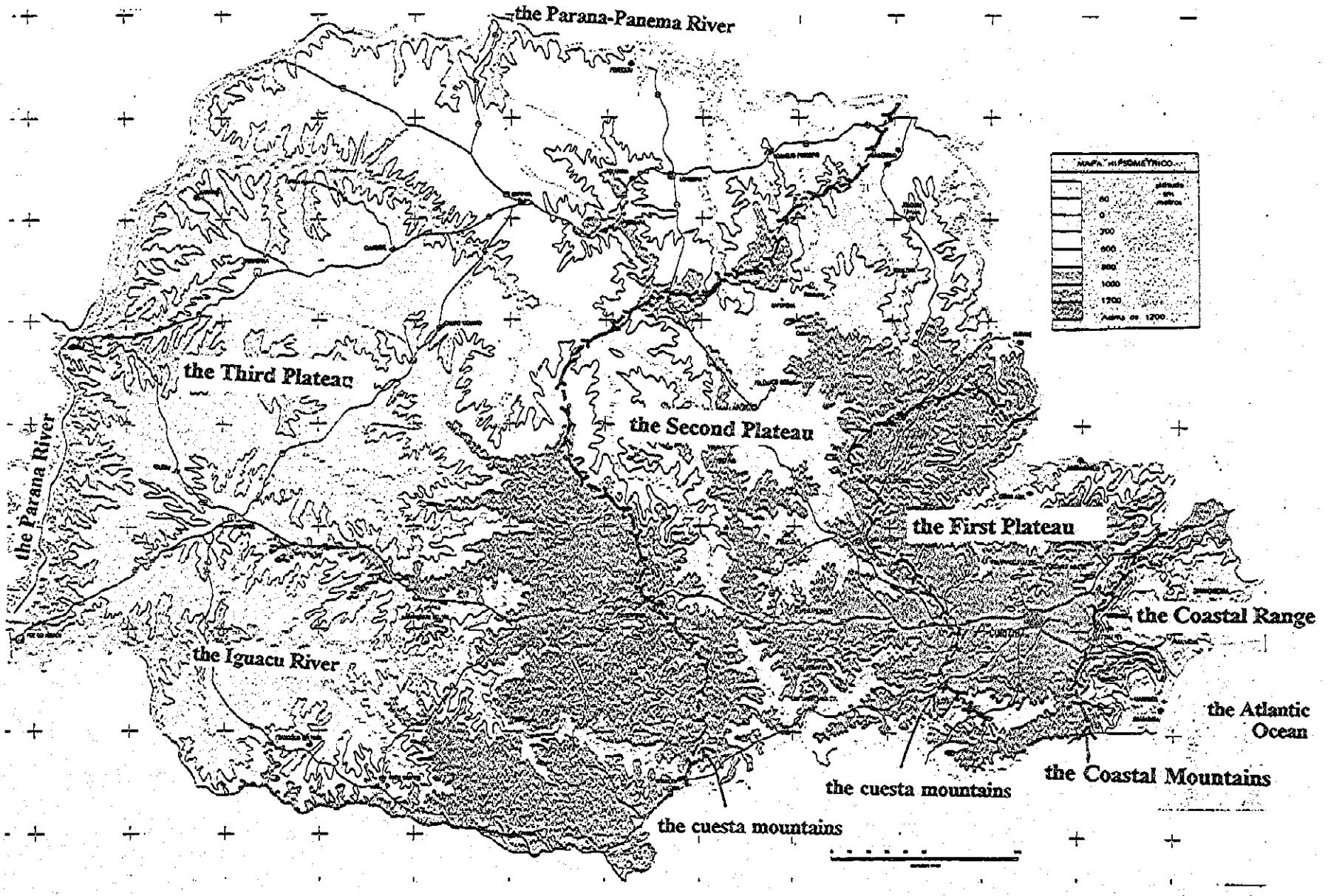

Figure-4.1 Topography Map of Paraná State

4.2 Meteorology

4.2.1 General Meteorological Conditions

The climate and meteorological conditions of a region are mainly determined by atmospheric circulation that acts on the various scales where the region is inserted. The south of Brazil as a result of localization in the middle latitudes, is subject to the following basic atmospheric actions; (Source : Sugai et al, 1993)

- the Subtropical anticyclone of the South Atlantic
- the Migratory Polar Anticyclone
- the Chaco Center of Low Pressure
- the Amazon Tropical High Pressure
- the Pacific Anticyclone

Along the year, these centers of atmospheric action change position and vary their intensities, and they cause the so called air mass. These air masses have almost uniform physical properties at the same level, such as temperature ,humidity, air pressure and wind, and can be classified as tropical and polar and subclassified as continental and maritime. The influence of air masses in Paraná state is characterized as follows;

<From October to March>

A predominance of the Atlantic Tropical air mass of low pressure occurs in the direction of the south of Brazil bringing good dry weather with few clouds.

<From April to September>

An Atlantic Polar air mass occurs more intense in this period, and infiltration occurs north provoking good weather and few clouds, as well as cold nights and droughts.

<Whole Season>

When the tropical air mass goes over the polar one, there are the formation of warm fronts and shorter duration rainfall. When the opposite occurs, there is a formation of cold fronts which provoke instability of great extension and long duration rains, it is called frontal rains.

4.2.2 Selected Meteological Stations

In the Study Area, there are 51 main meteorological stations and 844 rain-gauge stations (as of March, 1995). The Team selected 33 meteorological stations with additional three rainfall stations (See Figure-4.2). And considering the accuracy and availability of observed data, simulation period was adapted for the last 20 years (1974-1993).

No.	Station No.	Station Name	Basin	Altitude (m)
1	02251027	Bela Vista	P.P. 3	600
2	02349030	Joaquim Tavora	Cinzas	512
3	02350017	Cambara	P.P. 1	450
4	02350018	Bandeirantes	Cinzas	440
5	02351003	Londrina	Tibagi	585
6	02351008	Apucarana	Pirapo	746
7	02351011	Ibipora	Tibagi	484
8	02352017	Paranavai	Ivai	480
9	02352019	Cianorte	Ivai	530
10	02353008	Umuarama	Piquiri	480
11	02449013	Cerro Azul	Ribeira	443
12	02450011	Telemaco Borba	Tibagi	768
(13)	02451051	Candido Abreu	Ivai	600
13	02451052	Candido Abreu	Ivai	645
14	02452050	Nova Cantu	Piquiri	540
15	02453003	Palotina	Piquiri	310
16	02453023	Cascavel	Parana	760
17	02548038	Morretes	Litoranea	59
18	02548039	Guaraqueçaba	Litoranea	40
19	02548070	Antonina	Litoranea	60
20	02549041	Piraquara	Iguacu	930
(21)	02549025	Lapa	Iguacu	907
21	02549091	Lapa	Iguacu	910
22	02550024	Ponta Grossa	Tibagi	880
23	02550025	Teixeira Soares	Tibagi	893
24	02551010	Guarapuava	Iguacu	1,020
25	02552009	Laranjeiras	Iguacu	880
26	02553015	Planalto	Iguacu	400
27	02553018	Quedas Iguacu	Iguacu	513
28	02554026	Sao Miguel	Parana	260
(29)	02651000	Uniao da Vitoria	Iguacu	736
29	02651007	Porto Uniao	Iguacu	778
30	02651043	Palmas	Iguacu	1,100
31	02652003	Clevelandia	Iguacu	930
32	02652035	Pato Branco	Iguacu	700
33	02653012	Francisco Beltrao	Iguacu	650

( ) : only rainfall gauging stations

LEGEND

- Boundary of River Basin
- State Boundary

SCALE 10km 0 10 20 30 40km

Figure-4.2 Selected Meteorological Stations

4.2.3 Rainfall

The rainfall data in Paraná has been measured with different agencies and different observation periods by stations. At present, about 900 rain gauge stations are registered.

(1) Monthly Rainfall Distribution

Seasonal variations of monthly totals are similar in different parts of the Paraná. Fluctuation of monthly rainfall by regions are summarized as follows;

Two different fluctuation pattern exists between Litoranea and Northern region, and Southern region. Litoranea and Northern region rainfall pattern only fluctuates once a year on December or January, but at the Southern region has two times a year on both May and October.

(2) Annual Rainfall Distribution

Using the last 20 years annual mean rainfall data, an Iso-hyetal map was developed as shown in Figure-4.3. In Paraná, the following rain characteristics can be observed;

a) Litoranea at the eastern side of the coast mountain range has the highest annual rainfall volume.

b) The region including Curitiba at the western side of the coast mountain range has the lowest annual rainfall.

c) The south-western region has second highest annual rainfall volume because of high altitude between 1100 m and 1200 m, and rainfall volume decrease toward the eastern side.

4.2.4 Temperature

The observation of temperature is normally made by three times a day (9:00, 15:00 and 21:00 hr). Annual mean temperature in Paraná has generally ranged between 16°C and 22°C throughout the year. According to collected data, maximum temperature 41.5°C at Paranavai in the north-west area and minimum temperature -6.8°C both at Palmas and Guarapuava in the south highland area were recorded respectively during the recent 20 years. Figure-4.4 shows Iso-thermal map of annual mean temperature.

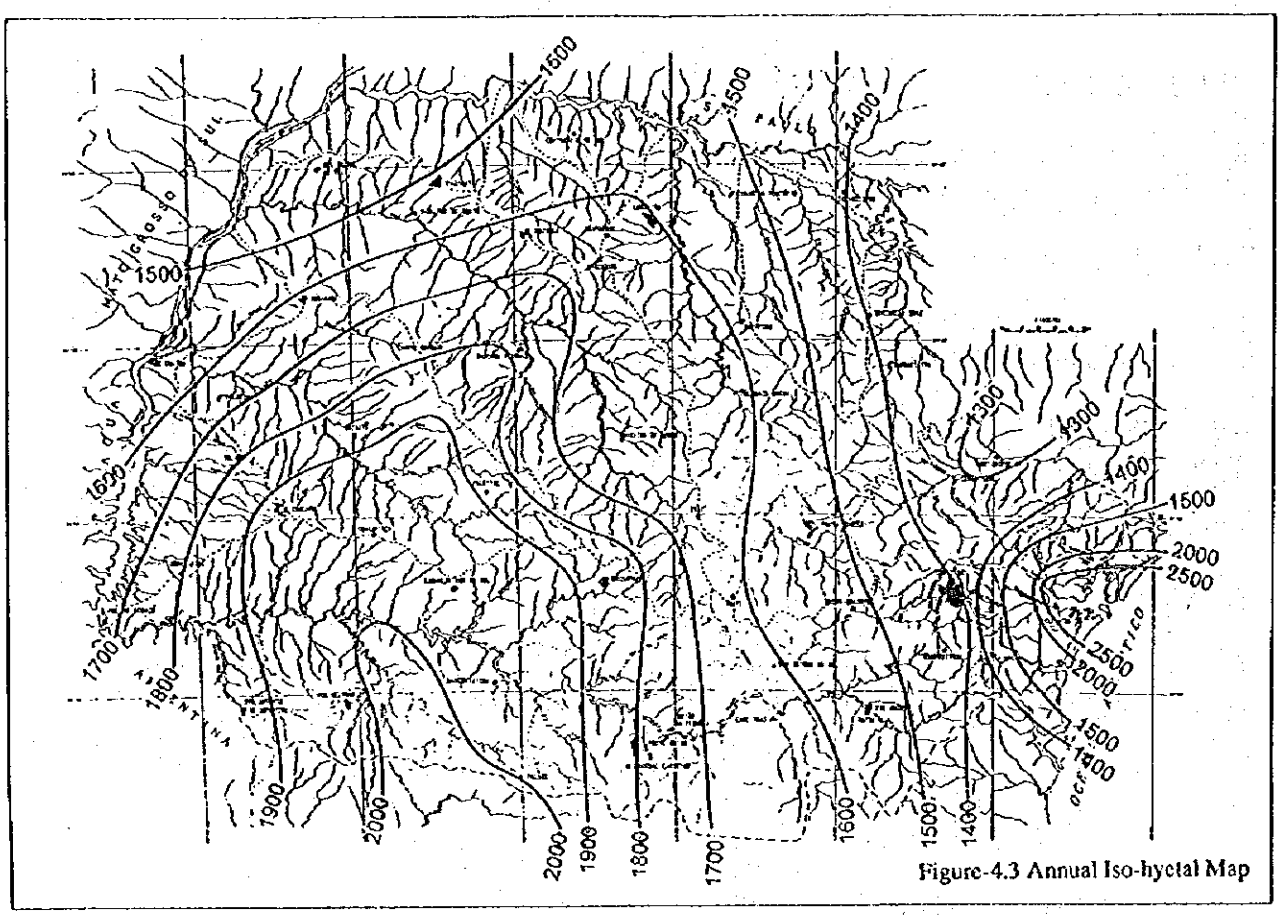

Figure-4.3 Annual Iso-hyetal Map

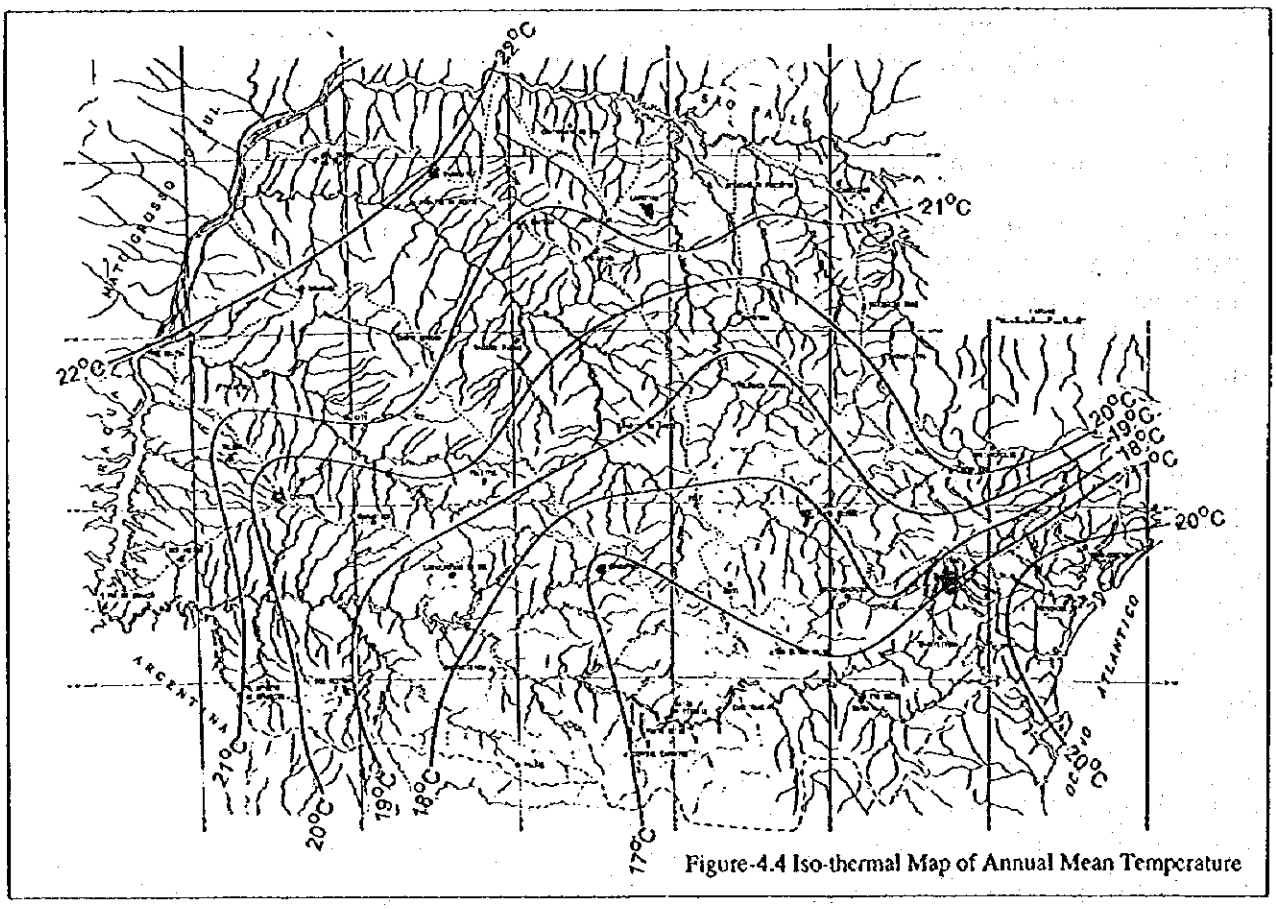

Figure-4.4 Iso-thermal Map of Annual Mean Temperature

4.2.5 Evaporation and Evapotranspiration

(1) Penman's Evaporation

COPEL, IAP and other related agencies are commonly computed an evaporation rate by using Penman's equation. The Team determined the relation between evaporation pan data after converting by using a mean of pan coefficient 0.7 (: Evpan) and evaporation data by Penman's equation (: Evp) at several stations. Using both annual evaporation data, the ratio of Evpan / Evp ranges from 0.7 to 0.9, with a mean of 0.8. The mean value of 0.8 will be employed to estimate the evaporation value for planned dam reservoirs in surface water development study.

(2) Potential Evapotranspiration

Evapotranspiration is the evaporation from all water, soil, vegetative, and other surfaces, plus transpiration. COPEL computed the value of potential evapotranspiration by using Penman's equation (by Frere, 1979) which is commonly used in Brazil.

The calculated results was plotted as an Iso-potential evapotranspiration map (Figure-4.5).

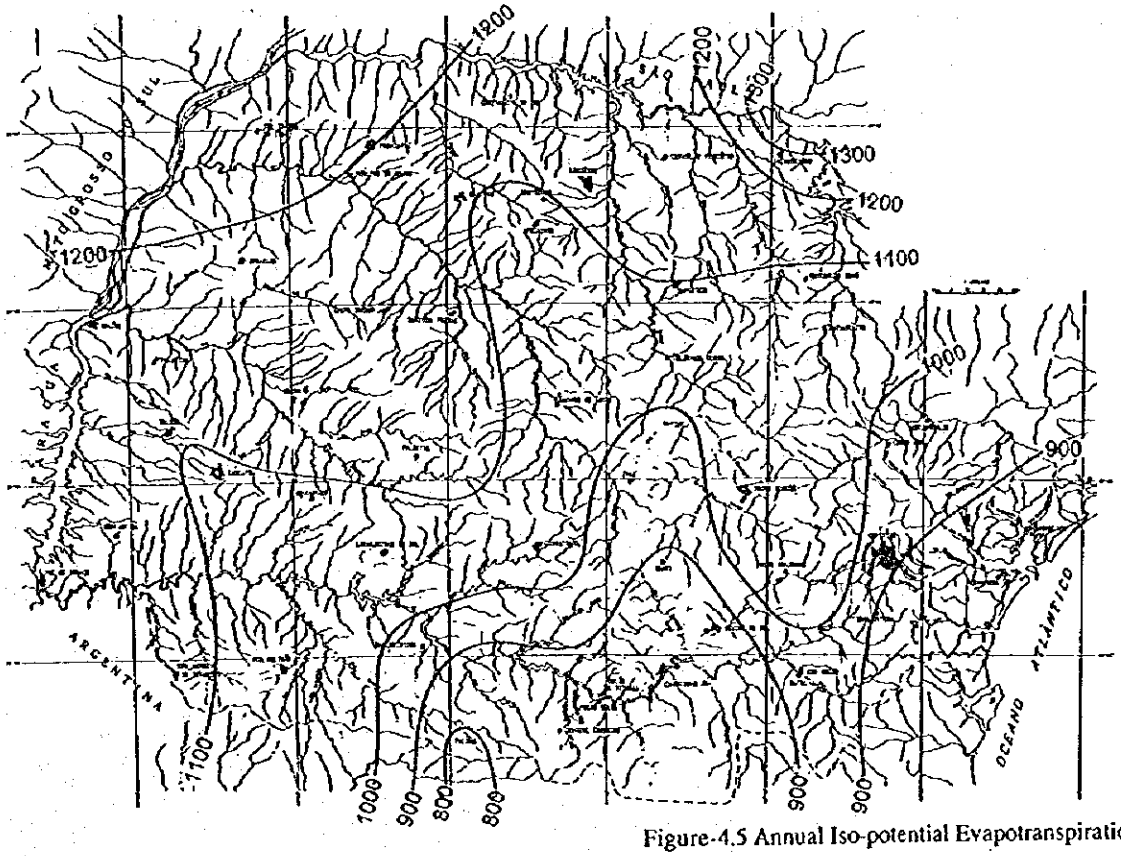

Figure-4.5 Annual Iso-potential Evapotranspiration M

4.3 Hydrology

4.3.1 Hydrological Data

(1) General

There are 217 hydrological stations (as of March, 1995) operated by mainly DNAEE, COPEL, IAP, of which 69 stations are provided with automatic level recorder. The actual field works such as discharge measurement, water quality sampling and sediment sampling by each hydrological station are carried out by 11 observation teams of IAP. The frequency of field measurements is either once a month or once in two months, and at times when the floods occur.

(2) Discharge Reference Point

To clarify the flow characteristics of each river basin, 31 hydrological stations were selected as discharge reference points by considering the data availability, balance of catchment area and accuracy of existing data (refer to Figure-4.6).

(3) Hydrological Database

At present, the following three database systems are used by the different public agencies in Paraná;

1) MSDHD (DNAEE)
2) SISTEMA DAD (COPEL)
3) CADASTRO-PLU-FLU (IAP)

The database system developed in this Study are composed of the following components. The database prepared by JICA Study Team covers all registered stations except for the closed stations in Paraná State.

1) Filling System
   - H-Q Table by Station
   - Cross Section Data by Station
   - Flow Measurement Data by Station
   - Daily River Water Level

2) Analyzing System
   - Discharge Rating Curve by using Manning's Formula
   - Discharge Rating Curve by using Least Square Method
   - Daily Discharge
   - Monthly Discharge
   - Correlation Analysis between Stations
   - Flow Regime Table and Graph

No.	Basin	River	St. No.	St. Name	Area (km²)
1	Itarare	Jaguariaiva	64 -242 -000	Tamandua	1,622
2	Cinzas	Cinzas	64 -360 -000	Tomazina	2,015
3			64 -370 -000	Andira	5,622
4	Tibagi	Tibagi	64 -444 -000	Uvala	4,450
5			64 -465 -000	Tibagi	8,948
6			64 -491 -000	Barra Rib. Das Antas	15,600
7			64 -507 -011	Jatalzinho (Extendido)	21,955
8	Pirapo	Pirapo	64 -550 -000	Vila Silva Jardim	4,627
9	Ival	Ival	64 -625 -000	Tereza Cristina	3,572
10			64 -645 -000	Porto Espanhol	8,600
11			64 -675 -002	Porto Bandeiras	24,200
12			64 -685 -000	Porto Paraiso do Norte	28,427
13			64 -693 -000	Novo Porto Taquara	34,432
14	Piquiri	Piquiri	64 -771 -500	Porto Guarani	4,223
15			64 -795 -000	Ponte do Piquiri	11,303
16			64 -820 -000	Porto Formoso	17,500
17			64 -830 -000	Baixa do Santa Maria	20,982
18	Iguacu	Iguacu	65 -010 -000	Fazendinha	110
19			65 -025 -000	Gualuvira	2,304
20			65 -035 -000	Porto Amazonas	3,662
21			65 -060 -000	Sao Mateus do Sul	6,065
22			65 -310 -000	Uniao da Vitoria	24,211
23			65 -895 -002	Salto Osorio	45,824
24			65 -993 -000	Salto Cataratas	67,317
25		Negro	65 -175 -000	Divisa	7,970
26		Timbo	65 -260 -000	Foz do Cachoeira	693
27		Jordao	65 -825 -000	Santa Clara	3,913
28		Chopim	65 -960 -000	Aguas do Vere	6,696
29	Ribeira	Ribeira	81 -200 -000	Capela do Ribeira	7,252
30	Litoranea	Nhundiaquara	82 -170 -000	Morretes	217
31		Marumbi	82 -195 -002	Morretes	53

Figure-4.6 Selected Discharge Reference Points (Discharge Reference Points)

4.3.2 Runoff Analysis

Based on the river flow data for the last 20 years period (1974-1993), daily discharge at each discharge reference point were determined, and the missing daily discharge were determined by monthly discharge correlation analysis among the stations.

The flow regime shows the annual condition using the calculated daily discharge at a certain hydrological station and shall be indicated by the daily discharge and number of exceeded days. The annual flow regime of each selected stations in the Study area shows as follows;

- High Discharge (95th daily discharge from the greatest)
- Normal Discharge (185th daily discharge from the greatest)
- Low Discharge (275th daily discharge from the greatest)
- Drought Discharge (355th daily discharge from the greatest)

The flow regime is commonly used in Japan to find the fluctuation in the daily discharge, and utilized for determining the potential water characteristics.

The flow regime computed by station was adapted for 20 years period (1974-1993), and mean value of the 95th, 185th, 275th and 355th daily discharge for the last 20 years period were calculated. The results of mean flow regime for the last 20 years period are summarized in Table-4.1.

Table-4.1 Flow Regime (mean values for the last 20 years period (1974 - 1993))

Basin	River	No.	St. No.	St.Name	Area (km2)	Daily Discharge (m3/sec)			
						95 day	185 day	275 day	355 day
Itarare	Jaguariaiva	1	64-242-000	Tamandua	1,622	33.86	23.56	16.13	13.04
Cinzas	Cinzas	2	64-360-000	Tomazina	2,015	38.19	25.11	16.09	12.20
		3	64-370-000	Andira	5,622	88.26	50.03	34.18	22.32
Tibagi	Tibagi	4	64-444-000	Uvaia	4,450	116.02	64.61	40.58	24.83
		5	64-465-000	Tibagi	8,948	229.39	132.92	87.08	51.69
		6	64-491-000	Barra Rib.das Antas	15,600	381.96	230.94	153.34	95.24
		7	64-507-011	Jataizinho (Extendido)	21,955	502.08	312.46	211.73	128.70
Pirapo	Pirapo	8	64-550-000	Vila Silva Jardim	4,627	79.54	61.36	49.43	37.74
Ival	Ival	9	64-625-000	Tereza Cristina	3,572	80.26	38.23	21.57	10.98
		10	64-645-000	Porto Espanhol	8,600	220.04	115.48	67.89	37.24
		11	64-675-002	Porto Bananeiras	24,200	661.65	311.55	199.13	120.84
		12	64-685-000	Porto Paraiso do Norte	28,427	650.69	381.95	262.71	173.59
		13	64-693-000	Novo Porto Taquara	34,432	777.78	491.69	355.97	246.35
Piquiri	Piquiri	14	64-771-500	Porto Guarani	4,223	120.83	60.39	33.58	16.61
		15	64-795-000	Ponte do Piquiri	11,303	345.65	186.73	111.87	65.20
		16	64-820-000	Porto Formosa	17,500	498.85	315.78	219.41	143.22
		17	64-830-000	Balsa do Santa Maria	20,982	551.77	368.49	262.97	172.25
Iguacu	Iguacu	18	65-010-000	Fazendinha	110	3.13	1.86	1.29	0.85
		19	65-025-000	Guajuvira	2,304	58.29	35.78	22.03	12.53
		20	65-035-000	Porto Amazonas	3,662	84.96	49.48	30.73	17.17
		21	65-060-000	Sao Mateus do Sul	6,065	136.44	78.47	50.85	30.30
		22	65-310-000	Uniao da Vitoria	24,211	656.67	365.42	232.03	131.34
		23	65-895-002	Salto Osorio	45,824	1310.22	829.66	532.17	262.67
		24	65-993-000	Salto Cataratas	67,317	1690.20	1126.20	792.05	436.78
	Negro	26	65-175-000	Divisa	7,970	195.67	112.64	76.21	49.50
	Timbo	26	65-260-000	Foz do Cachoeira	693	22.90	12.47	7.92	4.52
	Jordao	27	65-825-000	Santa Clara	3,913	128.17	77.18	49.67	28.19
	Chopim	28	65-960-000	Aguas do Vere	6,696	224.80	131.11	78.13	40.14
Ribeira	Ribeira	29	81-200-000	Capela do Ribeira	7,262	130.63	101.75	86.87	72.60
Litoranea	Nhundiaquara	30	82-170-000	Morretes	217	14.43	8.04	4.86	2.56
	Marumbi	31	82-195-002	Morretes	53	5.02	2.77	1.61	0.77

4.3.3 Runoff Ratio

Using the annual rainfall depth and annual surface runoff over the same catchment area, surface runoff volume and surface runoff ratio by stations were summarized in Table-4.2. The simulation period was applied for the last 20 years(1974-1993), and Figure-4.7 shows relation between catchment area and runoff ratio.

Based on the results, runoff ratio at all basins except for Litoranea basin ranges from 30 to 50 % with a mean of 41 %, and Litoranea basin ranges from 69 to 80 % because the riverbed profile has a steep slope. Especially, runoff ratio at some reference points in Tibagi, Cinzas and Pirapo basins shows at the ranges from 30 to 40 %, because high evapotranspiration condition as compared with other basins.

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Table-4.2 Summary of Mean Annual Surface Runoff Ratio
(Simulation Period : 1974 - 1993, 20 Years)

Basin	River	No.	St. No.	St.Name	Area (km2)	Rainfall (mm/year)	Runoff (mm/year)	Balance (mm/year)	Runoff Ratio
Itarare	Jaguariaiva	1	64-242-000	Tamandua	1,622	1335.4	632.4	703.0	0.47
Cinzas	Cinzas	2	64-360-000	Tomazina	2,015	1491.3	565.8	925.4	0.38
		3	64-370-000	Andira	5,622	1440.3	480.5	959.8	0.33
Tibagi	Tibagi	4	64-444-000	Uvaia	4,450	1560.2	640.7	919.4	0.41
		5	64-465-000	Tibagi	8,948	1565.7	639.8	925.9	0.41
		6	64-491-000	Barra Rib das Antas	15,600	1569.7	622.3	947.4	0.40
		7	64-507-011	Jataizinho (Extendido)	21,955	1587.6	604.9	982.6	0.38
Pirapo	Pirapo	8	64-550-000	Vila Silva Jardim	4,627	1615.2	492.7	1122.4	0.31
Ivai	Ivai	9	64-625-000	Tereza Cristina	3,572	1694.5	715.8	978.6	0.42
		10	64-645-000	Porto Espanhol	8,600	1659.9	729.7	930.3	0.44
		11	64-675-002	Porto Bananeiras	24,200	1665.1	648.9	1016.2	0.39
		12	64-685-000	Porto Paraiso do Norte	28,427	1657.6	646.9	1010.7	0.39
		13	64-693-000	Novo Porto Taquara	34,432	1642.2	645.1	997.1	0.39
Piquiri	Piquiri	14	64-771-500	Porto Guarani	4,223	1928.9	855.6	1073.2	0.44
		15	64-795-000	Ponte do Piquiri	11,303	1936.9	926.2	1010.8	0.48
		16	64-820-000	Porto Formosa	17,500	1865.1	823.7	1041.4	0.44
		17	64-830-000	Balsa do Santa Maria	20,982	1843.0	763.6	1079.4	0.41
Iguacu	Iguacu	18	65-010-000	Fazendinha	110	1557.3	741.2	816.0	0.48
		19	65-025-000	Guajuvira	2,304	1416.5	634.8	781.8	0.45
		20	65-035-000	Porto Amazonas	3,662	1445.9	591.8	854.0	0.41
		21	65-060-000	Sao Mateus do Sul	6,065	1483.6	574.8	908.8	0.39
		22	65-310-000	Uniao da Vitoria	24,211	1584.2	663.8	920.4	0.42
		23	65-895-002	Salto Osorio	45,824	1725.6	765.3	960.3	0.44
		24	65-993-000	Salto Cataratas	67,317	1802.9	724.7	1078.3	0.40
	Negro	25	65-175-000	Divisa	7,970	1515.9	616.9	899.0	0.41
	Timbo	26	65-260-000	Foz do Cachoeira	693	1738.7	884.9	853.7	0.51
	Jordao	27	65-825-000	Santa Clara	3,913	1893.4	895.8	997.6	0.47
	Chopim	28	65-960-000	Aguas do Vere	6,696	2003.2	958.8	1044.4	0.48
Ribeira	Ribeira	29	81-200-000	Capela do Ribeira	7,252	1378.1	545.8	832.3	0.40
Litoranea	Nhundiaquara	30	82-170-000	Morretes	217	*) 2537.7	1745.5	792.2	0.69
	Marumbi	31	82-195-002	Morretes	53	*) 3300.0	2646.9	653.1	0.80
Mean	All Basins					1723.9	787.9	936.0	46%
						100%	*46%*	*54%*	
	Basins except for Litoranea Area					1641.5	690.8	950.7	42%
						100%	*42%*	*58%*	

Note : *) : It was determined by using an existing Iso-hyetal Map (COPEL)

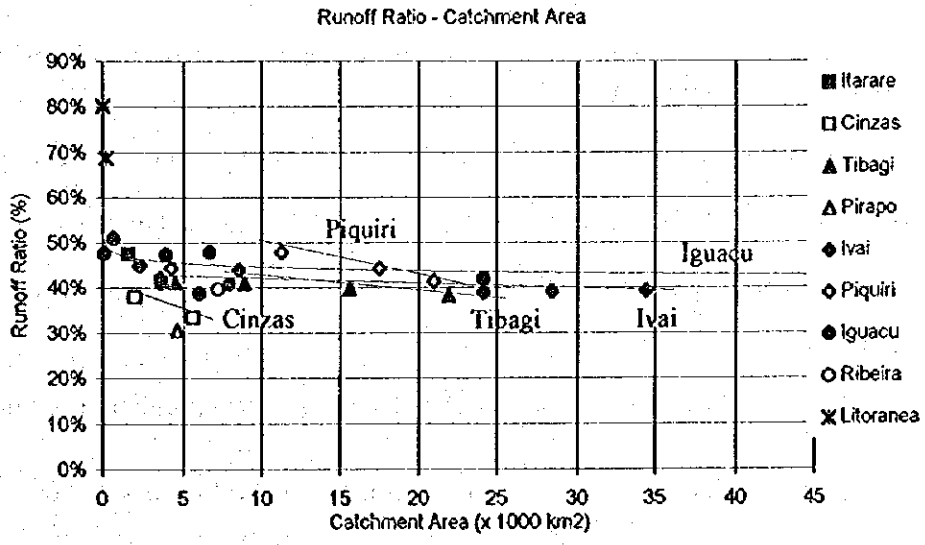

Figure-4.7 Relations between Catchment Area and Runoff Ratio

4.4 Geology and Hydrogeology

4.4.1 Geology

The area of Paraná State is underlain chiefly by Precambrian (composed of Archean and Proterozoic) metamorphic rocks intruded by granitic intrusive rocks ranging Precambrian - Paleozoic age, and sedimentary rocks of Paleozoic to Cenozoic with Mesozoic volcanics (Table-4.3, Figure-4.8).

Precambrian occupies the First Plateau and the Coastal Range in Paraná State. It seems to form the geological core of Plateau in Paraná State. Paleozoic occupies the Second Plateau and Mesozoic occupies the Third Plateau. The younger formations are overlying to the core of Precambrian in order of age from Paleozoic to Mesozoic. The shape of overlying shows a arc toward north and/or west side in the order of age (Geological profile in Figure-4.8). The all geological units are cut by faults and/or dikes. The axis of arc is trending to NW-SE in direction and it is called "Ponta Grossa Arc".

The stratigraphy of Paraná State is composed of the groups and formations in order of older age as described in Table-4.3.

4.4.2 Hydrogeology

In Paraná State, there are various kinds of aquifers such as cave in carbonate rocks, fractures in basalt and crystalline rocks, porous in sandstone and/or sand, etc.

Such characteristics of aquifers are based on the rock formation, so that the aquifers are able to be classified as set out below in order of older age. The aquifer distribution is shown in Figure-4.9.

(1) the "Karst"; - Composed of carbonate rocks and intercalated with schists and sedimentary rocks of Precambrian.

(2) Crystalline rocks ; - Composed of granitic rocks and metamorphic rocks in the age from Precambrian to Cambrian.

(3) Lower to Middle Paleozoic ; - Composed of Castro Group and Paraná Group.

(4) Middle to Upper Paleozoic ; - Composed of Itarare Group and Guata Group.

(5) Late Paleozoic ; - Composed of Passa Dois Group with partial porous media.

(6) Mesozoic

1) Botucatu Formation ; - Overlain by Serra Geral Formation within the Third Plateau.

2) Serra Geral Formation; - Reservoirs composed of basalt lavas intercalated with sandstone lenses.

3) Caiua Formation : - Reservoirs composed of mainly sandstone intercalated with arglirous layers.

(7) Cenozoic - Guabirotuba Formation ; - Restricted to Curitiba Metropolitan Area

Table-4.3 General Stratigraphy

ERA	SYMBOL	PERIOD	GROUP	FORMATION	LITHOLOGY (MAIN FOSSILS)
CENOZ. < 65 m.y.	Qa	QUATERNARY < 1.8 m.y.			alluvium.
	Qm				inconsolidated marine sediments.
	Qg			GUABIROTUBA	clays, arkoses, loams, sands and gravels.
MESOZOIC 230 to 65 m.y	Kba	CRETACEOUS 140 to 65 m.y.	BAURU	ADAMANTINA	thin sandstones, siltstones and brownish laminites.
	Kbsa			SANTO ANASTACIO	sandstones and laminites.
	Kbc			CAIUÁ	violet sandstones (Theropoda)
	KJs				doleritic dikes and sills, syenite plutons, phonolite and carbonatites.
	JKsg	JURASSIC TRIASSIC 140 to 230 m.y.	SÃO BENTO	SERRRA GERAL	basalt lavas and sills, with andesite lavas.
	TRpb			PIRAMBÓIA AND BOTUCATU	sandstones and siltstones with few conglomerates (Colluroussaria and Therapsida)
PALEOZOIC 570 to 230 m.y.	Pb	PERMIAN 280 to 230 m.y. UPPER MEDIUM LOWER			gabbro intrusions with alkaline differentiations green or red siltstones, snadostones and
	Pprr		PASSA DOIS	RIO DO RASTO	calcarenite (Endothiodon, Leinzia, Terralopsis, Phyloteca and Calamites)
	Ppt			TEREZINA	siltstones and calcarious rocks (Pinzonella neotropica)
	Ppsal			SERRA ALTA	laminites and shales (Maackia, Tholonotus, Acantholeaia)
				IRATI	mudstones, shales and pyrobituminous shales (Mesosaurus brasiliensis)
	Pg		GUATA	PALERMO	gray siltstones (Cardiocarpus and Dadoxylon) sandstones, siltstones, shales, limestone and
				RIO BONITO	and coal beds (Plicoplasia sp; Sanguinolites brasiliensis, Glossopteris and Gangamopteris)
	Pi		ITARARÉ	RIO DO SUL	gray shales and siltstones, sandstones and dynmictites (Chonetes sp; Langella imbituvensis; Warthia sp; Heteropectem catharina)
				MAFRA CAMPO DO TENENTE	sandstones, siltstones and laminites (Elonichthys gondwanus)
					coarse sandstones, siltstones, dyamictites.
	Dppg	DEVONIAN 345 to 395 m.y.	PARANÁ	PONTA GROSSA	gray shales and siltstones (Australocoelia tourteloti and Metacryphaeus australis)
	Dpf			FURNAS	sandstones and siltstones (Rounaltia furnai)
	Oc	ORDOVICIAN 500 to 435 m.a	CASTRO		siltstones, sandstones, arkose, conglomerates, rhyolite, rhyolitic pyroclastics; few andesites.
	Cg	CAMBRIAN 570 to 500 m.y.		GUARATUBINHA	rhyolites, andesites, siltstones, sandstones and conglomerates.
	Cc			CAMARINHA	siltstones, mudston, conglomerates and arkose.
	Cya		GRANOTOIDS		alkaline granites, syenites and alaskites.
	Cym				gray hornblend and hornblend + biotite granodiorites, monzonites and granites
	Cyg				creamy and reddish gneissose granites, with megacrystals of K feldspars.
	PSygn				gneissose granites of anatexite.
PROTEROZOIC 2500 to 570 m.y.	PSaa	UPPER PROTEROZOIC 1000 to 570 m.y.	AÇUNGUI	ANTINHA SEQUENCE	metaritmites, metasandstones and metalimestones. few metaconglomerates.
	PSai			ITAIACOCA	metasiltstones, metaritmites, dolomitic marbles, dolomites, metasandstone, quartzites and micaschists.
	PSac			CAPIRU	metasiltstones, metamudstones, graphitic phyllites, dolomitic marbles, dolomits, metasandstones.
	PSav			VOTUVERAVA	metasiltstones, metamudstones, metaritmites, slates, metarenites and micaschists. limestones and dolomites.
	PSm				banded migmatites, micaschists and quartzites.
	PIsac	LOWER PROTEROZOIC 2500 to 1800 m.y.	SETUVA	ÁGUA CLARA	calcareous schists, marbles, micaschists, metabasite. manganese rocks.
	PIste			TURVO-CAJATI	garnet-sillimanite schists, actinolite-biotite schist, calc-silicate schists, dolomitic marbles and calc-silicate rocks.
	PIsp			PERAU	calcareous-schists, micaschists, metabasites, amphibolites and qartzites. metavolcanics.
	PIpsm		PRESETUVA COMPLEX		banded migmatites, gneisses on strips, ocelar gneisses, quartzite to magnetite.
	PIpss				amphibolites, metabasites, serpentines and talcschists.
ARCHEAN 2,500 m.y.	Asn		SERRANEGRA COMPLEX		charnockites, granulites, magnesian schists, amphibolites, micaschists and quartzites.

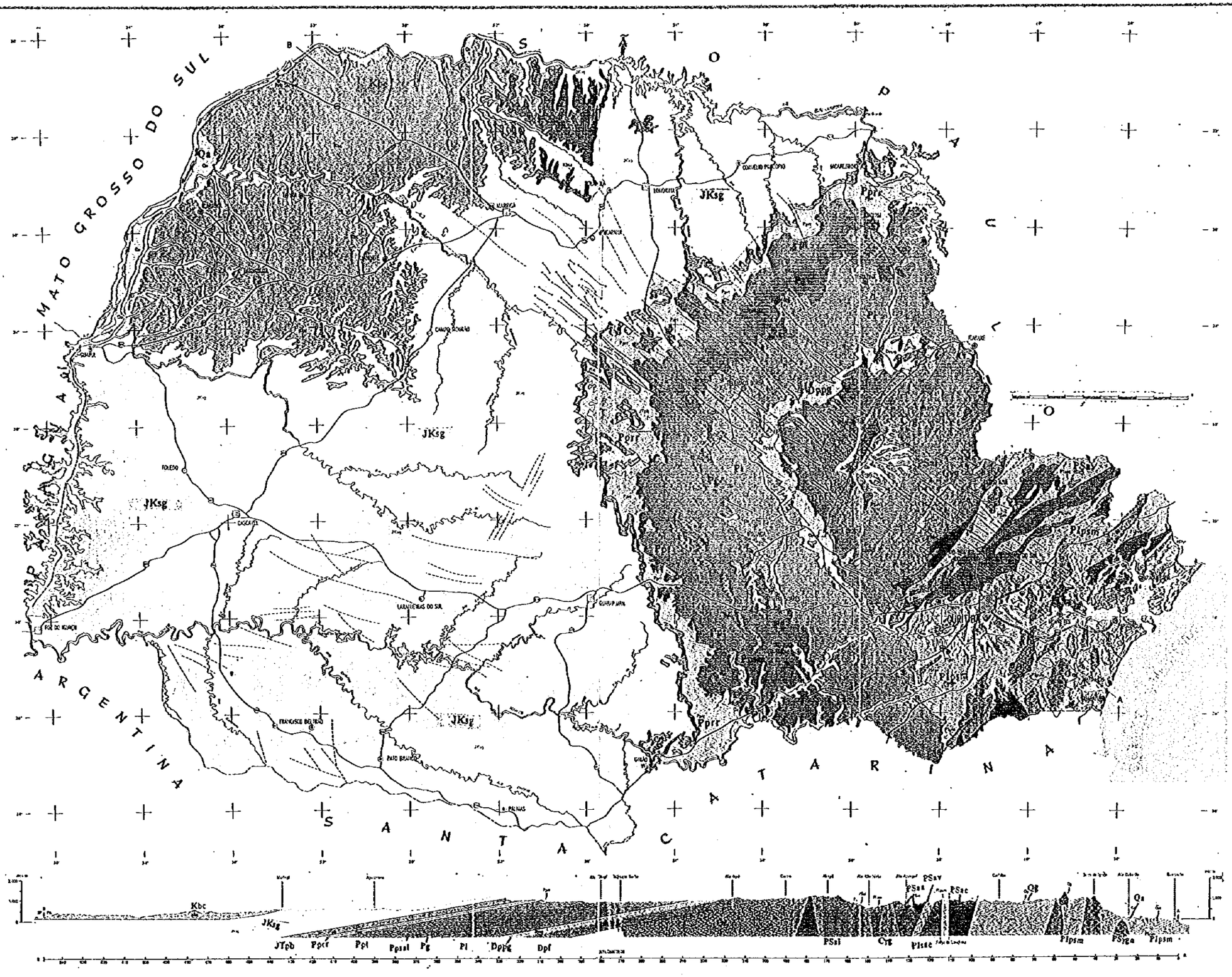

Figure-4.8 Geological Map of Paraná State

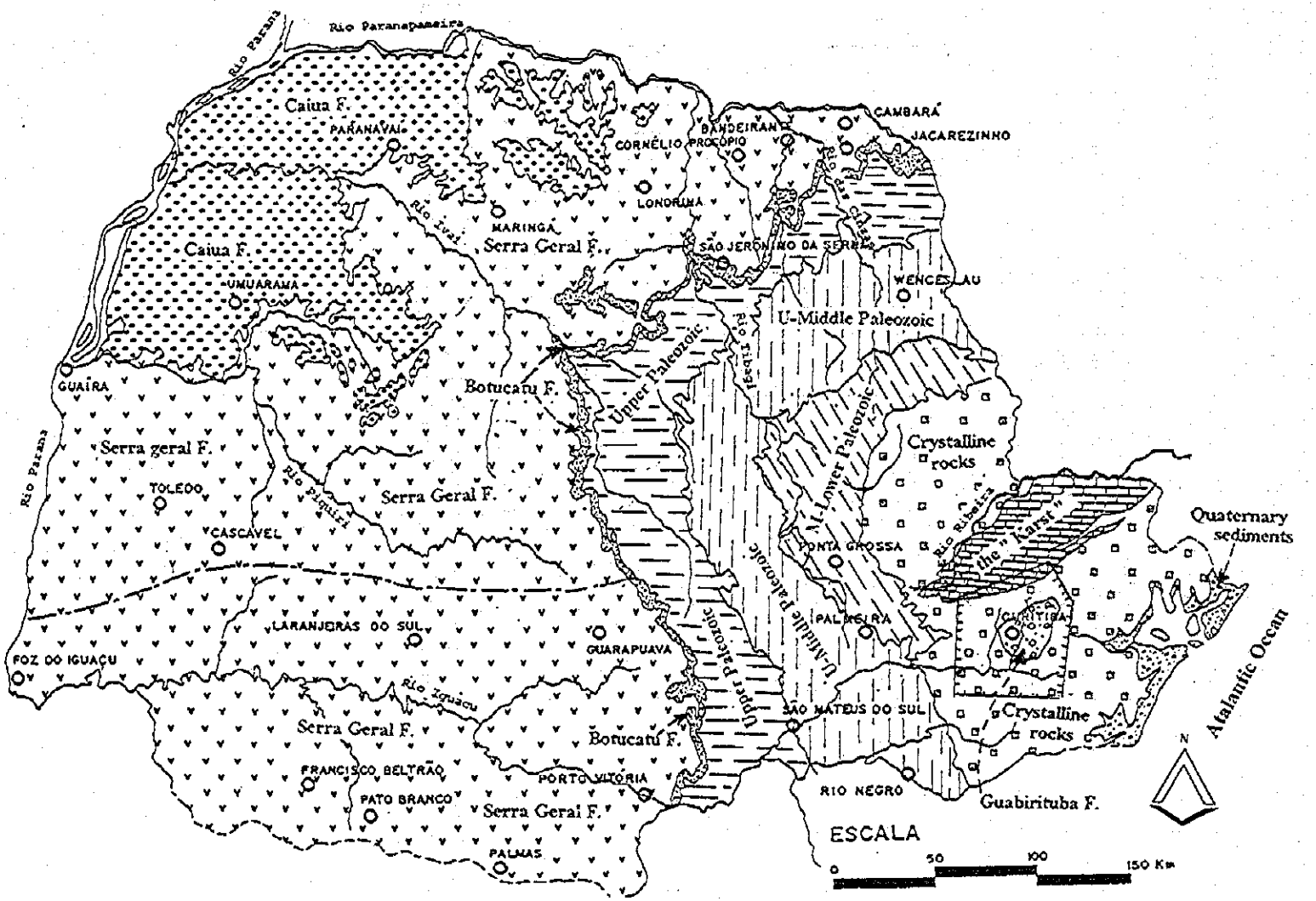

Figure-4.9 Distribution of Principal Aquifers in Paraná State

4.5 Landuse

IAP conducted the satellite imagery analysis in 1990 with the interpretation of Landsat TM data of 1989 and 1990, and reviewed the same data in 1994. Based on the result of the satellite imagery analysis by IAP and GIS computation by SANEPAR, the landuse of each river basin was summarized in Table-4.4 and Figure-4.10. Secondary vegetation in the legend means where the natural bush grows after some use, such as slash and burn farming.

One of the important characteristics of landuse is that in Litoranea river basin more than 70 % of its area is covered by forest and agriculture is limited to 10.2 % of the area. In contrast to Litoranea river basin, agriculture is dominat landuse in other river basins.

Table-4.4 Landuse of 11 River Basins in Paraná

		Total Area (km^2)	Land Use (%)							
			Swamp	Sand Bank	Forest	2nd Veg.	Reforest.	Pasture	Crop Land	Others
State		197882.0	0.1	0.2	9.0	26.0	3.2	23.1	37.6	0.8
River Basin	Cinzas	9290.7	0.0	0.1	2.9	13.3	6.2	22.2	55.1	0.2
	Iguacu	55318.0	0.0	0.0	14.3	27.0	1.7	17.6	37.9	1.5
	Itarare	5197.7	0.0	0.0	1.3	20.0	21.7	17.5	39.4	0.1
	Ivai	35878.9	0.0	0.0	5.0	31.0	1.8	28.8	33.0	0.4
	Litoranea	5766.0	3.8	7.0	68.9	4.6	3.9	5.4	4.8	1.6
	Parana	13156.3	0.0	0.0	7.5	24.3	0.0	25.5	42.1	0.6
	Paranapnema	9797.0	0.0	0.0	4.9	18.5	0.0	32.0	44.5	0.1
	Piquiri	24707.9	0.0	0.0	2.1	20.3	0.3	34.1	42.8	0.4
	Pirapo	5005.9	0.0	0.0	2.5	25.2	0.0	38.0	34.0	0.3
	Ribeira	9129.3	0.0	0.0	5.7	51.8	5.3	11.5	25.4	0.3
	Tibagi	24634.7	0.0	0.0	3.8	27.6	9.4	18.1	40.1	1.0

2nd Veg.: Second Vegetation, Reforest.: Reforestation
Source: SANEPAR GIS computation based on IAP satellite imagery analysis

Although the satellite imagery analysis is based on the data of 1989 and 1990, it was assumed that the current landuse does not vary from one in 1990 throughout the study.

During reviewing the satellite imagery analysis in 1994, an expert of JICA Study Team was dispatched from the middle of June to the beginning of August, 1994, to assist and guide the work.

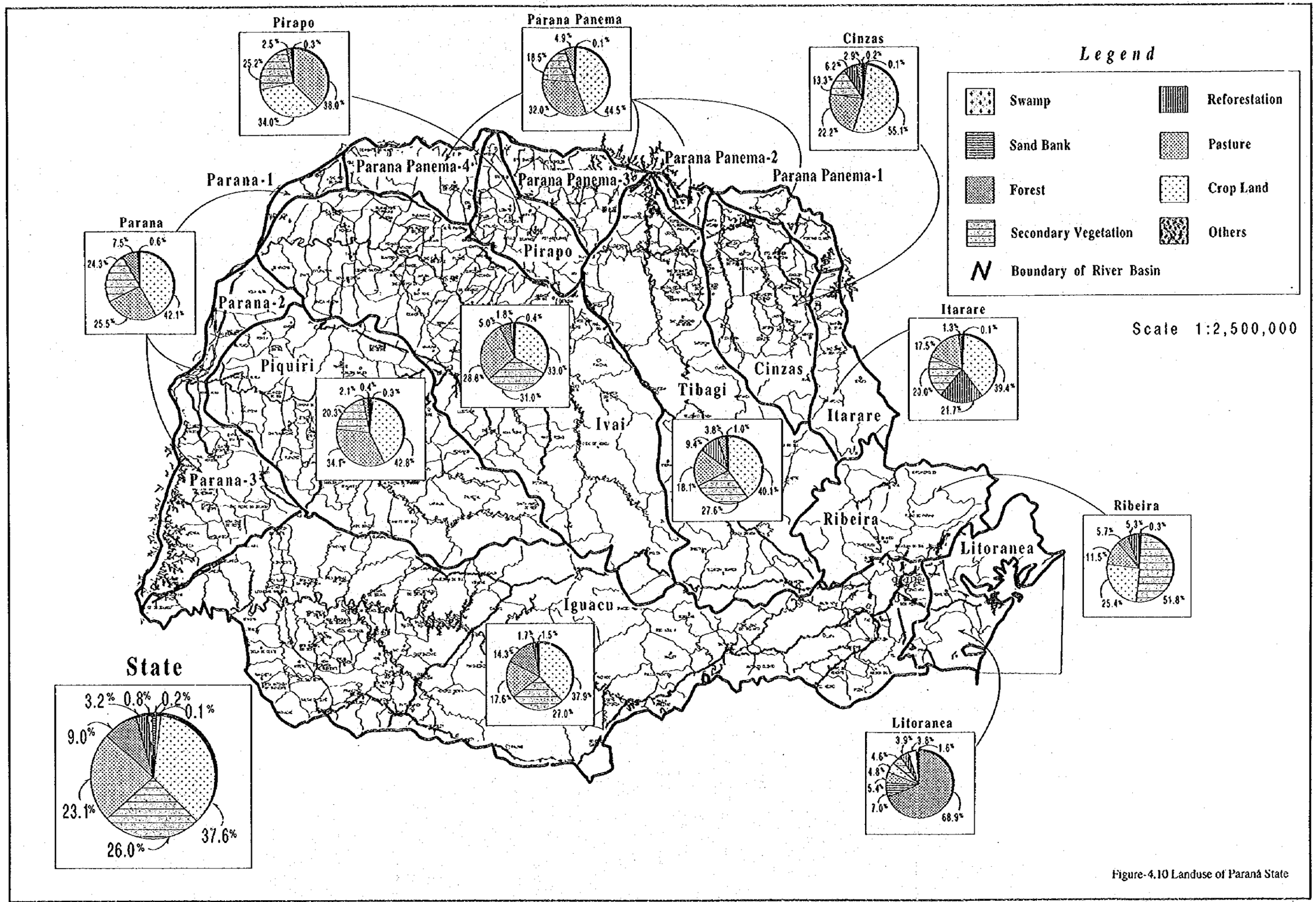

Figure-4.10 Landuse of Paraná State

4.6 Socio-Economy

4.6.1 Administrative Units

Presently, according to the Constitution of the Federative Republic of Brazil and the Constitution of the State of Paraná, the State's central government is divided into two types of organs: the organs of the direct administration and those of the indirect administration.

The State of Paraná was composed of 371 municipalities in 1993. These municipalities have their City Hall and City Council and a certain degree of autonomy and competence to administrate within the limits of each municipality. Each municipality is divided into urban area and rural area in accordance with urban perimeter determined by the municipality. IPARDES made preliminary estimation for these 371 municipalities with their names, estimated population and populational density in 1993 and area of each municipality, formulated into 24 Homogeneous Micro-Regions (mentioned in Section-4.6.4). In terms of population, the largest municipality is Curitiba, with a population of 1,337,890 people and the smallest one is Nova Aliança do Ivaí, with a population of 1,220 people in 1993.

4.6.2 Population of the State of Paraná

According to the census of 1970, 1980 and 1991, the total population of the State of Paraná was of 6,929,868 , 7,629,392 and 8,448,713 , respectively. The annual growth rate of 0.95% in the State during the period of 1970 to 1991 was very low if compared to the annual growth rate of Brazil as a whole (2.12%) and of the South Region of Brazil (1.35%).

Paraná's remarkable characteristics are not only the low population growth rate, but also the concentration of population in urban areas. In other words, the migration of rural population to urban centers. In terms of percentage, the average annual population growth indicates (4.41%) in urban areas and (-3.17%) in rural areas during the same period mentioned above.

Population of Brazil, South Region and Paraná State is shown in Table-4.5.

Table-4.5 Population of Brazil, South Region and Paraná State

Year	Zone	Paraná State		South Region		Brazil	
		Population	(1) %	Population	*(1) %	Population	*(1) %
1970	Urban	2,504,378	36.14	7,434,196	44.56	52,904,744	55.98
	Rural	4,425,490	63.86	9,249,355	55.44	41,603,839	44.02
	Total	6,929,868	100.00	16,683,551	100.00	94,508,583	100.00
1980	Urban	4,472,561	58.62	12,153,971	62.71	82,013,375	67.70
	Rural	3,156,831	41.38	7,226,155	37.29	39,137,198	32.30
	Total	7,629,392	100.00	19,380,126	100.00	121,150,573	100.00
1991	Urban	6,197,953	73.36	16,392,710	74.12	110,875,826	75.47
	Rural	2,250,760	26.64	5,724,316	25.88	36,041,633	24.53
	Total	8,448,713	100.00	22,117,026	100.00	146,917,459	100.00

Source : IBGE and IPARDES

Remark : *(1) Percentage is distribution for urban area and rural area.

*(2) Population of Paraná State in 1991 is final result of the Census of 1991, but the population of South Region (Paraná State, Santa Catarina State and Rio Grande do Sul State) and Brazil is a preliminary result.

4.6.3 Gross Domestic Product (GDP) - PARANÁ

According to information provided by IPARDES, the GDP-PARANÁ has increased in proportion to the GDP-BRAZIL in the recent ten years, and accounts for 5.96% of the GDP-BRAZIL in 1991. The GDP per Capita has increased 3.7%/year and reached almost current US$ 3,000 in 1991 (refer to Table-4.6).

Table-4.6 GDP - Brazil and Paraná, GDP per Capita - Brazil and Paraná / 1980 - 1991

Year	GDP (Million US$)				GDP per Capita (US$)			
	Brazil	% *(1)	Paraná	% *(1)	Brazil	% *(1)	Paraná	% *(1)
1980	228,519		15,288		1,926.43		2,003.93	
1981	239,399	4.76	16,125	5.47	1,979.85	2.77	2,094.16	4.50
1982	255,957	6.92	15,921	(-1.26)	2,076.73	4.89	2,048.77	(-2.19)
1983	256,504	0.21	16,793	5.48	2,041.58	(-1.69)	2,141.14	4.51
1984	280,167	9.23	18,573	10.60	2,187.61	7.15	2,346.23	9.58
1985	310,876	10.96	20,238	8.96	2.381.33	8.87	2,533.23	7.97
1986	342,748	10.25	20,334	0.47	2,575.66	8.16	2,521.89	(-0.45)
1987	366,343	6.88	23,442	15.28	2,700.73	4.86	2,880.31	14.24
1988	378,090	3.21	25,353	8.15	2,734.43	1.25	3,087.31	7.16
1989	405,744	7.31	25,619	1.05	2,878.77	5.28	3,091.10	0.12
1990	403,415	(-0.57)	24,286	(-5.20)	2,807.92	(-2.46)	2,903.29	(-6.08)
1991	423,239	4.91	25,225	3.87	2,890.01	2.92	2,988.04	2.92
Average Annual Growth Rate 1980-1991		5.76		4.66		3.76		3.70

Source : Desempenho Macroeconômico do Paraná - maio/94 (Paraná Macroeconomical Performance May/94)/ IPARDES

Remark : *(1) Percentage of Annual Growth Rate

The estimated share of GDP-PARANÁ by primary, secondary or tertiary sector, approximately 15%, 31% and 54%, respectively, in 1991, indicates that the economic structure of Paraná has reached those of industrialized countries. The information regarding the GDP and GDP by the three sectors is shown in Table-4.7. The annual growth rate during the period of 1980 to 1991 of primary, secondary and tertiary sector was of 2.22%, 5.50% and 5.00%, respectively, while the annual growth in GDP-PARANÁ was of 4.66%.

Table-4.7 GDP - Paraná by Sector/1980 - 1991

Unit: Current Million US$

Year	Primary Sector		Secondary Sector		Tertiary Sector		GDP - Paraná	
	Million US$	%	Million US$	%	Million US$	%	Million US$	%
1980	2,970.4	19.43	4,404.5	28.81	7,913.1	51.76	15,288.0	100.00
1981	3,302.4	20.48	4,831.1	29.96	7,991.5	49.56	16,125.0	100.00
1982	2,712.9	17.05	4,518.4	28.39	8,684.4	54.56	15,921.0	100.00
1983	2,994.2	17.83	4,854.9	28.91	8,943.9	53.26	16,793.0	100.00
1984	3,679.3	19.81	4,992.4	26.88	9,901.3	53.31	18,573.0	100.00
1985	4,205.5	20.78	5,138.4	25.39	10,894.1	53.83	20,238.0	100.00
1986	3,676.4	18.08	5,130.3	25.23	11,527.3	56.69	20,334.0	100.00
1987	3,938.2	16.80	5,811.3	24.79	13,692.5	58.41	23,442.0	100.00
1988	3,615.3	14.26	6,860.6	27.06	14,877.1	58.68	25,353.0	100.00
1989	3,579.0	13.97	6,740.3	26.31	15,299.7	59.72	25,619.0	100.00
1990	3,408.0	14.03	7,316.0	30.12	13,562.0	55.85	24,286.0	100.00
1991	3,784.0	15.00	7,936.0	31.34	13,535.0	53.66	25,225.0	100.00

Source : Desempenho Macroeconômico do Paraná - Maio/94(Paraná Macroeconomical Performance May/94)/ IPARDES
Análise Conjuntural - U13, N.4, P.6, Abril 1991 (Conjecture Analysis - April 1991)/IPARDES, Fundo de Participação dos Municípios - Índices Provisórios/95 (Municipalities' Participation Fund - Preliminary Indexes/95)

Remark: The share by Sector in 1990 and 1991 was estimated by JICA Team
Primary Sector: Agriculture, Livestock etc., Secondary Sector: Industry, Tertiary Sector: Commerce and Services

4.6.4 Regional Unit

For the analysis of the past tendency, and for planning and strategic purposes regarding the socio-economy of the State of Paraná, the State, composed of 371 municipalities, is divided into 24 Homogeneous Micro-Regions (Microrregiões Homogêneas - MRH) composed of municipalities located in the same area and with similar characteristics, regarding production and potential for industrial and/or agricultural development and others. In the socio-economic study of "Strategy for Paraná State", these 24 Homogeneous Micro-Regions are used as regional units. This division is shown in Figure-4.11, with the division of the river basin.

4.6.5 Population per Region

Based on the census of 1970, 1980 and 1991, population and its distribution in urban and rural areas per MRH show two remarkable points regarding the movement of the population, as summarized below:

1) Urban population has increased in all MRH, although total population has decreased in some MRH, for example MRH 284 - N. N. Apucarana, MRH 285 - N.N. Umuarama.

2) Five regions with large population, such as MRH 268 - Curitiba, MRH 273 - C. de Ponta Grossa, MRH 281 - N .N. Londrina, MRH 282 - N. N. Maringá and MRH 288 - Ext. Oeste Paranáense (Cascavel), occupied approximately 58% of the total urban population in 1970, and their share increased to 65% in 1991.

From these facts, it can be considered that the migration process in the Paraná State has two directions, as follows:

1) towards big urban centers, such as Curitiba Metropolitan Area, and local urban centers, for example, Londrina, Maringá, etc.

2) towards small urban centers located adjacent to rural areas.

4.6.6 Gross Regional Domestic Production (GRDP) per MRH

Based on the recent situation of the estimated GRDP of the 24 MRH, from 1980 to 1991, it can be observed that the GRDP of the five big regions (MRH 268/Curitiba, MRH 273/Campos de Ponta Grossa, MRH 281/N.N. Londrina, MRH 282/N.N. Maringá and MRH 288/Extr. Oeste Paranáense) has increased in larger rates than the increase of the urban population. Urban population increased 43% and GRDP increased 84% during the period mentioned above. While the GRDP of the six medium MRH and the other 13 small MRH has increased in a slightly lower rate than the one of urban population, each urban population increased 29% and 36% and each GRDP increased 29% and 30%, respectively, during the same years. This means that the gap of economic activity, namely "wealth", between the five big MRH and the six medium MRH, and between the six medium MRH and the other 13 small MRH, has widened in the last 10 years.

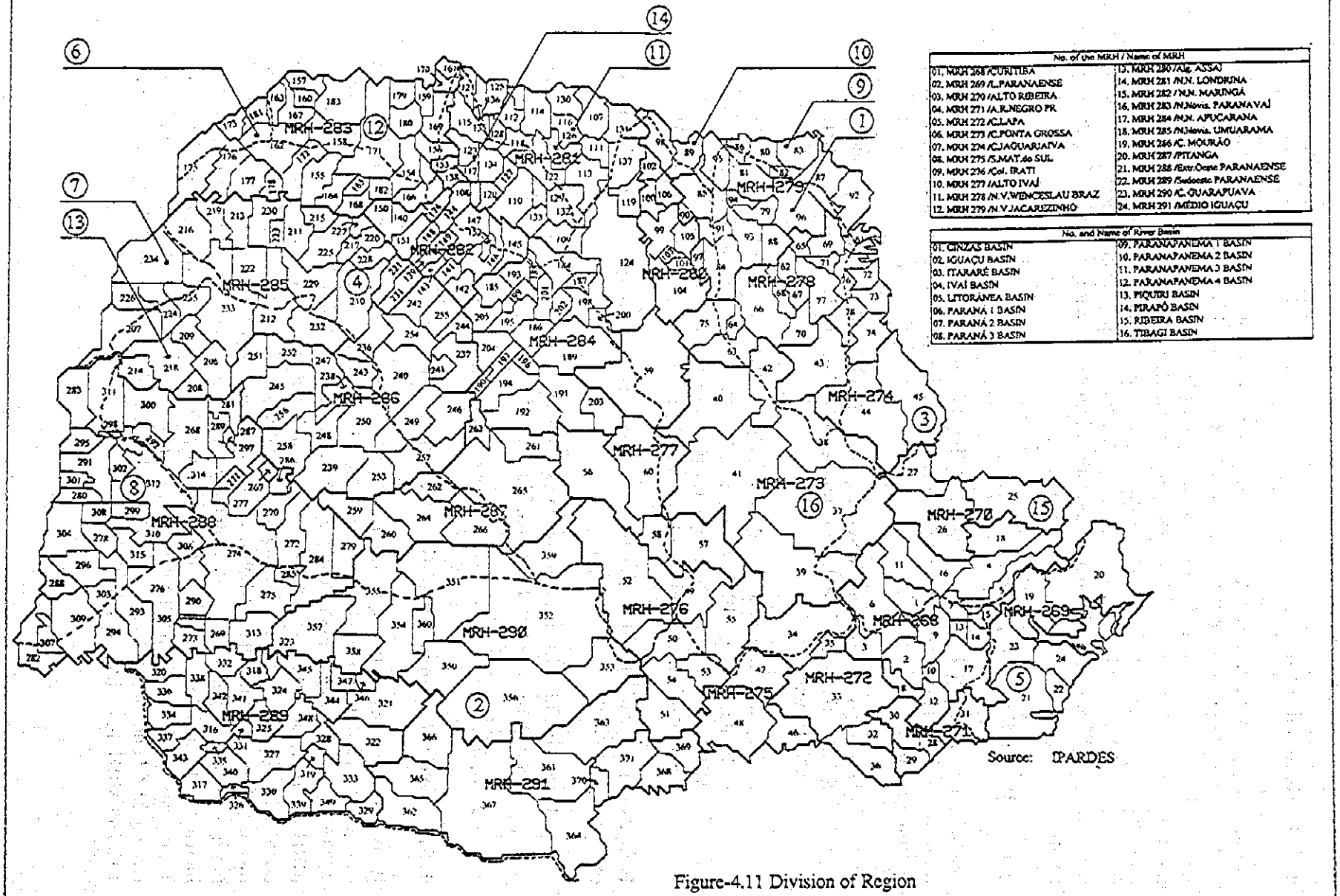

Figure-4.11 Division of Region

4.6.7 Present Socio-Economic Framework

The present socio-economic framework can be estimated by classifying the MRH in four categories, as shown in Table-4.8, and it can be observed that MRH 268/Curitiba occupied the share of about 30% and 37%, and the five big MRH mentioned above had the share of 65% and 73% in terms of population and GRDP of Paraná State in 1991, respectively. However, it should be noted that the GRDP of some of the MRH in 1991 was estimated including the contribution to the Value Added of Hydroelectric Power Stations. Four MRH were considerably influenced by this contribution: MRH 288, MRH 289, MRH 290 and MRH 291.

Table-4.8 Classification of MRH in terms of Urban Population and GRDP per MRH in 1980 and 1991

Category	No./Name of MRH	Urban Population				Gross Regional Domestic Product-GRDP			
		1980		1991		1980		1991	
		Population	%	Population	%	GRDP million US$	%	GRDP million US$	%
1st	1 MRH 268/Curitiba	1,325,275	29.63	1,877,232	30.29	5,047.2	33.01	9,263.3	36.72
	6. MRH 273/C. Ponta Grossa	249,833	5.59	338,225	5.46	968.5	6.34	1,538.2	6.10
	14. MRH 281/N. N. Londrina	527,638	11.80	713,505	11.51	1,578.2	10.32	2,182.4	8.65
	15. MRH 282/N. N. Maringá	247,364	5.53	383,102	6.18	667.3	4.37	1,210.1	4.80
	21. MRH 288/Extr. Oeste Paranaense	484,504	10.83	728,448	11.75	1,703.8	11.14	4,153.6	16.46
2nd	Sub-Total	1,509,339	33.75	2,163,280	34.90	4,917.8	32.17	9,084.3	36.01
	12. MRH 279/N. V. Jacarezinho	169,589	3.79	216,130	3.49	578.4	3.78	677.3	2.69
	17. MRH 284/N. N. Apucarana	169,930	3.80	210,412	3.39	412.3	2.70	511.2	2.03
	18. MRH 285/N.Novis. Umuarama	207,169	4.63	256,354	4.14	563.6	3.69	570.1	2.26
	19. MRH 286/Campo Mourão	169,558	3.79	233,673	3.77	696.7	4.56	841.4	3.34
	22. MRH 289/Sudoeste Paranaense	166,906	3.73	225,666	3.64	562.2	3.68	794.9	3.15
	23. MRH 290/ C. de Guarapuava	138,931	3.11	176,072	2.84	460.5	3.01	824.4	3.27
3rd	Sub-Total	1,022,083	22.85	1,318,307	21.27	3,273.7	21.42	4,219.3	16.73
4th	Other 13 MRH	615,864	13.77	839,134	13.54	2,049.3	13.40	2,658.1	10.54
	Total Paraná State	4,472,561	100.00	6,197,953	100.00	15,288.0	100.00	25,225.0	100.00

Source : Census 1980 and 1991/IBGE and IPARDES - Population, Estatística Econômico Financeira (Finance Economical Statistics) 78/85, 86/87, 88/89 / SEFA - GRDP, and Análise Conjuntural (Conjecture Analysis) UI3, N. 4, P6, Abril 1991/IPARDES-GRDP, Fundo de Participação dos Municípios - Índices Provisórios - 95 (Municipalities' Participation Fund - Preliminary Indexes - 95) / SEFA

Remark : Percentage of GRDP in 1991 was estimated by IPARDES and value of GRDP was estimated by JICA Team

: GRDP in 1991 includes estimated contribution to the Value Added of Hydroelectric Power Stations