JAPAN INTERNATIONAL COOPERATION AGENCY

MINISTRY OF LOCAL GOVERNMENT,
RURAL AND URBAN DEVELOPMENT
REPUBLIC OF ZIMBABWE

THE STUDY ON WATER POLLUTION CONTROL IN THE UPPER MANYAME RIVER BASIN IN THE REPUBLIC OF ZIMBABWE

VOLUME 1

SUMMARY REPORT

MARCH 1997

NIPPON JOGESUIDO SEKKEI CO., LTD.
NIPPON KOEI CO., LTD.

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PREFACE

In response to a request from the Government of the Republic of Zimbabwe, the Government of Japan decided to conduct a study on Water Pollution Control in the Upper Manyame River Basin in the Republic of Zimbabwe and entrusted the study to the Japan International Cooperation Agency (JICA).

JICA sent to Zimbabwe a study team headed by Mr. Masatoshi Momose, Director, Project Department, International Division, Nippon Jogesuido Sekkei Co., Ltd., 3 times between March 1996 and March 1997.

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

March, 1997

Kimio Fujita
President
Japan International Cooperation Agency

March, 1997

Mr. Kimio Fujita
President
Japan International Cooperation Agency
Japan

Dear Mr. Fujita,

Letter of Transmittal

We are pleased to submit herewith the Final Report of the Study on Water Pollution Control in the Upper Manyame River Basin in the Republic of Zimbabwe.

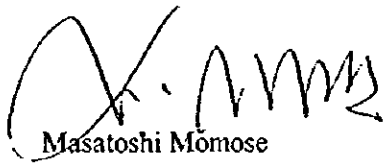
The Study was completed through the discussions with the officials of the Government of the Zimbabwe and the field investigation during three visits from April 1996 to March 1997.

The Final Report consists of four volumes consolidating the two progress reports and the draft final report; Volume I - Summary Report which succinctly describes the study and recommendations; Volume II - Main Report which covers not only physical development plans; the water pollution control plan and feasibility study of the selected project, but also institutional and financial strengthening plan for the central and local governments; Volume III - Supporting Report which includes detailed analysis and relevant information; and Volume IV - Data Report covering field findings and data.

We hope that the implementation of the proposed sewerage project would greatly contribute to the improvement of water quality in the public water body and sanitation conditions in the study area.

We wish to take this opportunity to express our sincere gratitude to your Agency, the Ministry of Foreign Affairs, the Ministry of Construction and Environment Agency. We also would like to show our appreciation to the officials of the Ministry of Local Government, Rural and Urban Development of Zimbabwe, the JICA Zimbabwe Office, and the Embassy of Japan in the Republic of the Zimbabwe for their kind cooperation and assistance throughout our field survey.

Very truly yours,



Masatoshi Momose
Team Leader for the Study on
Water Pollution Control in
the Upper Manyame River Basin in
the Republic of Zimbabwe

EXECUTIVE SUMMARY

This study comprises two (2) parts: (1) Water Pollution Control Master Plan and (2) Feasibility Study for the Priority Project.

PART-I WATER POLLUTION CONTROL MASTER PLAN

1. Study Area: five urban authorities (Harare, Chitungwiza, Norton, Ruwa and Epworth) and seven rural district councils; total area 3,900 km^2

2. Population Projection (two scenarios)

Scenario	Present	2000	2005	2015
Scenario-1	1,957,877	2,289,505	3,145,768	4,035,097
Scenario-2	1,957,877	2,319,790	2,707,119	3,575,878

3. Water Quality Standard and Future Water Quality

Projected Future BOD Concentration at WQCPs of Rivers unit: mg/l

River	WQ CP	Stan-dard	Present	Scenario 1		Scenario 2	
				2005	2015	2005	2015
Manyame (u/s)	C_{R1}	<3	1.1	1.32	1.48	1.03	1.13
Ruwa	R_{R1}	-	3.8	4.70	18.70	4.38	19.24
Nyatsime	R_{R2}	-	2.1	3.28	3.28	4.56	4.57
Manyame (d/s)	R_{R3}	-	1.0	10.52	10.28	8.20	6.38
Mukuvisi	R_{R4}	-	2.0	3.72	3.60	3.87	3.99
Manyame (d/s)	C_{R2}	<5	1.4	5.69	5.63	5.48	4.90
Marimba	R_{R5}	-	8.7	6.18	5.85	7.68	7.29
Muzururu	R_{R6}	-	0.5	0.89	0.95	0.78	0.82
Gwebi	R_{R7}	-	1.6	1.56	1.68	1.35	1.43

The projected BOD concentration at the C_{R1} WQCP is less than the environmental water quality standard through the future under the assumed conditions. While, that at the C_{R2} seems to be at the ceiling to meet the water quality standard.

Projected Future Pollution Load Concentration at WQCPs of Lakes unit: mg/l

Lake/Dam	WQ CP	Quality Standard		Present	Scenario 1		Scenario 2	
		2005	2015		2005	2015	2005	2015
T-N								
Seke & Harava	C_{L1}	<0.4	<0.2	0.65	0.73	0.83	0.71	0.80
L. Chivero	C_{L2}	<0.4	<0.2	0.51	0.77	0.94	0.66	0.86
L. Manyame	C_{L3}	<0.4	<0.2	0.75	0.74	0.76	0.73	0.74
T-P								
Seke & Harava	C_{L1}	<0.05	<0.01	0.07	0.08	0.11	0.08	0.11
L. Chivero	C_{L2}	<0.10	<0.01	0.27	0.46	0.55	0.41	0.51
L. Manyame	C_{L3}	<0.03	<0.01	0.04	0.04	0.04	0.04	0.04
COD_{Cr}								
Seke & Harava	C_{L1}	<10	<6	20.63	22.31	31.18	21.86	30.57
L. Chivero	C_{L2}	<16	<6	25.30	38.65	44.77	35.51	42.69
L. Manyame	C_{L3}	<16	<6	22.70	20.30	21.44	19.92	21.02

The Seke/Harava Dams and Lake Manyame show almost constant water quality from the present time through the future. However, the water quality of Lake Chivero will be worse to some extent in the future.

4. Recommendations on the Reduction of Pollution Load

- Rehabilitation and augmentation of the existing sewerage systems
- Provision of wastewater treatment facilities at the WTW
- Removal of sedimentation on bottom of lakes/dams, and purification of lake water by cultivation and removal of water hyacinth
- Relocation of population, industries and livestock to outside of the basin
- Monitoring of water quality and flow at selective sampling points to update/modify measures

5. Sewerage Master Plan

Physical Development Requirements

Sewerage System	Sewer Reticulation			Sewage Treatment			Construction Cost	
	Diameter (mm)	Length (km)	No. of P.S.	Required Expansion Capacity (m^3/day)		Treatment Method	(million Z$)	
				2005	2015		2005	2015
Crowborough	500-1,350	35.6	1	94,100	124,900	BNR	1,004.62	283.10
	400-1,200	35.6	1	38,700	70,200	BNR	611.32	287.18
Firle	800-1,200	34.7	1	176,100	237,700	BNR	1,456.06	478.51
	800-1,200	34.7	1	133,300	205,900	BNR	1,196.52	551.28
Marlborough	None	None	None	0	2,800	WSP	0	84.27
	None	None	None	0	600	WSP	0	50.35
Donnybrook *	None	None	None	2,400	6,800	WSP	44.84	84.27
	None	None	None	2,900	6,200	WSP	51.78	68.12
Harare South	700-1,800	20.5	1	63,600	92,100	BNR	843.89	356.35
	600-1,350	20.5	1	47,100	47,400	BNR	664.33	151.42
Harare East	900-1,350	12.0	None	6,300	37,600	BNR	156.18	322.62
	900-1,350	12.0	None	6,300	37,600	BNR	156.18	322.62
Sub-Total	500-1,800	102.8	3	342,500	501,900	N/A	3,505.59	1,609.31
	400-1,350	102.8	3	228,300	367,900	N/A	2,680.13	1,430.97
Zengeza	450-1,000	35.2	3	18,300	49,800	BNR	239.96	423.03
	500-1,200	35.2	3	37,700	87,300	BNR	404.89	551.48
Norton	300-1,100	26.3	2	9,000	37,900	TF	186.20	438.71
	250-900	26.3	2	4,200	23,100	TF	139.56	336.59
Ruwa	200-1,000	22.8	4	7,900	13,100	WSP	298.21	101.75
	150-600	22.8	4	0	400	WSP	131.58	31.07
Total	200-1,800	187.1	12	377,700	602,700	N/A	4,229.96	2,572.80
	150-1,350	187.1	12	270,200	478,700	N/A	3,356.16	2,350.11

Note: Scenario-1 Cost; 1996 price base
Scenario-2

*; The City of Harare currently undertakes the feasibility study for the BNR process

O & M Cost unit: Mill Z$/year

Scenario	2005	2015
Scenario-1	78.67	114.87
Scenario-2	62.00	97.04

6. Institutional and Legal Arrangements (to be established/strengthened)

- "Upper Manyame River Basin Authority"
- Water Act and relevant water regulation
- "Water Pollution Control Board"
- monitoring and feedback system

7. Implementation Schedule (two alternatives)

(1) Alternative 1 (Scenario 1 & 2)

First Phase (- 2000)	Second Phase (2001 - 2005)	Third Phase (2006 - 2015)
Short-term development	Medium-term development	Long-term development
Sewer Reticulation	Sewer Reticulation	Sewer Reticulation
Harare (4 works) Norton Ruwa Chitungwiza	Harare (4 works) Norton Ruwa Chitungwiza	Harare (6 works) Norton Ruwa Chitungwiza
Sewage Treatment Works	Sewage Treatment Works	Sewage Treatment Works
BNR Chitungwiza	BNR Harare (4 works) Chitungwiza WSP Harare Ruwa	BNR Harare (4 works) Chitungwiza WSP Harare Ruwa TF Norton

(2) Alternative 2 (Scenario 1 & 2)

The third phase in alternative 1 is postponed beyond the year 2015.

PART-II FEASIBILITY STUDY FOR THE PRIORITY PROJECT

1. Study Area: Chitungwiza Municipality; area covered - 42 km^2; present population - 400,000

2. Design Fundamentals in 2000: population - 489,000; sewage flow - 41,500 m^3/day

3. Sewage Collection System

- Rehabilitation/modification plan: three existing pump stations (St.Mary's No.1, No.2 and Tilcor)
- Expansion plan: gravity trunk sewer (AC pipe, 525 mm^{dia}, 4,280m^{L}), a pump station and force main (AC pipe, 300 mm^{dia}, 2,600m^{L})

4. Sewage and Sludge Treatment and Disposal

- Rehabilitation of existing facilities: existing Zengeza STW, effluent transmission pump facility and Tilcor pre-treatment facility
- Expansion of the Zengeza STW:

Facility	Unit	Facility	Unit
Distribution Chamber	2 units	Anaerobic Digestion Tank	2 units
Screen & Grit Chamber	2 units	Sludge Drying Bed	6 units
Primary Sedimentation Tank	6 units	Sludge Stock Yard	1 unit
BNR Reactor	2 units	Sludge Disposal Pit	1 unit
Final Sedimentation Tank	4 units	Laboratory & Elect. Room	1 unit
Outlet Work	1 unit	Inplant Pipe	1 unit
Sludge Thickener	2 units		

5. Construction and O & M Cost

- Construction Cost

Description	Foreign (Z$)	Local (Z$)	Total (Z$)	Total (US$)
I. Direct Construction Cost	105,040,937	78,140,785	183,181,722	17,445,878
II. Land Acquisition and Compensation	0	0	0	0
III. Administration Expenses	0	4,000,000	4,000,000	380,952
IV. Engineering Services	14,013,402	2,472,953	16,486,355	1,570,129
Total (I,II,III and IV)	119,054,339	84,613,738	203,668,077	19,396,960
V. Physical Contingency	11,905,434	8,461,374	20,366,808	1,939,696
Total (I,II,III,IV and V)	130,959,773	93,075,112	224,034,885	21,336,656
VI. Price Escalation	7,688,000	51,588,000	59,276,000	5,645,333
Grand Total	138,647,773	144,663,112	283,310,885	26,981,989

Note: Foreign - imported materials and equipment; Local - indigenous materials and labor;
Direct Construction Cost - including direct, indirect (overhead and profit) construction cost

- O & M Cost: Sewer reticulation; Z$ 3,646,000 /year
  Sewage Treatment Works; Z$ 9,069,000 /year

6. Institutional and Legal Arrangements (to be established)

- Project Coordination Committee (PCC)
- Project Management Office (PMO)
- Water Quality Laboratory
- Wastewater Inspectorate
- Task Force for Legal Arrangement

7. Implementation Plan

(1) First stage : Action Programs for institutional, legal and financial arrangements
(2) Second stage : Detail design of the facilities
(3) Third stage : Construction of the facilities

8. Project Evaluation

The project will contribute to the improvement of water environment and to replenish water sources. In addition, sludge reuse and provision of sustainable organisation and employment opportunities are expected. However, a serious constraint was identified to finance construction cost, although revenue would be sufficient to recover O & M enpenses.

WATER POLLUTION CONTROL MASTER PLAN
FOR
THE UPPER MANYAME RIVER BASIN

VOLUME 1
SUMMARY REPORT

TABLE OF CONTENTS

PART II
FEASIBILITY STUDY
FOR
REHABILITATION/EXPANSION
OF
THE ZENGEZA SEWAGE WORKS

LIST OF TABLES

PART I
WATER POLLUTION CONTROL MASTER PLAN
FOR
THE UPPER MANYAME RIVER BASIN

PART II

FEASIBILITY STUDY
FOR
REHABILITATION/EXPANSION
OF
THE ZENGEZA SEWAGE WORKS

LIST OF FIGURES

PART I
WATER POLLUTION CONTROL MASTER PLAN
FOR
THE UPPER MANYAME RIVER BASIN

PART II

FEASIBILITY STUDY

FOR

REHABILITATION/EXPANSION

OF

THE ZENGEZA SEWAGE WORKS

GENERAL INTRODUCTION

1.1 Background of the Study

The Upper Manyame River Basin covers some 3,900 km^2 and is home to the capital of city of Zimbabwe, Harare. The river basin provides an important resource for water supply, irrigation, navigation, fishing and recreation. Within the basin are located an estimated 1.5 million people and five (5) urban areas. The main water source for these people are two (2) lakes, Lake Chivero and Lake Manyame.

However, water pollution, due to rapid urbanization and industrialization within the basin, as well as the increasing use of fertilizers in the agricultural sector, has become an increasingly serious threat to the human and animal life in the river basin.

To combat the dangers posed to the environment in the Upper Manyame River Basin, the Government of the Republic of Zimbabwe requested assistance from the Government of Japan. In response to this, the Japan International Cooperation Agency (JICA) extended technical cooperation assistance to Zimbabwe, represented by the Ministry of Local Government, Urban and Rural Development (MLGRUD), to prepare a water pollution control master plan for the basin and feasibility study for the urgent project selected in the master plan.

1.2 Objectives of the Study

The objective of the study are; (1) to formulate a comprehensive water pollution control master plan for the Upper Manyame River Basin for the target year 2015 to secure a potable water supply and to establish sustainable pollution control systems; (2) to conduct a feasibility study for the priority project identified in the master plan.

1.3 Study Area

The study area covers the Upper Manyame River Basin, which entails Harare City and three (3) provinces: Mashonaland East, Mashonaland Central and Mashonaland West. The total area of the Study Area is 118,575.45 km^2 and encompasses the following administrative entities:

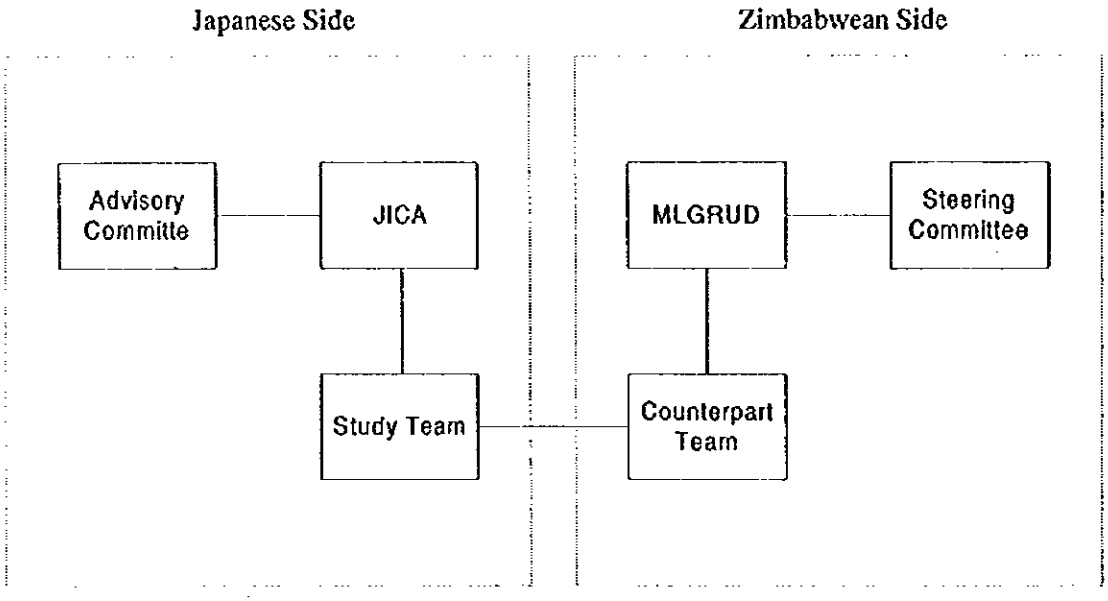
Mashonaland East	Mashonaland Central	Mashonaland West	Harare City
- Chitungwiza Municipality Council - Ruwa Local Board - Epworth Local Board - Goromonzi RDC - Manyame RDC - Harare RDC - Marondera RDC	- Mazowe RDC	- Norton Town Council - Chegutu RDC - Zvimba RDC	- Harare City Council

Note: RDC is Rural District Council

1.4 Study Organisation

1.4.1 General Organisation

The General Organisation for the Study is shown below.



Note: JICA Japan International Cooperation Agency
MLGRUD Ministry of Local Government, Rural and Urban Development

1.4.2 Japanese Organisation

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

The members of the Study Team are as follows:

Name	Field of Expertise/Responsibility
Mr. Masatoshi Momose	Project Manager
Mr. Hirofumi Sano	Sewerage Planning
Mr. Takafumi Kiguchi	Water Pollution Analysis
Mr. Toshiki Naka	Sewerage Facilities
Mr. Shushaku Ueno	Water Use Planning
Mr. Fumihiko Furuichi	Organization and Institution
Mr. Munenori Tada	Economic and Financial Analysis
Mr. Takuo Kozawa	Construction Planning and Cost Estimation
Mr. Hiroshi Terayama	Water Quality Analysis and Monitoring
Mr. Takashi Watanabe	Environmental Study

The members of the Advisory Committee are as follows:

Name	Position	Present Post
Dr. Kuniharu Yoshimoto	Chairman	Counselor, Japan Regional Development Corp.
Mr. Akira Morishima	Water Pollution Control	Japan Environment Corp.

1.4.3 Zimbabwe Organisation

The Zimbabwe organization consists of the Counterpart Team and the Steering Committee, operating in coordination with the MLGRUD. The members of the Counterpart Team are as follows:

Local Government	Name	Related Field
Harare City	Mr. Z. Hoko	Engineer, Dept. of Works
Chitungwiza Municipality	Mr. Petros Mbira	Engineer, Water & Sewerage
Norton Town Council	Mr. Phakamile Ndebele	Deputy Town Engineer
Ruwa Local Board	Mr. Cornelius Piroro	Technician, Water and Sewerage

The members of the Steering Committee are as follows:

Ministry/Name	Position
<u>MLGRUD</u>	
Mr. A.C. Mpamhanga	Director, Dept. of Development, Planning and Coordination
Mr. J.T. Mutamiri	Deputy Director, -ditto-
Mrs. S. N. Musungwa	Assistant Secretary, -ditto-
Mr. P.F. Duri	Senior Administrative Officer, -ditto-
Mr. A. F. N. Mangena	Acting Assistant Secretary, -ditto-

Ministry/Name	Position
MLGRUD	
Mr. M. R. Ziracha	Principal Planner
Mr. J. Mugabe	Administrative Officer, Dept. of Development, Planning and Coordination
President's Office & Cabinet	
Mrs. S.C. Madzinga	Deputy Director, Scientific Liaison Office
NEPC	
Mr. Lovemore Mujuru	Assistant Chief Economist
Ministry of Finance	
Mr. Njodzi Bwerinofa	Senior Administrative Officer
Min. of Tranporat & Energy	
Mr. L.D. Sigauke	Act. Chief Testing & Research Officer, Dept. of State Roads
Mr. J. Hwindingwi	Chief Testing & Research Officer, Dept. of State Roads
Ministry of Environment & Tourism	
Mr. G. Mangwiro	Assist. Director, Environmental Health Services Dept.
Mr. M. Kadzatsa	Port Health Coordinator, Environ. Health Services Dept.
Mr. G. Chaumba	Pollution Officer, Environmental Health Services Dept.
Ministry of Agriculture	
Mr. M. Chizanbire	Project Section
Mr. S.M. Mushiri	Soil Chemist, Dept. of Research & Specialist Services
City of Harare	
Mr. E. Mudzuri	Deputy Chief Engineer, Water & Sewerage, Dept. of Works
Mrs. Mufaro Jarawaza	Chief Chemist, Engineering Services Dept., Dept. of Works
Mr. Z. Hoko	Engineer, Dept. of Works
Chitungwiza Municipality	
Mr. M. Khosla	Director, Engineering Services
Mr. Petros Mbira	Engineer, Water & Sewerage
Norton Town Council	
Mr. Mr. G. Magombedze	Town Engineer
Ruwa Local Board	
Mrs. J. Makombe	Secretary
Mr. Cornelius Piroro	Technician, Water and Sewerage
Epworth Local Board	
Mrs. R.S. Chakazamba	Administration Officer

1.5 Reports

The study reports prepared are as follows:

(1) Summary Report (Volume I)

(2) Main Report (Volume II-1, Volume II-2)

(3) Supporting Report (Volume III)

(4) Data Report (Volume IV)

The main report presents the results of the entire study. It consists of two (2) parts: Part-I, the Water Pollution Control Master Plan and Part-II, the Feasibility Study for Rehabilitation/ Expansion of the Zengeza Sewage Works in Chitungwiza Municipality.

Part-I presents a water pollution analysis and recommendations on the required counter-measures for water pollution control in the Upper Manyame River Basin. The findings and field measurement results conducted during the Stage I field work in Zimbabwe formed the primary study base of this comprehensive basin-wide water pollution control master plan. Numerous sectoral reports prepared by agencies of the Government of Zimbabwe were also fully reviewed in this study.

Part-II presents a preliminary engineering design for the Zengeza Sewage Works in Chitungwiza Municipality, which was selected from among five (5) municipalities to be a priority project.

PART I

WATER POLLUTION MASTER PLAN FOR THE UPPER MANYAME RIVER BASIN

PART-I WATER POLLUTION CONTROL MASTER PLAN

CHAPTER 1 Introduction

The basin-wide water pollution control plan was prepared in full use of the investigation results stemming from field work in Zimbabwe carried out during the Stage 1 work. The planning work for the water pollution control in Chapter 2 covers the following main components:

(1) Establishment of fundamentals for water pollution analysis
(2) Present and future pollution analysis
(3) Pollution load to be reduced by different pollution source
(4) Countermeasures to be required by pollution source
(5) Implementation plan for countermeasures

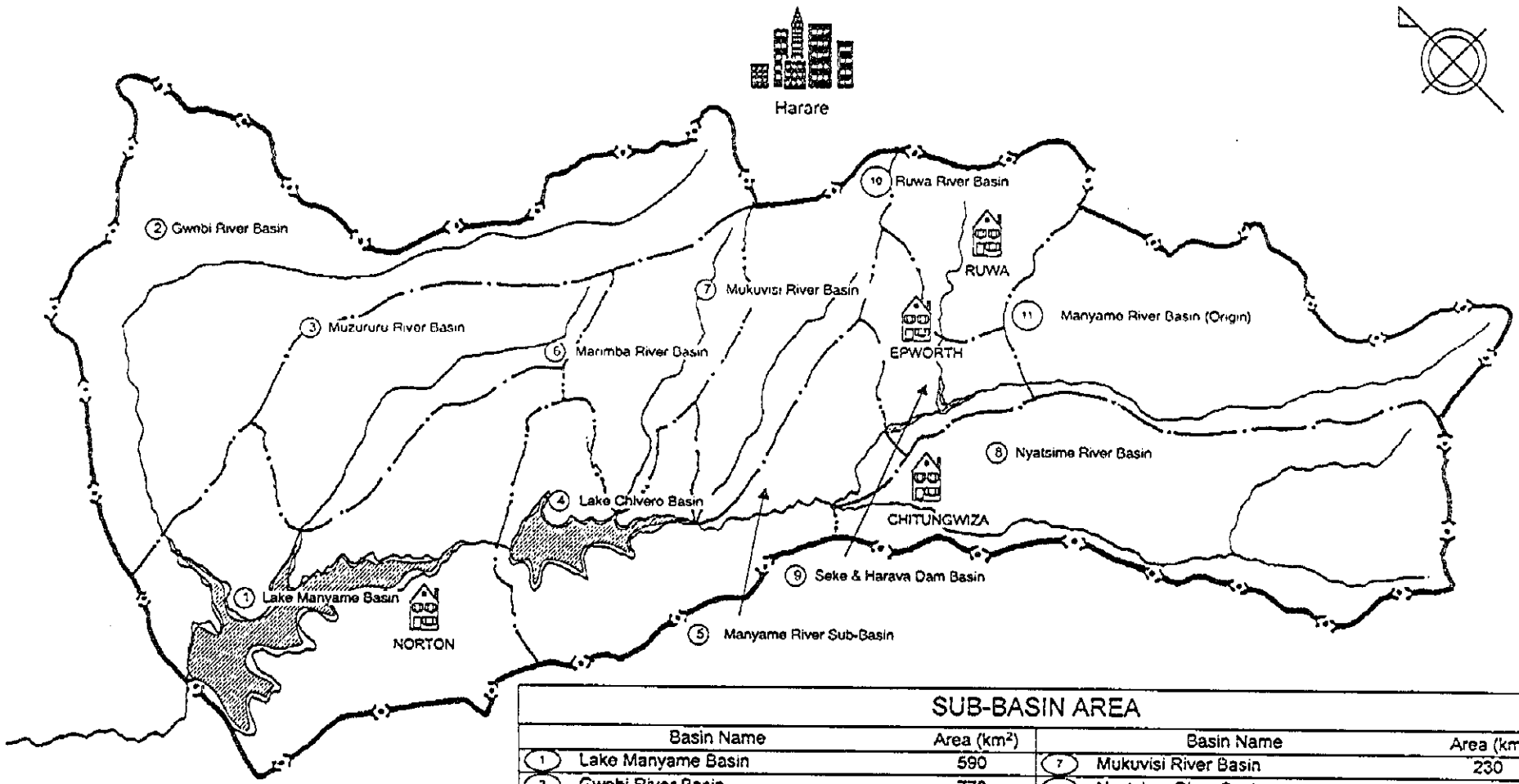
The priority project to meet the urgent needs of the Study Area was selected based on the study conducted in the Stage 1 field work as summarized in Supporting Report in reference to the public sewerage projects. The IEE was also completed and included in Chapter 3.

CHAPTER 2 Master Plan for Water Pollution Control in the Upper Manyame River Basin

2.1 Administrative Composition and Physical Characteristics in the Study Area

The Study Area covers Harare City and some portions of the three provinces, including Mashonaland East, Mashonaland Central and Mashonaland West. The urban councils in the Study Area include the City of Harare, the Municipality of Chitungwiza, the Town of Norton, and the Ruwa and Epworth Local Boards. The study basin covers a total of 3,900 km^2 , consisting of 551 km^2 of urban areas and 3,349 km^2 of Rural District areas. The total population in the Study Area at present is 1,870,000 (92 % urban). Figure 2.1 shows the Upper Manyame River Basin and Table 2.1 shows the present population and areas in the Study Area.

The mean total annual rainfall is approximately 820 mm, about 80 % of which is concentrated in the summer season. Most of the Study Area lies 1,400 to 1,500 meters above sea level and is generally a gently undulating featureless plateau. There are six tributaries of the main river and four lakes/dams (Harava Dam, Seke Dam, Lake Chivero and Lake



SUB-BASIN AREA			
Basin Name	Area (km²)	Basin Name	Area (km²)
1 Lake Manyame Basin	590	7 Mukuvisi River Basin	230
2 Gwebi River Basin	770	8 Nyatsime River Basin	580
3 Muzururu River Basin	310	9 Seke & Harava Dam Basin	115
4 Lake Chivero Basin	255	10 Ruwa River Basin	195
5 Manyame River Sub-Basin	166	11 Manyame River Basin (Origin)	474
6 Marimba River Basin	215	Total	3,900

FIGURE 2.1 UPPER MANYAME RIVER BASIN

Table 2.1 Present population and Areas in the Study Area

Province/Charted City			Urban Council (within Study Area)			Rural District Council (within Study Area)		
Name	Area (km^2)	Population (1992)	Name	Area (km^2)	Population (1992)	Name	Area (km^2)	Population (1992)
Harare City	557.45	1,126,473	Harare City	447.1	* 1,214,119	N.A		
Mashonaland East	32,230.00	1,034,342	Chitungwiza Municipality	42.0	274,912	Goromonji	495.6	29,325
			Ruwa Local Board	31.4	1,447	Manyame	534.1	15,521
			Epworth Local Board	11.1	62,630	Harare	258.9	21,600
						Marondera	226.6	6,828
Mashonaland Central	28,347.00	856,736	N.A			Mazowe	254.0	11,360
Mashonaland West	57,441.00	1,112,955	Norton Town	19.5	20,405	Chegutu	261.1	6,776
						Zvimba	1,318.6	48,950
Total	118,575.45	4,130,506		551.1	1,573,513		3,348.9	140,360

Note: *; Present population in 1993 (refer to Table 6.2.3 (1) to 6.2.3 (2) in Water Pollution Master Plan)

Manyame). The mean annual run-off of the Manyame River in the last ten years was 97 x 10^6 m^3.

The Study Area falls in the Natural Region II Agro-Ecological classification and is considered as an intensive farming region of the country.

2.2 Environmental Management and Water Pollution Status

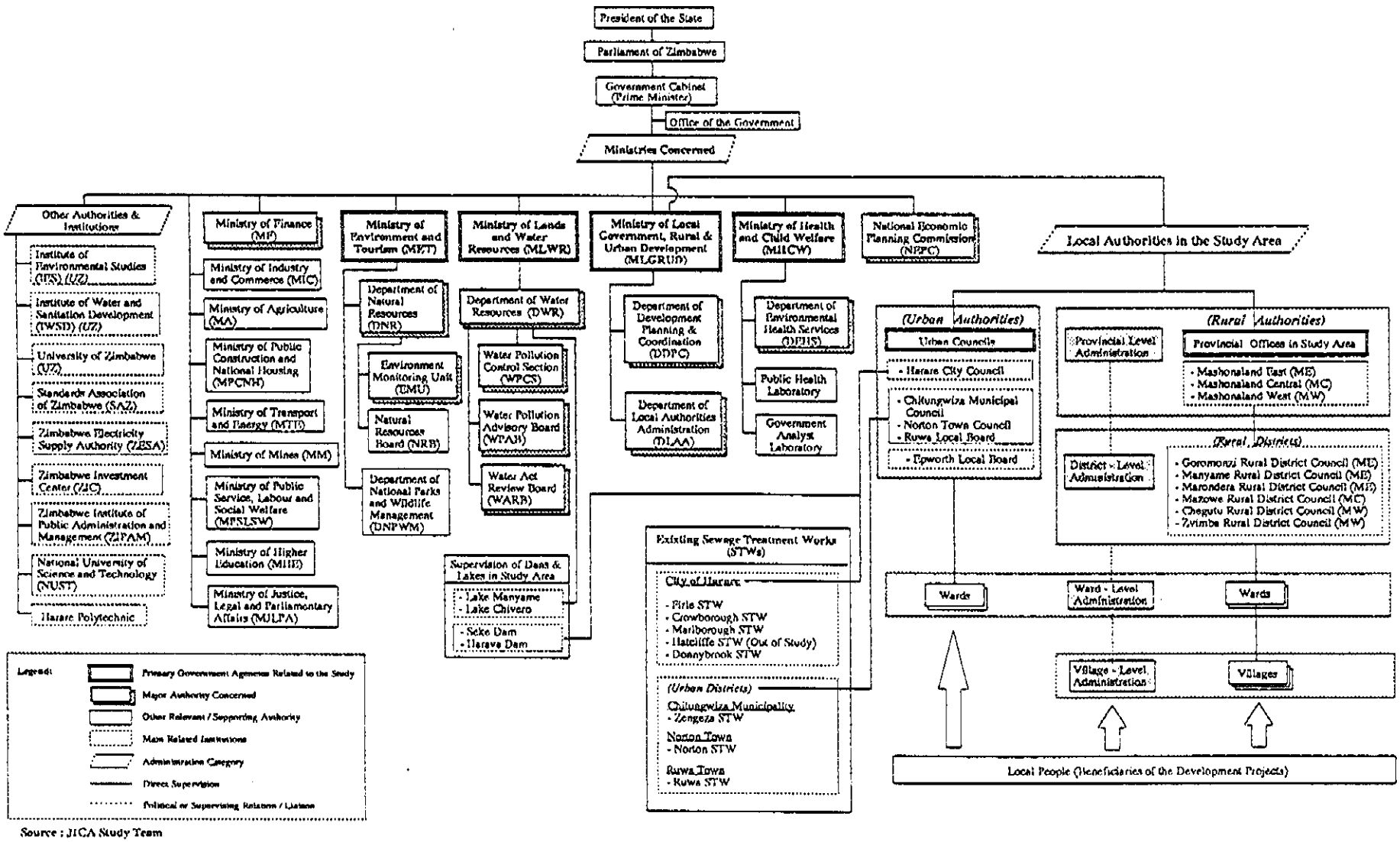
The administrative/institutional arrangements related to water pollution control are made both at the national and local levels, while sewage works are essentially a local function. Figure 2.2 presents the organisation structure for water pollution control in Zimbabwe.

In Zimbabwe, there exist various institutions which train/educate people in the courses directly and indirectly related to water pollution control.

The Government of Zimbabwe promotes policies to decentralize the present administrative system to the provincial and local authorities. The Government is in the process of formulating a national vision including a long-term development strategy which is called "Zimbabwe Vision 2020". In addition, the "Medium Term Action Plan Framework" to follow-up the "Second Five-Year National Development Plan" is under preparation. The local authorities have prepared development plans/projects especially relating to sewage treatment improvement based on the "Regional, Town and Country Planning Act, 1976".

The relevant laws and regulations currently dealing with water pollution control are the Water Act, the Public Health Act, the Public Health (Effluent) Regulations, 1972 and the Water (Effluent and Wastewater Standards) Regulations, 1977.

The implementation of water supply and sanitation projects is principally under the responsibility of the local authorities. The public investment in the urban sector takes the form of lending from the central government to the local authorities. Capital is credited to the local authorities in the form of long-term loans, whose sources are the domestic financial market as well as multilateral and bilateral aid. Except for the general administration account, the revenue of the local authorities are financed by tariffs, flat monthly charges and rent levied by the urban councils and are intended to cover the full cost required for their



Source : JICA Study Team

Figure 2.2 Organization Structure for Water Pollution Control in Zimbabwe
(Main Agencies & Institutions Related to the Implementatin of Water Pollution Control Projects)

respective services. Figure 2.3 shows the procedure flow for implementation of the water pollution control projects.

The environmental management takes the form of project components (public sewerage systems, and solid waste collection and disposal), and supporting activities (monitoring of water quality, and institutional and training programs) in the field of sanitation and water pollution control. Financial arrangements for the project components consist of capital expenditure, and operation and maintenance of the facilities. Projects for water pollution control are principally under the jurisdiction of local governments. The National Government provides capital funds to local governments on a loan basis only. Operation and maintenance costs are financed by the local governments. Accordingly, the financial status of the local authority is the key issue for the analysis of financial arrangements for capital expenditures and operation and maintenance costs. Water quality monitoring and training programs are financed through the budget of the relevant institutions such as central government agencies and the local governments.

The competent authorities for water quality examination and monitoring are MLWR at the national government level and the City of Harare at the local government level. Figure 2.4 shows the locations of self-recording water level surveillance stations and water sampling points in the study area.

The present water pollution status of the water body was analyzed and the present water quality of the rivers was found to be within the allowable levels in terms of fishery purposes (organic substances). The recent improvement of the water quality was mainly attributed to countermeasures provided in 1995, wherein it was decided to cease effluent discharge from the Zengeza STW into the Nyatsime River.

The water quality of the lakes/dams is characterized by its high concentration of T-N and T-P, which exceeds the critical eutrophication level/oligotrophic lake (T-N > 0.2 mg/l and T-P > 0.02 mg/l). In addition, the COD concentration is three to six times higher than the allowable level for drinking water purpose. Heavy metals (Zn, Ni, Fe and Cd) were detected in the water body; however, the concentrations were within the allowable levels for drinking water sources (WHO standard). Agricultural chemicals were not detected through the examination of this study.

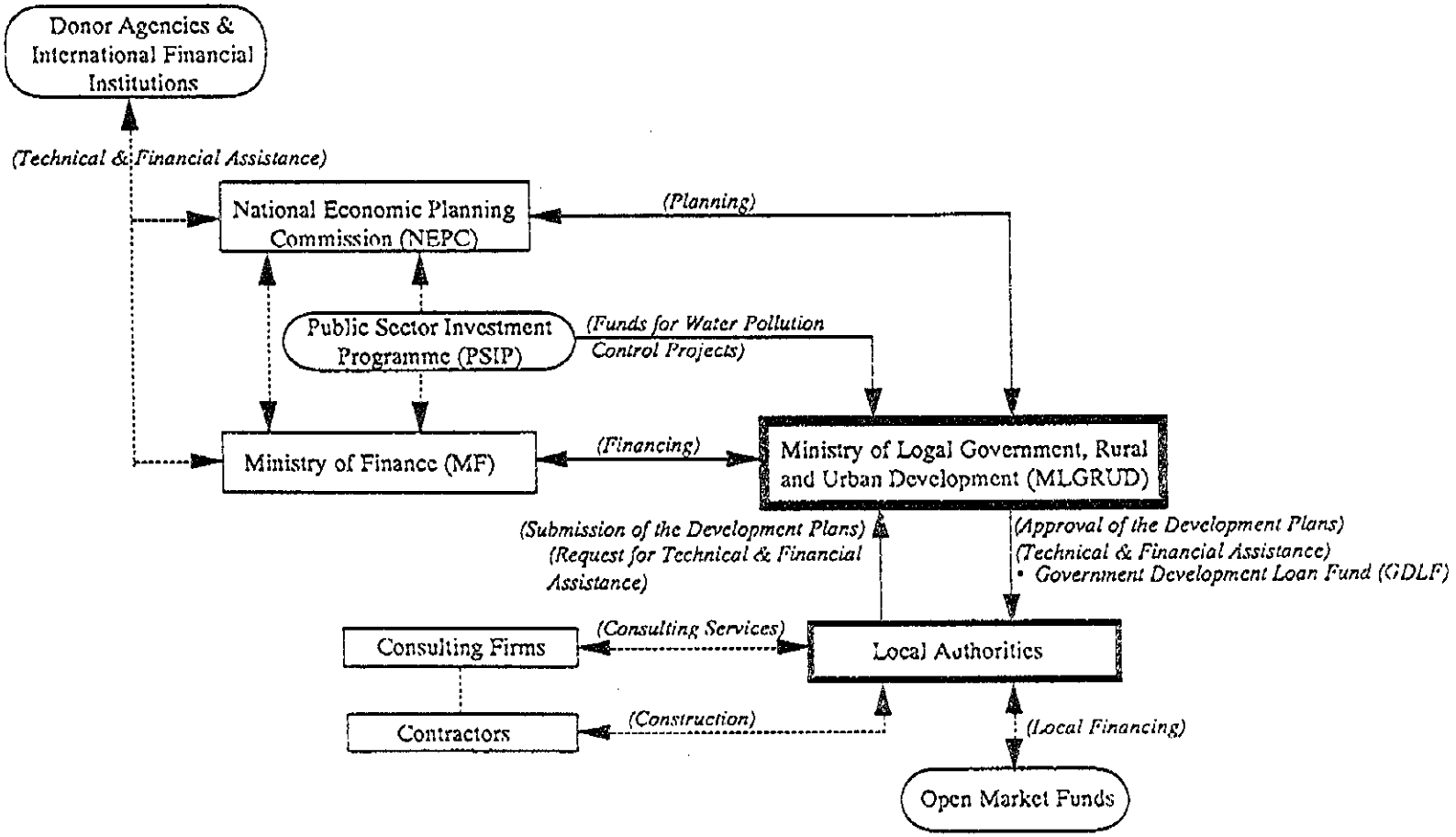


Figure 2.3 Procedure Flow for Implementation of the Water Pollution Control Projects

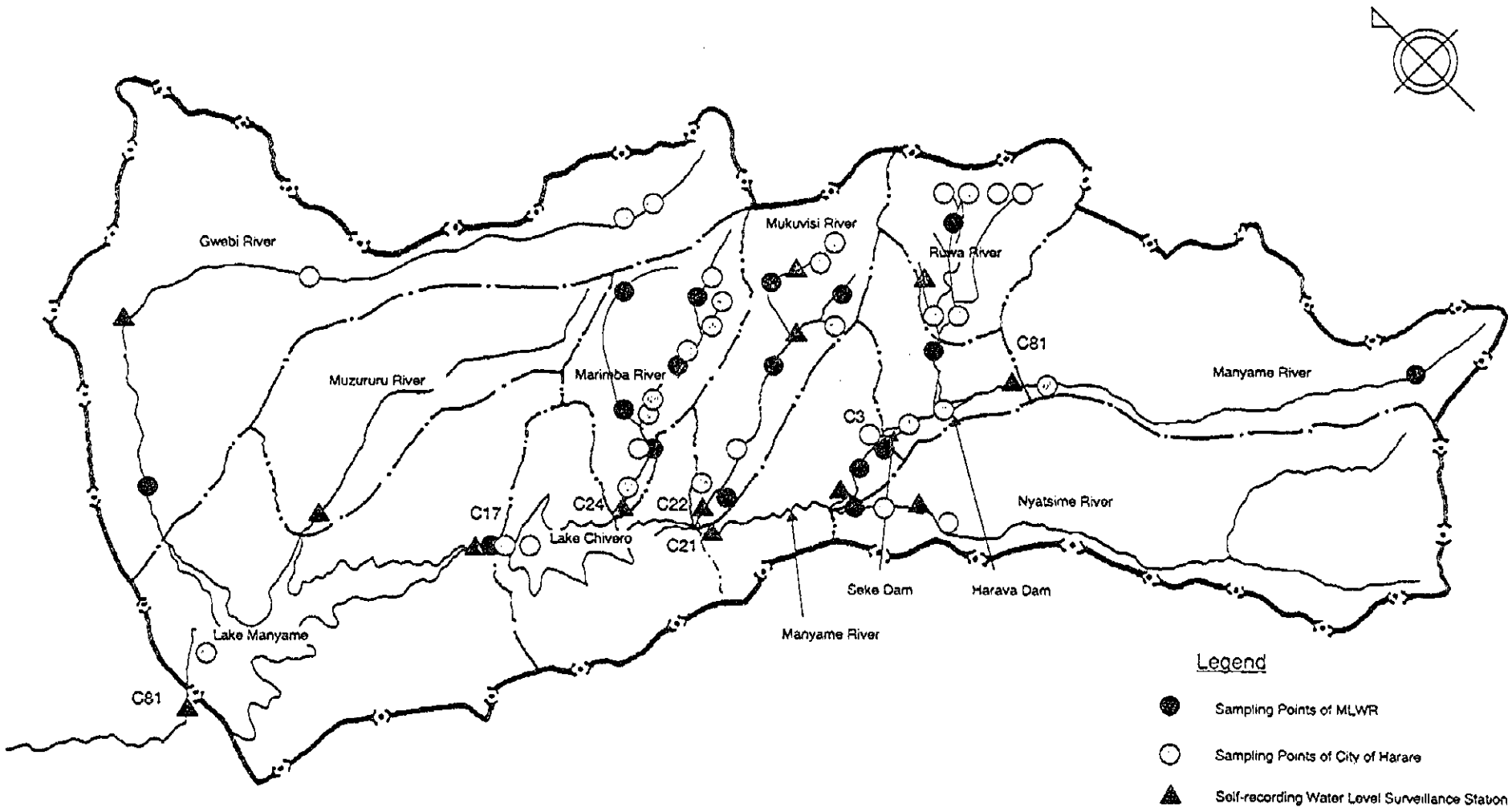


Figure 2.4 The Locations of Self-recording Water Level Surveillance Station and Water Sampling Points in the Upper Manyame River Basin

A water quality examination of 45 large-scale factories belonging to eight major types of industry in the Study Area was conducted especially in relation to organic substances. Almost all factories were exceeding the effluent standards of the major pollution indices; BOD; COD, SS, TN, TP, Fe, Ni, Pb and Zn. Three industrial types: processed foodstuffs, pulp/paper and related products, and chemicals were found to be major pollution sources.

The BOD of the inflow sewage to the existing STWs ranges from 480 to 970 mg/l. Only the effluent from the process of BNR at the Crowborough and Firle STWs, which conform to the requirements of the Water Act, is discharged to the rivers, while the rest are discharged to pasture or forestry lands for irrigation purpose. As to heavy metals the influent load is small.

2.3 Sanitation Conditions and Water Pollution Control Measures at Present and in the Future

A part of the low density residential areas in the urban areas and entire rural areas use septic tanks and other types of toilet facilities, while many of the residents in the remaining urban areas are served by public sewerage systems.

The urban areas in the Study Area have public sewerage systems except for Epworth. There are five individual served areas in Harare, while other urban councils operate each one sewerage system. The service coverage by the respective existing sewerage systems is almost 100 %, except for the Norton and Ruwa Sewage Works. The existing sewer systems in Harare City and Chitungwiza municipality are reported to have some sections with damage resulting in rising offensive odour problems and health hazards. With regard to sewage treatment, the File and Zengeza STWs are considerably overloaded, while the Norton and Ruwa STWs have room at their treatment capacities. Of the larger three STWs, only the Zengeza STW does not have facilities to discharge treated effluent to the water course. Most of the treated effluent is used for irrigation, which is common to all STWs. Table 2.2 and 2.3 presents the sewered area and population, and the list of the existing STWs.

Improvement project for the sewers were planned within a limited scope of work in the Firle and Ruwa STWs, while there is no on-going construction work for sewers in the five STWs. Plans and designs were prepared for expansion of the sewage treatment facilities at the Crowborough, Donnybrook, Zengeza, Norton and Ruwa STWs. The BNR treatment facilities at the Firle

Table 2.2 Sewered Area and Population in 1995

Item	Harare City		Chitungwiza Municipality	Norton Town	Ruwa Local Board	Total
Municipal Area (ha)		55,745	4,200	1,950	3,140	65,035
Sewered Area (ha)	Crowborough	17,400	4,200	1,950	3,140	48,193
	Firle	19,435				
	Marlborough	378				
	Donnybrook	1,690				
	Hatcliff					
	Total	38,903				
Municipal Population *1		1,296,000	420,000	22,000	2,000	1,740,000
Served Population *2	Crowborough	506,200	420,000	21,000	1,600	1,638,400
	Firle	600,800				
	Marlborough	9,800				
	Donnybrook	79,000				
	Hatcliffe	N.A.				
	Total	1,195,800				
Treatment Area No.	5		1	1	1	
Trunk Sewer and	Crowborough		Zengeza	Norton	Ruwa	
Pump Station (PS)	835mm		675mm		375mm	
by each treatment Area	875mm		675mm			
	PS 3		300mm			
			PS 4	PS 2	PS 2	
	Firle					
	1,200mm in 1972					
	1,350mm in 1972					
	PS 3					

Note: *1; Projected population (refer to Table 6.2.7 (3) in Water Pollution Master Plan)
*2; Refer to Table 9.3.1 in Water Pollution Master Plan

Table 2.3 List of Existing Sewage Treatment Works

Urban Authority	Sewage Treatment Works	Treatment method	Design Capacity m3/d	Present influent Flow m3/d	Note (Construction Time)
Harare City	Crowborough	TF	36,000	39,325	Unit 1 1957
					Unit 2 1970's
		BNR	18,000	15,986	Unit 3 1980's
		BNR	*1 (25,000)	-	Unit 4 1996 to
			(79,000)		Total in the future
			54,000	55,311	
	Firle	TF	36,000	104,636	Unit 1 1960
					Unit 2 1970's
		BNR	36,000	12,403	Unit 3 1979 to 1981
				15,252	Unit 4 1986 to 1996
		BNR	(72,000)	-	Unit 5(I) 1994 to 1996
					Unit 5(II) 1995 to 1997
			(144,000)		Total in the future
			72,000	132,291	
	Marlborough	WSP	2,000	2,000	
	Donnybrook				
	Block 1	WSP	-	400	
	Block 2	WSP	-	1,350	
	Block 3	WSP	-	1,396	
	Block 4	WSP	-	2,351	
		Total	*2 5,500	5,497	
	Hatcliffe	AL	1,300	2,500	
Chitungwiza Municipality	Zengeza	TF	21,750	36,405	Under repair
Norton Town	Norton	TF	3,400	2,700	Unit 1 1953
					Unit 2 1975
					Under repair
Ruwa Local Board	Ruwa	WSP	5,300	2,865	1993
Total			(262,250)		
			165,250	239,569	

Note: Present influent flow is estimated based on the Average Dry Weather Flow (ADWF)
*1; The latest on-going plan for BNR of Crowborough is 60,000 m^3/day
*2; Design capacity (5,500 m^3/day) of Donnybrook (refer to Section 4.2, Chapter 2, Supporting Report)

TF; Trickling Filter
BNR; Biological Nutrient Removal
WSP; Wastewater Stabilitation Pond
AL; Aerated Lagoon

STW are under construction, while limited rehabilitation/construction work is being undertaken at the Zengeza and Norton STWs.

Strategic and staged improvements of sewer systems are required particularly in Harare City and Chitungwiza municipality. Environmental problems at the STW site and its surroundings are found at the Zengeza STW. A storage pond for irrigation at Norton STW is also identified to have such problems.

The control of wastewater from industry is subjected to the Urban Council Act. Each factory has a pre-treatment facility. The method of treatment is primarily settling along with fat and oil traps.

The urban drainage system in the Study Area has been constructed together with the roads and sewers. There are sometimes flooding problems during wet season and some channels are obstructed by dumped solid wastes, mainly in high density residential areas.

With regard to solid waste disposal, each local authority is managing in their respective jurisdictions. Solid waste collection is provided to both residential and industrial areas by means of trucks and tractors. The normal disposal method is dumping, compacting and covering with gravel to present flies, odour and other nuisances. The common problems identified are shortage of collection vehicles and dumping sites.

Effluent including back washing discharge and settled sludge at the existing WTWs was regarded as point pollution source. The countermeasures shall be taken to treat generated sludge containing chemicals and organic substances.

2.4 Socio-Economic Profile and Land Use at Present and in the Future

The settlement densities of the Study Area are among the highest in the country, accounting for 47 % of the national urban population. The city of Harare and the three urban centers designated as growth points make the Study Area one of the fastest growing areas in the country. The area's population growth rates are 6.5 % to 8.1 % per year. The households in the Study Area have substantially higher net incomes than the national average.

Land use in the Study basin is comprised of cultivated land, grazing land, forest land, and residential and business-related land as shown in Table 2.4. About two thirds of the Lake

Table 2.4 (1) Present and Future Land Use

Unit : km^2

Land Use			Present	2000	2005	2015
Harare City	Residential Area	Low Density	210.13	215.06	217.79	233.46
		Medium Density	12.21	24.26	37.02	37.02
		High Density	45.57	58.15	94.45	123.78
		Low/Medium Mixed Density	2.00	2.00	7.83	13.67
		Medium/High Mixed Density	6.01	6.01	6.01	7.47
		High Density High Income	2.72	2.72	2.72	2.72
		Sub-Total	278.64	308.20	365.82	418.12
	Central Business Area		3.83	3.83	3.83	3.83
	Suburban Business Area		0.00	0.00	0.00	14.38
	Industrial/Commercial Area		26.96	31.12	53.00	69.95
	Airport Area		0.00	15.13	15.13	15.13
	Cemetery Area		0.00	0.00	3.65	3.65
	Open Spaces		248.02	390.32	307.17	223.54
	Total		**557.45**	**748.60**	**748.60**	**748.60**
	Inside of Study Area		447.10	638.25	638.25	638.25
	Outside of Study Area		110.35	110.35	110.35	110.35
Chitungwiza Municipality	Residential Area	Low Density	0.00	0.00	0.00	2.14
		Medium Density	3.35	3.35	3.35	8.26
		High Density	19.47	21.22	21.22	26.67
		Sub-Total	22.82	24.57	24.57	37.07
	Industrial Area		1.35	1.35	1.35	9.41
	Town Centre (Commercial) Area		0.85	0.85	0.85	0.85
	Institutional Area		0.74	0.74	0.74	0.74
	Sewage Treatment Works Area		0.93	0.93	0.93	0.93
	Open Spaces		15.31	13.56	13.56	5.50
	Total		**42.00**	**42.00**	**42.00**	**54.50**

Table 2.4 (2) Present and Future Land Use (cont'd)

Unit : km^2

Land Use			Present	2000	2005	2015
Norton Town Council	Residential Area	Low Density	1.83	2.92	5.39	17.95
		Medium Density	0.20	0.20	2.12	5.50
		High Density	3.25	5.15	5.15	8.00
		Sub-Total	5.28	8.27	12.66	31.45
	Industrial Area		2.73	2.73	3.86	10.83
	Commercial Area		0.18	0.18	0.18	0.31
	Institutional Area		0.29	0.29	0.29	1.36
	Farm Land Area		0.00	0.00	1.04	4.90
	Sewage Works Area		1.22	1.22	1.22	1.22
	Refuse Dumping Area		0.00	0.00	0.00	0.56
	Open Spaces		9.80	8.81	7.65	8.97
	Total		19.50	21.50	26.90	59.60
Ruwa Local Board	Residential Area	Low Density	2.95	3.89	9.44	9.44
		Medium Density	0.18	0.18	0.18	2.66
		High Density	1.76	4.89	6.50	7.50
		Sub-Total	4.89	8.96	16.12	19.60
	Industrial Area		2.11	5.06	5.06	5.06
	Commercial Area		0.18	0.18	0.59	0.76
	Institutional Area		0.47	0.47	0.47	0.68
	Open Spaces		23.75	23.73	16.16	12.30
	Total		31.40	38.40	38.40	38.40
Grand Total			650.35	850.50	855.90	901.10

Chivero basin is vegetated and two thirds of the remaining third is cultivated. A future land use for the urban areas was prepared for the years 2000, 2005 and 2015.

2.5 Projection of Frame Values

A projection of the various frame values from the present (1995) to the final target year (2015) was made for the identified water pollution sources.

The national census results in 1992 were, in principle, employed for the 1992 urban population as the projection base for planning years. However, the present population of Chitungwiza as used in Harare Combination M/P was employed to meet the current situation. A distribution of the present population to the relevant river/lake sub-basins in Harare City was attempted. The population of the Study Area by local authority was projected referring to the previous study results.

Two scenarios on future population were constructed for the purpose of water pollution control planning among the four studied cases. The projected population of the Study Area in the year 2015 for scenario 1 and 2 are 4,035,097 and 3,575,878 as shown in Table 2.5, respectively.

Table 2.5 Population Projection for Two Scenarios

Scenario	Year 2000	Year 2005	Year 2015
Scenario-1	2,289,505	3,145,768	4,035,097
Scenario-2	2,319,790	2,707,119	3,575,878

The number of employees was adopted as a frame value for industrial development. Industry was classified into 19 types and then the number of employees and their ratio by type of industry was calculated. The future number of employees was estimated for each sub-basin on the assumption that this number will increase in accordance with the increase rate of the industrial area in the future land use plan. The total number of employees at present and in the year 2015 was estimated at 93,800 and 296,700 persons, respectively.

The present number of major livestock in the Study Area was provided by the Department of Veterinary Services of Ministry of Agriculture. The future figures for water pollution analysis are assumed to be unchanged under the current status of development.

Farmland and natural land were not separated for the water pollution study. With regard to solid waste dumping sites as potential pollution sources, the quantity of leachate at the landfill site was assumed to increase in proportion to the population growth.

2.6 Water Use and Hydrological Conditions of the Water Body through the Future

The direct use of river water is minimal due to the limited flow available during the dry season, while the reuse of treated effluent is dominant in the entire Study Area. On the other hand, lakes/dams are utilized for water supply (presently 477,000 m^3/d is availed), recreation and commercial fisheries purposes. At the present time, there is no plan on future water use in the study basin.

The Harare Water Supply System covers Harare City and its adjoining urban areas for the reported demand of 360,000 m^3/d. The raw water sources depend on four impoundments. Two existing WTWs, Prince Edward and Morton Jaffray, adopt conventional water treatment systems. The future water consumption for the year 2012 was projected using the Harare water supply master plan with three options ranging from 1,230,000 m^3/d to 1,868,000 m^3/d. Even under the assumption of full use of the treated effluent discharged from the STWs (600,000 m^3/d), a shortfall of 800,000 m^3/d is projected regarding the medium water demand (1,390,000 m^3/d). At present, a water source development program has been studied to utilize the water from Nyagui River.

Water quality standards are proposed for the main river and lakes/dams, in terms of environmental items taking into account of water use. While for health related items, it is deemed appropriate to adopt the same items with respective values as the WHO standards. Provisional standards are recommended for BOD, COD, T-N and T-P under the present water quality levels. For the monitoring of the water quality, water quality checking points and reference points are proposed as shown in Figure 2.5.

The flow pattern of the rivers, the water level and the discharge rate of the lakes were analysed to come up with the flow balance. The average overall run-off ratio in the study basin was 8.7 % in the last ten years, which is almost same as that in the whole of Zimbabwe (8 %). The balances between inflow and outflow in the annual average at the respective lakes/dams were studied considering the control factors: river flow, rainfall to the surface of

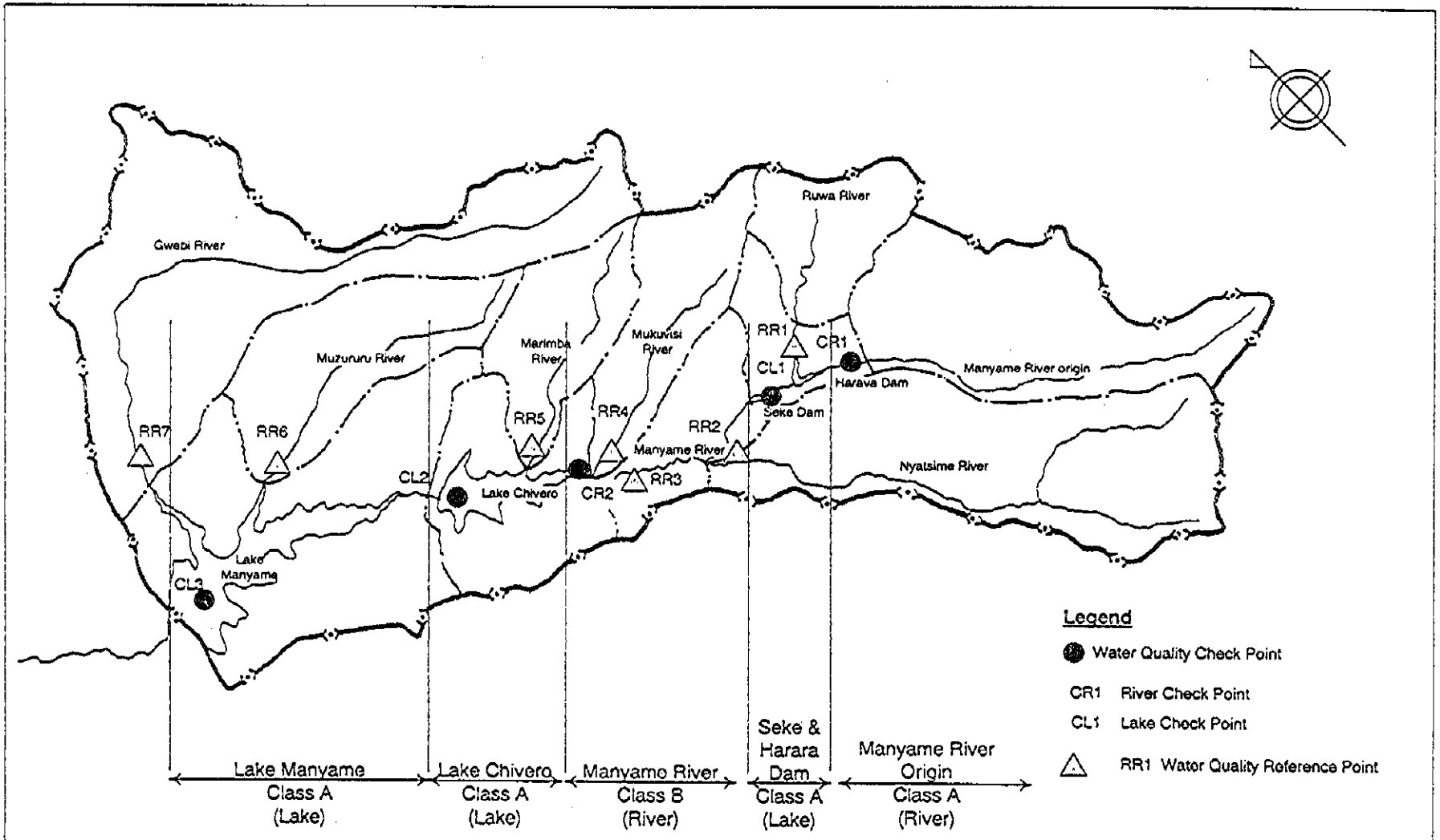


Figure 2.5 Environmental Water Quality Classification Check Points and Reference Points

the lake/dam and the flow from direct lake/dam catchment area for inflow and evaporation from the surface of lake/dam, water intake and discharge to the main river for outflow. In addition, the fluctuation of the water level of the lake/dams and miscellaneous flow were taken into account for the flow balance estimation. Future flow balance was studied using the relevant data in the last ten years. The STWs discharge to the rivers was assumed to be equivalent to the projected sewage flow of adopted BNR treatment process. The present discharge flow from Lake Manyame is assumed to be maintained through the future, assuming that the intake amount at the WTW will be controlled with reference to the treated effluent discharge levels from the STWs. Figure 2.6 and 2.7 show the flow model to be adopted in analysis of rivers or lakes by scenario.

2.7 Unit Wastewater Quantity and Quality

The unit wastewater quantity and quality for the target years by major pollution source were studied. References were made to the previous studies conducted in Zimbabwe for water supply and sewerage expansion/development. The factors used for this purpose are population, the number of employees by industrial type, the number of livestock and the land area for domestic sewage, industrial wastewater, livestock and farm land/undevelopped land, respectively. For the unit domestic sewage quantity, the figures used in "Harare Water Supply Master Plan" were employed. The unit industrial wastewater quantity and quality were derived from the results of the field survey.

2.8 Present Water Pollution Analysis

The present water pollution analysis was undertaken to establish the simulation model to be adopted for future water pollution analyses. The pollution load covers human-related and natural pollution both for point and non-point sources as shown in Figure 2.8. The flow model of the entire study basin was based on the average flow rates of the last 10 years.

The water quality indices to be used in the analysis for rivers is BOD; representing the water pollution by organic substances mainly caused by human activities. The run-off model for the dry season was applied for the pollution analysis of rivers. The pollution load remaining ratios of each river were derived through the pollution analysis of the rivers.

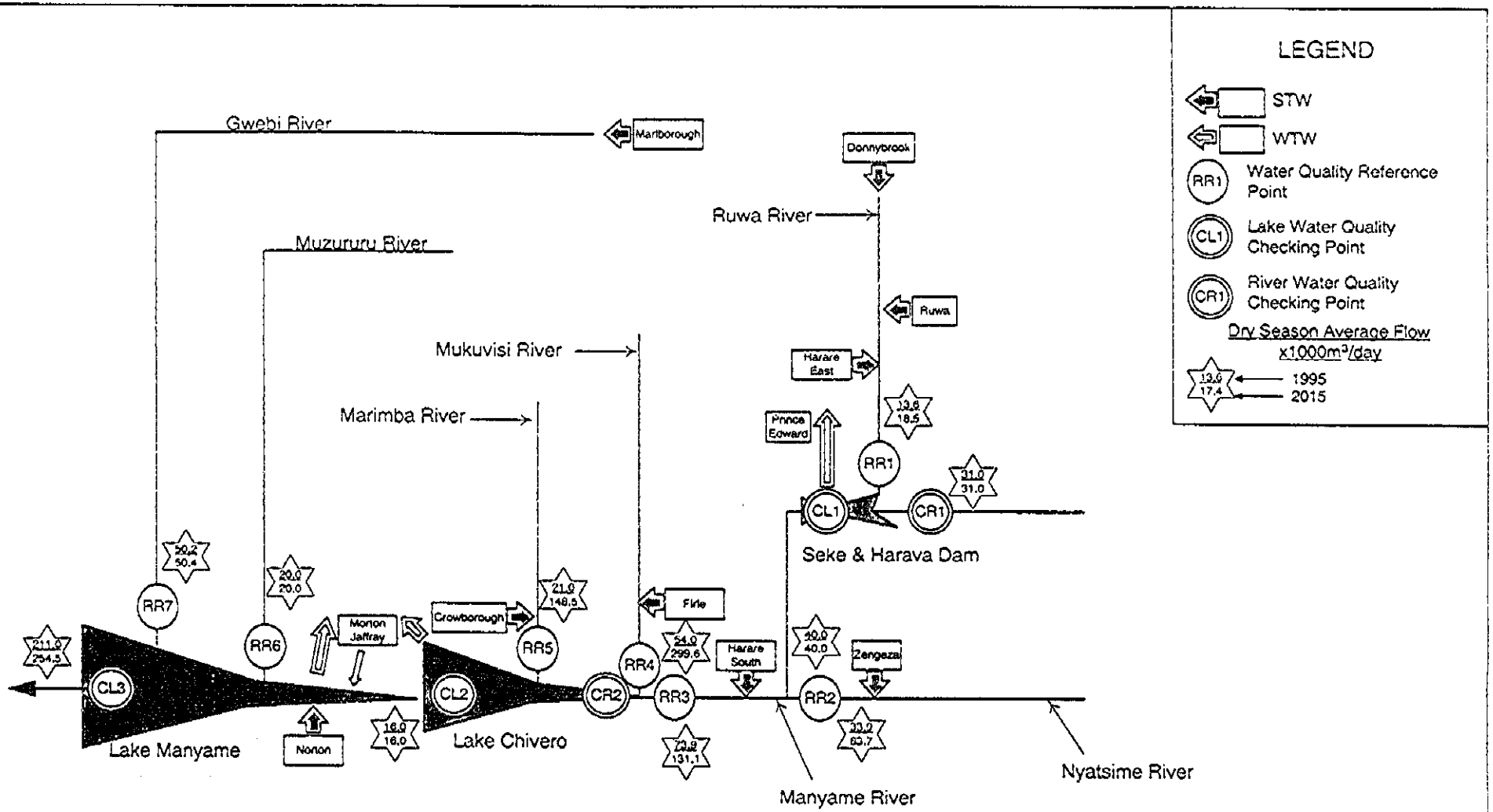


Figure 2.6 (1) Flow Model to be Adopted in Analysis of Rivers (Scenario-1)

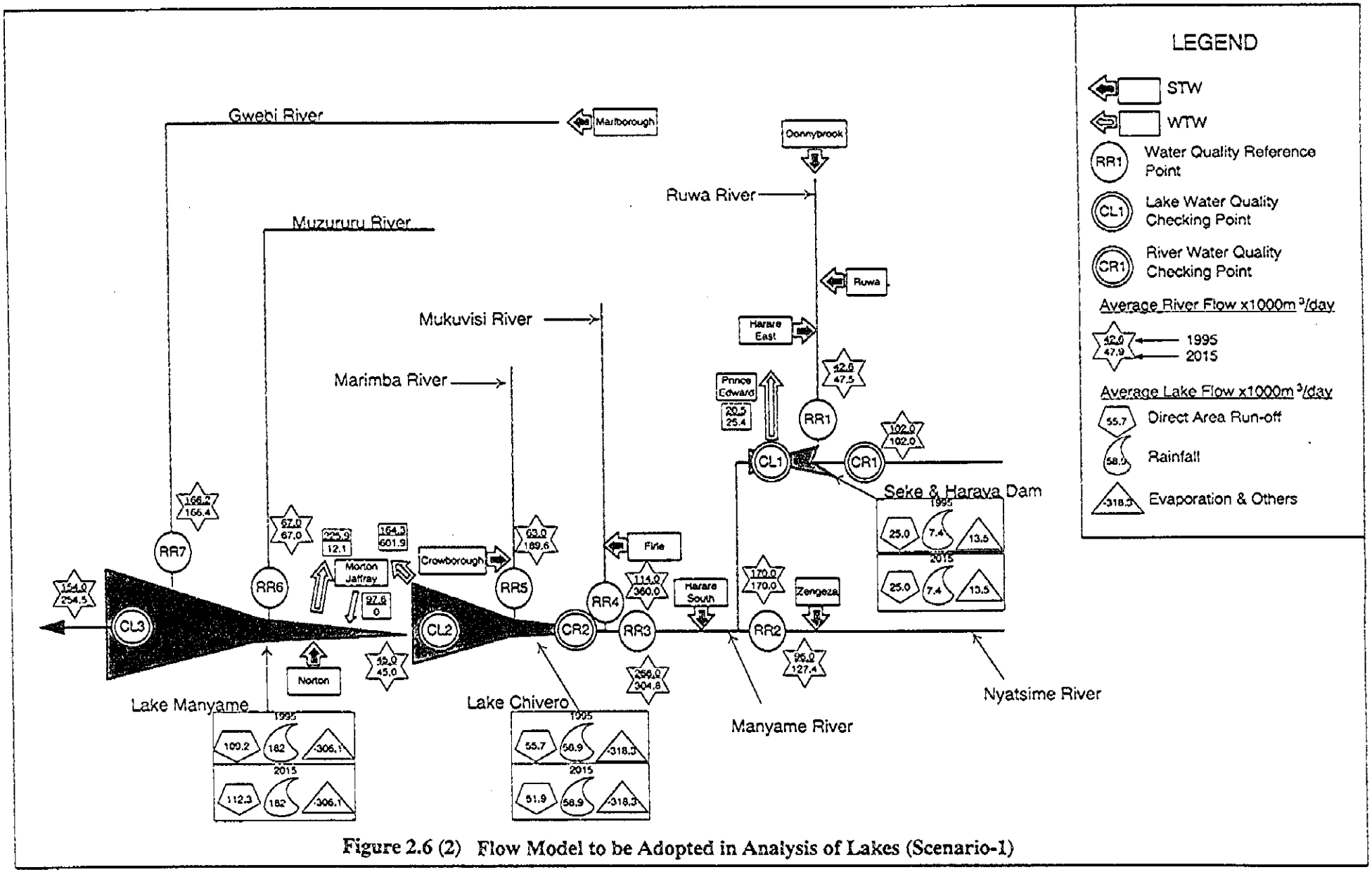


Figure 2.6 (2) Flow Model to be Adopted in Analysis of Lakes (Scenario-1)

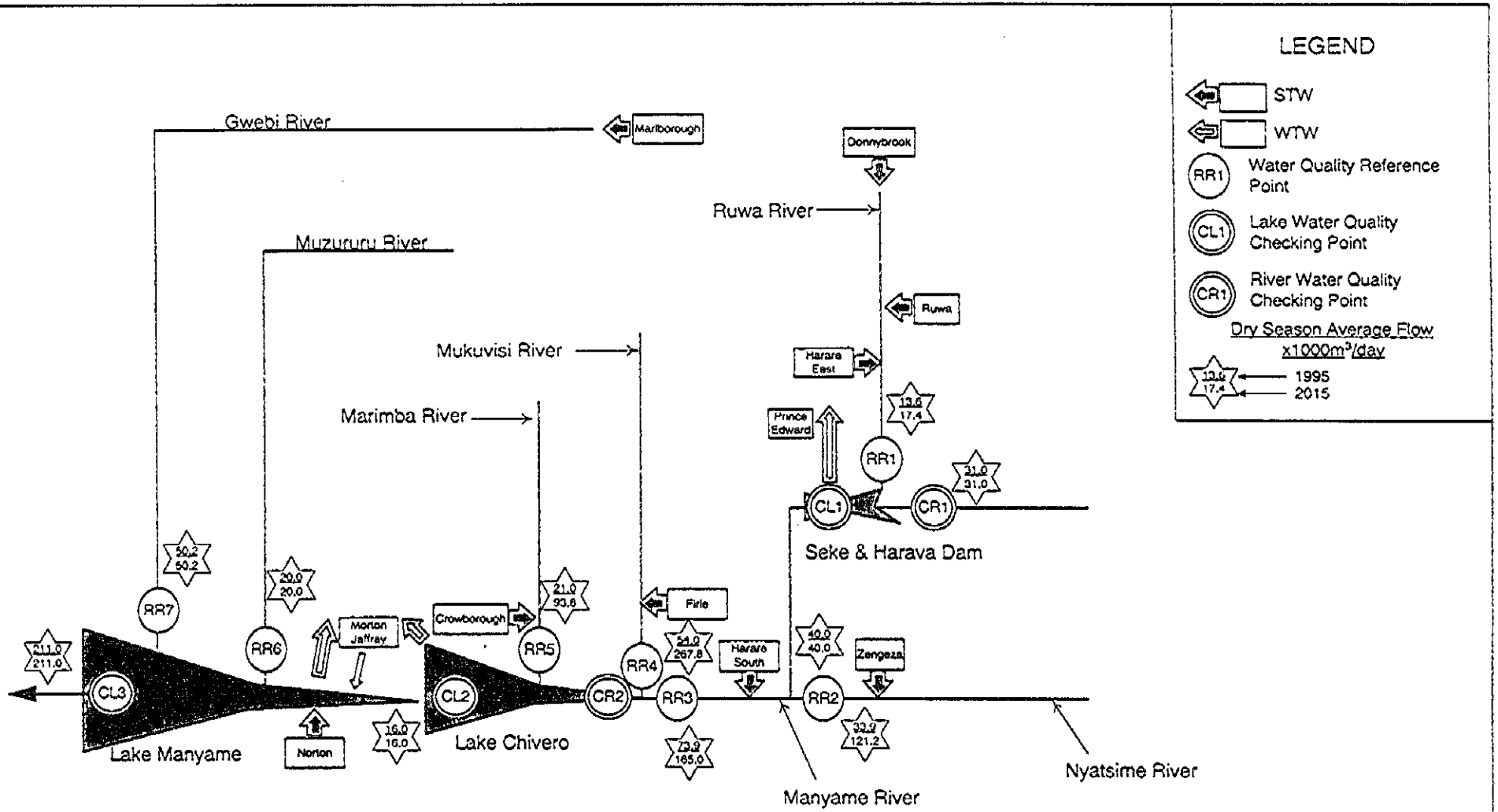


Figure 2.7 (1) Flow Model to be Adopted in Analysis of Rivers (Scenario-2)

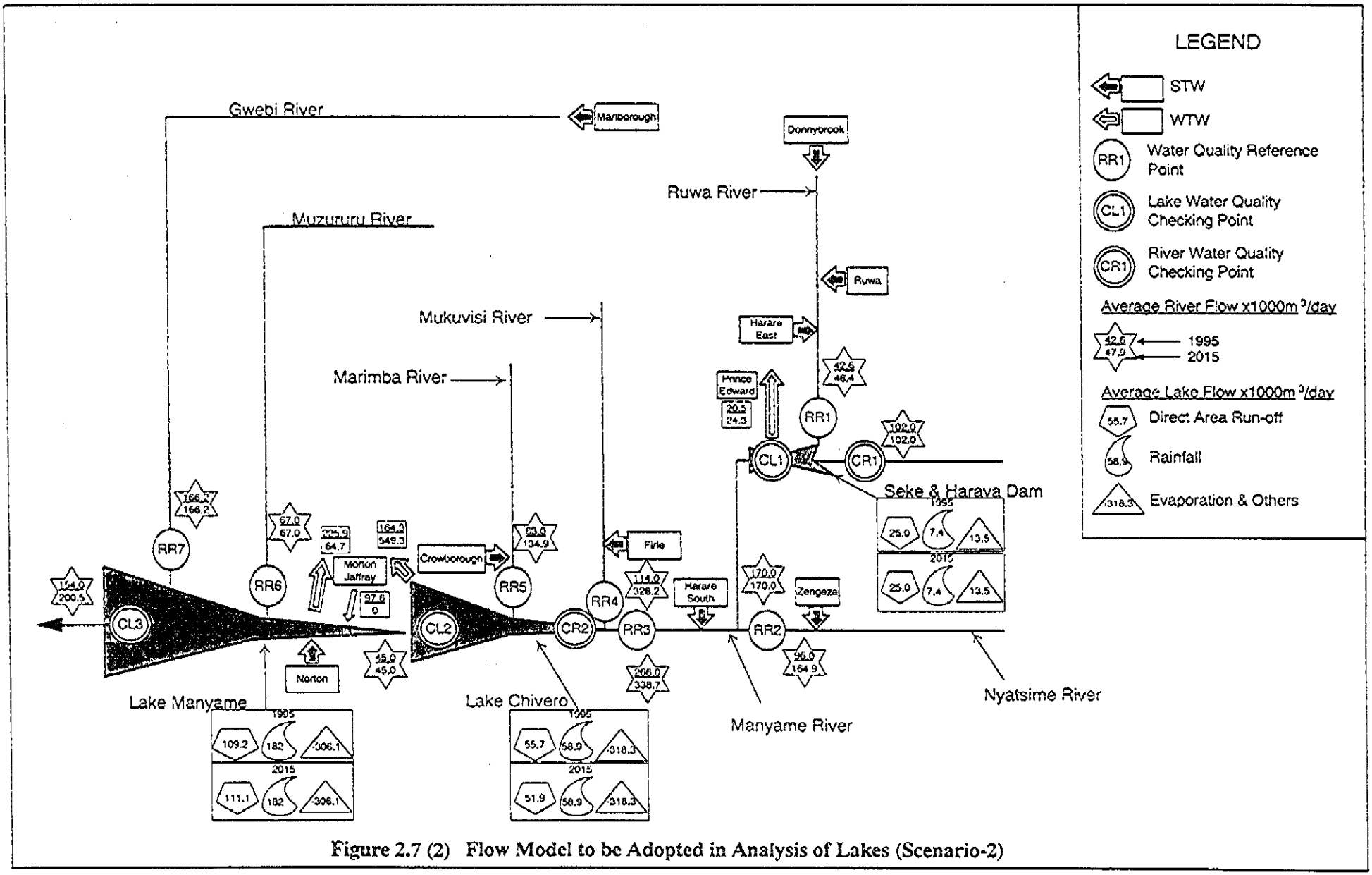


Figure 2.7 (2) Flow Model to be Adopted in Analysis of Lakes (Scenario-2)

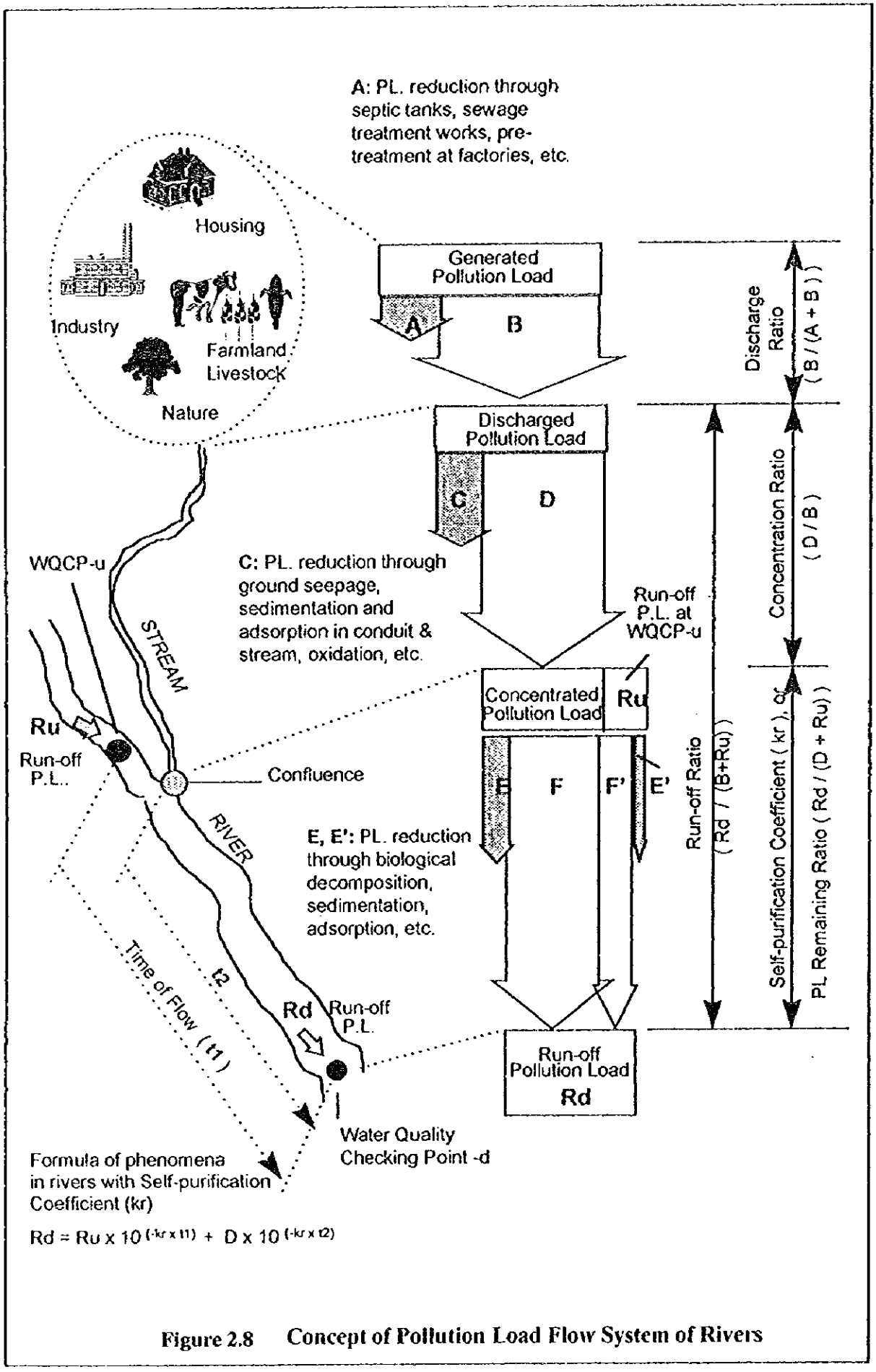


Figure 2.8 Concept of Pollution Load Flow System of Rivers

The calculated remaining ratios imply not only the self-purification capacity of the rivers, but also the adjustment factor of the assumptions of the concentration ratios. The pollution load remaining ratios of the respective rivers are shown in Table 2.6 and these were modified for application in future pollution analyses:

Table 2.6 Pollution Load Remaining Ratio of Rivers

River	Calculated PLRR	Applied in Future Analysis
Manyame R. (upstream)	18.6%	20%
Ruwa R.	17.4%	20%
Nyatsime R.	29.3%	30%
Mukuvisi R.	18.6%	20%
Manyame R. (downstream)	35.9%	35%
Marimba R.	31.5%	30%
Muzururu R.	6.0%	10%
Gwebi R.	21.7%	20%

The Vollenweider Model was adopted as the water pollution simulation model of the lakes/dams in terms of T-N, T-P and inflow-COD. The pollution analysis, in terms of COD, was conducted for the inflow-COD and the secondary produced COD mainly produced by phytoplankton in the lake. The secondary produced COD was analysed by the ΔCOD method.

Based on the estimated water balance models, self-purification coefficients of the lakes for each pollutant were computed as summarised in Table 2.7.

Table 2.7 Self-purification Coefficients of Lakes

Coefficients*	Seke & Harava Dams	Lake Chivero	Lake Manyame
σN	0.18797	0.04270	0.01151
σP	0.20574	0.00868	0.02769
σCOD	0.07551	0.00908	0.00440
α(N)	82.5%	100.2%	42.9%

*: Self-purification coefficients in following formula

$N = L(N) / ((\rho w+\sigma N) \times V)$

$P = L(P) / ((\rho w+\sigma P) \times V)$

$COD = L(COD) / ((\rho w+\sigma COD) \times V) + \Delta COD$

$\Delta COD = \alpha(N) \times T\text{-}N \times 17.73$

2.9 Future Water Pollution Analysis

In general, the future pollution analysis is conducted under the assumption that there would be no countermeasure for pollution load reduction. In this study, however, the development of two new STWs and the augmentation of the existing STWs were assumed for the future sewage treatment situation in the study area by considering the present prevailing condition:

Based on the established BOD load run-off model of each river, applying the computed pollution load remaining ratios, a projection of BOD concentration at water quality checking points of rivers was made for each scenario as shown in Table 2.8

Table 2.8 Projected Future BOD Concentration at WQCPs

River	WQ CP	Stan-dard	Present	Scenario 1		Scenario 2	
				2005	2015	2005	2015
Manyame (u/s)	C_{R1}	<3	1.1	1.32	1.48	1.03	1.13
Ruwa	R_{R1}	-	3.8	4.70	18.70	4.38	19.24
Nyatsime	R_{R2}	-	2.1	3.28	3.28	4.56	4.57
Manyame (d/s)	R_{R3}	-	1.0	10.52	10.28	8.20	6.38
Mukuvisi	R_{R4}	-	2.0	3.72	3.60	3.87	3.99
Manyame (d/s)	C_{R2}	<5	1.4	5.69	5.63	5.48	4.90
Marimba	R_{R5}	-	8.7	6.18	5.85	7.68	7.29
Muzururu	R_{R6}	-	0.5	0.89	0.95	0.78	0.82
Gwebi	R_{R7}	-	1.6	1.56	1.68	1.35	1.43

(unit: mg/l)

The projected BOD concentrations at the C_{R1} WQCPs are less than the environmental water quality standard through the future under the assumed conditions. While, those at the C_{R2} seems to be at the ceiling to meet the water quality standard.

After applying the simulation model with the computed self-purification coefficients, a projection of the water quality of the lakes/dams in the future was conducted. The results were summarised in Table 2.9

Table 2.9 Projected Future Pollution Load Concentration at WQCPs of Lakes

Lake/Dam	WQ CP	Quality Standard 2005	Quality Standard 2015	Present	Scenario 1 2005	Scenario 1 2015	Scenario 2 2005	Scenario 2 2015
T-N (mg/l)								
Seke & Harava	C_{L1}	<0.4	<0.2	0.65	0.73	0.83	0.71	0.80
L. Chivero	C_{L2}	<0.4	<0.2	0.51	0.77	0.94	0.66	0.86
L. Manyame	C_{L3}	<0.4	<0.2	0.75	0.74	0.76	0.73	0.74
T-P (mg/l)								
Seke & Harava	C_{L1}	<0.05	<0.01	0.07	0.08	0.11	0.08	0.11
L. Chivero	C_{L2}	<0.10	<0.01	0.27	0.46	0.55	0.41	0.51
L. Manyame	C_{L3}	<0.03	<0.01	0.04	0.04	0.04	0.04	0.04
COD_{Cr} (mg/l)								
Seke & Harava	C_{L1}	<10	<6	20.63	22.31	31.18	21.86	30.57
L. Chivero	C_{L2}	<16	<6	25.30	38.65	44.77	35.51	42.69
L. Manyame	C_{L3}	<16	<6	22.70	20.30	21.44	19.92	21.02

The Seke/Harava Dams and Lake Manyame show almost constant water quality from the present time. However, the water quality of Lake Chivero will be worse to some extent in the future. Figure 2.9 and 2.10 shows the pollution load run-off model (T-N as a sample) for the present and the year 2015.

2.10 Study on Pollution Load Reduction

The allowable PL at each WQCP of the river was calculated using the environmental water quality standards and the projected flow rates. The calculation results indicates that the reduction of the PL is not necessary or minor at C_{R1} and C_{R2} because of the projected comparatively lower BOD concentrations during the dry season.

The allowable PL at each WQCP of the lakes/dams was calculated using the environmental water quality standards and the projected water balances. The calculation results indicate that the required pollution load reduction is quite large at all WQCPs for all pollution indices especially for the year 2015.

The calculation results for Scenario-1 and Scenario-2 show almost the same pollution level, though the individual figures are different.

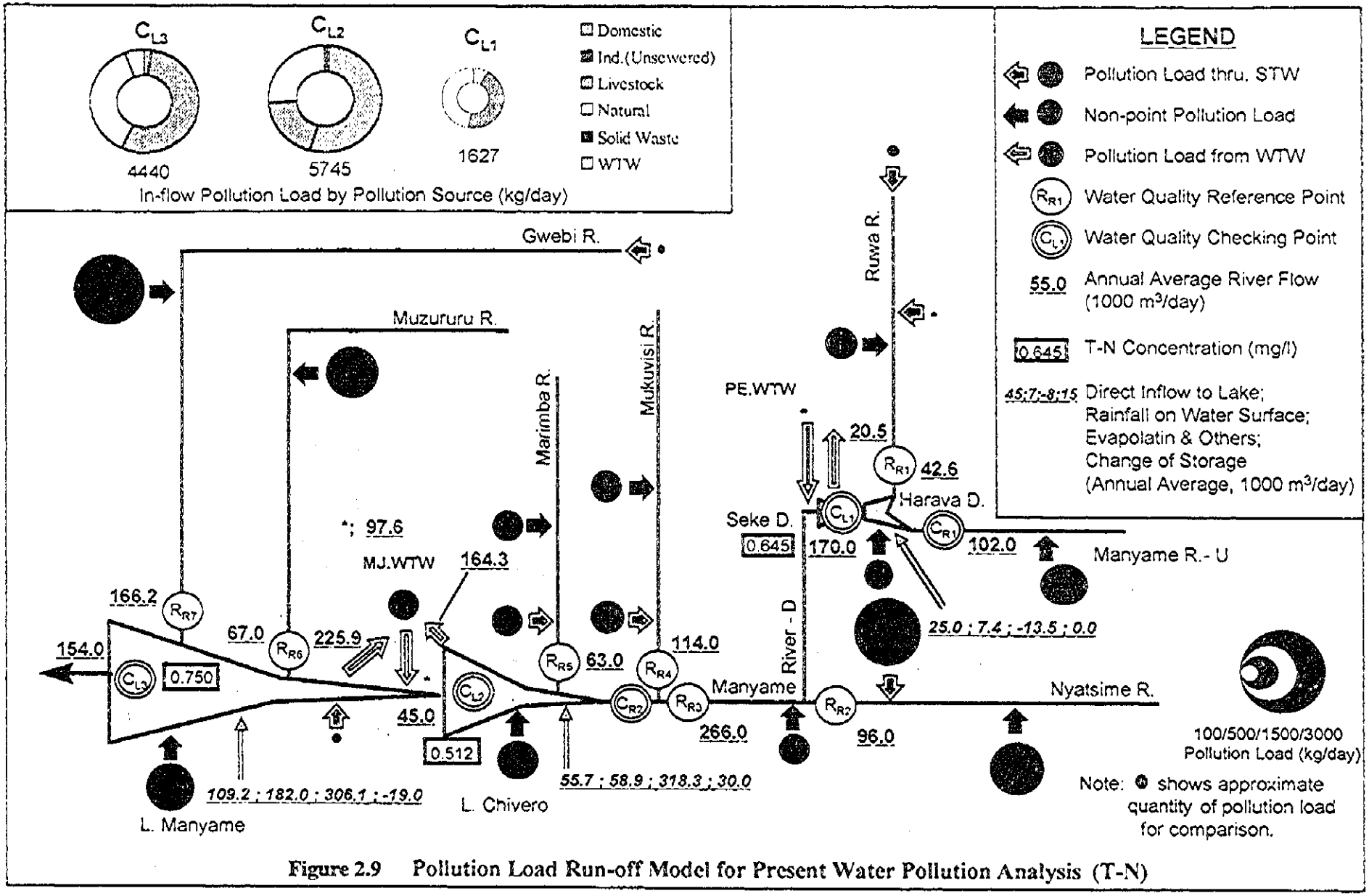


Figure 2.9 Pollution Load Run-off Model for Present Water Pollution Analysis (T-N)

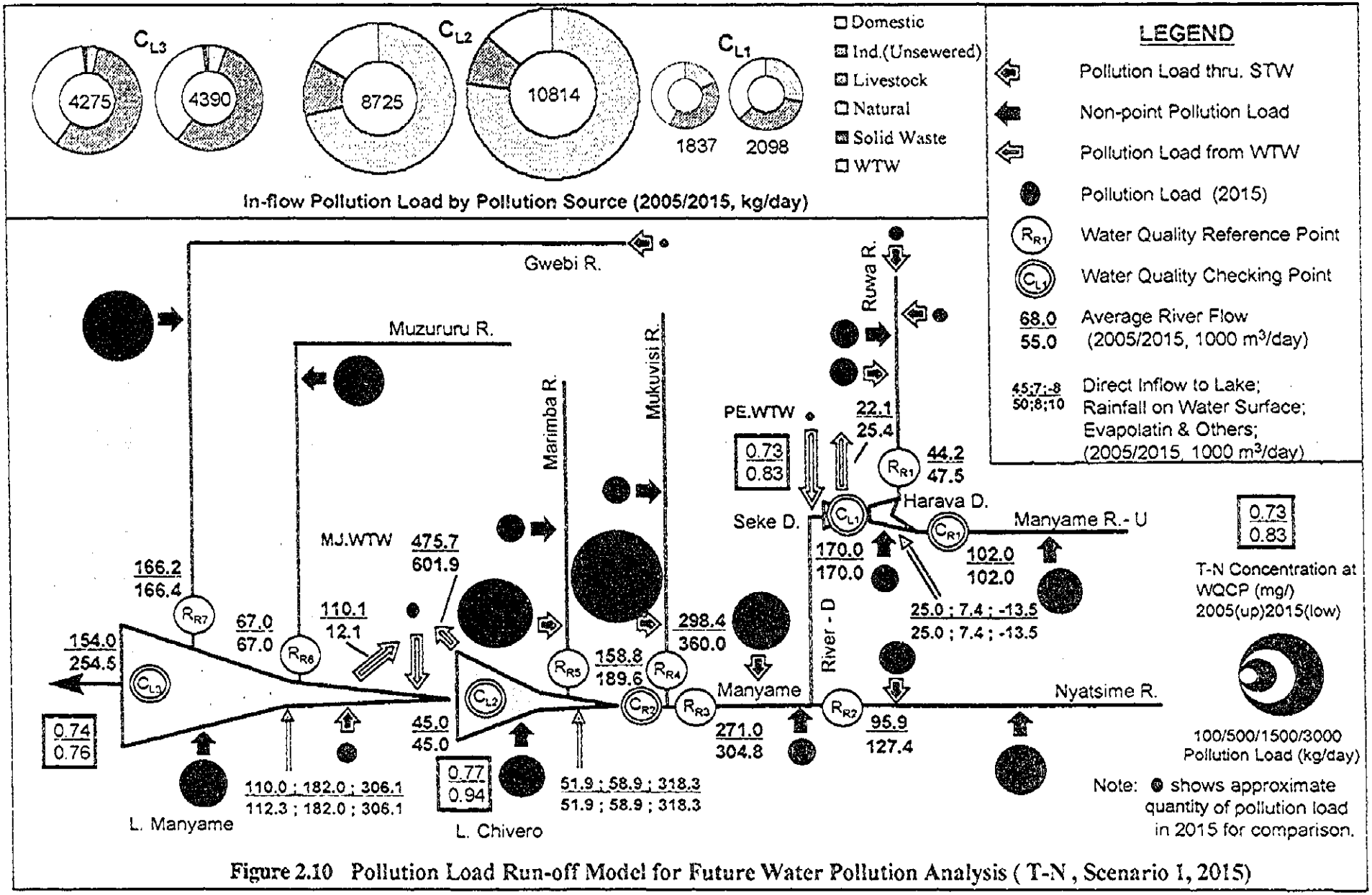


Figure 2.10 Pollution Load Run-off Model for Future Water Pollution Analysis (T-N , Scenario 1, 2015)

In the year 2015, most of the allowable PL becomes less than the natural PL because of the assumed strict water quality standards. Therefore, the accomplishment of the environmental water quality standards in the year 2015 seems to be difficult at all WQCPs.

At the point C_{L1} (Seke and Harava Dams), the PL reduction shall be conducted mainly for the domestic and livestock PLs. Since the possible countermeasures have been assumed for the projection of the domestic PL and the livestock PL accounts for a large share (about 80%) of PL to be reduced, the effort for PL reduction shall be concentrated on the livestock PL.

At the point C_{L2} (Lake Chivero), the PL reduction shall be conducted mainly by the domestic PL (about 90% of the PL to be reduced). Since practical countermeasures were already counted for the sewage treatment, drastic countermeasures shall be introduced even in the year 2005.

At the point C_{L3} (Lake Manyame), more than 90% of the PL to be reduced is allotted to the livestock. Therefore, the PL reduction shall be attained mainly by the livestock PL. The allotted PL to be reduced to the solid waste is negligible comparing with the total requirement. The PL reduction at the WTW will be accomplished before the year 2005 in assumption of the introduction of the wastewater treatment facilities at the Morton Jaffray WTW.

It may be possible to maintain roughly the future water quality at the present level with the countermeasures assumed in the water quality projection. In other words, those countermeasures, i.e. the augmentation of the sewerage systems and the provision of wastewater treatment facilities at the WTW, are minimum requisites to maintain the present water quality level through the future.

These countermeasures are adopted in the water quality projection as practical and possible ones to be implemented, and the calculation result is acceptable in terms of effluent water quality standard and in securing the river flow, this is in line with the policy of the Ministry of Lands and Water Resources.

Though the improvement of the water quality of the lakes/dams is desirable for the low cost operation of water treatment works and other water use purposes, it is difficult in practice to introduce advanced and expensive technical countermeasures. The operation cost of the

WTWs and the STWs have a trade-off relationship, and it is economical to treat the necessary water only at the WTWs, if the raw water quality is acceptable.

It is strongly recommended that continuous water quality and flow monitoring at selective sampling points shall be conducted to obtain reliable data and to establish a reliable pollution analysis model. In addition, periodical reviews and updating of the water pollution analysis shall be implemented. Thus, the introduction of the advanced and costly countermeasures shall be discussed through the periodical reviews.

2.11 Study on Countermeasures for Water Pollution Control in the Study Area

The required countermeasures for water pollution control for the years 2005 and 2015 were studied focusing on the public sewerage systems. In this regard, sewage treatment level is assumed to meet the requirements of the water pollution control to preserve present water quality of the water body through the future. Other countermeasures for the remaining pollution sources are also studied to come up with reference information. Furthermore, the relevant laws and regulations to be enforced were studied, including the requirements to accept industrial wastewater into the public sewerage systems, as well as water quality monitoring systems.

(1) Public Sewerage Systems

The design sewage flow of respective STWs in 2015 was estimated by Scenario, average dry weather flow of which are shown in Table 2.10.

Table 2.10 Design Sewage Flow of Respective STW by Scenario (2015)

Sewage Works	Scenario-1 (m^3/day)	Scenario-2 (m^3/day)
Crowborough	178,900	124,200
Firle	309,700	277,900
Marlborough	4,800	2,600
Donnybrook	12,300	11,700
Harare South	92,100	47,400
Harare East	37,600	37,600
Zengeza	70,200	107,700
Norton	41,300	26,500
Ruwa	18,400	5,700
Total	765,300	641,300

The trunk and lateral sewers for the expansion area by scenario were planned by sewage collection area, as shown in Table 2.11, provided with some pump stations, as required.

Table 2.11 Required Sewage Reticulation Facilities for the Expansion Area

Sewage Works	Scenario	Diameter (mm)	Length (km)	No. of Pump Station
Crowborough	1	500-1,350	35.6	1
	2	400-1,200	35.6	1
Firle	1	800-1,200	34.7	1
	2	800-1,200	34.7	1
Marlborough	1	None	None	None
	2	None	None	None
Donnybrook	1	None	None	None
	2	None	None	None
Harare South	1	700-1,800	20.5	1
	2	600-1,350	20.5	1
Harare East	1	900-1,350	12.0	0
	2	900-1,350	12.0	0
Zengeza	1	450-1,000	35.2	3
	2	500-1,200	35.2	3
Norton	1	300-1,100	26.3	2
	2	250-900	26.3	2
Ruwa	1	200-1,000	22.8	4
	2	150-600	22.8	4

The three types of sewage treatment method currently used by local authorities are adopted as alternatives; WSP, TF and BNR. The treatment capacities for the expansion of respective sewerage systems with treatment methods for the year 2005 and 2015 are summarized in Table 2.12 and the layout plan of the respective STWs are shown in Figure 2.11 to 2.19. The BNR method may be supplemented the polishing pond after the secondary sedimentation tank in consideration with further strict effluent standard in the future.

Table 2.12 Required Expansion Capacity with Treatment Method by Scenario

Sewage Works	Required Expansion Capacity (m^3/day)		Treatment Method
	2005	2015	
Crowborough	94,100	124,900	BNR
	38,700	70,200	BNR
Firle	176,100	237,700	BNR
	133,300	205,900	BNR
Marlborough	0	2,800	WSP
	0	600	WSP
Donnybrook *	2,400	6,800	WSP
	2,900	6,200	WSP
Harare South	63,600	92,100	BNR
	47,100	47,400	BNR
Harare East	6,300	37,600	BNR
	6,300	37,600	BNR
Zengeza	18,300	49,800	BNR
	37,700	87,300	BNR
Norton	9,000	37,900	TF
	4,200	23,100	TF
Ruwa	7,900	13,100	WSP
	0	400	WSP

Note: *; The City of Harare currently undertakes the feasibility study for the BNR process

Scenario-1
Scenario-2

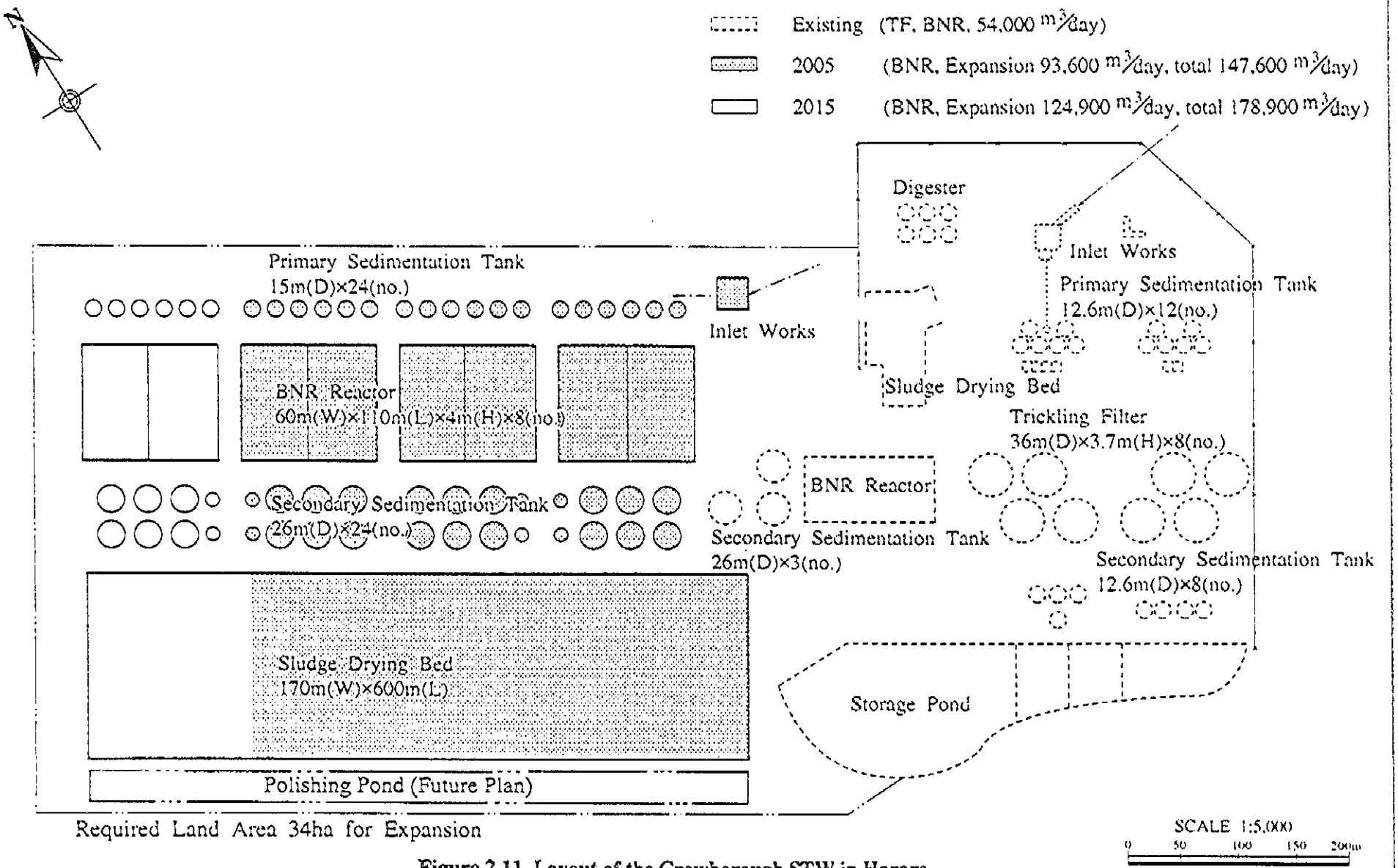


Figure 2.11 Layout of the Crowborough STW in Harare

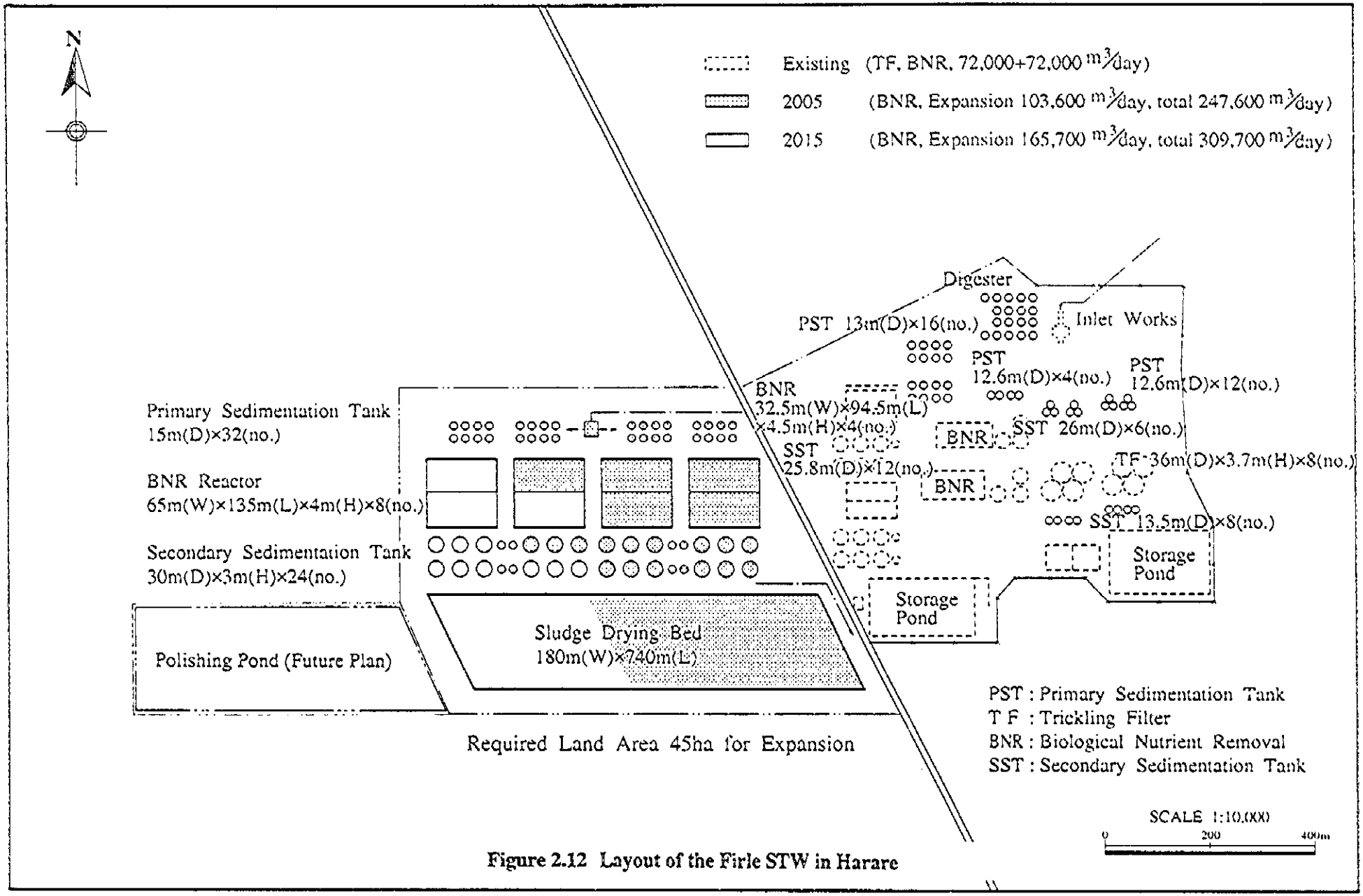


Figure 2.12 Layout of the Firle STW in Harare

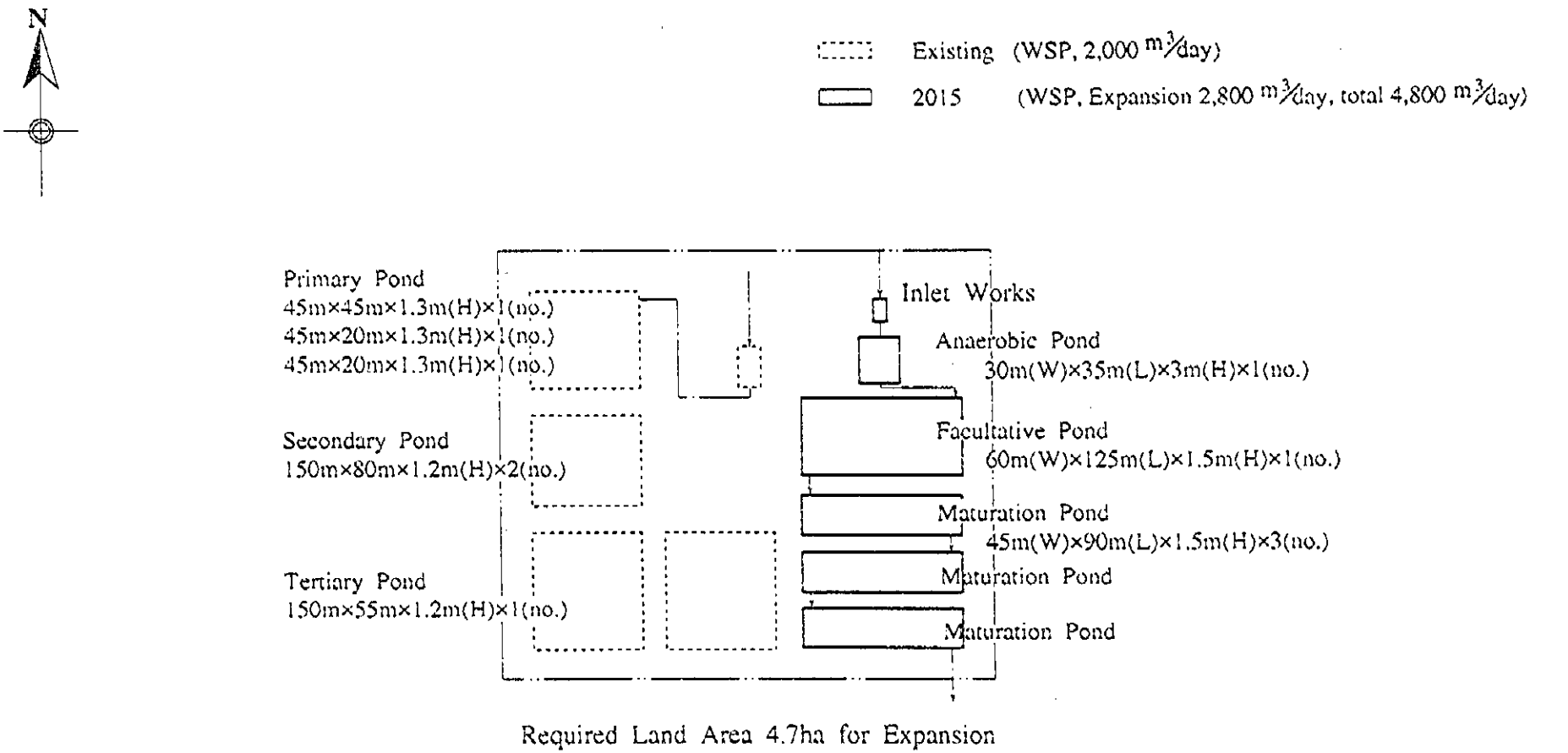


Figure 2.13 Layout of the Marlborough STW in Harare

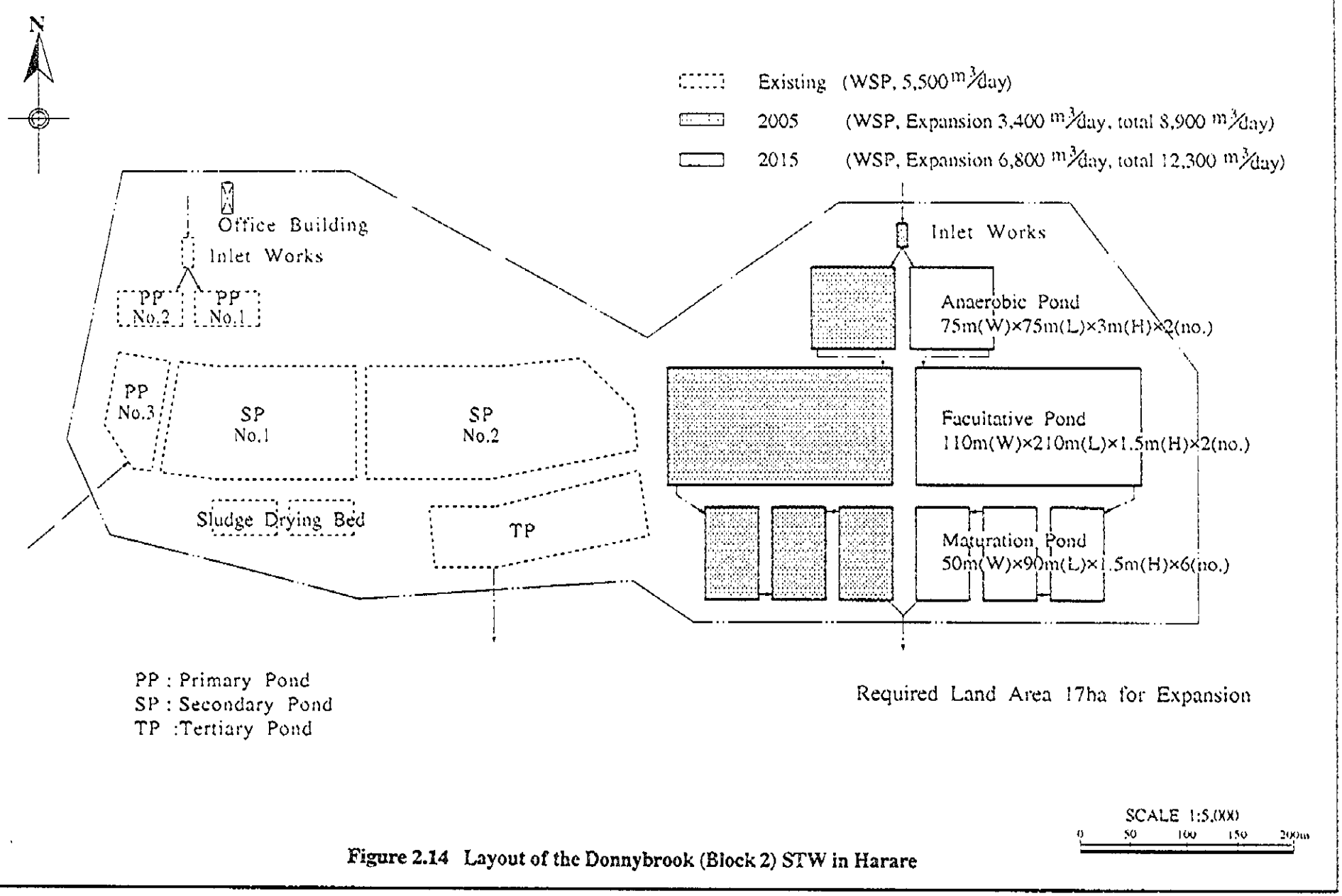


Figure 2.14 Layout of the Donnybrook (Block 2) STW in Harare

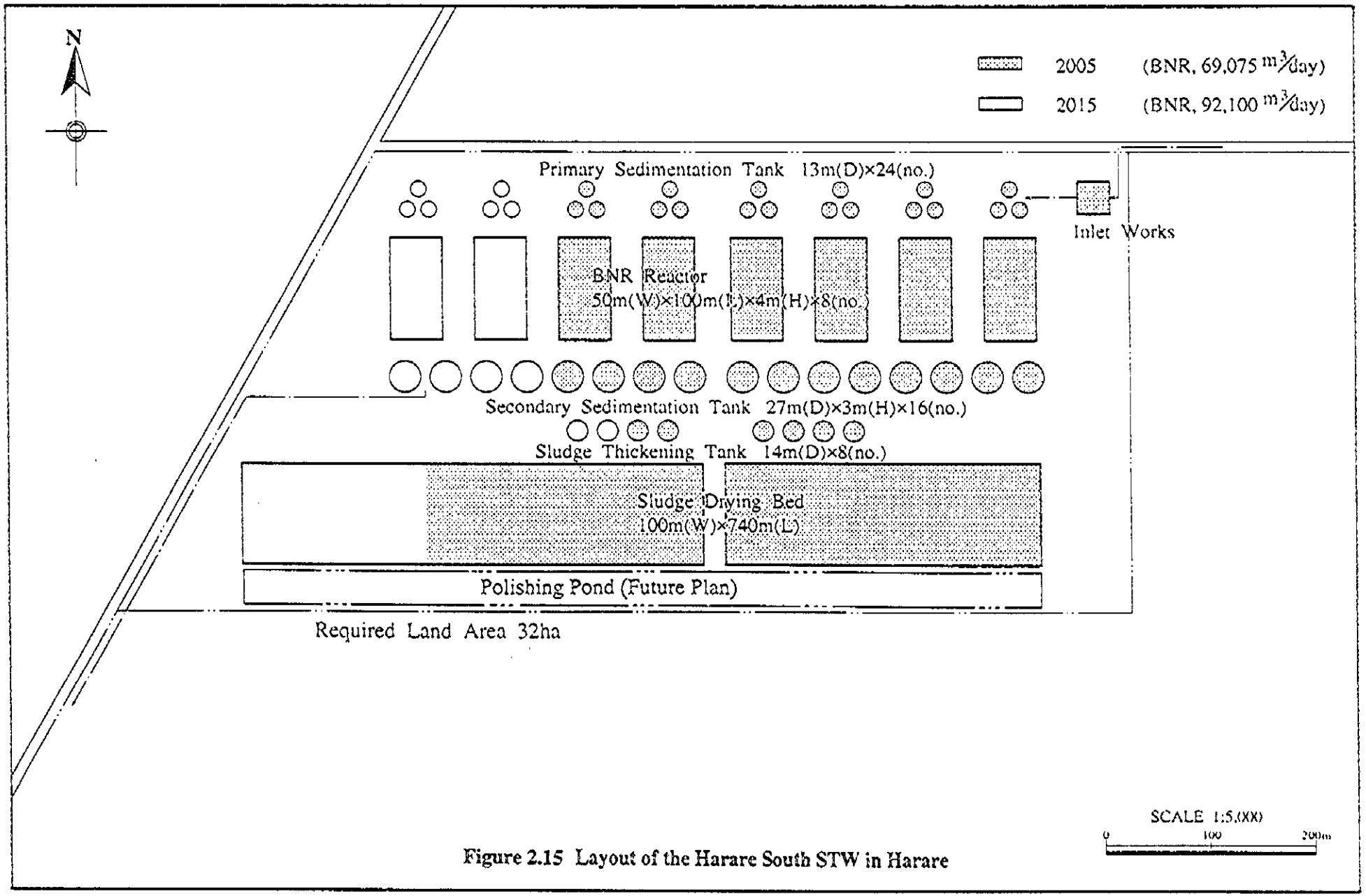


Figure 2.15 Layout of the Harare South STW in Harare

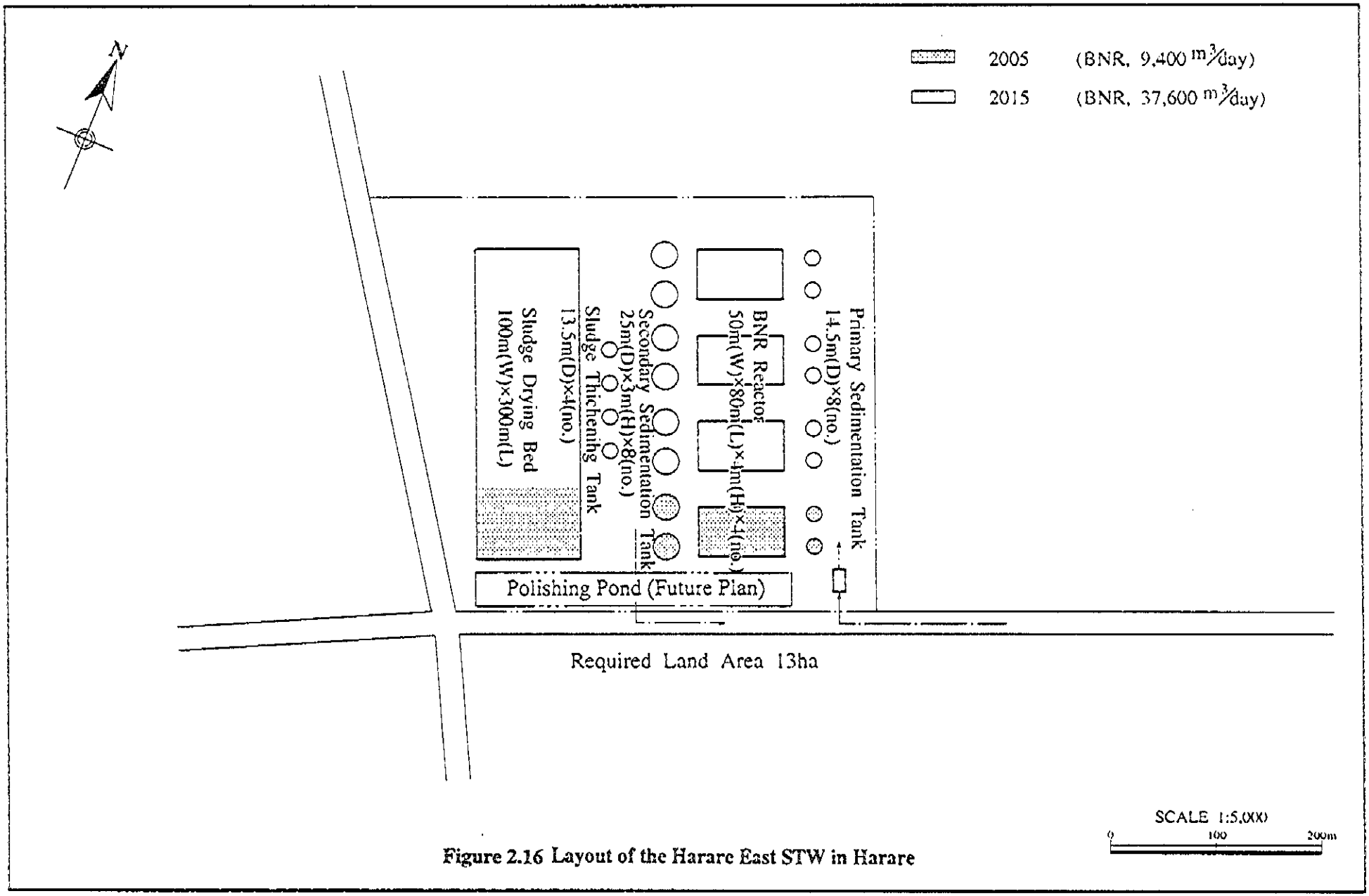


Figure 2.16 Layout of the Harare East STW in Harare

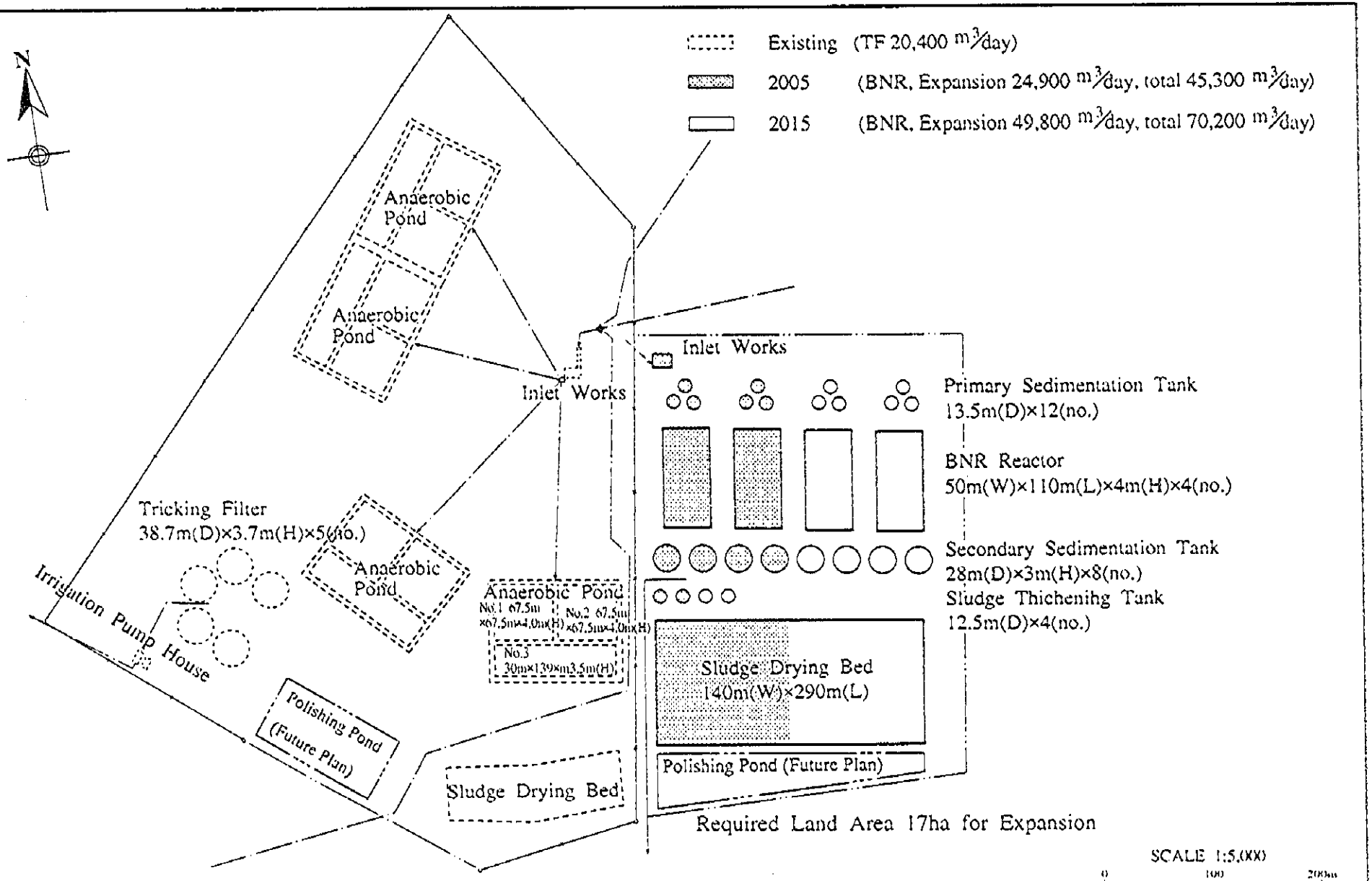


Figure 2.17 Layout of the Zengeza STW in Chitungwiza

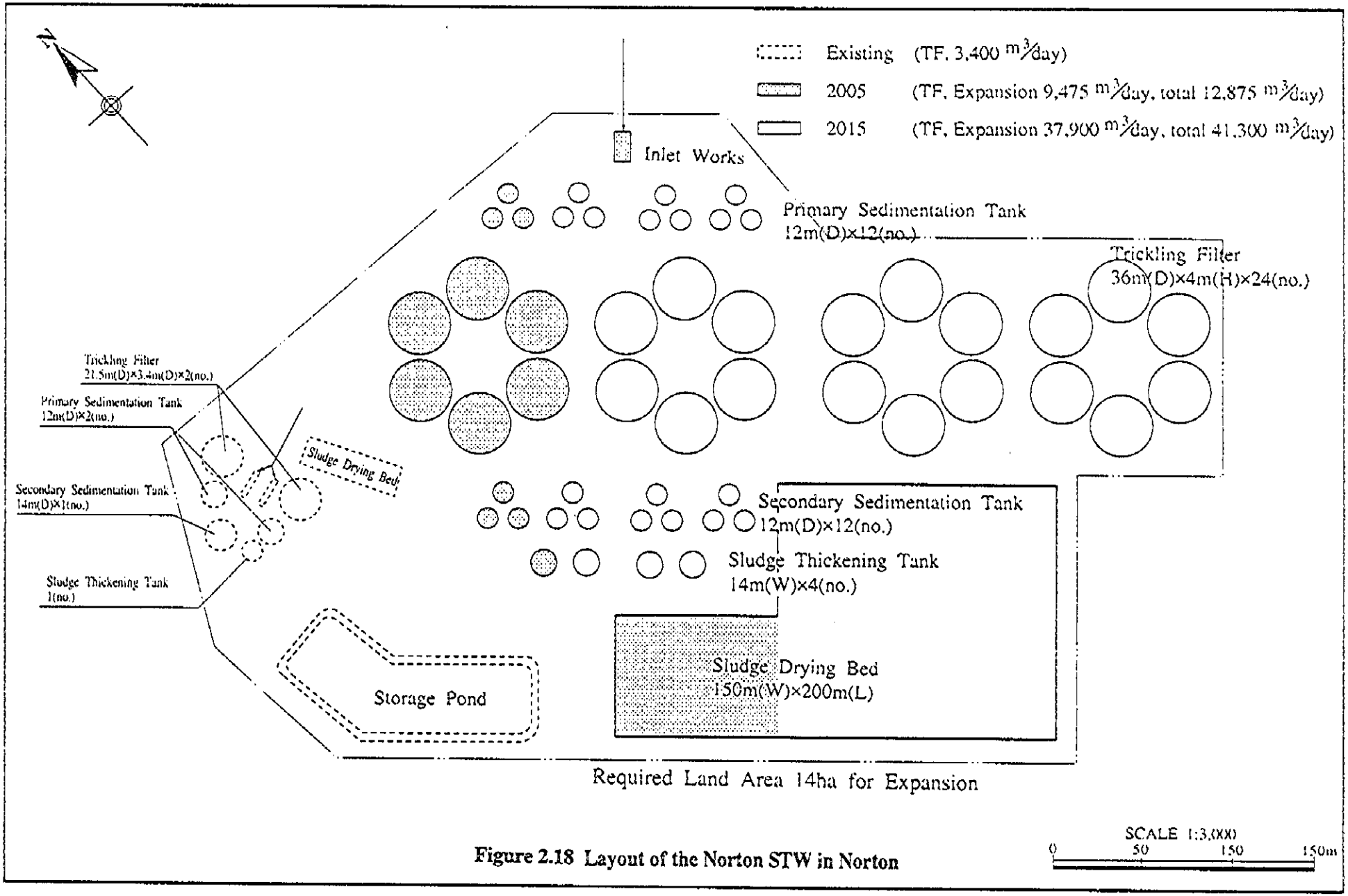


Figure 2.18 Layout of the Norton STW in Norton

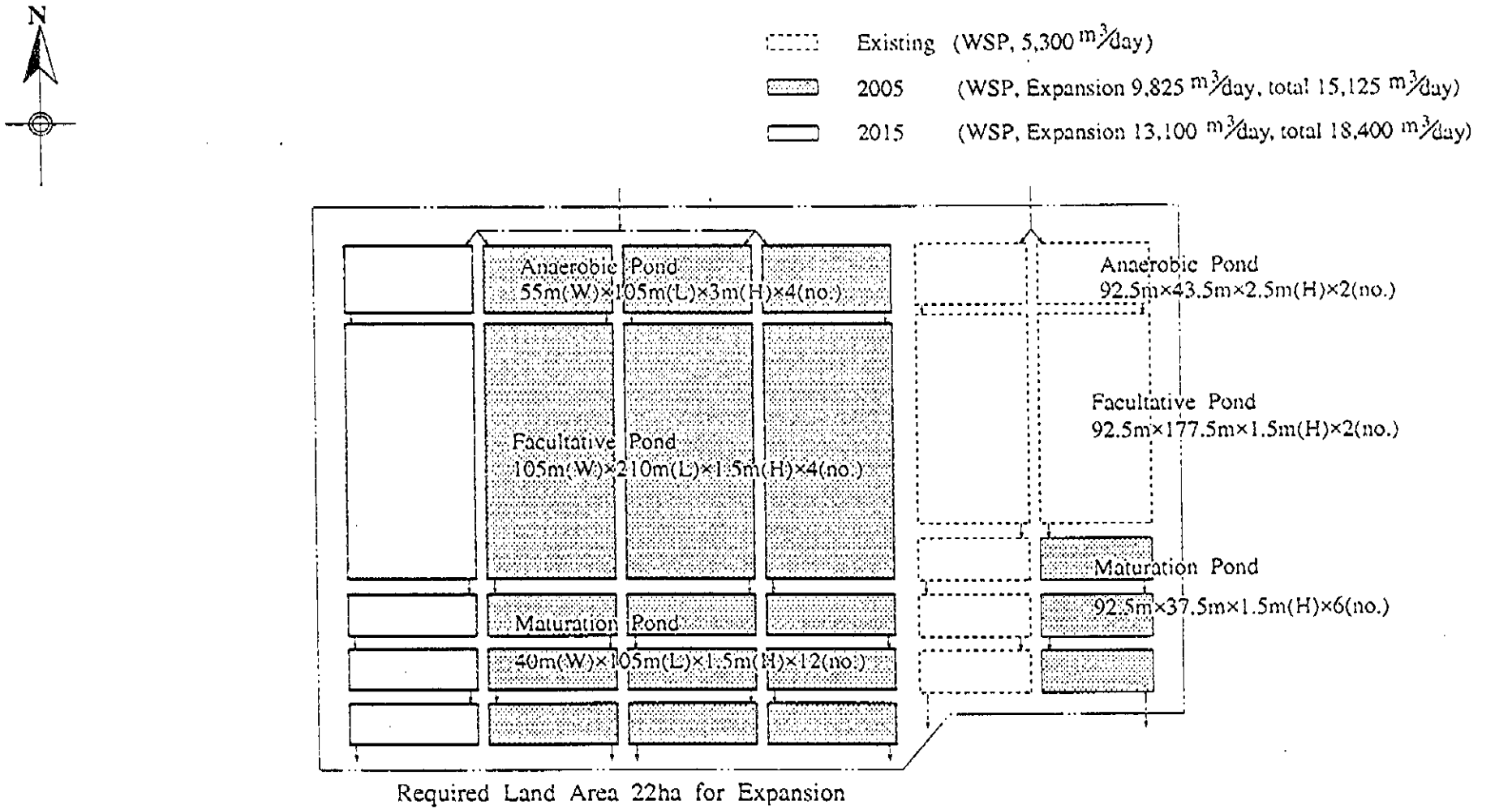


Figure 2.19 Layout of the Ruwa STW in Ruwa

(2) Industrial/Slaughterhouse Wastewater Treatment

The pre-treatment facilities for industrial/slaughterhouse wastewater is necessary for the combined treatment with domestic sewage. Processed Foodstuffs, Slaughterhouse and Pulp & Paper related products are major types needed to provide the measures,due to the discharge of highly concentrated organic substances. The pre-treatment process entails Anaerobic Pond and Facultative Pond (target treated effluent quality : BOD less than 600-1,000 mg/l).

(3) Solid Waste Collection and Disposal

The WSP was recommended as a standard treatment method to treat leachate at the solid waste dumping site.

(4) Livestock and Other Pollution Sources

The countermeasures to reduce pollution loads caused by livestock and other non-point sources are recommended as follows:

- Secondary treatment (Wastewater Stabilization Pond) of discharged drainage before flowing into nearby streams
- Re-location of the livestock breeding area to the outside of the study basin.

(5) Other Technical Countermeasures

Aside from technical countermeasures, the following are possible methods.

- Removal of the nutrients by fishery to the outside of the study basin
- Forestration to remove the nutrients and re-location of their plant to the outside of the study basin

In addition, dredging of the sediments accumulated at the bottom of lakes/dams is recommended to remove nutrients in the closed water body.

(6) Basic Strategy for Legal and Institutional Arrangements

To ensure the coherent water pollution control in the Study Area, it is proposed to establish the well-coordinated inter-agency bodies; Upper Manyame River Basin Authority (UMRBA) and Water Pollution Control Board (WPCB) as shown in Figure 2.20.

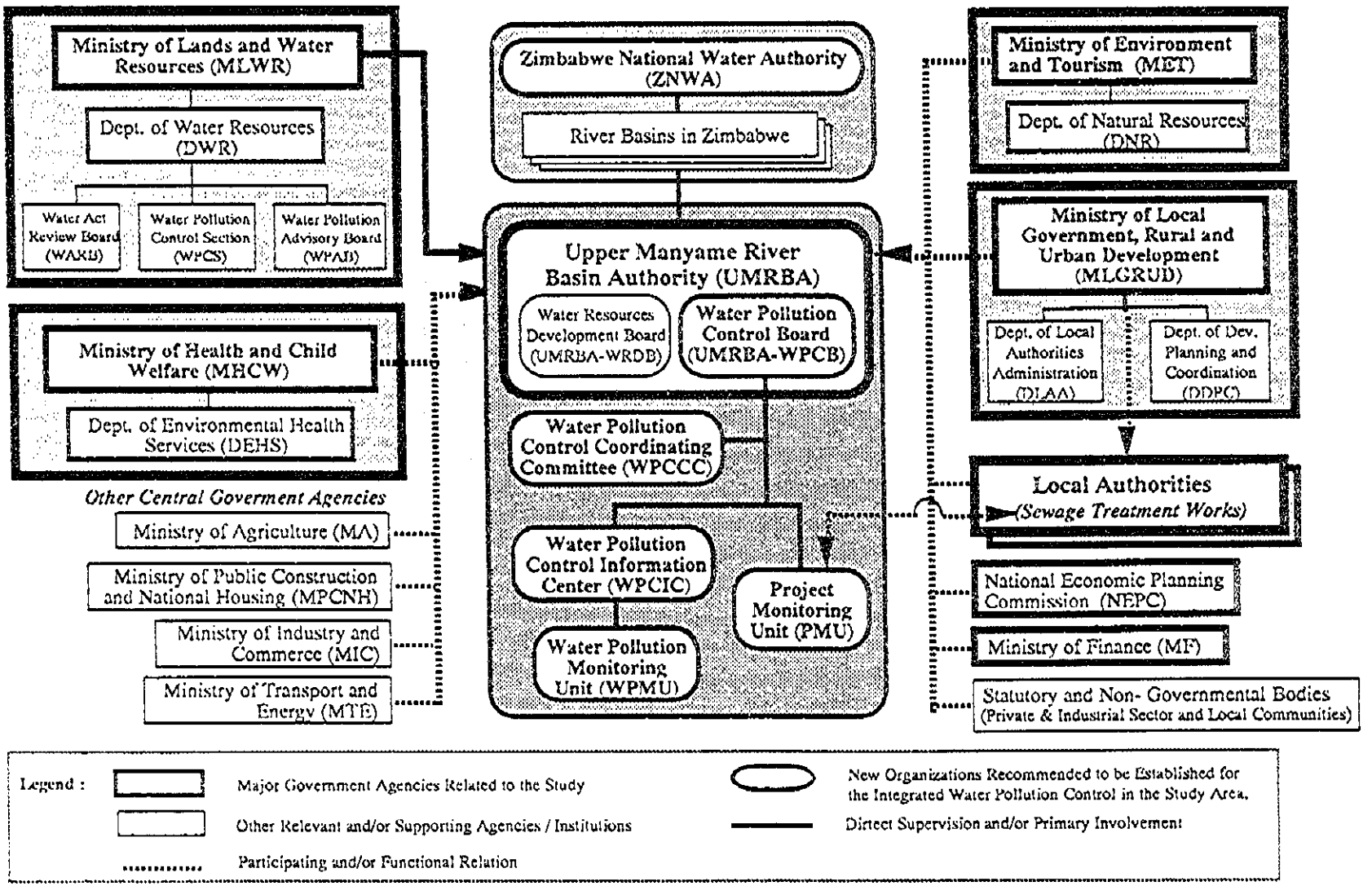


Figure 2.20 Proposed Institutional Set-up for Water Pollution Control in Zimbabwe
(Focusing on the Water Pollution in the Study Area)

In addition, it is a prerequisite to strengthen the institutional capabilities of the implementing agencies consisting of the MLGRUD and local authorities concerned. In order to ensure the long-term success of the water pollution control project, it is "must" to consolidate their institutions in terms of information system, manpower and financial resources.

To solve the legislative and administrative problems on water pollution, the Water Act and relevant water regulations are to be reviewed and updated to define the responsibilities of the national government, local authorities and business enterprises, and to clearly formulate the basic principles for the implementation of water pollution measures. The proposed legal arrangements comprise the following countermeasures:

- Establishment of environmental water quality standards
- Strengthening of effluent regulations
- Enactment of trade effluent control by-laws
- Review and updating of other legislation relating to water pollution control

(7) Monitoring and Feedback System for Water Pollution Control

The review of Water Act is necessary for a more intersectoral and participatory approach so as to achieve coordination.

The sampling points shall be determined considering current and future water uses, the location and number of existing monitoring stations for water quality and flow rate. Water quality indices for water quality examination shall be determined in the light of water quality standards. Figure 2.21 shows the proposed sampling points in the water bodies.

(8) Community Involvement

To ensure the sustainable development of the country, there is a need for the government to establish enabling legal and policy frameworks to facilitate community involvement in natural resources management.

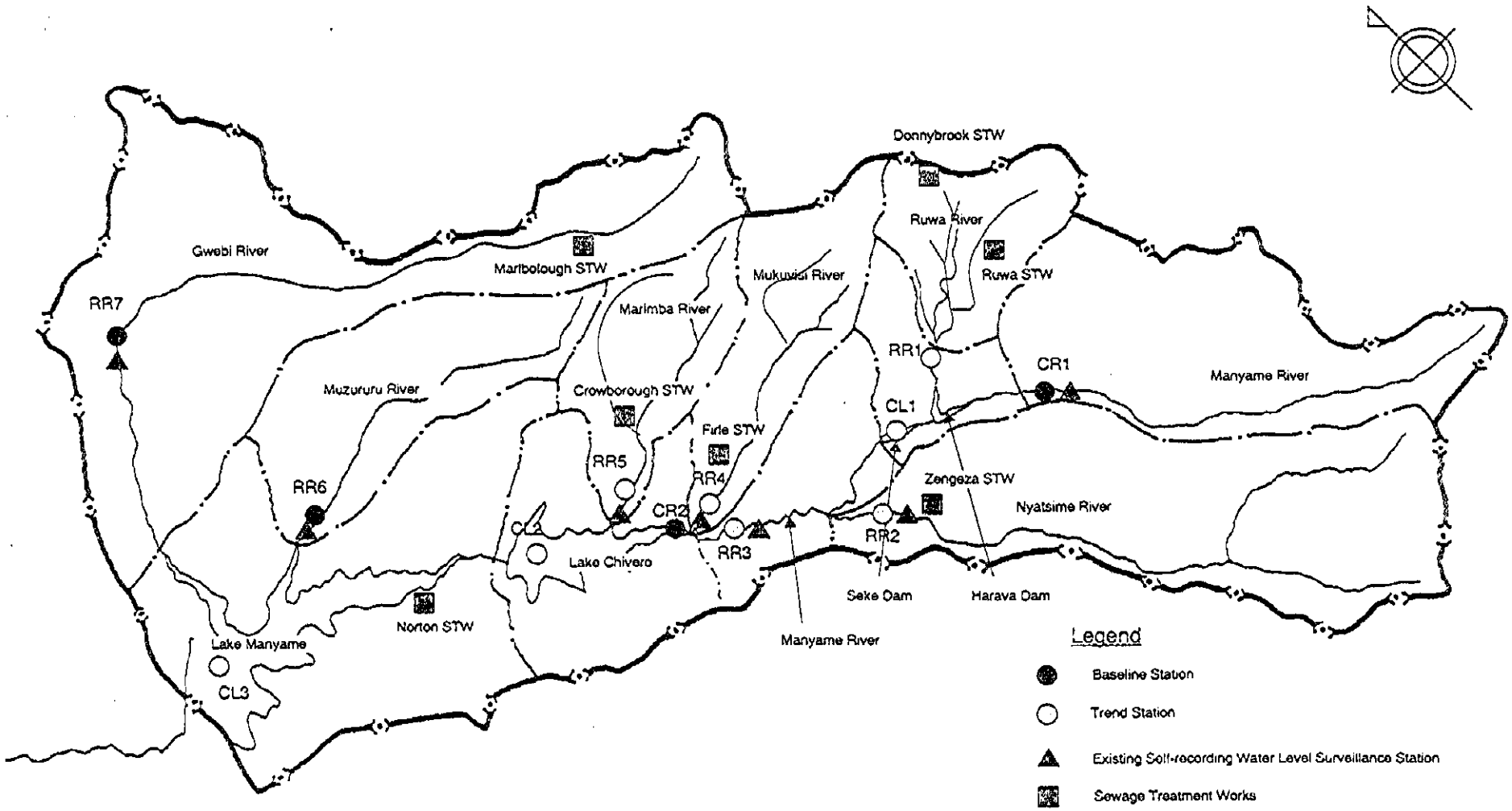


Figure 2.21 The Proposed Sampling Points in the Water Bodies

The proposed "Water Pollution Control Information Centre" shall undertake, together with the local authorities, the dissemination of water pollution related information to the private sector and the public. It is also vital to accelerate the "community development" to organize people's participation in the environmental management.

2.12 Cost Estimate by Public and Private Investment and Financial Study

The total cost, both for construction and O & M, for the year 2005 and 2015 was estimated for the public sewerage projects using different scenarios, while the standard cost for other countermeasures was prepared as a reference. The sewage works comprise treatment facilities in application of either BNR, TF or WSP and sewage collection systems.

The cost functions using a 1996 price base were established for the estimation of the construction costs required by the applicable treatment method, pump station and sewer. The total construction costs required by scenario for the public sewerage projects from 2000 to 2015 are:

Scenario 1 6,802.76 Million Z$

Scenario 2 5,706.27 Million Z$

The O & M cost required by scenario for the public sewerage systems at the target year of 2000, 2005 and 2015 are shown in Table 2.13.

Table 2.13 O & M Cost by Scenario

Scenario	Target Year	O & M Cost (Mill Z$/year)
Scenario-1	2000	5.700
	2005	78.670
	2015	114.865
Scenario-2	2000	7.553
	2005	62.007
	2015	97.043

2.13 Implementation Plan for the Countermeasures

Implementation plan for water pollution control in the upper Manyame River Basin refers to physical development of public sewage works, and leagal, institutional and financial arrangements. Two alternatives of the implementation schedule are worked out mainly because of the financial capabilities of the local authorities concerned. The mid-term

development plan is recommended to implement in the third phase in the case of Alternative 2 (refer to Table 2.14).

The management system for water pollution control was proposed based on the existing administrative structure and the envisioned reform under the Public Sector Investment Programme. The well-coordinated inter-agency bodies called "Upper Manyame River Basin Authority" shall be established. In addition, the institutional capability of the implementing agencies/authorities shall be strengthened. In this connection, the institutional/legal measures proposed in this Master Plan are recommended to put into practice within the Action Plan period up to the year 2000.

Table 2.14 Implementation Schedule by Alternative

(1) Alternative 1, Scenario 1 & 2

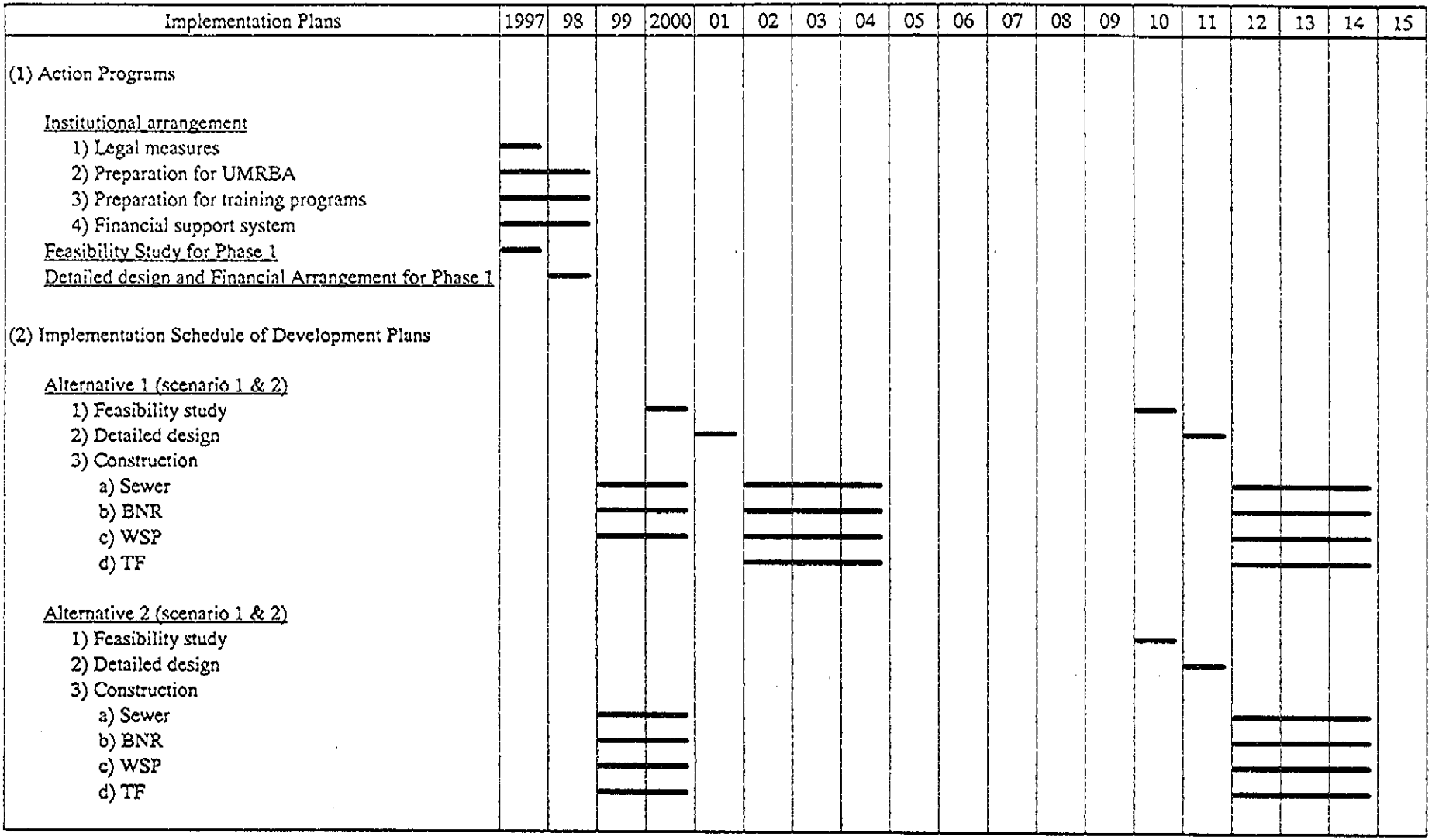
First Phase (- 2000)	Second Phase (2001 - 2005)	Third Phase (2006 - 2015)
Short-term development	Middle-term development	Long-term development
Sewer Harare (4 works) Norton Ruwa Chitungwiza BNR Chitungwiza	Sewer Harare (4 works) Norton Ruwa Chitungwiza BNR Harare (4 works) Chitungwiza WSP Harare Ruwa	Sewer Harare (6 works) Norton Ruwa Chitungwiza BNR Harare (4 works) Chitungwiza WSP Harare Ruwa TF Norton

(2) Alternative 2, Scenario 1 & 2

First Phase (- 2000)	Second Phase (2001 - 2015)
Short-term development	Middle-term development
Sewer Harare (4 works) Norton Ruwa Chitungwiza BNR Chitungwiza	Sewer Harare (4 works) Norton Ruwa Chitungwiza BNR Harare (4 works) Chitungwiza WSP Harare Ruwa TF Norton

Figure 2.22 shows the implementation plans of two scenarios.

Figure 2.22 Implementation Plans



CHAPTER 3 Study on Priority Project and Initial Environmental Examination

The previous studies and political measures on water pollution control were reviewed. Among the water pollution sources, the rehabilitation and expansion of existing sewage works are recommended as potential projects including the institutional strengthening, as required. Of the potential projects (the Crowborough, Firle, Zengeza, Norton and Ruwa STWs), the Zengeza STW was selected as an urgent project after a comparative study in terms of the technical, environmental improvement, economic and financial aspects. The implementing capacity of the concerned authorities and the sustainability of the project were also considered. The scope of the project was recommended to construct sewage treatment facilities using the BNR method with a capacity of 20,000 m^3/d.

An IEE report was prepared in compliance with the guidelines of JICA and the Zimbabwe Government. The report comprises a project description, a site description, the IEE methodology and an analysis of the potential environmental impacts entailing the tabulation of the IEE findings. After clarification of the positive and negative environmental impacts, it was recommended that a Preliminary Environmental Impact Assessment (PEIA), as defined in the Zimbabwe Environmental Impact Assessment Policy of 1994, be carried out.