JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)

MUNICIPALITY OF LA PAZ
THE REPUBLIC OF BOLIVIA

THE STUDY ON
CONTROL OF WATER CONTAMINATION OF THE RIVERS
IN THE CITY OF LA PAZ

Main Report

MAY 1993

PACIFIC CONSULTANTS INTERNATIONAL

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In this report, project cost is estimated in June 1992 prices at an exchange rate of 1 US$ = Bs. 3.87 (=¥127).

PREFACE

In response to a request from the Government of the Republic of Bolivia, the Government of Japan decided to conduct a master plan and feasibility study on Control of Water Contamination of the Rivers in the City of La Paz and entrusted the study to the Japan International Cooperation Agency (JICA).

JICA sent to Bolivia a study team headed by Dr. Akira Uchida, Pacific Consultants International, three times between February 1992 and March 1993.

The team held discussions with the officials concerned of the Government of Bolivia, 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 Republic of Bolivia for their close cooperation extended to the team.

May 1993

Kensuke Yanagiya
President
Japan International Cooperation Agency

THE STUDY ON CONTROL OF WATER CONTAMINATION OF THE RIVERS IN THE CITY OF LA PAZ

Mr. Kensuke YANAGIYA

President
Japan International Cooperation Agency

LETTER OF TRANSMITTAL

Dear Sir,

We are pleased to submit to you the final report entitled "THE STUDY ON CONTROL OF WATER CONTAMINATION OF THE RIVERS IN THE CITY OF LA PAZ". This report has been prepared by the Study Team in accordance with the contract signed on 28 January 1992, 13 October 1992 and 27 April 1993 between the Japan International Cooperation Agency and Pacific Consultants International.

The report examines the existing conditions concerning river water pollution in La Paz, presents a basic plan for control of water pollution in La Paz and the results of a feasibility study on a priority project for sewerage development selected by the basic plan.

The report consists of the Summary, Main Report, and Supporting Report. The Summary summarizes the results of all studies. The Main Report presents the results of the whole study including background conditions, formulation of the basic plan for control of the river water pollution, selection of the priority project, and the feasibility study on the priority project. The Supporting Report describes in detail the same contents in the Main Report, and includes relevant appendices and a complete list of references. In addition, a Data Book has been prepared and is submitted herewith.

All members of the Study Team wish to express grateful acknowledgment to the personnel of your Agency, Advisory Committee, Ministry of Foreign Affairs, Ministry of Construction, and Embassy of Japan in Bolivia, and also to officials and individuals of the Municipality of La Paz and the Government of Bolivia for their assistance extended to the Study Team. The Study Team sincerely hopes that the results of the study will contribute to the improvement of aquatic environment and the social and economic development in La Paz.

Yours faithfully,

内田 顕

Akira UCHIDA
Team Leader

Abbreviations

ABIS :	Asociación Boliviana de Ingenieria Sanitaria y Ambiental (Bolivian Association of Sanitary and Environmental Engineering)
ANESAPA :	Asociación Nacional de Empresas e Instituciones de Servicio de Agua Potable y Alcantarillado (National Association of Enterprises and Institutions for Water Supply and Sewerage Service)
CORDEPAZ :	Corporación Regional de Desarrollo de La Paz (Regional Development Corporation of La Paz)
DICOMAC :	Dirección de Control y Manejo de Cuencas y Medio Ambiente, HAM-LP (Bureau of Control and Management of Watershed and Environment, HAM-LP)
DINASBA :	Dirección Nacional de Saneamiento Básico, MAU (National Bureau of Basic Sanitation, MAU)
DSU :	Dirección de Saneamiento Urbano, HAM-LP (Bureau of Urban Sanitation, HAM-LP)
GTZ :	Deutsche Gesellschaft für Technische Zusammenarbeit (German Technical Cooperation Agency)
HAM :	Honorable Alcaldía Municipal (Mayor's Office of the Municipality)
HAM-LP :	Honorable Alcaldía Municipal de La Paz (Municipality of La Paz)
IGE-UMSA :	Instituto de Geología Económica, UMSA (Institute of Economic Geology, UMSA)
IIS-UMSA :	Instituto de Ingeniería Sanitaria, UMSA (Institute of Sanitary Engineering, UMSA)
INE :	Instituto Nacional de Estadística (National Institute of Statistics)
MACA :	Ministerio de Asuntos Campesinos y Agropecuarios (Ministry of Peasant and Stockbreeding Affairs)
MAU :	Ministerio de Asuntos Urbanos (Ministry of Urban Affairs)
MPC :	Ministerio de Planeamiento y Coordinación (Ministry of Planning and Coordination)
MPSSP :	Ministerio de Previsión Social y Salud Pública (Ministry of Social Security and Public Health)

SAMAPA :	Servicio Autónomo Municipal de Agua Potable y Alcantarillado (Municipal Corporation of Potable Water and Sewerage in La Paz)
SENAMHI :	Servicio Nacional de Meteorología e Hidrología (National Service for Meteorology and Hydrology)
UMSA :	Universidad Mayor de San Andres (University of San Andres)

The Study on Control of Water Contamination of the Rivers in the City of La Paz

Main Report

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PART (I)

INTRODUCTION

CHAPTER 1
INTRODUCTION

1.1 BACKGROUND OF THE STUDY

The City of La Paz is the largest city in Bolivia and the de facto capital of the country with a population of about 720,000. The city has developed along the Choqueyapu River which constitues the central axis of the urban area.

The Choqueyapu River and some of its tributaries have been suffering serious water pollution as the city developed intensively during the recent decades. Major causes of the river water pollution are domestic and industrial wastewaters that are discharged into the rivers directly or via sewer outlets.

The degree of the pollution is such that the BOD value of the Choqueyapu River in the central zone of the city often exceeds 300 mg/l, a level surpassing that of normal domestic sewage.

This situation has brought about offensive odors and aesthetic deterioration along the rivers in the urban area, and damages to the use of the river water in the downstream farm lands.

In order to improve the degraded quality of the aquatic environment of the city and the adjoining areas, development of a water pollution control plan that can be materialized with a reasonable degree of resources input is required.

With this background, the Study on Control of Water Contamination of the Rivers in the City of La Paz (hereinafter referred to as "the Study") was undertaken by the Japan International Cooperation Agency (JICA) responding to the request made by the Government of Bolivia. The Scope of Work for the Study was signed between JICA and the Bolivian Government on February 27, 1991.

1.2 OBJECTIVES OF THE SUTYE

The objectives of the Study are to prepare a basic plan for control of water pollution of the Choqueyapu River and its tributaries, and to conduct a feasibility study on the first priority project to be selected from the components of the basic plan.

1.3 STUDY AREA

The study area is the catchment area of the Choqueyapu River above the Lipari bridge as shown in Fig. 1.3.1, with a total area of 535 km^2.

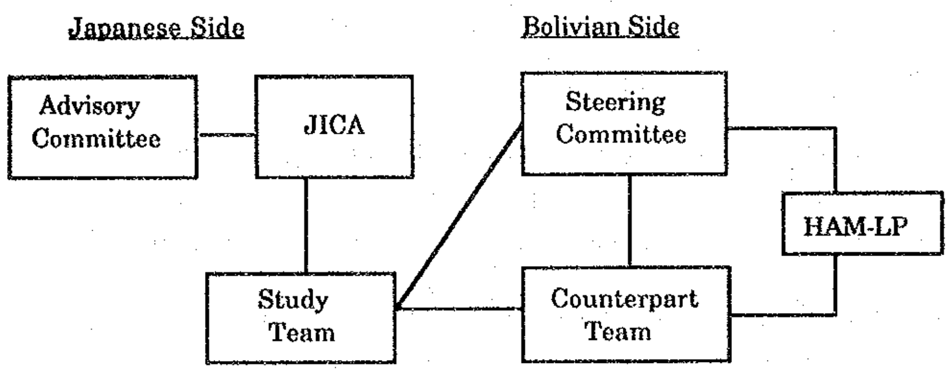
The study area covers most of the administrative area of the City of La Paz and a large area composing upstream catchments of the Choqueyapu, the Orkojahuira, and the Irpavi Rivers.

The Choqueyapu (or the La Paz) River, in fact, changes its name as shown in Fig. 1.3.1. In the present Study, however, the stretches of the Kaluyo, the Choqueyapu, and the La Paz Rivers within the study area will be called by the unified name "the Choqueyapu River".

1.4 STUDY ORGANIZATION

1.4.1 General Organization

The General organization for the Study is as shown below.



Note : JICA: Japan International Cooperation Agency.
HAM-LP: The Municipality of La Paz.

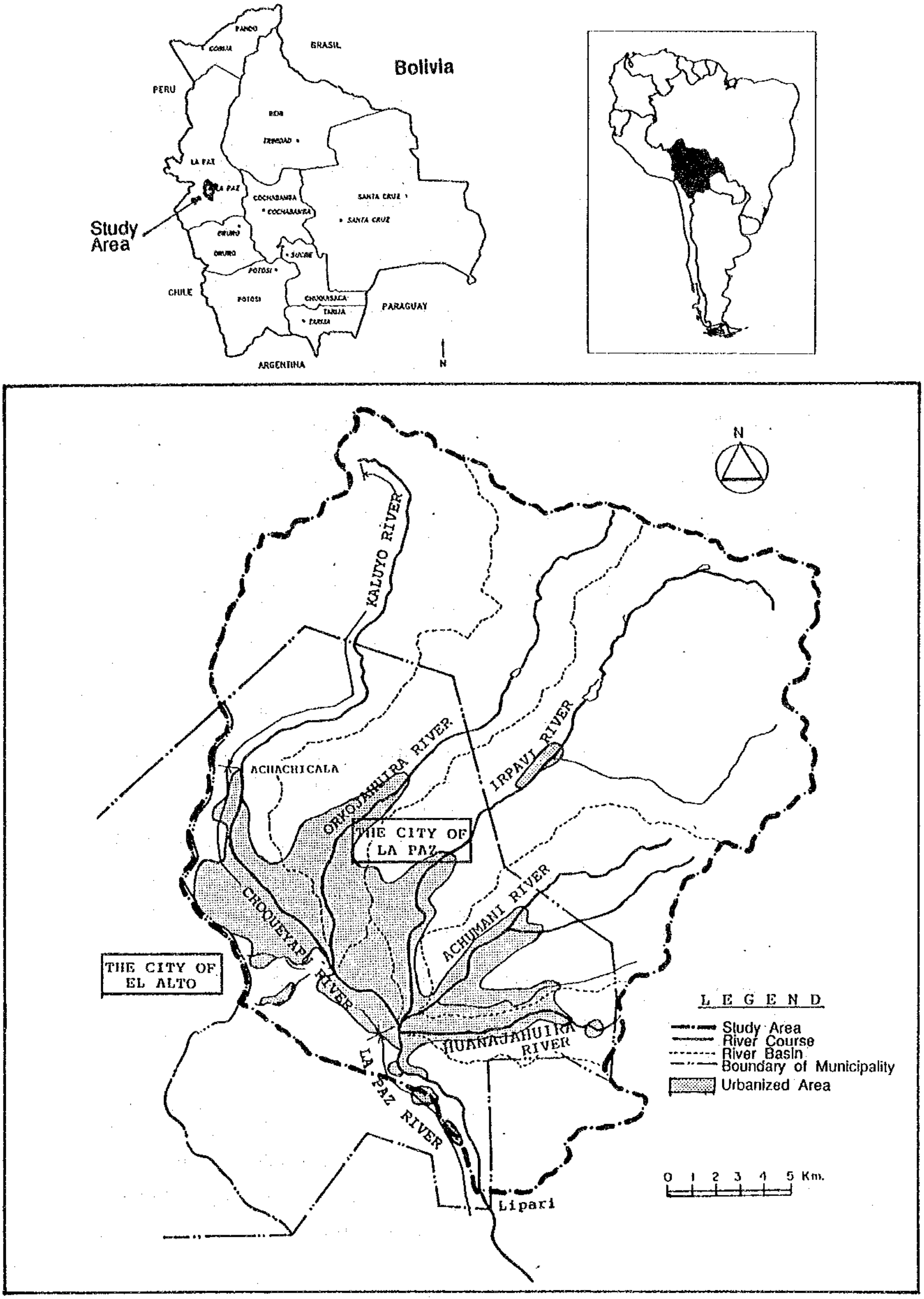


Fig. 1.3.1 Study Area

1.4.2 Japanese Organization

The Japanese Organization consists of the Study Team under the JICA headquarters and the Advisory Committee for the JICA headquarters.

The members of the Study Team are as follows:

Name	Field in Charge
Akira Uchida	Team Leader
Akira Takechi	Sewerage Planning
Akira Mihara	Sewage Treatment Planning
Tsutomu Kurihara	Water Pollution Analysis
Kenichi Takashima	Water Quality Analysis
Toshio Ago	Water Quality Analysis
Mitsugu Futaka	Environment/Sanitation
Dennis R. Harris	Facilities Design / Construction Planning / Cost Estimation
Tatsuo Tashino	Organization / Economic and Financial Analysis

The members of the Advisory Committee are as follows:

Name	Field in Charge	Present Post
Hitoshi Murakami	Leader	Executive Director, Japan Sewage Works Agency
Hironori Suzawa	Sewage Treatment	Assistant Manager, Planning Section, Construction Department, Sewage Bureau, Kitakyushu City

Eijirou Takashima	Water Pollution Control	Senior Researcher, Water Quality Division, Public Works Research Institute, Ministry of Construction
Yasushi Irie	River Environment	Director of Investigation, Chikugo River Works Office, Kyushu Regional Construction Bureau, Ministry of Construction

1.4.3 Bolivian Organization

The Bolivian organization consists of the Counterpart Team, to the JICA Study Team, and the Steering Committee, with the general coordination of the Municipality of La Paz.

The principal members of the Counterpart Team are as follows:

Name	Field in Charge	Position
Joaquín Aguilar A.	Overall Coordination	Director of DICOMAC, HAM-LP
Alberto Yutronic C.	Technical Field	DICOMAC, HAM-LP
Jose Luis Márquez G.	Technical Field	DICOMAC, HAM-LP
Gaston Araoz T.	Development Planning	DICOMAC, HAM-LP
Camille Ponce F.	Economy and Management	DICOMAC, HAM-LP
Javier Marza T.	Main Sewer Interceptor/ River Course Protection	DICOMAC, HAM-LP
Eddy Jaén F.	Sewerage Planning	Director of GIP, SAMAPA
Roger Saravia L.	Sewerage Operation and Maintenance	Director of GOM, SAMAPA
Andres Zegada L.	Sewerage Planning / Field Survey	GOM, SAMAPA

Diego Contreras V.	Sewage Planning / Field Survey	GOM, SAMAPA
Jose A. Diaz B.	Sewage Treatment	Director of IIS, UMSA
Grover Rivera B.	Sewage Treatment / Water Quality Analysis	IIS, UMSA

Note:

DICOMAC	:	Bureau of Control and Management of Watershed and Environment
SAMAPA	:	Municipal Corporation of Potable Water and Sewerage in La Paz
GIP	:	Management of Engineering and Project
GOM	:	Management of Operation and Maintenance
UMSA	:	University of San Andres
IIS	:	Institute of Sanitary Engineering

The members of the Steering Committee are as follows:

Name	Position
Oscar Paz R.	Technical Major Official, HAM-LP
Joaquín Aguilar A.	Director of DICOMAC, HAM-LP
Hernando Poppe A.	Director of DINASBA, MAU
Eddy Jaén F.	Director of GIP, SAMAPA

Note :

MAU	:	Ministry of Urban Affairs
DINASBA	:	National Bureau of Basic Sanitation

1.5 REPORTS

The study reports prepared are as follows:

(1) Main Report (English)

(2) Main Report (Spanish)

(3) Supporting Report (English)

(4) Summary Report (English)

(5) Summary Report (Spanish)

(6) Data Book (English)

The main report presents the summarized results of the whole study. It consists of three Parts: Part (I) Introduction, Part (II) Basic Plan, and Part (III) Feasibility Study. Part (II) consists of Chapter 2 through Chapter 6, and describes existing conditions related to the water pollution, general framework for the basic plan for water pollution control, simulation model analysis of river water quality, formulation of the basic plan, selection of a priority project out of the basic plan, and recommendations. Part (III) consists of Chapter 7 through Chapter 10 and is devoted to the feasibility study on the priority project.

The supporting report describes in detail the same contents presented in the main report. It includes Appendices concerning discussions on various water pollution control measures that were not adopted for the basic plan (appendices A, B and C) and detailed description on the preliminary design of wastewater treatment plant; aerated lagoons for Lipari option (Appendix D). A complete list of references is also included in the supporting report.

PART (II)

BASIC PLAN

CHAPTER 2

EXISTING CONDITIONS

2.1 NATURAL CONDITIONS

2.1.1 Topography and Geology

(1) Topography

The City of La Paz is located in deeply incised valleys near the eastern edge of the Altiplano. The Choqueyapu River originates in the Central Mountains and flows down through the city. The basin of the Choqueyapu River is in the natural depression formed by the past erosion and consists of relatively young valleys. The difference in height between the northern limit (Mt.Charquini) and the southern limit (Lipari district) of the study area is 2,372 meters, and the length of the stretch of the Choqueyapu River is about 44 kilometers. In the northern limit of the basin, there are high mountains belonging to the Central Mountains. In the southern limit of the basin, there are mountains and settlements. Urbanized area of the City of La Paz extends along the main channel of the Choqueyapu River and major tributaries, i.e., the Orkojahuira River, the Irpavi River and the Achumani River, and is located between 3,200 m and 3,900 m above the sea level. The western limit is the edge of the Altiplano which is roughly the same as the administrative limit of the La Paz municipality, and the eastern limit is the Murillo Mountains. The total catchment area of the basin is 535 km^2

(2) Geology

Generally, 30 % of the basin of the Choqueyapu River is composed of the sequence of the Paleozoic with the major area made up of Silurian. The Paleozoic is composed of sandstone mixed with intercalated mica, quartzite and slate of the marine origin. The other 70 % of the basin is constituted of slightly consolidated clay, silt, sand and gravel of the La Paz Formation, and also includes a large quantity of fluvial-glacial deposits distributed in moraines that have formed the surface of the river basin and the terrace of Miraflores and central part of the city.

2.1.2 Meteorology

The climate of Bolivia depends on three wind systems and the high mountains of the Andes. The first wind system is a northeasterly trade wind which blows from the

Atlantic Ocean and carries a warm and humid atmosphere. The second system is a southeasterly trade wind which blows from the Argentine pampas and carries a cold and dry atmosphere. The third system is a southwesterly wind which blows from the Pacific Ocean and carries a cold and dry atmosphere.

The City of La Paz is located in the valleys near the eastern edge of Altiplano where the third wind system is rather dominant, and its climate is therefore rather cool and dry. Its seasons are classified into two, according to the level of rainfall, because monthly variation of the precipitation but not in temperature . The rainy season is generally defined as the period from December to March and the dry season is defined as the period from April to November. The first wind system (northeasterly trade wind) may slightly influence the weather in the rainy season, and the meso-scale system around the Titicaca Lake may also influence the weather.

The annual precipitation is about 510 mm, the average temperature is aprox. 11°C, and the atmospheric pressure is about 660 mb in Central La Paz.

2.1.3 Hydrology

There are some observation stations of river flowrate in the Choqueyapu River basin. Observations are conducted by SENAMHI, HAM and others. The location of the stations are shown in Fig. 2.1.1.

The flow data observed for a decade have been obtained for three stations, and monthly mean flow rates are shown in Table 2.1.1. The largest monthly average flowrate was observed in January: Achachicala(1.8 m^3/sec), Holguin(2.0 m^3/sec), Obrajes(13.8 m^3/sec). The smallest monthly average flowrate was observed in July, August and September: Achachicala(0.4 m^3/sec), Olguin(0.3 m^3/sec), Obrajes(2.3 m^3/sec).

Sub-surface flows seem to contribute the water balance of the river systems. However, according to the existing data, the groundwater outflow from the El Alto zone in the dry season is about 0.5 lit/sec at most.

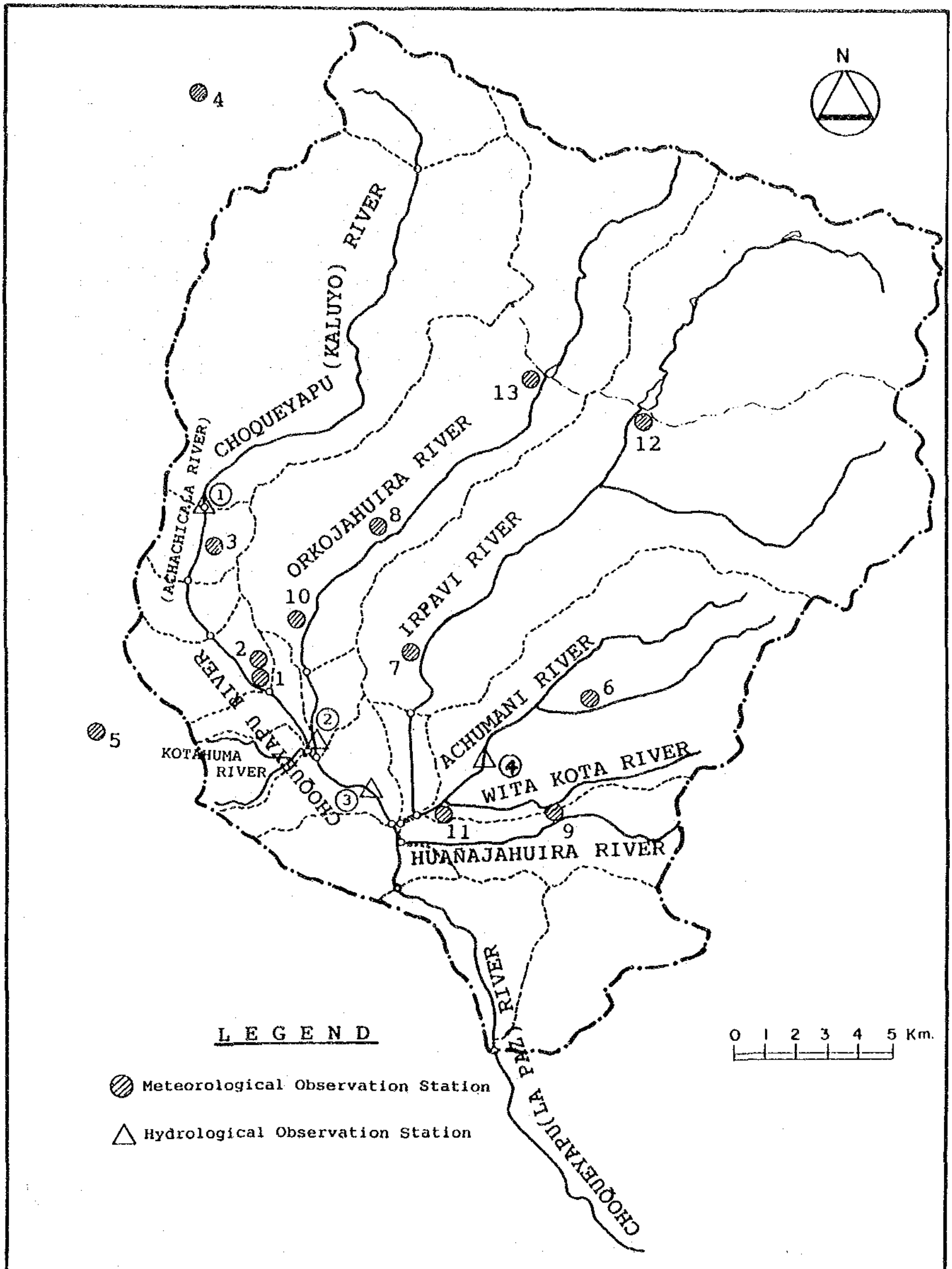


Fig. 2.1.1 Location Map of Meteorological & Hydrological Observation Stations

Table 2.1.1 River Flowrate (Monthly Mean) (m^3/sec)

		Month												
Station	Value	1	2	3	4	5	6	7	8	9	10	11	12	Year
1. ACHACHICALA	Ave.	1.81	1.67	1.92	1.14	0.57	0.42	0.41	0.41	0.47	0.67	0.90	1.14	0.98
(1980.2 -->	Max.	3.06	2.56	4.24	2.31	1.05	0.73	0.77	0.68	0.74	1.06	1.76	3.12	1.52
1992.3)	Min.	0.82	0.80	0.73	0.48	0.21	0.09	0.12	0.15	0.22	0.31	0.43	0.52	0.47
2. HOLGUIN	Ave.	2.02	1.72	0.99	1.00	0.76	0.51	0.40	0.33	0.33	0.53	0.50	0.93	0.79
(1981.10 -->	Max.	3.09	3.84	2.26	3.07	1.77	1.52	0.61	0.51	0.49	0.88	0.68	1.93	1.05
1991.8)	Min.	0.44	0.49	0.57	0.36	0.31	0.12	0.23	0.20	0.18	0.23	0.18	0.27	0.41
3. OBRAJES	Ave.	13.78	11.97	8.35	4.22	3.57	3.32	2.27	2.28	2.36	3.23	3.48	7.49	6.36
(1981.2 -->	Max.	22.70	32.20	17.70	5.85	9.39	9.52	3.36	4.06	3.53	4.46	7.36	16.50	8.31
1991.8)	Min.	5.08	4.24	4.80	2.50	1.52	1.42	1.34	1.24	1.04	1.70	1.66	2.45	4.14

2.2 SOCIAL AND ECONOMIC CONDITIONS

2.2.1 Population

The national census of Bolivia was conducted in 1950, 1976 and 1992. Since the last one was just conducted in June 1992, the available results for the latest census are partial and tentative. Between 1976 and 1992, INE also made a check investigation of the population in 1988. Table 2.2.1 shows historical change in the population of the whole country and the metropolitan area extracted from the results of these censuses and investigations.

Table 2.2.1 Historical Change in the Population of the Country and the Metropolitan Area

		Population (persons)				Annual Average Growth Rate (%)	
		1950	1976	1988	1992	1976-1988	1976-1992
(1)	National Total	3,023,031	4,613,486	6,405,100	-	2.89	-
(2)	Metropolitan Area	321,073	635,283	976,793	1,103,714	3.65	3.51
(3)	City of La Pza	-	538,598	669,399	710,940	1.83	1.75
(4)	City of El Alto	-	96,685	307,394	392,774	10.12	9.16
(2)/(1)	(%)	10.62	13.77	15.25	-		
(3)/(2)	(%)	-	84.78	68.53	64.41		
(4)/(2)	(%)	-	15.22	31.47	35.59		

The annual average population growth in the City of La Paz during the last 16 years shows a moderate rate of about 1.8%, while the rate in the metropolitan area including El Alto is about 3.5%. This indicates that the City of La Paz is approaching the limit of its development potential because only a little land available for new residential development, while available land in El Alto permits large-scale development of residential areas at relatively low cost.

The information on population distribution within the City of La Paz in 1992 was obtained from the Sanitation Unit, La Paz. From this information, the City is divided into 6 districts and each district is divided into several sub-districts. The location of each district and the populations of each sub-district are shown in Fig. 2.2.1. The Figure gives a total population of the city as about 720,000 which is very close to the tentative result of the 1992 census.

The area covered by the above information is almost 100 % contained within the study area. The study area further covers upstream areas of the Districts along each river for which the population in such upstream areas was estimated by an interview survey in each area. The present population in the study area is summarized as follows:

La Paz city	Central zone	616,025
	South zone	103,931
	Total	719,956
Upstream areas		1,550
Grand total for the Study area		721,506

2.2.2 Land Use

A large part of the urbanized area in the City of La Paz is residential particularly in the South zone.

A densely developed commercial area is located at the very center of the Central zone across the covered section of the Choqueyapu River. The commercial center is surrounded by the commercial-residential-mixed area which stretches up the slope towards the City of El Alto.

An industrial area lies a little upstream from the commercial center along the Choqueyapu River. There is another industrial area on the right bank of the Orkojahuira river in the northern part of the Central zone.

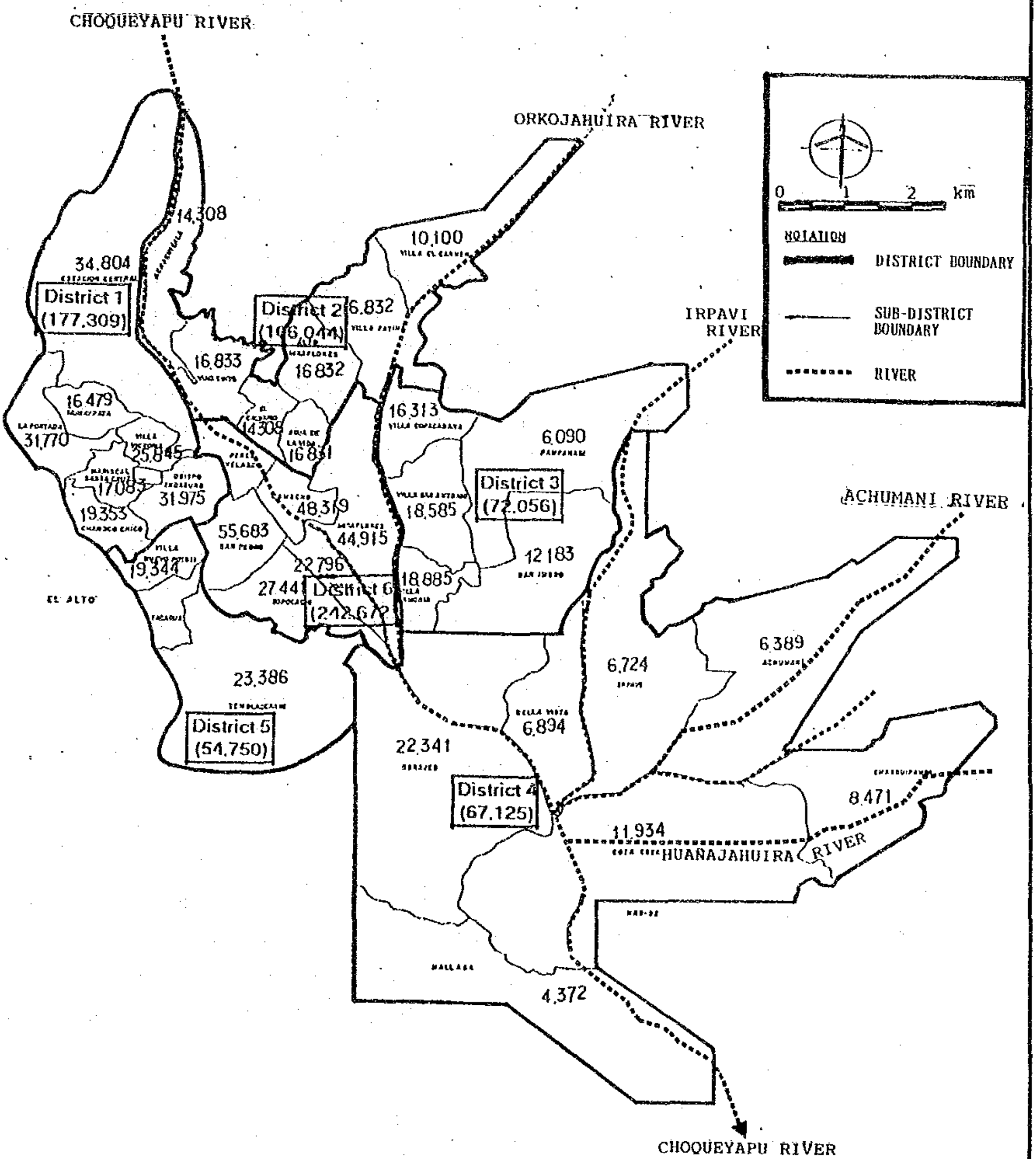
Forests are scarce in the study area, but there are significant afforestations along the border between El Alto and the Central zone, and at outskirt of the South zone on the both sides of the Choqueyapu River.

Relatively large farmlands within the study area are located upstream from the urbanized area along the Choqueyapu and the Irpavi Rivers. Below Lipari, a number of farmlands are scattered along the lower reach of the Choqueyapu River.

2.2.3 Economic Profile of La Paz

(1) GDP and GRDP

The gross domestic product (GDP) of Bolivia recorded continuously negative growth from 1981 to 1986. During this period from 1982 and 1985, Bolivia experienced serious hyper inflation, and in August 1985 its economy almost reached a point of chaos. The new government moved swiftly and decisively, and promulgated a new economic policy. The new policy succeeded quickly in restoring macro economic



(numbers in the figure indicate the population)

Fig. 2.2.1 Population by the Sanitation Districts in La Paz stability. However, the recover of the economy has been slow. GDP grew for the first time in six years in 1987, although at only 2.6%. Thereafter, it grew by 3.0% in 1988, 2.8% in 1989, 2.6% in 1990 and 4.1% in 1991.

In spite of the steady growth of GDP , per capita GDP has not grown as expected even after the recession. GDP per capita in 1986 was US$765 at current price. In 1991, however, it was US$832 or 8.8% increase from 1986.

Figures for gross regional domestic product (GRDP) are available for the La Paz Department, but GRDP data after the recession period are not available. GRDP in the recession period has constantly decreased in proportion to the national GDP. GRDP of La Paz City accounted for less than 30% of the total national GDP. Population in La Paz Department, however, continuously accounted for more than 30% of the country total. Therefore, GRDP per capita was lower than the national average.

(2) Agriculture and Livestock

The agricultural sector, absorbing more than half of the labour force of the country, is one of the most important sectors. However, the GDP share of the sector is only about 20%. This might be because the native people, who accounts for more than half of the total population and most of whom live in high land area called "altiplano", carry on traditional and labour intensive subsistence farms and their economic activities are not completely included in the national accounts.

La Paz Department is located in high land areas, so it is not always suitable for crop cultivation. In spite of that, some crops such as coffee, tea, and cocoa, including cash crops, are produced in the Department. On the other hand, the staple foods in the department, potatoes and wheat, are not produced sufficiently to cover self-consumption. In addition, their production system is primitive and the productivity is very low. Around the study area particularly, fertilizer is sometimes used to cultivate potatoes only, and not be used for other crops. Within the river basin of the study area, no large-scale cultivated areas with significant production of agricultural crops were found by inspction of the basin by the JICA study team.

Instead of crop production, stock farming seems to be an important industry in La Paz Department. The production of Alpaca and Llama accounted for 59% and 34% of the country total for these animals, respectively. In the study area, they are raised in many places. However, there are no large-scale ranches in the area, and all of them are managed in small-scale grazing.

(3) Mining and Manufacturing

In the Bolivian economy, the extraction industries such as crude oil, natural gas, mining and quarrying are quite important for earning foreign money through exportation. It accounted for 15% of GDP in 1991, and is expected to grow as the most significant foreign money earner in the future. However, there are no crude oil and natural gas fields or major mines in La Paz Department. In fact, the extraction production in the department occupies only 9% of the country total for these industries, which is broken down to 0% in the crude oil and natural gas sub-sector and 20% in mining sub-sector, respectively. There are some small-scale mines in the study area. From the environmental point of view, even these small-scale mining sources cause water pollution of rivers in the study area.

Although the manufacturing sector is important in the Bolivian economy as well as the extraction industry, it is biased toward light industry such as food and beverage processing. Therefore, basic capital goods and intermediate materials are provided by imports. In terms of production, a) flour and bread, b) meat products, c) petroleum refinery, d) basic metal products, and e) beverages are the top five manufacturing types in order in the country. In the Department, a) flour and breads, b) beverages, b) meat products, d) sugar and confectionery , and e) textile and garment are the top five manufacturing types.

(4) Tourism

The foreign currency earning through tourism was US$74.4 million in the country in 1989. This amount accounted for approximately 10% of the merchandise exports (US$724 million in FOB) in 1989, so its rate was not small in the Bolivian economy.

Of the national total arrivals, 116.1 thousand or 55% arrived in La Paz City. Thus, La Paz City keeps the most important position in the tourism industry. Moreover, tourists into La Paz City stay somewhat longer and spend more money in the city than the national average. From the economic point of view, tourism in La Paz City should be promoted to increase the tourist arrivals by means of improvements in the infrastructure for tourism.

2.2.4 People's Income and Expenditure

People's income data is part of the essential information needed for appraising the viability of water supply and sanitation projects. Data on income and its distribution are not available in the census. According to the household sample survey conducted by INE in 1990, in which households were divided into four classes of income, the average monthly household income of each quartile was Bs.225, Bs.407, Bs.609 and Bs.1,890 in order, respectively. The average monthly household expenditure was Bs.359, Bs.599, Bs.935 and Bs.1,816, respectively. Only the fourth quartile group's income can cover their expenditures.

The expenses for utilities such as water, gas and electricity were 3.1%, 2.6%, 1.9% and 2.2% of the total expenditure of the respective quartile groups. In monetary terms, they were Bs.10.9, Bs.15.6, Bs.18.1 and Bs.39.8 per month, respectively. If the expenses for water is assumed to be one-third of the above amounts, they would be estimated at Bs.3.6, Bs.5.2, Bs.6.0 and Bs.13.3 per month.

2.2.5 Financial Status

The public entities concerned with water are categorized into four groups as follows.

1) Central government
2) Government enterprise
3) Departmental government
4) Municipal government

The total budgets of these entities were: Bs.4.57 billion in 1986 at current prices; Bs.4.64 billion in 1987; and Bs.6.46 billion in 1988. On the other hand, the GDP in the same period were: Bs.8.92 billion in 1986 at current prices; Bs.10.18 billion in 1987; and Bs.12.30 billion in 1988. Thus, the budgets by these public entities as a percentage of total GDP accounted for: 51% in 1986; 46% in 1987; and 52% in 1988.

After the recession period, the new economic policy has led the public accounts to succeed gradually in restoring stability. Moreover, since foreign assistance is increasing year by year, the public finance is expected to increase public investment for infrastructure development.

The municipal government is the responsible organization regarding water pollution control of the Choqueyapu river. The government used public finance for basic infrastructure between 1986 and 1989 as follows: Bs.2.72 billion in 1986; Bs.11.87 million in 1987; Bs.54.10 million in 1988; and Bs.11.04 million in 1989. The Bureau of Control and Management of Watershed and Environment (DICOMAC), in charge of the Choqueyapu river management, was allocated Bs.2.99 million in 1991 and Bs.42.08 million in 1992.

The Municipal Corporation of Potable Water and Sewerage in La Paz (SAMAPA) operates and maintains water supply and sewerage facilities in La Paz City and El Alto City. According to the profit and loss (P/L) statement of SAMAPA for the latest five years, it seems to be managed soundly from the point of view of financial management. In particular, the income covers completely the expenditure for the latest three years. The major income consists of water supply and sewerage service, which accounted for: Bs.25.41 million or 73% of the total income through water supply and Bs.6.99 million or 20% through sewerage service in 1990; and Bs.31.48 million (73%) and Bs.8.98 (21%), respectively, in 1991. In the same years, its fixed assets holdings were evaluated at Bs.324 million (US$95.4 million equivalent) in 1990 and Bs.377 million (US$100.7 million) in 1991.

2.2.6 Consciousness of the Public Toward River Water Pollution

A questionnaire survey was carried out by HAM-LP during the first site study period to throw light on people's consciousness of river water pollution such as the water color/smell, the contraction of diseases, the expectation of water quality improvement and the conditions of water supply services in the objective zones of Central and South.

(1) Consciousness and Utilization of River Water

955 respondents or 98% of the residents polled were aware that purification of river water around their houses is important. This figure proves that the rivers in the city are contaminated and give an unfavourable impression to citizens. 62% of the respondents answered that the rivers are used for sewerage. Also, 15% of the respondents answered that the rivers are used for dumping garbage, as well.

Although a quarter of respondents think that there are no problems with river conditions, other people are conscious of the following problems: 1) 59%, obnoxious odours from the rivers; 2) 42%, eye-sore in riparian conditions; and 3) 25%, breeding ground of mosquitoes and germs.

(2) Contraction of Diseases

According to the poll, the people were most susceptible to diarrhoeal diseases. Additionally, people in the area were susceptible to the following water-borne diseases in order of the number of patients: 2) skin sepsis and ulcers; 3) typhoid; 4) dysentery; and 5) infective hepatitis. 174 people spent Bs.17,249 in total for medical care during the previous 5 years with Bs.99 per patient on average.

(3) River Water Quality

More than 60% of the respondents desired that the quality of the river water be clear. Also, 17% of them desired to deodorize the contaminated rivers, and14% desired to get rid of the eye-sore in the river courses.

For improvement of river water quality, 58% of the respondents desired the people to stop throwing garbage into rivers. 24% agreed to establish a public sewage treatment plant, although the people realize they will have to bear a fair share of the cost. 13% approved the regulation and control of industrial waste water, although the prices of industrial products may increase a little as a result.

(4) Household Income and Willingness to Pay for Purification of Rivers

Family size of respondents was 5.6 persons on average, of whom 1.7 persons on average were income earners in the family. The total monthly income of household was Bs.763 on average. Likewise, willingness to pay for purification of rivers was Bs.2.8/month on average or 0.37% of the total household income.

2.3 INSTITUTIONAL FRAMEWORK FOR WATER POLLUTION CONTROL

2.3.1 Legal Framework

(1) General Law of Environment

On April 27, 1992, the General Law of Environment was enacted as Law No. 1333. The law provides, for the first time in Bolivia, the objectives and the general policy concerning protection and conservation of the environment and natural resources in harmony with the sustainable development of the country. The law also provides the institutional arrangements including the creation of the National Environment Agency (Secretaría Nacional del Medio Ambiente; SENMA).

It is expected that provision of specific laws, rules, regulations and standards to effect control and abatement of water pollution will now be made by the relevant national and local authorities, based on the requirements of Law No. 1333.

(2) Organization of the Basic Sanitation Sector

On November 1, 1991, the Government promulgated the Supreme Decree No. 22965 concerning reorganization of the basic sanitation sector in Bolivia.

The decree designated the Ministry of Urban Affairs (MAU) as the national authority of the basic sanitation sector in charge of planning administrative reorganization of the sector. The functions of MAU and the national and the local organizations of the sector is described in Section 2.3.3.

2.3.2 Water Quality Standards

Under the provisions of the Article 80 of Law No. 1333 and the Supreme Decree No. 22965, MAU has been authorized to establish and enforce water quality standards for environmental waterbodies and wastewater effluents.

A draft of these standards was prepared during the period of 1983 to 1984 by the regulation commission composed of the members from the Ministries of Urban Affairs (then Urbanization and Housing, MAV), Industry and Commerce, Social Security and Public Health, Mining and Metallurgy, and Peasant and Stockbreeding Affairs, and San Andres University, SAMAPA, and the relevant industrial groups. The content was publicized as the Ministerial Resolution No. 010/85 by MAV. At that time, however, it was regarded that MAV did not have the authority to establish and enforce such regulation; therefore, the regulation has not been implemented until recently.

Having recently given such authority to MAU , the regulation called "Regulation on Discharge of Industrial Wastes into Waterbodies", which was already prepared in 1984, has just become effective.

The regulation gives specific water quality values as the upper limits for the environmental waterbodies and the industrial wastewater effluents. The former is shown in Table 2.3.1 and the latter is shown in Table 2.3.2.

In Table 2.3.1, environmental waterbodies are divided into the five (5) classes according to the usage of the water as follows:

Class Special: Waters designated for public water supply without treatment or with simple disinfection.

Class A: Waters designated for public water supply after sedimentation, filtration and disinfection, for the irrigation of vegetables to be eaten raw, and for bathing.

Class B: Waters designated for public water supply after conventional treatment, i.e., coagulation, flocculation, sedimentation, filtration and disinfection, for preservation of flora and fauna, and for drinking water for animals.

Class C: Waters designated for public water supply after special treatment, for irrigation, scenic harmony, navigation, and for power generation.

Class D: Waters designated for transport and removal of wastes.

The maximum permissible values of water quality of wastewater effluents shown in Table 2.3.2 are applicable not only to industrial wastewaters but also to any wastewater when it causes water pollution.

The regulation also stipulates the details of wastewater discharge conditions, procedures for registering the discharge, reporting of the effluent quality, qualification of wastewater analysis, penalties, and others.

TABLE 2.3.1 Water Quality Standards for Environmental Waterbodies

PARAMETER	SPECIAL CLASS	CLASS A	CLASS B	CLASS C	CLASS D
Physical-biological parameters					
BOD5 (mg/l)	<2	<5	<10	<50	<300
DO	80% sat.	70% sat.	60% sat.	50% sat.	2 mg/l
Floating Solids	Absent	Absent	Absent	None that could be retained on a 2 mm sieve	None that could be retained on a 2 mm sieve
Suspended solids (mg/l)	500	1000	1500	2000	5000
Greases and oils (mg/l)	Absents	0.8	1	10	20
Coliform Bact. (MPN/100ml)	<500 < 50 in 80% of the samples	<5000 <1000 in 80% of the samples	<10000 <2000 in 80% of the samples	<20000 < 5000 in 80% of the samples	100000
PH	6.5 - 9.0	6.0 - 9.5	5.5 - 9.5	5.0 - 10.0	4.5 - 10.0
Color (Color unit)	<20	<50	<100	<200	<1000
Chemical parameters (mg/l)					
As	0.05	0.05	0.05	0.1	1
Ba	1	1	2	5	10
B	0.1	0.1	0.5	2	5
Cd	0.01	0.05	0.2	0.5	1
Cu	1	1.5	2	3	5
Cr 6+	0.05	0.05	0.1	1	5
Hg	0.001	0.005	0.01	0.02	0.05
Pb	0.05	0.1	0.1	0.2	2
Se	0.01	0.01	0.05	0.1	0.5
Cyanide	0.05	0.05	0.1	0.2	1
Phenols	0.001	0.002	0.005	0.01	0.1
Detergents (ABS and LAS)	0.15	0.5	1	2	5
Total Nitrogen NO3	45	50	60	80	100
Zn	5	10	15	20	50
Mn	0.5	1	2	5	10
Fe	0.5	1	2	5	10
Mg	100	200	300	400	500
Ca	200	300	400	500	700
F	0.6 - 1.7	0.6 - 1.7	2	3	5
Chlorides	500	500	700	1000	5000
Sulfates	400	400	600	1000	8000
Herbicides (mg/l)					
Aldrin	0.017	0.017			
Chlordane	0.003	0.003			
D.D.T.	0.042	0.042			
Dieldrin	0.017	0.017			
Endrin	0.001	0.001			
Heptachlorine	0.018	0.018			
Epoxyheptachlorine	0.018	0.018			
Lindane	0.056	0.056			
Metoxychlorine	0.035	0.035			
Organic Phosphate with Carbonates	0.1	0.1			
Foxatene	0.005	0.005			
Total Herbicides	0.1	0.1			

Source : Ref. K3

Note : ABS=Alkyl Benzene sulfonate
LAS=Linear alkylate Sulfonate
MPN=Most Probable Number

TABLE 2.3.2 Maximum Allowable Values for Industrial Wastewater Discharge to Waterbodies

PARAMETER	UNIT	MAXIMUM VALUE
Temperature	°C	40
PH	-	4.5 - 10.0
Sulfate (SO4)	mg/l	8000
Settleable solids	mg/l	1
BOD	mg/l	300
COD	mg/l	500
Floating solids	mg/l	None that could be retained on a 3 mm sieve
Greases and oils	mg/l	20
Coliform Bacteria	MPN/100 ml	100000
Color	color unit	1000
As	mg/l	1
Ba	mg/l	10
B	mg/l	5
Cd	mg/l	1
Cu	mg/l	5
Cr 6+	mg/l	5
Hg	mg/l	0.05
Pb	mg/l	2
Se	mg/l	0.5
Cyanide	mg/l	1
Phenols	mg/l	0.1
Detergents (ABS and LAS)	mg/l	5
Total Nitrogen NO3	mg/l	100
Zn	mg/l	50
Fe	mg/l	10
Mg	mg/l	500
Mn	mg/l	10
Ca	mg/l	700
Chlorides	mg/l	5000

Source : Ref. K3

Note : ABS = Alkyl Benzene Sulfonate
LAS = Linear Alkylate Sulfonate
MPN = Most Probable Number

2.3.3 Organization

The Bolivian Government Decree 22965, proclaimed on November 1, 1991, classified the basic sanitation sectors as follows:

1) The Ministry of Urban Affairs (MAU)
2) The Regional Development Corporations
3) The Municipalities
4) The Administrative Entities
5) The Financial Entities
6) The Advisory Bodies

In addition to these domestic entities, 7) Foreign Organizations contribute to the sanitation sectors as financing agencies.

(1) Ministry of Urban Affairs (MAU)

The MAU is the national government authority in charge of basic sanitation and water services. It attempts to improve and preserve the health and quality of life of the Bolivian people regarding services of potable water, sewerage, excretal elimination, solid waste disposal and environmental pollution control.

Under MAU, the National Bureau of Basic Sanitation (DINASBA) was created to provide integral plans and projects of basic sanitation programs in the country. It also elaborates the other national development plans and programs, along with private, national and international financing organizations, in coordination with the Ministries concerned with these issues, such as the Ministry of Planning and Coordination (MPC) and the Ministry of Social Security and Public Health (MPSSP).

(2) Regional Development Corporations

There are nine Regional Development corporations in the country. They were created to take over the administrative offices of basic sanitation in their respective Department. The Regional Development Corporation of La Paz (CORDEPAZ) is the one in charge of regional development in La Paz Department. Its objective is to ensure an efficient execution of the projects regarding regional development, coordinating with the basic sanitation plans in urban and rural areas and with the provincial government concerned.

(3) Municipalities

The Municipal Government of La Paz (HAM-LP) is a self-supported local government. It functions to coordinate urban development plans with local basic sanitation programs and to cooperate in procurement of financing for the local entities from the national authorities. HAM-LP itself is obliged to keep the Choqueyapu river clean and to prevent it from contamination. The Bureau of Control and Management of Watershed and Environment (DICOMAC) is the responsible section .

(4) Administrative Entities

Administrative entities are categorized as follows: administrative bodies, cooperatives, private entities, associations and NGOs. These entities are self-supporting in administrative and financial matters. They are, of course, responsible for supplying basic sanitation services in their respective assigned areas.

The Municipal Corporation of Potable Water and Sewerage in La Paz (SAMAPA) is a monopolistic enterprise regarding water supply and sewerage systems, covering both the cities of La Paz and El Alto. Thus, the water supply and sewerage systems in the study area are mainly implemented, operated and maintained by SAMAPA.

In addition to SAMAPA, cooperatives, religious groups and neighbouring groups implement water supply and sewerage systems on behalf of SAMAPA in the study area. Because, SAMAPA is administratively so young and financially weak these entities can implement sanitation systems independently. However, they must conform to the technical standards of SAMAPA which will be entrusted with the maintenance and operation of the works after completion.

SAMAPA is the largest entity in terms of investment in these sectors. In recent years, its total investments for water supply and sewerage projects were as follows:

Year	Total Investments (1,000 US$)	Sewerage System (1,000 US$)
1987	1,611	55 (3.4%)
1988	9,261	1,675 (18%)
1989	22,217	3,234 (15%)
1990	18,375	1,838 (10%)
1991	5,552	574 (10%)

(5) Financial Entities

The National Fund for Regional Development (FNDR) is an official agency to support all regional development projects by means of loans. It is destined to cover public health sector projects in main urban areas having more than 2,000 people.

The Social Investment Fund (FIS) is a financial agent of the central government, functioning to finance sanitation projects through grants for poor people in rural and urban areas having less than 2,000 population .

(6) Advisory Bodies

The National Association of Enterprises and Institutions for Water Supply and Sewerage Services (ANESAPA) was created to exchange technical and management information, and to cooperate in establishing unified tariff systems and standard specifications. Nine public corporations in the country including SAMAPA are affiliated with ANESAPA at present.

(7)Foreign Organizations

Regarding water supply and sewerage sectors in La Paz, the following foreign organizations have contributed to related projects: World Bank, Interamerican Development Bank (BID), Germany (GTZ and KfW), Japan (JICA), United States (USAID) and CARE (NGO of the US). As for sewerage systems, World Bank, BID and Germany contributed between 1987 and 1991.

2.4 WATER QUALITY AND WATER USE

2.4.1 Water Quality Conditions

(1) General

The water quality survey was carried out in this study to understand the overall water quality conditions in the study area. Fig. 2.4.1 shows the locations of river water survey points

The water quality of the rivers in the urbanized area has been confirmed by means of field survey to be similar to that of influents to wastewater treatment plants rather than that of river water. The observed values of BOD of the rivers in the area were in a range between 100 and 300 mg/l as shown in Table 2.4.1.

(2) The Choqueyapu River

As illustrated in Fig. 2.4.2, the BOD concentration of the Choqueyapu River sharply increases at the point of the entrance to the urbanized area (No. R3) particularly when the water is taken into the Achachicala water treatment plant. Even in normal periods, the BOD values are in a range between 100 and 180 mg/l above the confluence with the Irpavi River (No. R9). It is evident that the river water in most parts of the urbanized area is badly polluted. However, since the Choqueyapu River in the Central Zone of the City is mostly covered and remaining open sections are deeply incised, people have little chance to recognize the actual quality of the river water. Also, deterioration of aesthetic condition is less than that expected from the actual water quality, because vigorous aeration of river water due to steep flow reduces the generation of septic conditions. Still, many residents in the downstream zones suffer from obnoxious odors of the river. Moreover, such deteriorated water quality conditions are said to be causing damage to irrigational uses of the Choqueyapu River. The river water is utilized as irrigation water for farm lands located downstream from the Lipari bridge. Hesitation against eating vegetables irrigated by the polluted river water is very common among the citizens of La Paz, and farmers in the area have suffered from the unpopularity of their products in the market.

(3) Tributaries

Conditions of the rivers other than the Choqueyapu River are almost the same as the Choqueyapu River. As shown in Table 2.4.1, the BOD concentration values at the most downstream points of these rivers ranged from 100 to 200 mg/l. These tributaries are not only major pollutant sources to the Choqueyapu River, but are also causing unpleasant living conditions to the residents along them.

2.4.2 Water Use

(1) General

The rivers in the urban area are mostly used for drainage of stormwater and wastewater, and many of them are covered especially in the Central zone. Beneficial uses such as water supply, irrigation, fishery, recreation and aesthetics are limited except for the rural area.

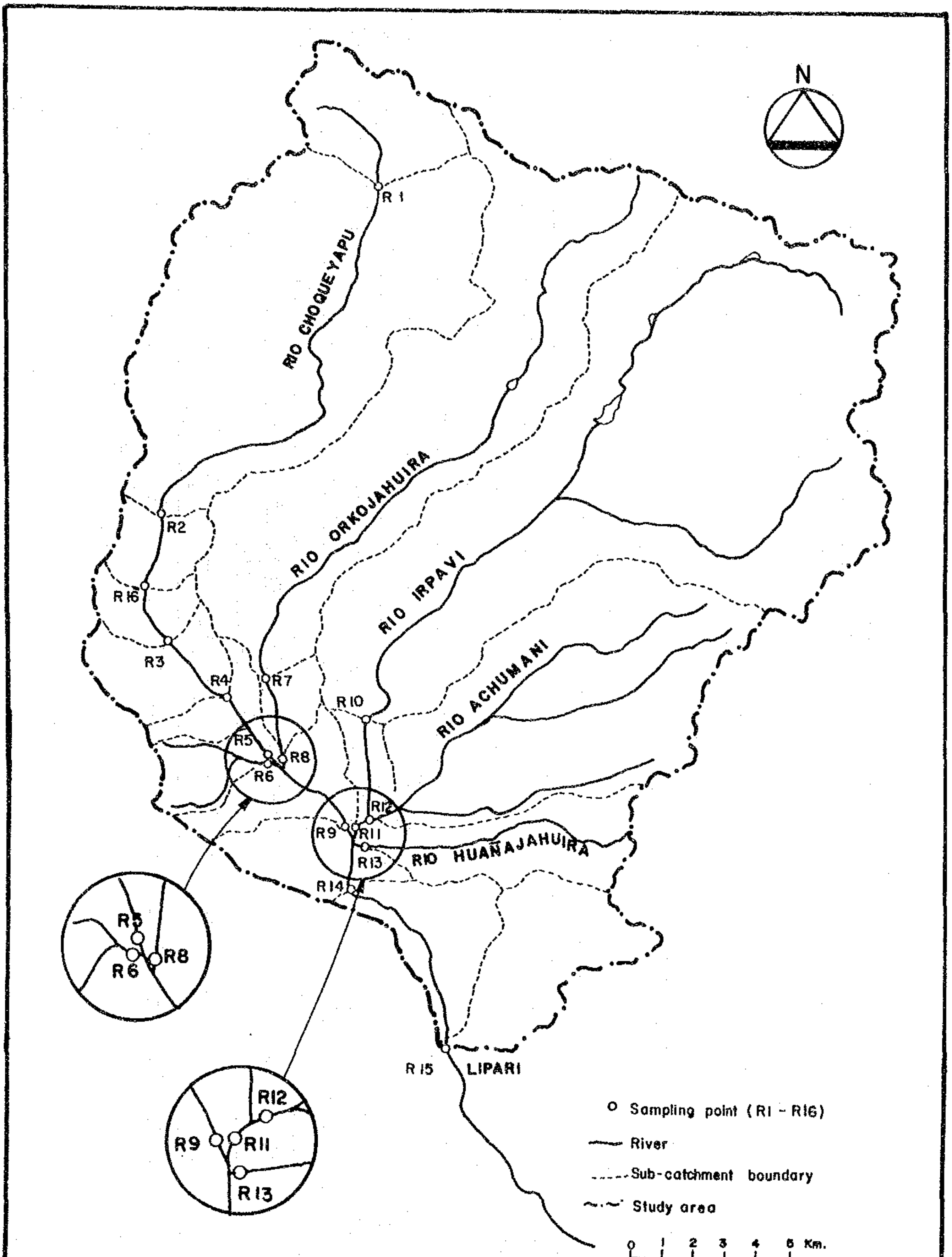
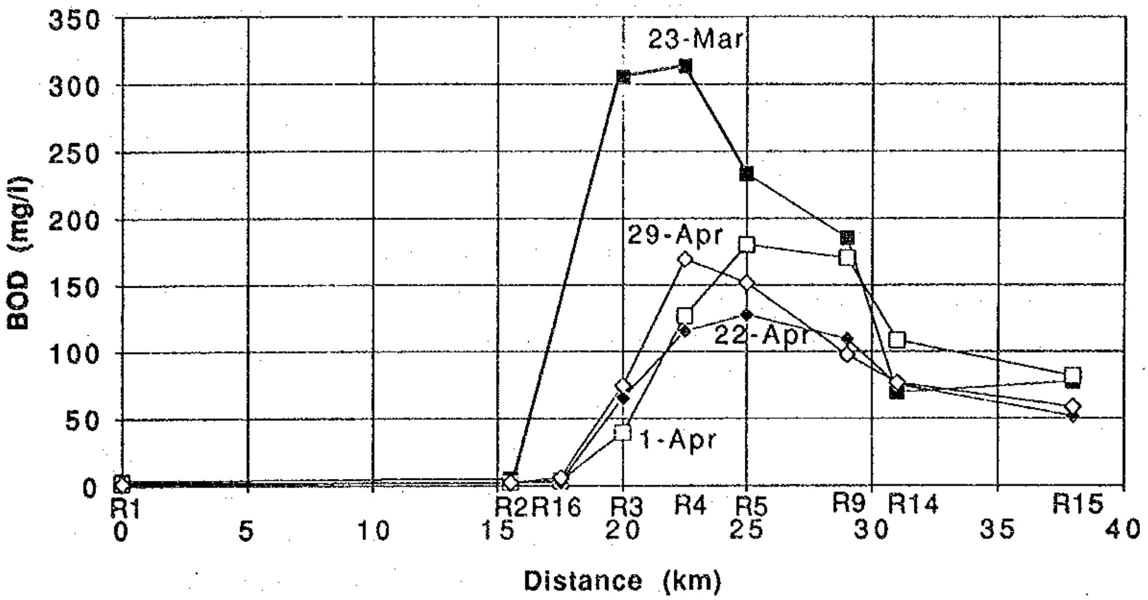


Fig. 2.4.1 Sampling Points for River Water Quality Survey

TABLE 2.4.1 **Results of Water Quality Analysis for the Choqueyapu river and its Main Tributaries**

		Choqueyapu River									Tributaries (Downstream)					Tributaries	
		R1	R2	R16	R3	R4	R5	R9	R14	R15	R6	R8	R11	R12	R13	R7	R10
		Alto Acha chicala	Achachicala	Achachicala Plant	Chalapampa	Av. del Ejercito	Ork. confluence	Irpavi confluence	Aranjuez	Lipari	Kotaurna	Orkojahuira	Irpavi	Achumani	Huañajahuira	Orkojahuira	Irpavi
Items	Date	0 km	15.5 km	17.5 km	20 km	22.5 km	25 km	29 km	31 km	38 km							
BOD	23-Mar	3.3	5.1	-	305	313	233	185	69	77	101	89	28	26	101	70	7.5
(mg/l)	1-Apr	1.5	2.1	3.4	39	126	180	170	108	81	97	105	15.5	152	138	77	2.4
	22-Apr	1.3	2.2	2.4	65	115	127	109	75	51	57	59	3.9	51	101	24	2.1
	29-Apr	1	2.1	5.7	74	169	151	97	76	58	57	55	6.5	52	109	133	1.8
SS	23-Mar	3.3	349	-	358	273	305	654	400	465	3030	756	352	160	298	850	118
(mg/l)	1-Apr	1.8	347	592	472	276	334	825	875	1810	6570	1500	231	1640	584	1350	180
	22-Apr	7.2	416	228	452	282	345	1100	880	740	3170	1640	307	620	880	1530	201
	29-Apr	1.8	347	235	415	354	268	774	791	655	2440	1590	576	474	394	1270	155
DO	23-Mar	5.7	6.3	-	5.9	6.4	3.6	3.9	4.0	4.7	4.4	4.4	4.8	4.6	3.4	4.1	5.0
(mg/l)	1-Apr	3.7	4.0	4.3	4.0	3.7	3.7	4.1	4.2	4.3	4.2	4.3	4.3	4.1	2.9	4.0	4.5
	22-Apr	2.3	2.7	2.9	2.8	2.4	3.3	3.6	3.2	3.7	3.3	3.7	4.3	3.2	2.6	3.4	4.0
	29-Apr	3.7	4.1	4.1	4.6	3.8	2.6	3.1	3.0	2.9	2.9	3.5	3.4	2.9	2.3	3.2	3.5
Coliform	23-Mar	1.0E+02	1.0E+02	-	2.0E+05	1.8E+05	8.6E+05	1.6E+07	7.3E+05	6.0E+05	6.5E+05	3.6E+06	1.4E+05	2.5E+05	9.6E+06	1.1E+05	1.7E+03
(cells/	1-Apr	2.0E+02	1.9E+03	4.0E+04	3.0E+05	1.0E+06	2.4E+06	2.4E+06	7.4E+05	5.5E+06	2.1E+06	1.5E+06	2.2E+05	1.0E+06	3.6E+06	1.2E+06	2.8E+03
100ml)	22-Apr	1.3E+03	1.3E+03	6.6E+04	1.2E+05	2.9E+06	1.1E+06	3.0E+06	1.5E+06	8.6E+06	3.6E+06	2.2E+06	4.0E+05	2.0E+06	5.3E+06	1.7E+06	4.2E+03
	29-Apr	0.0E+00	1.2E+03	1.5E+05	7.5E+05	2.4E+06	3.5E+06	4.4E+06	5.2E+06	5.2E+06	2.8E+06	1.6E+07	4.2E+05	4.3E+06	5.1E+06	1.8E+06	6.4E+03
Flow rate	23-Mar	0.33	0.60	-	0.12	0.57	1.11	1.40	3.32	2.68	0.16	0.48	1.05	0.17	0.03	0.36	0.85
(m3/sec)	1-Apr	0.22	0.53	0.49	0.67	0.99	1.58	2.05	2.55	3.03	0.16	0.35	0.76	0.09	0.05	0.24	0.67
	22-Apr	0.11	0.31	0.30	0.62	1.03	1.31	1.55	2.48	2.82	0.20	0.28	0.60	0.05	0.02	0.27	0.82
	29-Apr	0.08	0.17	0.24	0.31	0.74	1.34	1.58	2.62	3.00	0.19	0.37	0.56	0.07	0.03	0.23	0.54

(Table 2.4.1-4/26/1993)



Note : During the survey of March 23, the Achachicala water treatment plan was taking river water from just below the point R16. This caused the ruction of the flow rate and therefore the high BOD concentration in the downstream, since there were factory wastewater discharges between R16 and R3 as usual.

Fig. 2.4.2 BOD Changes Along The Choqueyapu River

(2) Water Supply Use

Part of the water supply in La Paz city is drawn from Hampaturi reservoir, which is located in the upstream of the Hampaturi/Irpavi river, and from Incachaca reservoir in the upstream of the Orkojahuira river. However, most of water supply sources are located outside of the study area.

(3) Industrial Water Use

Some of the factories draw water from wells located at their sites . However, most of the factories depend on the piped water system, and the overall volume of groundwater for industrial use is not considered to be large.

(4) Irrigation

The agricultural land use and production in the study area are small are small in scale. Comparatively large farmlands are developed along the lower reaches of the Choqueyapu river, outside the study area, and they are irrigated by the water of Choqueyapu river.

2.4.3 Water Supply

(1) Water Supply System

The overall water supply system of SAMAPA consists of four systems at present, three of which depend on surface water as the water source: Achachicala, El Alto and Pampahasi. The fourth one is the groundwater supply system of El Alto.

The water supply in the study area is covered by the whole of the Achachicala and the Pampahasi systems and a part of the El Alto surface water system. In the other areas where distribution pipes are not installed, the drinking water is provided by private wells, springs and water tank lorries.

(2) Water Consumption

The annual volumes of piped water consumption in 1991, by 5 categories of water usage, are as follows:

Water Use	Water Consumption (m^3/year)	Annual Average (m^3/day)	Percentage (%)
Domestic	18,465,102	50,589	61.5
Commercial	4,387,534	12,048	14.6
Industrial	2,106,988	5,773	7.0
Governmental	4,411,057	12,085	14.7
Public tap	661,680	1,813	2.2
Total	30,032,361	82,308	100.0

2.4.4 Water-borne Diseases

Among classical water-borne diseases, the two main diseases having a high mortality, if untreated, are typhoid and cholera. The La Paz sanitation unit of MPSSP reported the following seven diseases which infected people in La Paz Department during 1988 - 1990: gastroenteritis, salmonella, amebiasis, hepatitis, typhoid, dysentery and malaria.

In La Paz , cholera had not appeared until it occurred in Rio Abajo, the downstream of the Choqueyapu River, in August 1991, and spread over the Department. Earlier, in February 1991, cholera occurred in the Republic of Peru. Since then the Bolivian government prepared for an emergency. After a half year later, the first patient came out in Rio Abajo. Table 2.4.2 shows the infection number accumulated from August to December in 1991 within the territory of the La Paz sanitation unit. During the period, 124 patients were confirmed to have cholera and 43 were enumerated as patients suspicious of having cholera. The cholera panic has quieted down, but the sanitation unit is still taking special precautions against cholera.

Table 2.4.2 Number of Cholera Cases in La Paz Sanitation Unit: August 25 - December 28, 1991

(Unit: Persons)

Item	Total			Urban		Rural	
	Total	Conf.	Prob.	Conf.	Prob.	Conf.	Prob.
1. Age Group							
0 - 4	6	5	1	1	1	4	0
5 - 14	12	12	0	8	0	4	0
15 - 29	32	23	9	10	1	13	8
30 - 44	36	25	11	14	3	11	8
45 - 59	39	28	11	18	2	10	9
60 - 74	35	25	10	13	3	12	7
75 and over	7	6	1	3	0	3	1
2. Total	167	124	43	67	10	57	33

Source: Sanitation Unit of La Paz
Notes: Conf. means the number of infected cases.
"Prob." means the number of suspicious but not confirmed cases.
"Urban" does not include El Alto City.

A report of the WHO, prepared in November 1991, attributed the introduction of cholera into the Rio Abajo communities to pollution of the Choqueyapu River because the residents consumed the river water for drinking and crop cultivation. At the initial dissemination in La Paz city, the consumption of fresh vegetables coming from Rio Abajo was suspected of causing cholera infection. However, the analysis of causes indicated that the transmission can be attributed to consumption of other street foods and drinks of dubious quality, and not only the vegetables. The report recommended to look for alternatives in Rio Abajo, such as (a) to find other non-contaminated water sources like ground-water; (b) to look for other type of products not offering sanitary risk; and (c) as the final alternative, to construct treatment facilities which guarantee the necessary water quantity and quality for the irrigation.

2.5 WATER POLLUTION SOURCES

2.5.1 General

The following activities within the urbanized area of the city are recognized as the major water pollution sources :

- Domestic wastewater
- Public and commercial wastewater
- Industrial wastewater

Agricultural, stock-farming and mining activities are scattered in the upstream areas of the rivers, and their influence on the water quality of the rivers in the City of La Paz is considered to be small.

In this section, characteristics of those major pollution sources, as well as the sewage collection system and the solid waste disposal system are discussed hereinafter.

2.5.2 Sewage Collection System

Major parts of the City of La Paz are covered by a sewage collection system provided by SAMAPA and private developers.

The system covers 32 % of the total city area. The estimated population covered by the system is about 400,000, about 56 % of the total population.

The system consists of sewage collection pipelines and stormwater collection pipe lines, i.e., the separated system. Both lines discharge directly to the rivers.

There are many malconnections of sewage pipes to stormwater lines and vice versa. According to the SAMAPA's estimation, the number of the malconnections account for 40 % of the total connections.

2.5.3 Domestic Wastewater

The features concerning domestic wastewater in the City of La Paz can be discussed from the view points of the water supply system and the wastewater disposal system. The former affects the wastewater generation and the latter affects the amount of wastewater reaching the river system.

(1) Water Supply System

There are three types of the water supply in the City of La Paz as follows:

- The area where water is supplied by SAMAPA through the house connections. (Zone 1 and Zone 2)
- The area where water is supplied by SAMAPA through the public hydrants. (Zone 3)
- The area where water is not supplied by SAMAPA and people use water from private wells or water venders. (Zone 4)

The estimated population in each area is shown in Table 2.4.1.

(2) Wastewater Disposal System

In some areas in the City of La Paz, the wastewater is collected by the sewage collection system and discharged to the rivers. In the areas located near the rivers, the wastewater is discharged to the river not through the public sewage collection system, but through privately installed pipes or open channels. In other areas, there are no wastewater disposal facilities and some of the wastewater may reach the rivers but mostly penetrates into the ground.

The population in the above types of area as estimated by SAMAPA is shown in Table 2.5.1

Table 2.5.1 Area and Population by Type of Wastewater Disposal

Type of Sewage Disposal	Sewage Collection System	Discharge to Rivers	No Facilities	Total
Area (ha)	1,800	650	3,150	5,600
(%)	(32.1)	(11.6)	(56.3)	(100.0)
Population	403,000	123,200	193,500	719,700
(%)	(56.0)	(17.1)	(26.9)	(100.0)

2.5.4 Industrial Wastewater

There were a total of 769 factories having 4 or more employees in the City of La Paz in 1989. Of the total number, the factories of the food and the textile industries accounts for almost 50. The number of the small scale factories with less than 15 employees accounts for 75% of the total.

These facts suggest difficulty in implementation of wastewater treatment because the wastewaters from the food and the textile industries have a high content of organic substances, and small businesses can not often afford investment in wastewater treatment.

The quantity of wastewater generation can be estimated from the amount of water consumption. The total amount of SAMAPA supplied water to all the factories was about 130,000 cubic meters per month in 1992. One beer factory uses about 55 thousand m^3/month or 43 % of the total for all the factories. Because this factory is said to use ground water from their wells , the quantity of the wastewater from this factory probably exceeds 50 % of the total for all the factories.

The total water consumption by food and the textile industries, including the beer factory, accounts for almost 75 % of the industrial total. The total water consumption by the factories consuming more than 3,000 m^3/month accounts for 70 % of the total, while the number of such factories is only 20 % of the total. This indicates that the effects of the implementation of the industrial wastewater control would be significant even if the application of the control is limited to the factories having a large scale of the wastewater discharge.

2.5.5 Other Wastewaters

Table 2.5.2 shows the water consumption rates by the large scale consumers other than factories. The consumption by the public facilities is large at about 130,000 m3/month, being equal to the industrial consumption.

Table 2.5.2 Monthly Water Consumption by Large Scale Consumers Other Than Factories

	Scale of Mothly Consumption (cum/month)							
	750 - 1499		1500 - 2999		3000 -		total	
Type of Facilities	No. of facilities	Total Water Consumption (cum/month)	No. of facilities	Total Water Consumption (cum/month)	No. of facilities	Total Water Consumption (cum/month)	No. of facilities	Total Water Consumption (cum/month)
Public Facilities	52	2,624	28	58,594	11	70,479	91	131,697
Hotels	6	6,030	1	2,681	2	13,647	9	22,358
Commercial Buildings	17	16,934	7	13,477	1	5,062	25	35,473
Others	42	47,959	17	31,816	6	27,308	65	107,083

The public facilities consist of schools, hospitals, stadiums, parks, and other buildings for the public uses. In terms of the water quality, it is considered to be the same as the domestic wastewater. However, special consideration should be taken for the hospital wastewater in order to prevent pathological contamination.

2.5.6 Solid Waste Disposal

(1) General

The situation in the management of solid wastes in the City of La Paz was investigated mainly through interviews at the Bureau of Urban Sanitation (Dirección de Saneamiento Urbano; DSU) of HAM-LP in March through May, 1992.

The amount of domestic solid wastes generated in the City of La Paz is estimated by DSU at about 350 - 380 ton/day. Of this amount, 300 - 320 tons is regularly collected at present with the collection ratio being steadily increasing.

DSU was confident that the amount of solid waste collection would be increased to 350 ton/day by the end of 1992.

Uncollected wastes are disposed irregularly in nearby places such as river banks and slopes. DSU recently set up a campaign with the help of the military force to clean up those irregular dumping sites, and intends to continue this campaign.

The total amount of industrial solid wastes generated is not known to DSU. Although DSU is prepared to collect factory solid wastes at each site with a modest charge, the majority of factories have not yet been willing to accept this service. DSU is continuing their efforts to control factory solid wastes, and their prospects appear to be bright.

As regards construction wastes, the Bureau of Public Works, HAM-LP is responsible to specify disposal sites.

95% of hospital wastes are collected by DSU as the result of the campaign initiated 2 years ago.

Collected solid wastes are transported to a transfer station, where the wastes are re-loaded in large-size dump trucks. The wastes are then transported to a final disposal site in Mallasa for landfill.

The Mallasa landfill site has been used formally since August 1991, and its capacity is estimated to be sufficient to accept the wastes for the next 10 years.

The bed material of the landfill site consists mainly of clay which prevents leachate from seeping out of the landfill. Hospital wastes are buried in a clay-dominant portion and are covered with lime.

Aiming to increase the efficiency of the solid waste disposal service, DSU was planning to transfer most of the service operations to the private sector within the year 1992.

(2) Possible Contribution to Water Pollution

The solid waste disposal system in the City of La Paz has been much improved in the recent years. Thus, the amount of solid wastes dumped into the rivers has been drastically reduced from the year 1987 when the World Bank reported the contribution of the solid wastes to water pollution of the rivers.

As far as the water quality parameters such as BOD, COD and DO are concerned, the contribution of uncollected solid wastes to the water pollution of the Choqueyapu River is not considered to be significant at present as compared with the domestic and the industrial wastewaters. However, the old sanitary landfill at Sopocachi may be a source of some heavy metals such as Hg.

2.6 RELEVANT PLANS

2.6.1 National Plans

(1) Long-term Development Plan

In August 29, 1985, the government promulgated the new economic policy (Government Decree No.21060). The new policy stance aimed at quickly restoring macro economic stability, but it did not focus on long-term economic development planing. Then, the government formed the "Social and Economic Development Strategy, 1989-2000" and published it in April 1989. The "strategy" included water supply and sanitation projects

The average growth rate of GDP during the period 1989-2000 is estimated at 4.9% per annum in the "strategy".

The extraction, manufacturing and utility sectors are expected to grow more quickly than other sectors in the national economy.

(2) National Plan for Potable Water and Sanitation (1992-2000)

The national Plan for Potable Water and Sanitation 1992-2000 (Ref.I1) has been established by DINASBA, MAU and was published on May 19, 1992.

According to the plan, the national coverage of the population in water supply and sewerage in 1991 and the year 2000 are as follows:

National Coverage of Water Supply and Sewerage

		1991	2000
Water Supply:	National (%)	53	70
	Urban (%)	74	80
	Rural (%)	31	60
Sewerage:	National (%)	24	53
	Urban (%)	35	65
	Rural (%)	14	50

A total of US$ 768 million is to be invested to achieve the above coverage by the year 2000 by roughly equally allocating it to the water supply and the sewerage sectors.

2.6.2 Urban Development

(1) Present Situation

The city has been developed by following the natural topography. Therefore, the central axis of the urbanization lies on the Choqueyapu river, causing various problems including the pollution of the river. The DGDU (Dirección General de Dessarrollo Urbano) thinks it necessary to disperse this concentration in order to correct the situation.

The DGDU in 1983 prepared a map of future land use and township patterns (Ref.I3) based on a comprehensive geological study conducted in 1976.

The DGDU intends to develop a comprehensive city development plan based on the result of the latest national census which was conducted on June 3, 1992.

(2) Future View

The DGDU envisages a development model in which the whole urban area will be divided into several districts each having an urban center with a branch office of the Municipality.

At Present, the following division is being considered.

Central District
South District
East District
Western Slope District
Eastern Slope District

In the future, there will be 8 or so districts by further dividing some of the above districts.

In any case, however, the urban area within the City of La Paz is not expected to expand significantly from the present. Instead, urban expansion will be realized in the City of El Alto.

2.6.3 Water Resources Development and Water Supply

There is no authorized water resources development plan and water supply plan in the study area.

SAMAPA recognizes the necessity of developing new water supply sources to cope with the increasing water demands of the metropolitan area.

SAMAPA is considering their development plan from two aspects, i.e., improvement of the quality and increasing the quantity. One plan is to construct a new reservoir upstream of the existing Milluni reservoir which has been polluted by mine tailings. For another, they are seeking an alternative source in the Choqueyapu River basin, i.e., construction of a dam on the Choqueyapu River.

CORDEPAS is conducting a pilot project to treat the Choqueyapu river water in order to meet the quality requirements of irrigation water for the farm lands in Rio Abajo. The plant evaluation started in May, 1992. If the result is promising, they intend to construct practical-scale treatment plants for those farm lands.

2.6.4 Sewerage Development

A comprehensive plan for developing sewerage and stormwater drainage systems in the metropolitan area was prepared in 1982 through the technical cooperation of then West Germany. The sewerage development plan covered the Central and South Zones of the City of La Paz as well as the City of El Alto, then a part of the City of La Paz, and Achocalla Zone.

For the Central and the South Zones of the City of La Paz, one wastewater treatment plant was planned to be installed in Aranjuez beside the Coqueyapu River to treat all wastewater from these zones. Wastewaters in these areas were to be collected separately from stormwater through sewer networks and finally to be transferred to the treatment plant through a main sewer interceptor. The construction costs for this sewerage system were estimated at about $US210 million

However, this plan has not been implemented, mainly because of the high cost which exceeded the financial capacity of the country. The planned site for the treatment plant is no longer available at present because it has been developed for other purposes including houses and recreational facilities.

In consequence, there is no workable sewerage development plan at present for treating wastewater from the Central and South Zones of the City.

2.7 SUMMARY OF THE PROBLEMS

(1) Extent of the Water Pollution

The river water in the urban area of the City of La Paz is severely polluted. The concentration of BOD, which indicates the degree of pollution by organic substances, is in a range between 100 mg/l and 300 mg/l in the urbanized area. This level is similar to that of ordinary domestic sewage. The BOD value at the Lipari bridge, the downstream end of the City of La Paz, is around 50 mg/l to 80 mg/l exceeding the maximum allowable limit of the Bolivian standards for irrigation water.

Since a large part of the Choqueyapu River is covered in the central zone of the city, deteriorating effects of the water pollution in this zone may not be perceived often. But in the south zone of the city, where the rivers are mostly open-channeled, offensive odors, aesthetic degradation, and in some areas, breeding of flies are observed particularly in the dry season.

Damage by the river water pollution is particularly severe in the farmlands in the downstream areas. Since the outbreak of cholera in August 1991, the farmers have been forced to switch their products from freshly eaten vegetables to other less marketable or less profitable crops.

(2) Pollution Sources

Estimation of the BOD load of wastewaters generated in the study area indicates that the domestic wastewater accounts for some 50% or more, the industrial wastewater some 30% or more, and the rest is shared by commercial and institutional wastewaters. The contribution of solid wastes is considered to be insignificant in the terms of BOD loading as compared with the above wastewaters.

(3) Wastewater Collection and Disposal

The wastewaters are discharged into the rivers, without treatment, via relatively well-developed sewer networks, stormwater collection pipes or ditches, or directly.

Sewage discharge without treatment through sewer networks causes serious water pollution problems, because all of the collected wastewater reaches the river, and the amount of wastewater tends to increase when it is connected to a sewer system.

Malconnections of sewer pipes to stormwater drainage lines or vice versa that are common in the city also present a difficult problem.

One of the most difficult problems concerning treatment of wastewater is scarcity of lands usable for the treatment plants. The situation is most severe in the central zone.

(4) Consciousness Among Industries

Wastewater from factories in the city no doubt comprise a significant portion of the total pollutant load.

However, technical characteristics of the industrial wastewaters and their source facilities in La Paz have not been understood sufficiently yet. This is largely because of the uncooperative attitude of the factories. This will prevent development of a rational water pollution control plan in which each person contributes a fair share of the cost for its implementation.

It is of great importance that the industries deepen their consciousness more on the abatement of water pollution.

(5) Urban Development Planning

There has been no comprehensive urban development plan in the City of La Paz in order to achieve orderly and efficient development aimed at improving quality of the living environment. Therefore, developments of housing, roads, water supply, electricity, sewerage and so on have proceeded within the field of vision of each sector without adequate coordination among various sectors. Without a rational and comprehensive city development policy that precedes the policy of each sector, real improvement of the quality of the living environment will be difficult to achieve.

(6) Institutional Requirements

Although there have been no effective legal means in Bolivia to control water pollution until just recently, the introduction of the General Law of Environment has presented a bright prospect for the future. However, a great deal of work has yet to be done to establish an overall legal system consisting of practical rules and regulations, and to develop adequate national and local organizations with a sufficient number of competent personnel to implement this legal system. In order to succeed in these works, a high degree of determination by the relevant authorities and the cooperation of citizens and industries are required.

(7) Economic Condition

In order to reduce significantly the amount of pollutant load to the rivers, a large sum of public and private investments is required. In Bolivia, however, capital resources affordable to water pollution control are not sufficient so as to meet everyone's satisfaction.

Therefore, development of the pollution control plan must be made within the limit of capital availability for initial investments and the limit of affordable contribution of the public for its implementation and management.

CHAPTER 3
GENERAL FRAMEWORK FOR THE BASIC PLAN

3.1 TARGET YEARS

It is foreseen that improvements to the sewerage system will be one of the major components of the Basic plan. Implementation of a sewerage basic plan is usually divided into several phases with each phase comprising 5 years.

Therefore, it is proposed to set the target year at the year 2010 by assuming that the implementation of the Basic plan will be divided into 4 phases each taking 4 to 5 years. The formulation of the Basic plan will be based on the predicted values of various factors at the year 2010. However, for the time schedule for the implementation of the project, it may not be possible to complete the project by the target year, because major portions of the project are expected to be financed by foreign funds and it is not certain whether such financing can be implemented in accordance with the target dates. Although the target year determined here will be used for the year to predict future conditions, it should not be regarded as an absolute target for implementation.

3.2 GOALS

The final goal of the Basic plan is to achieve a suitable water quality improvement in the catchment area of the Choqueyapu River above the Lipari bridge. The goals are specified as follows:

3.2.1 Evaluation Points for Water Quality Improvement

The evaluation points for water quality improvement are selected as shown in Table 3.2.1 so as to be able to assess the water quality conditions along the Choqueyapu River above the Lipari bridge.

Table 3.2.1 Evaluation Points for Water Quality Improvement

Points	Characteristics
Achachicala (R2)*	To indicate the water quality of the Choqueyapu River at the upstream of the urbanized area
Ave. Ejercito (R4)*	To indicate the water quality in the urbanized area
Calacoto (R9)*	To indicate the water quality of the Choqueyapu River below the confluence with the Orkojahuira River
Lipari bridge(R15)*	To indicate the water quality for the irrigation water
Most downstream of the Orkojahuira river (R8)*	To indicate the water quality of the Orkojahuira River
Most downstream of the Irpavi river (R11)*	To indicate the water quality of the Irpavi River
Most downstream of the Achumani river (R12)*	To indicate the water quality of the Achumani River

* Numbers refer to the sampling points in this study; refer to Fig. 2.4.1.

(2) Urgent project

Apart from the above general water quality evaluation points for the whole basin, it is proposed to set up tentative evaluation points. The deterioration of the water quality conditions of the Choqueyapu river is so severe that one can not wait for the completion of all phases of the Basic Plan. Consequently, it will be necessary to implement an urgent project to tentatively improve the present conditions.

Considering the effects to irrigation water use and the aesthetic conditions to the residential area, the following two points at the Choqueyapu river are proposed as evaluation points for an urgent project.

- Lipari bridge
- Crossing of Avenida Libertadores

3.2.2 Water Quality Target

The water quality target is determined so that the improved water quality ensures the expected water uses in each river or in each section of the rivers.

The water quality targets for the Basic plan are determined as shown in Table 3.2.2, considering the expected water uses of each evaluation point and required water quality for each water use.

The required water quality limits are based on the Bolivian Standards. However, the water quality parameters include only BOD, DO and coliform bacteria, although the Standards specify limits for SS too. The SS concentrations in the rivers in this area are mainly caused by soil erosion in the catchment area, which is difficult to control by means of water treatment, thus it is not considered to be practical to include SS in the required water quality target.

Table 3.2.2 Water Quality Targets

Evaluation Points*	Location	Required Water Conditions	Required Water Quality	
R2	Upstream of urbanized area of each river	Water quality which is suitable for conventional water treatment for potable water and/or which does not worsen natural environment.	BOD: DO: Coliform:	10 mg/l 60% 10,000 MPN/100ml
R9, R8,R11,R12	In urbanized area	Water quality which does not generate obnoxious conditions along the stream.	BOD: DO: Coliform:	50 mg/l 50% 20,000 MPN/100ml
R15	Downstream of urbanized area	Same as above. For the Choqueyapu river , water quality suitable for irrigation water	BOD: DO: Coliform:	50 mg/l 50% 20,000 MPN/100ml

* Refer to Table 3.2.1 and Fig. 2.4.1.

3.3 PLANNING AREA

The study area covers the entire catchment of the Choqueyapu river above the Lipari bridge, comprising the catchments of the Orkojahuira, Irpavi, Achumani, Huañajahuira, and other rivers, as well as the Choqueyapu river, as shown in Fig.1.3.1. It is required that the Basic Plan improve water quality of the whole area.

As a result of the water quality survey in this Study and review of previous studies, it is evident that the water pollution problems are significant only in and below the urbanized areas, and that the water pollution is being caused by wastewaters from various urban activities which are discharged to the rivers without treatment. The measures to be proposed in the Basic plan for the water quality improvement will naturally focus on the reduction of pollutant discharges from urban activities. Therefore, areas covered by the water quality improvement measures are those areas within the urbanized areas in the study area.

3.3.1 Current Urbanized Areas

The current urbanized and semi-urbanized areas are scattered as shown in Fig. 3.3.1. Most of the urbanized areas with high population density are spread in the catchment of the Choqueyapu and the Orkojahuira rivers. Urbanized areas with lower population density are developed along the downstream reaches of the Irpavi, Achumani and Juañajahuira rivers in the South Zone and scattered in their catchments.

3.3.2 Future Urbanized Area

Fig. 3.3.2 indicates the expected scattering of the urbanized and semi-urbanized areas in the year 2010. These future urbanized areas have been projected by considering the population growth in the currently less populated areas and also expansion of the urbanized areas based on the planned urbanized area indicated in the Landuse Plan Map.

3.3.3 Planning Area

All the wastewaters from the urbanized and semi-urbanized areas both in the present and future are considered to be potential pollution sources to the rivers. Therefore, the urbanized and semi-urbanized areas indicated in Figs. 3.3.1 and 3.3.2 are considered to be a planning area for the formulation of the Basic Plan. Pollutant load generation in those areas will be taken into the considerations for pollution analysis and the study of improvement measures.

3.4 POLLUTANT SOURCES

Domestic wastewater and industrial wastewaters are considered to be the principal sources of the river pollution. The amount of pollutant generation from those wastewater are estimated from present and future population and industrial activities.

3.4.1 Population

(1) Present

The present population in the study area has been discussed in the Section 2.2.1 in this report. The population in the study areas is regarded as almost the same as that in the planning area because the population in the upstream areas is negligible as compared with the total of the Central Zone and the South Zone, i.e. the planning area.

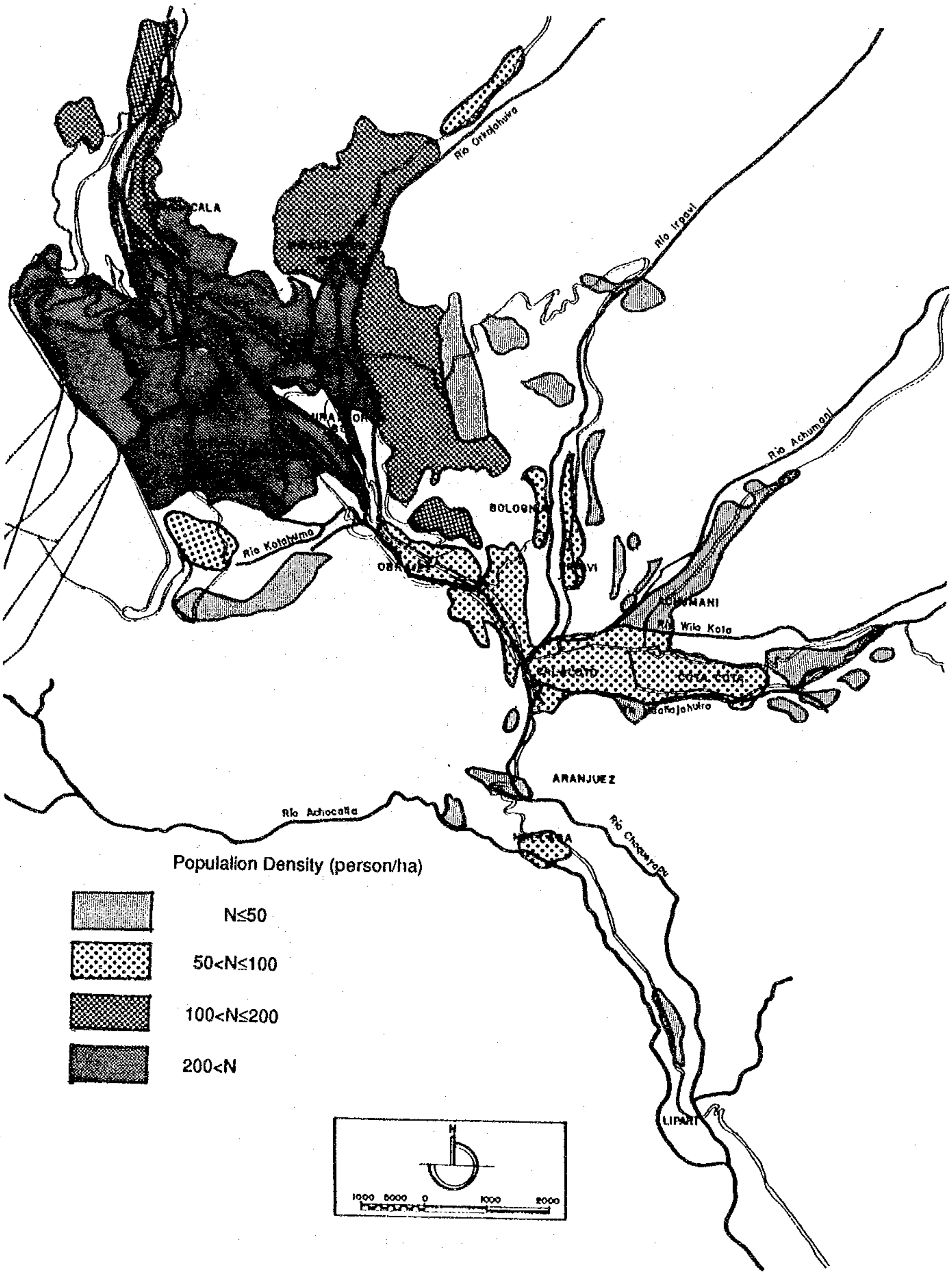


Fig. 3.3.1 Existing Urbanized and Semi-Urbanized Areas

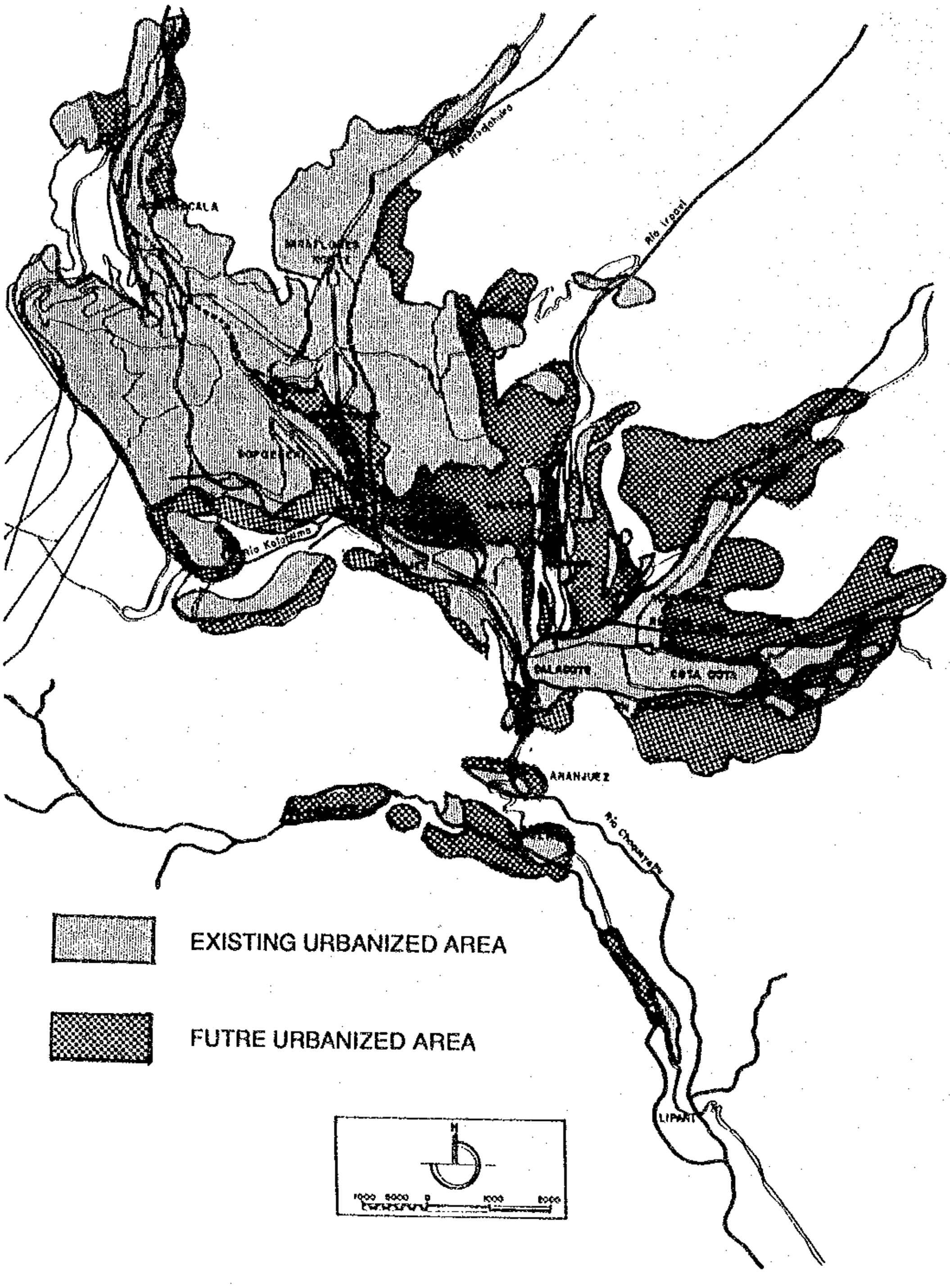


Fig. 3.3.2 Future Urbanized and Semi-Urbanized Area

(2) Future

The future population was estimated as follows from regression analyses and the calculation of possible land developments in the area.

Year	1992	1995	2000	2005	2010
Population	720,000	750,000	820,000	900,000	1,000,000

Distribution of the population in the planning area was estimated by allocating the population increase to each district considering the future development potential evaluated from the present population density. Table 3.4.1 shows the estimated future population distribution. A significant population increase is estimated to take place in the South Zone because the population in the Central Zone has nearly reached saturation.

Table 3.4.1 Estimated Population Distribution In Future

Zones	1992	2000	2010
Central Zone	631,000	640,000	650,000
South Zone	84,600	130,000	240,000
(Achocalla)	4,400	50,000	110,000
Total	720,000	820,000	1,000,000

3.4.2 Industries

The present conditions of industrial wastewater in the study area are discussed in the section 2.4.4. Based on this discussion, industries to be considered in the Basic plan are determined as shown in Table 3.4.2. The listed industries are those having more than 25 m^3/day of wastewater discharge. Total wastewater from these industries comprises 75 % of total industrial wastewater.

For the future industrial growth, the value added of the manufacturing sector in the Department was estimated to increase from Bs.0.8 billion in 1991 to Bs.3.0 billion in 2010. However the Central zone in the planning area has no room for future expansion and new factories are supposed to be located outside of the planning area, i.e. El Alto. Thus, in the consideration of the Basic plan, no increase is considered in the future industrial wastewater.

Table 3.4.2 List of Industries in the Planning Area

AMOUNT OF WASTEWATER (m^3/month)	NAME	MAIN PRODUCTS
Q>3,000	Universal Tex	Textile (Wool Dyeing & Textile)
	Industria Venado	Food (Instant Food)
	Garcia Maria	Other
	Enbotelladora Salvietti	Food (Soft Drink)
	Fabrica Indupel	Pulp & Paper (Paper Making)
	La Papelera	Pulp & Paper (Paper Making)
	Cerveceria Boliviana	Food (Beer)
3,000≥Q>1,500	Macobol Neptula Antonia	Textile (Wool Dyeing & Textile)
	Fabrica Estatex	Textile (Cotton & Synthetic Fiber)
	Cortiembre Illimani	Leather (Tannery of Raw Hide)
	Bebidas Gaseosas	Food (Soft Drink)
	Marboltex	Textile (Wool Dyeing & Textile)
	Manufacturas Textiles Forno	Textile (Wool Dyeing & Textile)
	Fabrica Famatex	Textile (Cotton & Synthetic Fiber)
	Marmolera Tiahuanaco	Food (Soft Drink)
	Laboratorio Vita	Pharmacy (Fermentative)
	Fabrica Cascada	Food (Confectionery)
	Marmolera	Other
1,500≥Q>750	Mendoza Oscar Vertiente	Food (Soft Drink)
	Industria Tabaco	Food (Cigarette)
	Cuaquira Gregorio	Other
	Liendo Romero	Other
	Fabrica Nacional de Vidrios	Glass
	Ponce Lucio	Other
	Pinel Laura Super Taxi	Taxi Service
	Fabrica D. Saligno	Car Repair Shop
	Combogel	Textile (Cotton & Synthetic Fiber)
	Ibusa	Textile (Felt)

CHAPTER 4
ANALYSIS OF WATER QUALITY OF THE CHOQUEYAPU RIVER FOR PRESENT AND FUTURE

4.1 UNIT LOADING FACTORS FOR POLLUTANT GENERATION

4.1.1 Outline

Pollutant sources are generally classified as follows:

1) Domestic

2) Industrial

3) Others (Commercial, Public Establishment, Natural)

Wastewater discharge and pollution load were estimated by using unit loading factors and socio-economical data: population, volume of water consumption, etc.

4.1.2 Domestic Wastewater

In this study, water supply modes were classified into two: SAMAPA's house connection service and the supply by other forms such as public hydrant, wells and tank trucks. There is a clear difference in water consumption between these two modes, which reflect living standards. Per capita wastewater discharge and pollution load were estimated according to this classification as described below.

(1) House Connection Service Area

By referring to existing data in Bolivia and Japan, the unit wastewater discharge in the future was estimated as shown in Table 4.1.1.

Table 4.1.1 Unit Wastewater Discharge

Unit: lit/day/person

Value	Ratio	1992	1995	2000	2005	2010
Daily Mean	0.8	130	140	145	150	160
Daily Max.	1.0	160	170	180	190	200
Hourly Max.	1.5	240	255	270	285	300

Per capita BOD loading, composition of daily mean wastewater discharge and BOD concentration for the various kinds of wastewater were estimated as shown in

Table 4.1.2.

Table 4.1.2 Composition of Daily Mean Wastewater Discharge and BOD Concentration

Kind	BOD (mg/l)	Unit Wastewater Discharge (lit/day/person)				
		1992	1995	2000	2005	2010
Human waste	600	30	30	30	30	30
Gray water	150	80	85	95	100	110
Business use	250	20	20	20	20	20
Total		130	140	145	150	160

From Table 4.1.2, the per capital BOD load in each year was calculated as follows.

Year	1992	1995	2000	2005	2010
BOD Load (g/day/person)	35	36	38	39	40

(2) Other area

For the "other areas" category (without piped water), the unit wastewater discharge was estimated to be 60 lit/day per capita, and the unit BOD load was estimated at 27 g/day per capita.

4.1.3 Industrial Wastewater

Industrial wastewater discharge was estimated by the water usage data of SAMAPA for factories, commercial buildings, hotels, etc. that use more than 750 m^3/month. The pollution load was calculated by multiplying the discharge amount by the BOD concentration. The BOD concentrations of wastewaters from these sources are found in the existing data. The BOD concentration of other wastewaters was assumed to be the same as that for the business use of domestic wastewater (250 mg/l). Wastewaters from smaller industries were included in the per capita load for domestic wastewater.

4.1.4 Others

Natural pollution load and pollution loads which are generated in or permeate into the river bed, farmland, etc. were integrally estimated as "others". Since it is not possible to predetermine the value for these loads, it was estimated through calibration of the water quality simulation model.

4.2 AMOUNT OF POLLUTANT GENERATION

4.2.1 Outline

The Choqueyapu basin was divided into blocks and the river course was divided into reaches. The amount of wastewater discharge and the pollution load were estimated for each block/reach to be used in a mathematical water quality simulation model.

4.2.2 Pollutant Generation Amount by River Catchment

(1) Domestic Wastewater

Distribution of population was firstly estimated for population blocks used in the census of 1976 and the data of the La Paz Sanitary Unit. The population was distributed according to the level of urbanization or the form of land use.

The estimated populations for population blocks were secondarily distributed to discharge blocks for the water quality simulation model. The amount of wastewater and the BOD load were obtained for each discharge block using the population and the unit loading factors described in Section 4.1.2.

(2) Industrial Wastewater

The wastewater discharge amount and the BOD load from the major water consumers (over 750 m^3/month) were estimated for each discharge block.

4.3 DEVELOPMENT OF WATER QUALITY SIMULATION MODEL

4.3.1 Outline of the Model

A water quality simulation model for BOD and DO was established essentially based on the Streeter-Phelps model.

The saturation concentration of DO varies with temperature and atmospheric pressure, and these meteorological parameters vary with altitude. Therefore, the effects of altitude difference was incorporated into the model.

The flowchart of the activities included in the model is shown in Fig. 4.3.1 .

4.3.2 Pollutant Run-off Model

The entire basin of the Choqueyapu River including all tributaries was divided into eight reaches as shown in Fig.4.3.2. The lower end of the reaches are the points of the water quality and flowrate survey conducted in this Study. These points used are also the representative points used to evaluate water quality of the Choqueyapu River.

[Reach]	[Representative Point]	[Remarks]
1	R1	Unpolluted Area
2	R2	Some Villages, Pasture of Alpacas, Sheep, etc.
3	R3	Industrial Zone, Some Community
4	R4	Densely Populated Area, Commercial Zone
5	R5	Residential Zone, Some Hospitals
6	R9	Residential, Industrial Zone, Inflow of Tributaries (Kotahuma, Orkojahuira)
7	R14	New Residential Zone, Inflow of Tributaries (Irpavi, Achumani, Huañajahuira)
8	R15	Suburban Area

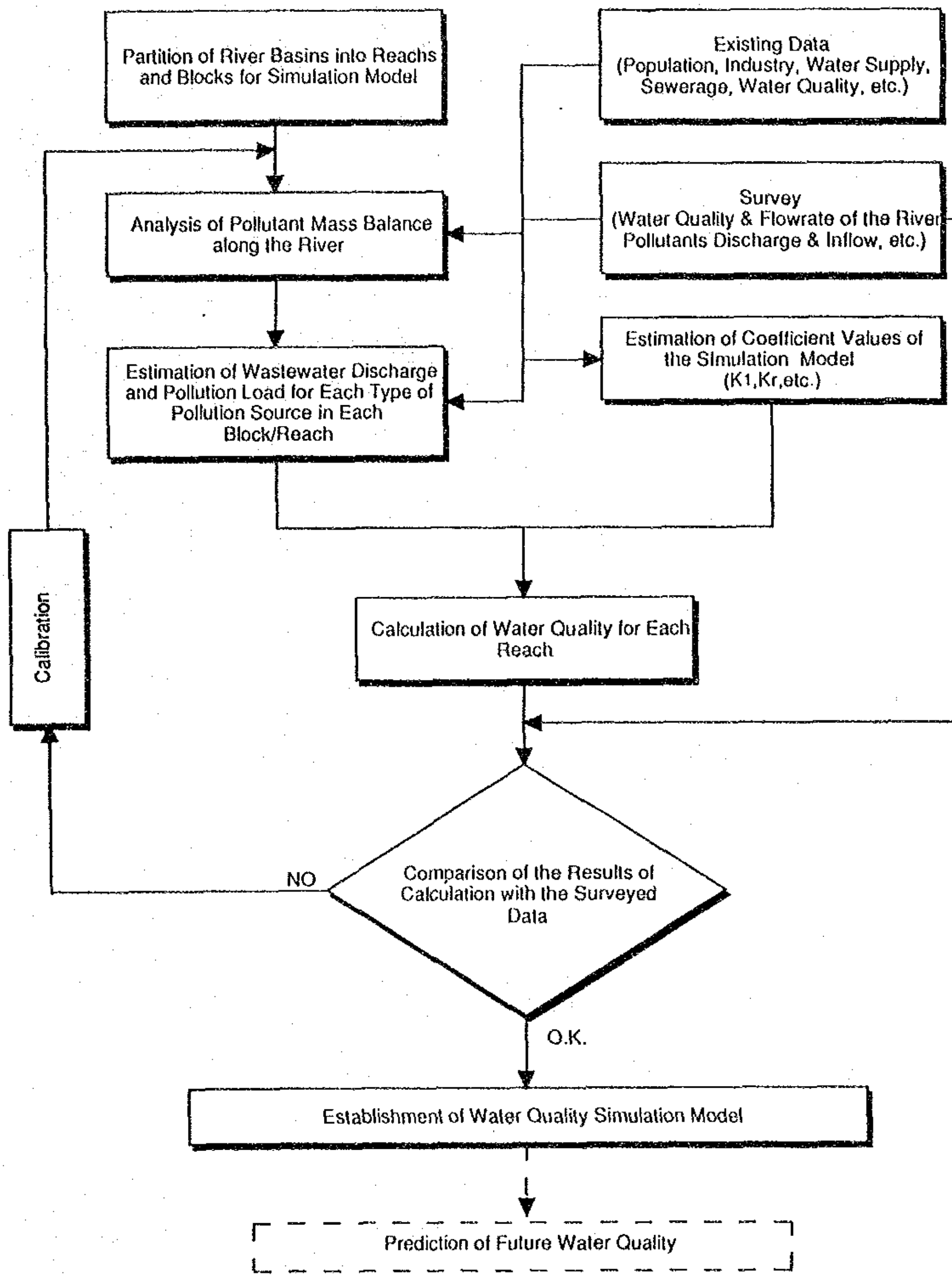


Fig. 4.3.1 Flowchart of Construction of Water Quality Simulation Model

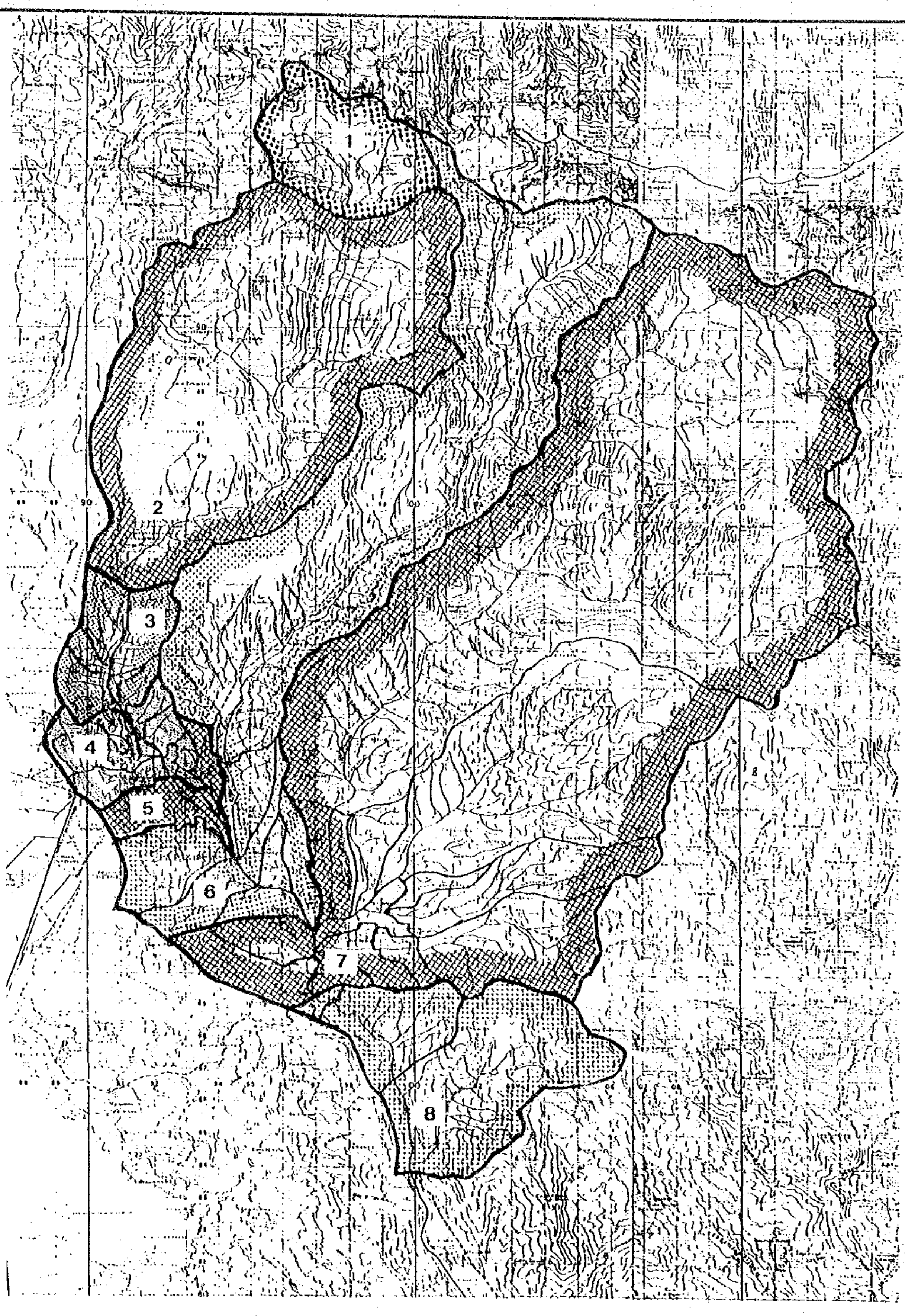


Fig. 4.3.2 Partition of Reaches for Water QUality Simulation Model

The reaches were further divided into blocks to estimate wastewater discharge and pollution load.

Amounts of wastewater discharge and pollution load for each discharge block were estimated through comparing the computed generated values with the actually observed values.

4.3.3 Discussion on the Present Water Quality

The simulated values for flowrate in the dry season are shown in Table 4.3.1 and Fig.4.3.3, those for BOD are shown in Table 4.3.2 and Fig.4.3.4, and for DO in Table 4.3.3 and Fig. 4.3.5, with each being compared with observed values. From these results, the model can be judged to be capable of simulating actual water quality of the Choqueyapu river. Therefore, this simulation model can be applied to predict future water quality and to evaluate the effects of pollution control measures to be considered in the present Study.

Table 4.3.1 Comparison of Simulated River Flowrate with Observed Data

Evaluation Point	Distance (km)	Flow Rate (m3/sec) Observed Value (22/Apr./1992)	(29/Apr./1992)	Result of Simulation
R1	0	0.11	0.08	0.10
R2	16	0.31	0.17	0.24
R3	20	0.62	0.31	0.43
R4	23	1.03	0.74	0.98
R5	26	1.31	1.34	1.33
R9	30	1.55	1.58	1.58
R14	32	2.48	2.62	2.55
R15	39	2.82	3.00	2.96

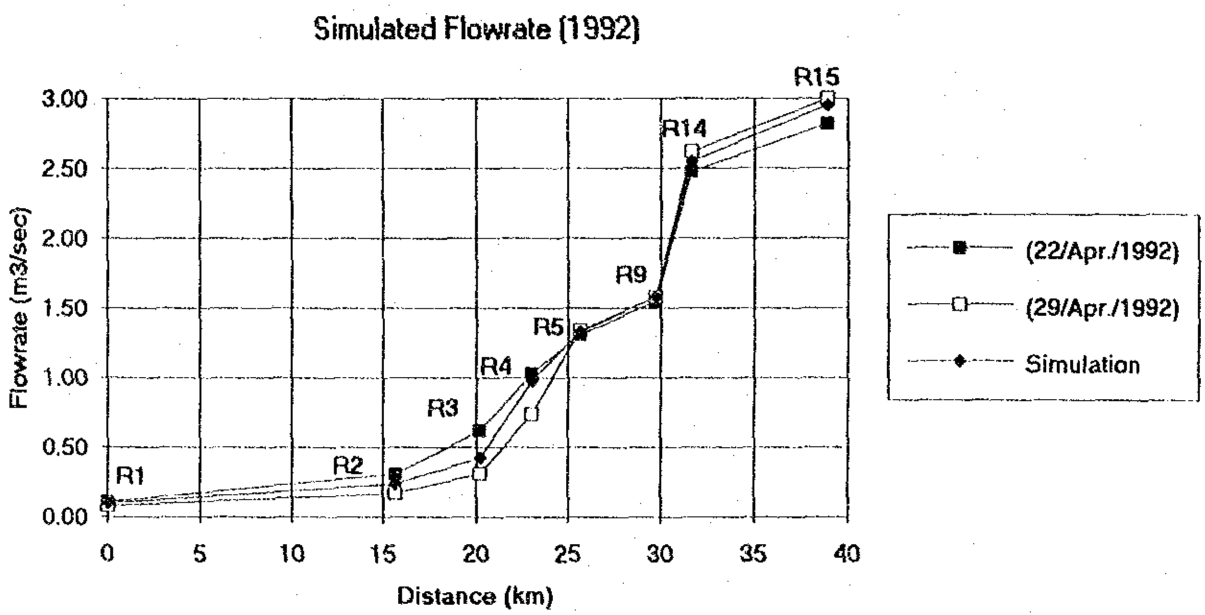


Fig. 4.3.3 Comparison of Simulated River Flowrate with Observed Data

Table 4.3.2 Comparison of Simulated River Water Quality (BOD) with Observed Data

Evaluation Point	Distance (km)	BOD Concentration (mg/l)		
		Observed Value		Result of Simulation
		(22/Apr./1992)	(29/Apr./1992)	
R1	0	1.3	0.9	1.2
R2	16	2.2	2.1	2.2
R3	20	67.5	68.4	67.8
R4	23	115.0	169.0	151.7
R5	26	127.0	151.0	143.0
R9	30	109.0	97.0	107.1
R14	32	75.0	76.0	71.1
R15	39	51.0	58.0	54.3

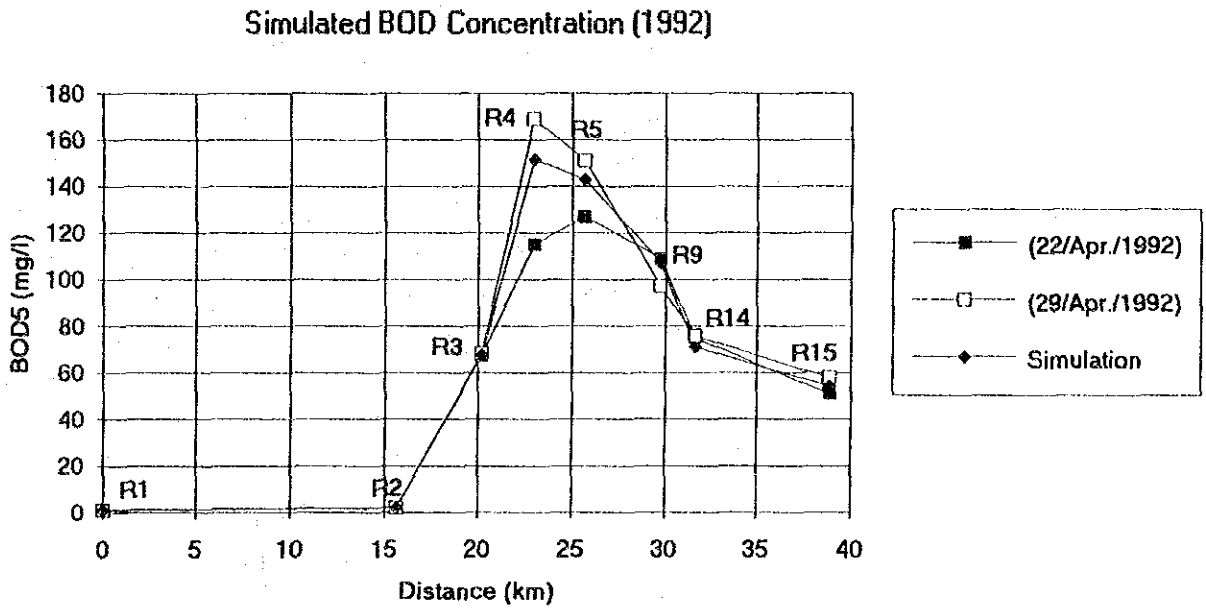


Fig. 4.3.4 Comparison of Simulated River Water Quality (BOD) with Observed Data

Table 4.3.3 Comparison of Simulated River Water Quality (DO) with Observed Data

Evaluation Point	Distance (km)	DO Concentration (mg/l)			Rate of Saturation (%)
		Observed Value		Result of Simulation	
		(22/Apr./1992)	(29/Apr./1992)		
R1	0	2.3	3.7	3.0	42.5
R2	16	2.7	4.1	3.4	47.9
R3	20	2.8	4.6	3.7	51.6
R4	23	2.7	3.8	3.3	45.2
R5	26	3.3	2.7	3.0	41.6
R9	30	3.6	3.1	3.4	46.3
R14	32	3.2	3.0	3.0	41.5
R15	39	3.7	2.9	3.2	44.5

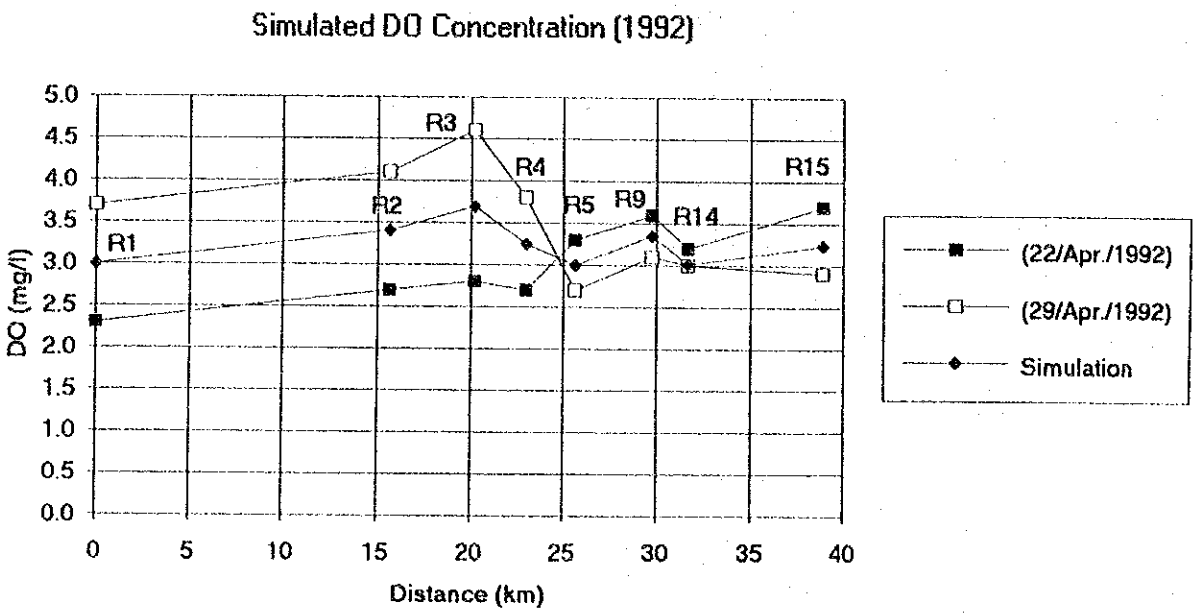


Fig. 4.3.5 Comparison of Simulated River Water Quality (DO) with Observed Data

4.4 PREDICTION OF FUTURE WATER QUALITY WITH OUT POLLUTION CONTROL

4.4.1 Amount of Pollutant Generation

The future water quality of the Choqueyapu river was predicted for the years 1995 and 2010. The manner to estimate pollutant generation is the same as that in Section 4.1. The social framework for the future, described in Section 3.4, was used as the basis to estimate the future amount of pollutant generation.

In the Central Zone (Block A ~ F), the population is expected to increase only 3.0% in the following eighteen years (from 1992 until 2010), because the present population has nearly reached the saturation point. On the other hand, the population of the South Zone is expected to increase about three times as high as in 1992. The increase of pollutant generation in the future will reflect such population increases. The rates of increase of wastewater discharge were estimated to be 5% (by 1995) and 35% (by 2010) in the Central Zone, and 38% (by 1995) and 500% (by 2010) in the South Zone. The rates of increase of BOD load were estimated to be 3% (by 1995) and 18% (by 2010) in the Central Zone, and 29% (by 1995) and 390% (by 2010) in the South Zone.

The increase of wastewater discharge in the Central Zone is mainly caused by the increase of the per capita discharge which reflects the improvement of living standard, and that in the South Zone is mainly caused by the increase in population.

Thus, water pollution of the Choqueyapu river tends to spread out toward the lower reaches corresponding to the direction of urban development of the City of La Paz.

4.4.2 River Water Quality

River water qualities in the dry season in 1995 and in 2010 were predicted by the simulation model. The results for BOD are shown in Fig. 4.4.1 and Fig. 4.4.2, and the results for DO are shown in Fig. 4.4.3 and Fig. 4.4.4.

As mentioned in the previous section, a significant increase of the BOD concentration in 2010 was predicted in the lower reaches represented by the points R14 and R15. A little decrease of the DO concentration in 2010 was predicted inversely proportional to the increase of BOD.

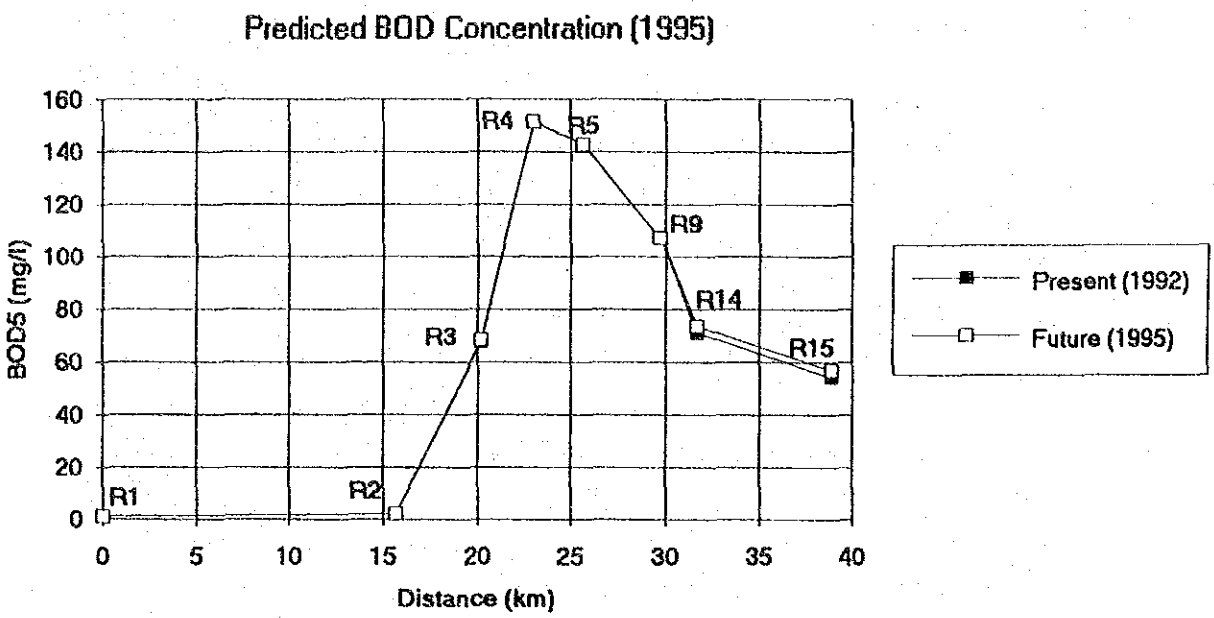


Fig. 4. 4. 1 Predicted Future (Uncontrolled) River Water Quality [BOD] in 1995

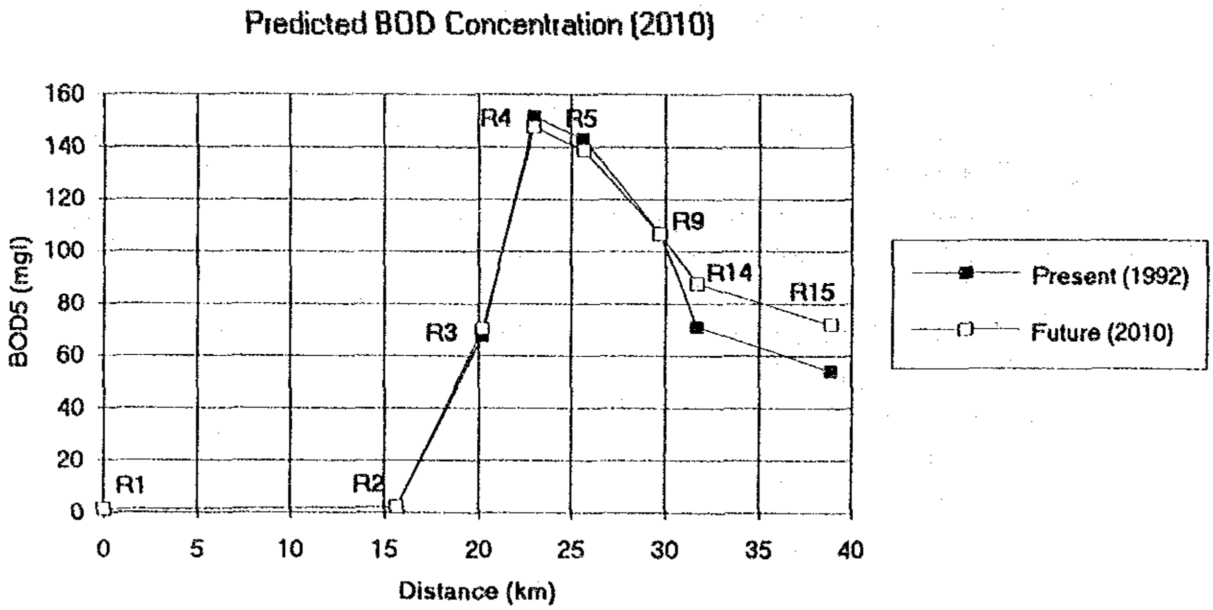


Fig. 4. 4. 2 Predicted Future (Uncontrolled) River Water Quality [BOD] in 2010

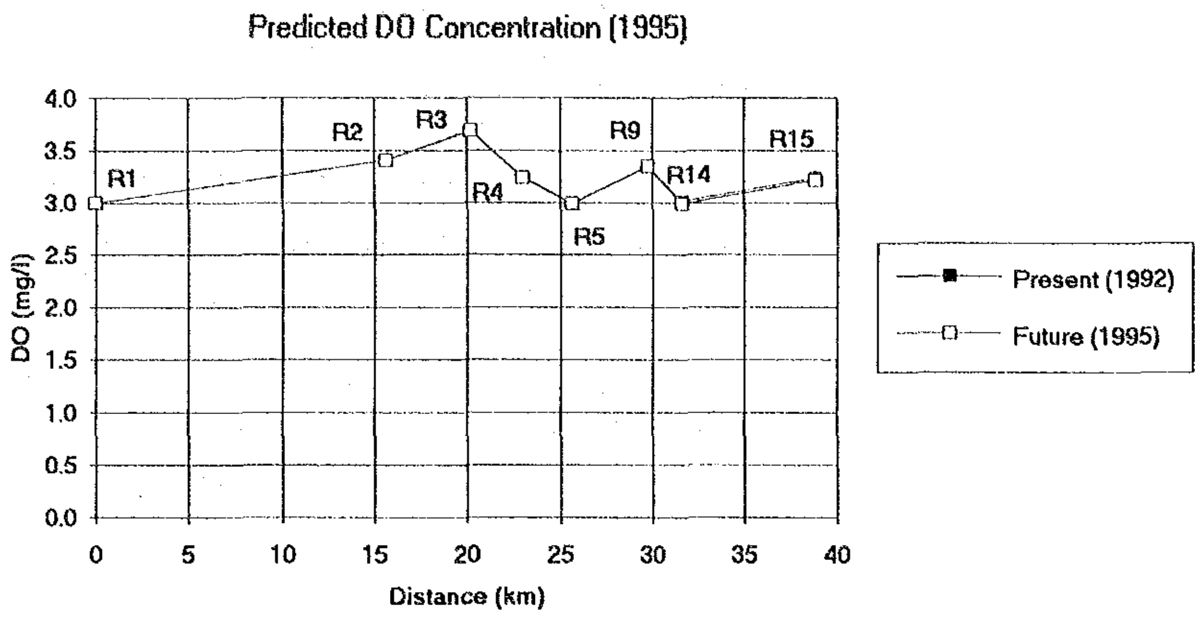


Fig. 4. 4. 3 Predicted Future (Uncontrolled) River Water Quality [DO] in 1995

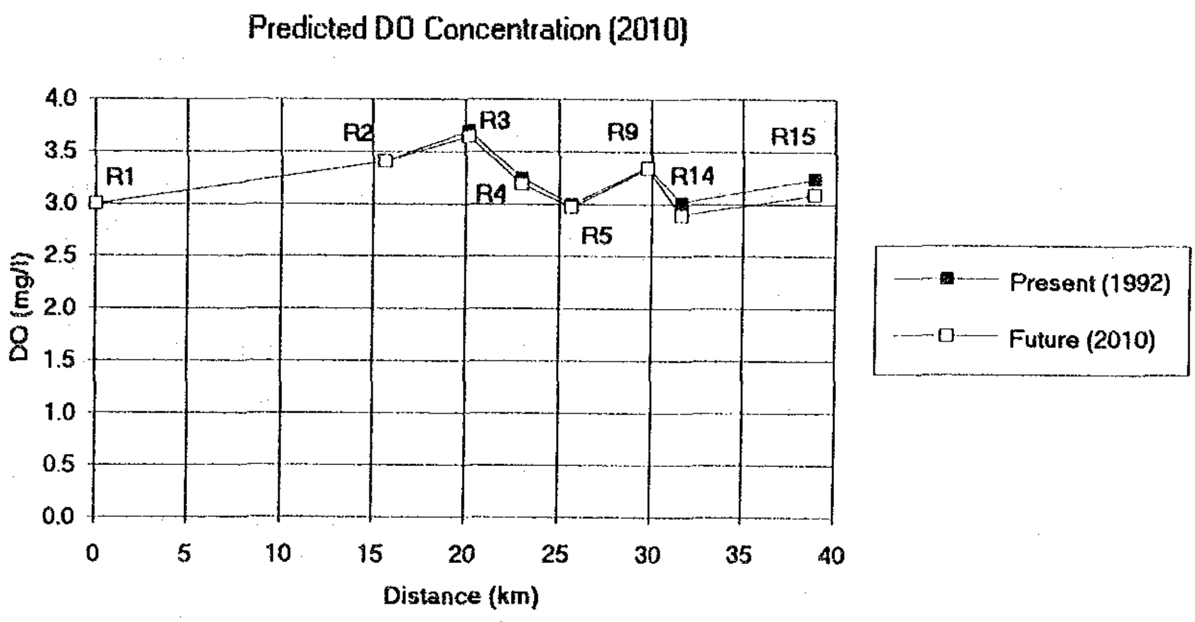


Fig. 4. 4. 4 Predicted Future (Uncontrolled) River Water Quality [DO] in 2010

CHAPTER 5
FORMULATION OF THE BASIC PLAN

5.1 CONCEPTS FOR THE BASIC PLAN

It is understood that the waters of the rivers in the urbanized areas and downstream are so polluted as to be regarded as sewage, and there is no doubt that the causes of this water pollution is untreated wastewater from residences, factories, hospitals, public buildings and so on. It is strongly recommended that the basic plan for water quality improvement should include measures to reduce the pollutant loads to the rivers from the urbanized area.

Therefore, the basic plan will propose, in addition to non-structural mitigation measures, a water quality improvement system that is based on the wastewater treatment. The wastewater treatment requires a large construction cost, a long implementation period and a strong organization for its management. Those may exceed the capability of the present organization. Even though it is not possible for each phase to exactly follow the schedules proposed in the basic plan, it will be worthwhile to draw up an ultimate goal and to make every effort to approach to the goal as much as possible.

5.2 SELECTION OF ALTERNATIVES FOR THE BASIC PLAN

5.2.1 Conceivable Measures

After a preliminary screening, the following 4 structural measures to improve the water quality of the rivers were considered:

- Reduction of pollutant loads to the river by wastewater treatment
- Dilution of the river water
- Direct purification of the river water
- Diversion

However, those measures other than reduction of pollutant loads were found to be not appropriate for the basic plan for the following reasons:

i) The river waters are too polluted to be improved substantially by these methods.

ii) The rivers carry a large amount of suspended solids, mainly silt and sand from upstream. If the river water is to be treated, a large amount of sludge containing silt and sand must be also treated, and this is not practical.

Therefore, it was proposed to implement a wastewater treatment system as a practical measure for the Basic Plan. This plan may be supplemented by other measures.

In the case of La Paz, the most critical condition for the planning of wastewater treatment system is considered to be its topography; large altitude differences within the area and a deficiency of flat lands. This causes severe restrictions on capacities of treatment plants located near to the sewage collection areas. Therefore, the possibilities of the construction of the wastewater treatment plant is carefully studied mainly from a view point of land availability.

The total maximum treatment capacity by utilizing all the available lands in the urbanized area is calculated at about 300,000 m^3/day by conventional treatment method while the wastewater amount to be treated from this area is estimated at about 200,000 m^3/day. The largest land located in the south zone (Calle Los Mardos) would be able to cover 200,000 m^3/day. However, available lands for treatment plant site in the central zone including the Orkojahuira River basin, where most of wastewater is generated, would permit the construction of plants with a total capacity of only 60,000 m^3/day. Even though it would be possible to construct wastewater treatment plants in all the available lands of the central zone and to treat the wastewater at the rate of the estimated maximum capacity, they would treat only less than 50% of the wastewater generated in the central zone. Actually, some of them would be difficult to construct because of environmental concerns, and pumping would be required for some sites, because they are located at high places. Thus the land for the treatment plant for the remaining wastewater must be found outside of the central zone; this will require the installation of the sewer transmission line from the central zone to the plant site.

In addition to the above discussion, further study was conducted to investigate the feasibility of constructing wastewater treatment plants in the central zone as presented in Appendix C of the Supporting Report. According to that study, only three sites in the central zone are considered to be possible to construct a plant, and for these sites the total capacity is only 25,000 m^3/day and the estimated costs to construct wastewater treatment plant in 15 proposed sites are 50% higher than those to construct one plant with capacity 20% larger than the total of the 15 plants.

From above consideration it is concluded that the decentralized treatment option of constructing several wastewater treatment plants is not feasible from view points of land availability and costs.

5.2.2 Alternatives for the Basic Plan

As a conceivable measure for the Basic Plan, it is propose to install a centralized wastewater treatment plant. There are two possible plant sites in the area; one along the lower Irpavi River and another near the Lipari Bridge. Therefore it is possible to propose two options with regard to sites. Also there would be more alternatives by treatment methods. These options and aternatives are outlined below.

(1) Irpavi Option

1) Water Intake Weir

A water intake weir would be installed in the Choqueyapu River at the upstream of the confluence with the Orkojahuira River in Kantutani. The Choqueyapu River above this water intake point is regarded as a sewer channel and the dry season flow would be transmitted to the wastewater treatment plant from this point.

2) Sewer Pipelines

The wastewaters from the Central zone would be collected from the Choqueyapu River as mentioned above. The wastewaters from other areas would be transmitted through sewer pipelines. The routes of the pipe lines throughout the area are shown in Fig 5.2.1, and the route for main sewer interceptor in Fig. 5.2.2.

3) Wastewater Treatment Plant

A provisional design of the wastewater treatment plant is shown as follows:

A. Design Conditions

Design flow in the year 2010 is 230,000 m^3/day; daily average wastewater flow plus dry season flow of the Choqueyapu River.

Influent water quality	BOD	250 mg/l
	SS	250 mg/l

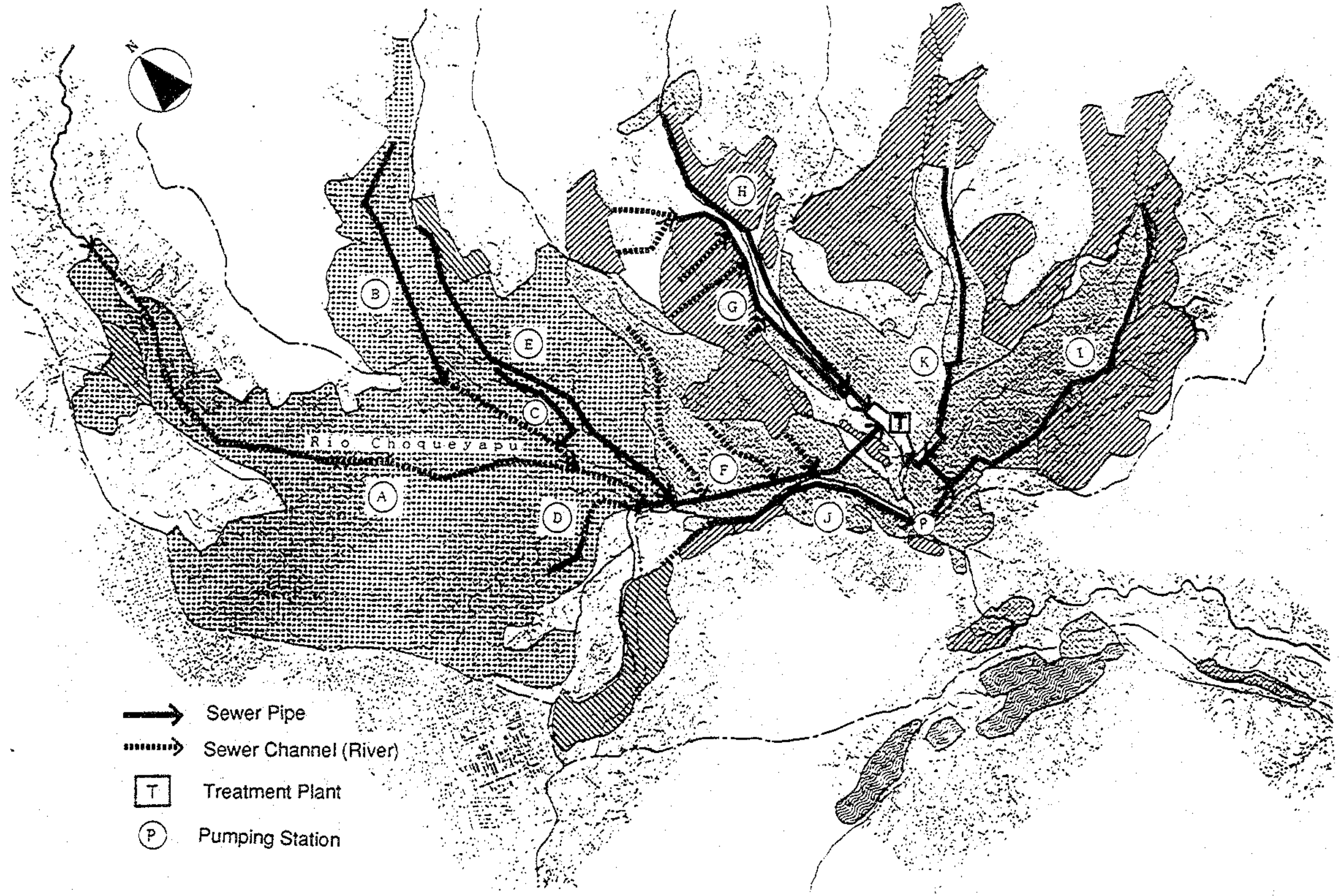


Fig.5.2.1 Routes of Sewer Interceptors (Irpavi Option)