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 2 - I

MAIN REPORT

MARCH 1997

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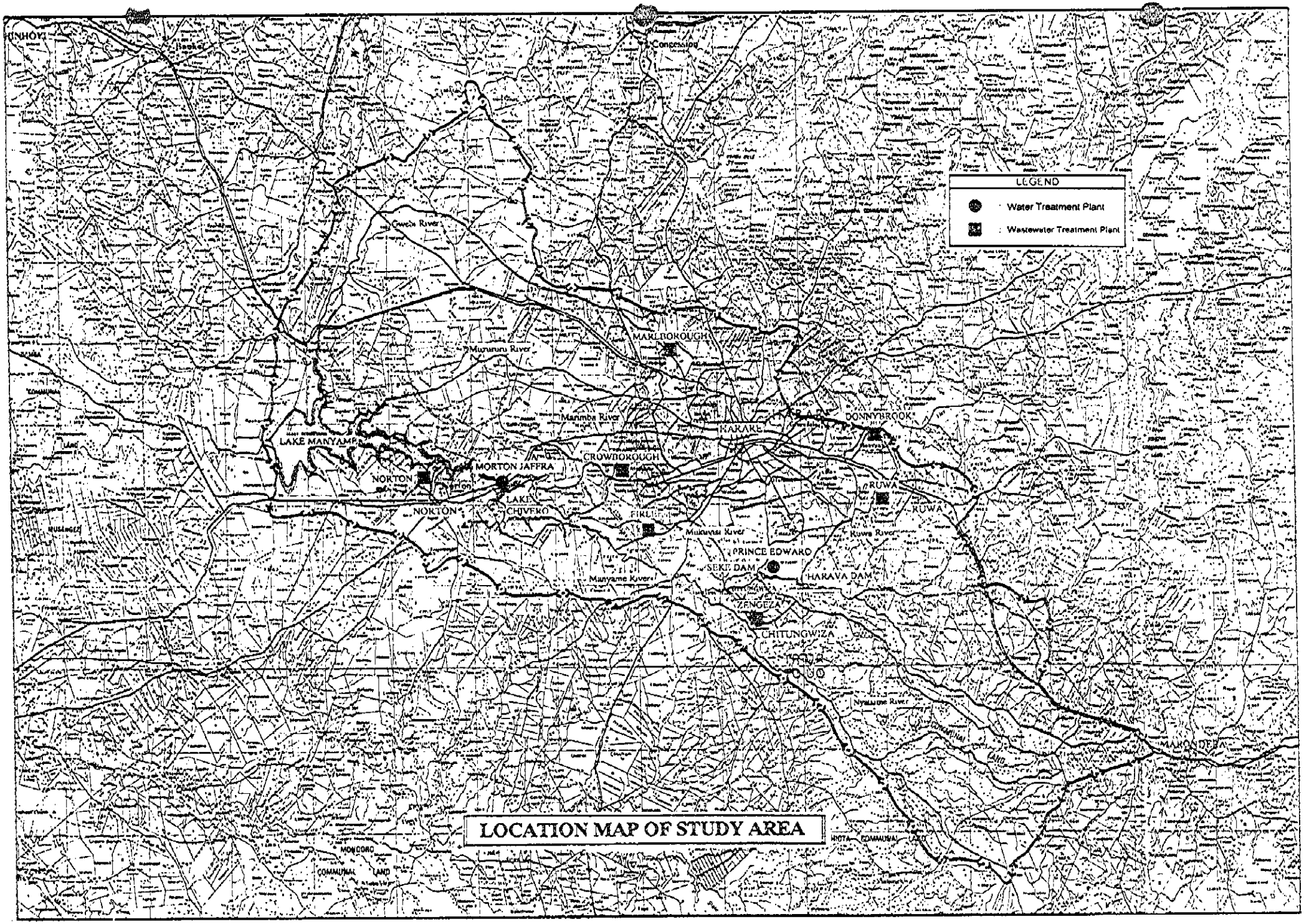

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WATER POLLUTION CONTROL MASTER PLAN
FOR
THE UPPER MANYAME RIVER BASIN

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ABBREVIATIONS

ADWF	Average Dry Weather Flow
ARDA	Agricultural and Rural Development Authority
BNR	Biological Nutrient Removal
CH	City of Harare
CMC	Chitungwiza Municipal Council
CSO	Central Statistical Office
DANIDA	Danish Development Agency
DDF	District Development Fund
DDPC	Department of Development Planning and Coordination (MLGRUD)
DEHS	Department of Environmental Health Services
DLAA	Department of Local Authorities Administration (MLGRUD)
DNPWM	Department of National Parks and Wildlife Management (MET)
DNR	Department of Natural Resources (MET)
DPP	Department of Physical Planning (MLGRUD)
DW	Department of Works (City of Harare)
DWR	Department of Water Resources (MLWD)
DWSSC	District Water Supply and Sanitation Sub-committee
EHO	Environmental Health Officer
EHT	Environmental Health Technician
ESA	External Support Agencies
EU	European Union
FC	Forestry Commission (MET)
GI	Galvanized Iron and S
GoZ	Government of Zimbabwe
GP	Growth Point
HCC	Harare City Council
HCMP	Harare Combination Master Plan
HHE	Health and Hygiene Education
IEE	Initial Environmental Examination
IES	Institute of Environmental Studies
IRWWS	Integrated Rural Water Supply and Sanitation
IRWSSP	Integrated Rural Water Supply and Sanitation Programme
IWSD	Institute of Water and Sanitation Development
JICA	Japan International Cooperation Agency
LGA	Local Government Area
LGB	Local Government Board
LPA	Local Planning Authority (Local Authority)

LSCF	Large-Scale Commercial Farming (Area)
MA	Ministry of Agriculture
MET	Ministry of Environment and Tourism
MF	Ministry of Finance
MFA	Ministry of Foreign Affairs
MHA	Ministry of Home Affairs
MHCW	Ministry of Health and Child Welfare
MHE	Ministry of Higher Education
MIC	Ministry of Industry and Commerce
MJLPA	Ministry of Justice, Legal and Parliamentary Affairs
MM	Ministry of Mines
MLGRUD	Ministry of Local Government, Rural and Urban Development
MLWR	Ministry of Lands and Water Resources
MNAECC	Ministry of National Affairs, Employment Creation and Cooperatives
MOHCW	Ministry of Health and Child Welfare
MPCNH	Ministry of Public Construction and National Housing
MPSLSW	Ministry of Public Service, Labour and Social Welfare
MTE	Ministry of Transport and Energy
NCU	National Coordination Unit
NEPC	National Economic Planning Commission
NGO	Non-Governmental Organization
NORAD	Norwegian Agency for Development
NTC	Norton Town Council
NUST	National University of Science and Technology
O & M	Operation & Maintenance
ODA	Overseas Development Agency
OECF	Overseas Economic Cooperation Fund (Japan)
PDD	Planning & Development Division (Department of Works, City of Harare)
PEIA	Preliminary Environmental Impact Assessment
PSIP	Public Sector Investment Programme
RDC	Rural District Council
RLB	Ruwa Local Board
RTCPA	Regional Town and Country Planning Act
SADCC	Southern African Development Coordination Conference
SAZ	Standards Association of Zimbabwe
SDF	Social Development Fund
SEDCO	Small Enterprise Development Corporation
SIDA	Swedish International Development Agency

SSCF	Small-Scale Commercial Farming (Area)
STW	Sewage Treatment Works
SWLTF	Solid Waste Leachate Treatment Facility
TF	Trickling Filter
UMRBA	Upper Manyame River Basin Authority (proposed in this M/P Study)
VIDCO	Village Development Committee
WARB	Water Act Review Board
WHO	World Health Organization
WPAB	Water Pollution Advisory Board
WPCB	Water Pollution Control Board (proposed in this M/P Study)
WPCCC	Water Pollution Control Coordinating Committee
WPCIC	Water Pollution Control Information Center (proposed in this M/P Study)
WPCS	Water Pollution Control Section (MLWD/DWD)
WPMU	Water Pollution Monitoring Unit (proposed in this M/P Study)
WSP	Wastewater Stabilization Pond
WQCP	Water Quality Checking Point
ZESA	Zimbabwe Electricity Supply Authority
ZIPAM	Zimbabwe Institute of Public Administration and Management

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PART I

WATER POLLUTION MASTER PLAN FOR THE UPPER MANYAME RIVER BASIN

CHAPTER 1

INTRODUCTION

CHAPTER 1 INTRODUCTION

The Upper Manyame River, one of the tributaries of the Zambezi River, is defined as the upstream reach from the Manyame Dam wall, and its basin covers about 3,900 km^2. The Upper Manyame River Basin has been playing an important role for water supply, irrigation, navigation, fishing and recreation purposes. However, the water pollution of the rivers and lakes/dams has been considerable in recent years due to rapid urbanisation and industrialisation in the basin. The Upper Manyame River Basin is shown in Figure 1.1.

The water supply for the five urban areas in the subject basin, with a total population of about 1.5 million as of 1992, is mainly dependent on Lake Chivero and Lake Manyame. Therefore, the preparation of a comprehensive water pollution control plan is essential, prior to the implementation of various countermeasures by different governmental agencies, to establish a common vision and to provide a mission statement for water quality improvement in the subject river basin based on a realistic assessment of the constraints, opportunities and demands of the area.

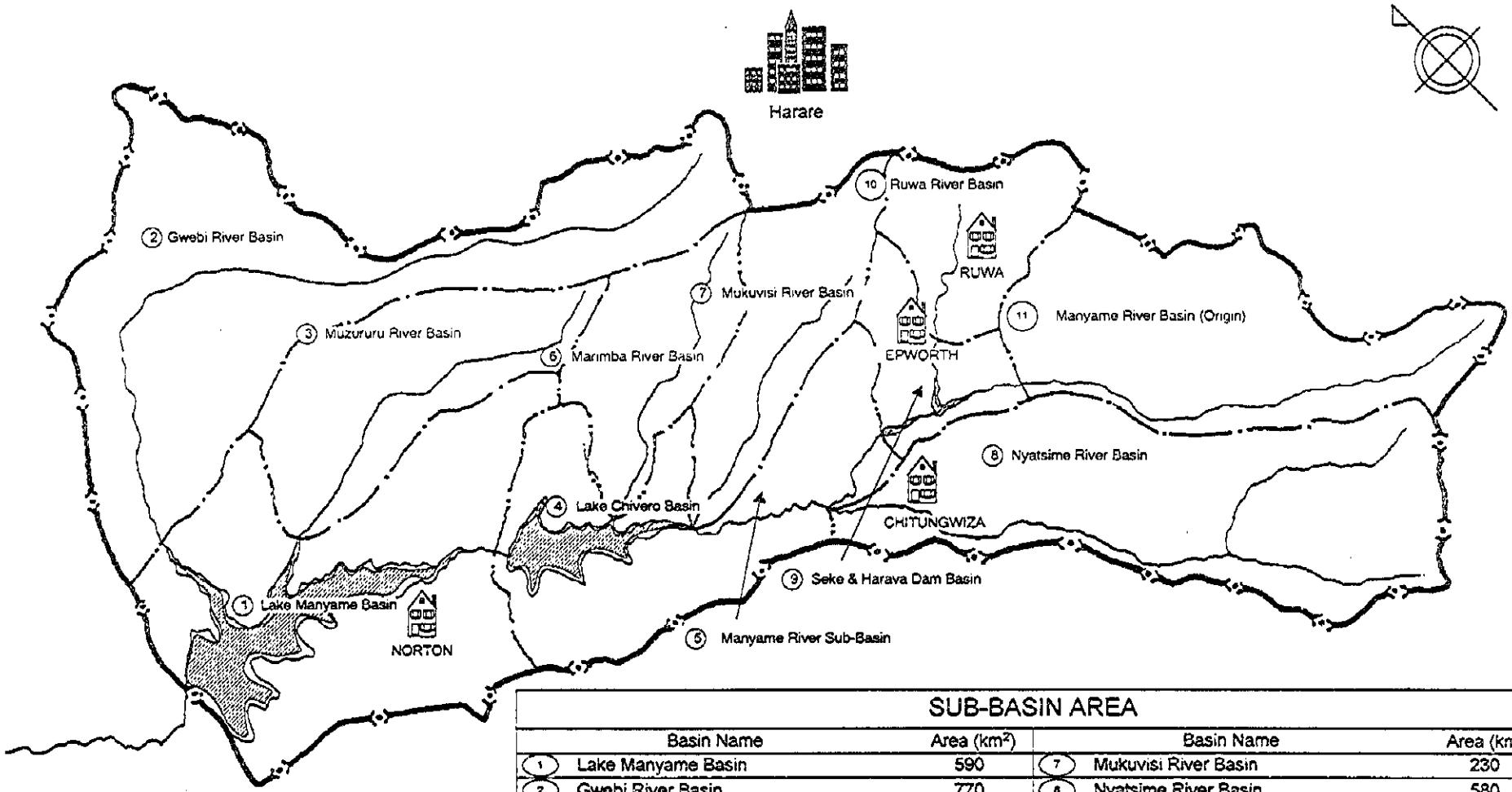
In response to a request from the Government of the Republic of Zimbabwe, represented by the Ministry of Local Government, Rural and Urban Development, JICA extended Technical Co-operation Assistance to prepare a water pollution control master plan for the Upper Manyame River Basin.

This master plan presents a water pollution analysis and recommendations on the required countermeasures for water pollution control with the target years of 2005 and 2015, in the subject river basin. The findings and field measurement results obtained during the conduct of the Stage 1 field work in Zimbabwe formed the primary study base of the plan.

In developing the water pollution control master plan, the following conditions and/or approaches to the major study items were employed:

(1) Major Water Pollution Sources

The water pollution sources are categorised into those of natural origin and human activities, comprising point and distributed sources in terms of the manner of the effluent



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 1.1 UPPER MANYAME RIVER BASIN

discharge into public water bodies. Major water pollution sources are identified including sewage discharged from urban areas, treated/untreated industrial wastewater, effluent from sewage treatment plants, agricultural chemicals, fertiliser and livestock from commercial/communal farmland.

(2) Future Development Scenarios in the Study Area

Future frame values are projected as the bases for the water pollution control study and sewage treatment plans including land use, population, industrial development and agricultural promotion. Local development plans, prepared in compliance with the "Second Five-Year National Development Plan", are fully referred to.

(3) Present and Future Water Supply in the Study Area

The effective use of limited water resources, entailing the reuse of treated effluent, is a major concern of a country in the semi-arid tropics where the overall water resources are limited. While, the present joint water supply capacity of the Morton Jaffray Waterworks and the Prince Edward Waterworks (used to supplement the peak demand) is 705,000 m^3/day. The annual intake amount from the lakes/dams (about 400,000 m^3/day) is almost equivalent to the storage capacity of Lake Chivero. In this regard, the water supply capacity comparing to the increasing demand in the study basin, seems to becoming increasingly critical year by year. The limitation of the water supply capacity is a control factor regarding future development. Future frame values are to be projected in consideration of the current conditions as well as any new water source development plans introducing water from outside of the study basin.

(4) Projection of Water Pollution and Allocation of Pollution Load to be Reduced by Different Pollution Source

The Upper Manyame River Basin is composed of two small dams (the Seke and the Harava) and two large lakes (Chivero and Manyame). The water pollution analysis in terms of T-N and T-P (preserved substances) is done for Lake Chivero, Lake Manyame and the Haraba and Seke dams to come up with countermeasures to combat the eutrophication problem. The water pollution mechanism of the rivers is roughly analysed (COD/BOD index), in consideration of the flow rate of the Manyame River during the dry season (only 1-2 m^3/sec) constituted by sewage and effluent discharged from STWs.

The required pollution load to be reduced by the different pollution sources are estimated according to the principle of polluters pay in proportion to their respective contributions to the water pollution problem.

(5) Countermeasure Plan for Water Pollution Control

Countermeasures for the conservation of water quality in the public water body are to be recommended by target year, referring to the pollution load to be reduced by the different type of pollution sources. Among the study factors, sewage treatment methods are discussed with the following considerations:

- Appropriate technologies, especially for the low-cost operation and maintenance of the facilities, shall be employed, taking into consideration the financial status of the government.
- Reuse of treated effluent shall be considered for irrigation and for replenishing water sources, as is already being practised in the study area.

The removal of nutritious substances out of the water bodies is another alternative including fishery and planting arrangements. Furthermore, the laws and regulations to be enforced are discussed, including the requirements to receive industrial wastewater into public sewerage systems and monitoring systems.

(6) Institutional, Financial and Managerial Aspects

The current conditions of the institutional, financial and managerial arrangements are analysed both for the national and local government levels. The financial arrangements required for the implementation of sector projects/programs are recommended based on sector investment experiences both in locally funded and foreign assisted projects. It is also essential to establish a water quality monitoring program for the particular water bodies. Recommendations are to be made reflecting the updated Water Act, which is under consideration by the appropriate review committee in Zimbabwe.

(7) Urgent Project(s) and Environmental Investigation

An evaluation of the potential projects for selection of urgent project(s) is made with an emphasis on the possible contribution to the improvement of the water environment. Other important factors for the comparative study include the urgency, cost requirements, and the effectiveness of financial/economic aspects. In connection to the selected

project, an initial environmental examination is conducted to analyse the negative impact of the project to the present environmental conditions and to identify the need of an environmental impact assessment.

CHAPTER 2

ADMINISTRATIVE COMPOSITION AND PHISYCAL CHARACTERISTICS IN THE STUDY AREA

CHAPTER 2 ADMINISTRATIVE COMPOSITION AND PHYSICAL CHARACTERISTICS IN THE STUDY AREA

2.1 Outline of the Study Area

2.1.1 Local Administrative Overview

Local administration in Zimbabwe consists of a series of political subdivisions, which are as follows in descending order: province, district, ward and village. Figure 2.1 1 shows the administrative structure in Zimbabwe. There are eight (8) provinces, five (5) cities, seven (7) municipalities, eight (8) towns, four (4) local boards, 57 rural districts and a thousand villages.

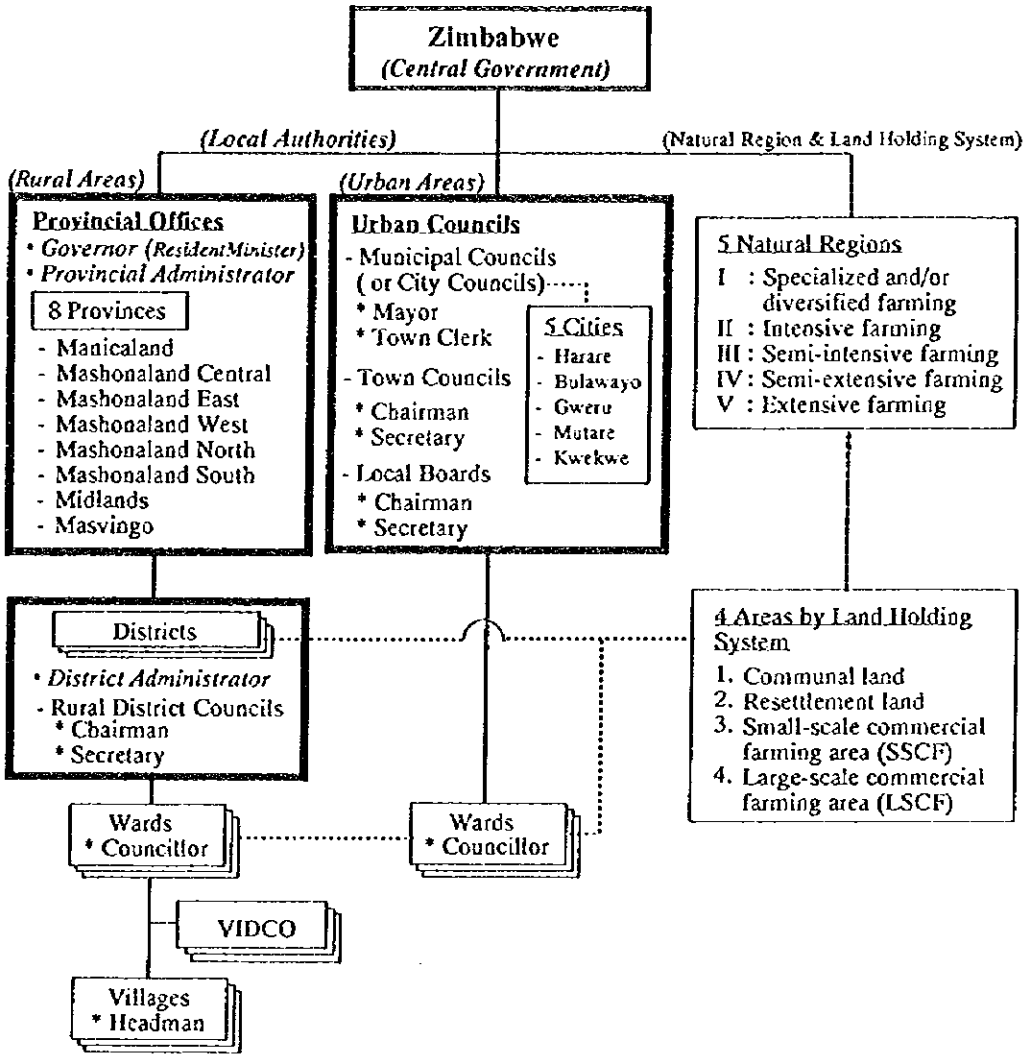


Figure 2.1.1 Administrative Structure in Zimbabwe

Each province has a provincial office of each department under the governor (exclusively in charge of political matters) who is appointed by the central government. The actual provincial administration is undertaken by the Provincial Administrator also appointed by the government and he conducts administration with a certain extent of autonomy. District-level administration is entrusted to district administrators and the district office of each department. The two cities of Harare and Bulawayo are endowed with the same political level of authority as the provinces in their respective jurisdictions.

Subordinate to the provinces are the Urban Councils and Rural District Councils with enactment of the Urban Councils act in 1995, which administer urban and rural areas, respectively. An Urban Council is comprised of City Council, Municipal Council, Town Council or Local Board, according to its developmental status. In the rural areas, the previous District Councils for Communal Lands and the Rural Councils for Commercial Land, which were designated by land use category, were merged to form Rural District Councils (RDCs) in 1988.

The RDCs can be considered as a major step forward in terms of "developing local government" or in a direction of "decentralization". Their current capacity, however, varies considerably from one part of the country to the other, as the human and physical resources they inherited from their predecessor councils is quite different.

A 10-Member Ministerial Committee has been established to oversee the government's decentralization programme, which will see the transfer of a wide range of powers, roles and functions from central government to rural districts. Decentralization aims to minimize bureaucracy, promote and strengthen democracy and civic responsibility as citizens participate in their governance and development.

2.1.2 Administrative Composition of the Study Area

The Study Area, the Upper Manyame River Basin, covers Harare City and three (3) provinces: Mashonaland East, Mashonaland Central and Mashonaland West. Figure 2.1.2 shows the local administrative composition of the Study Area.

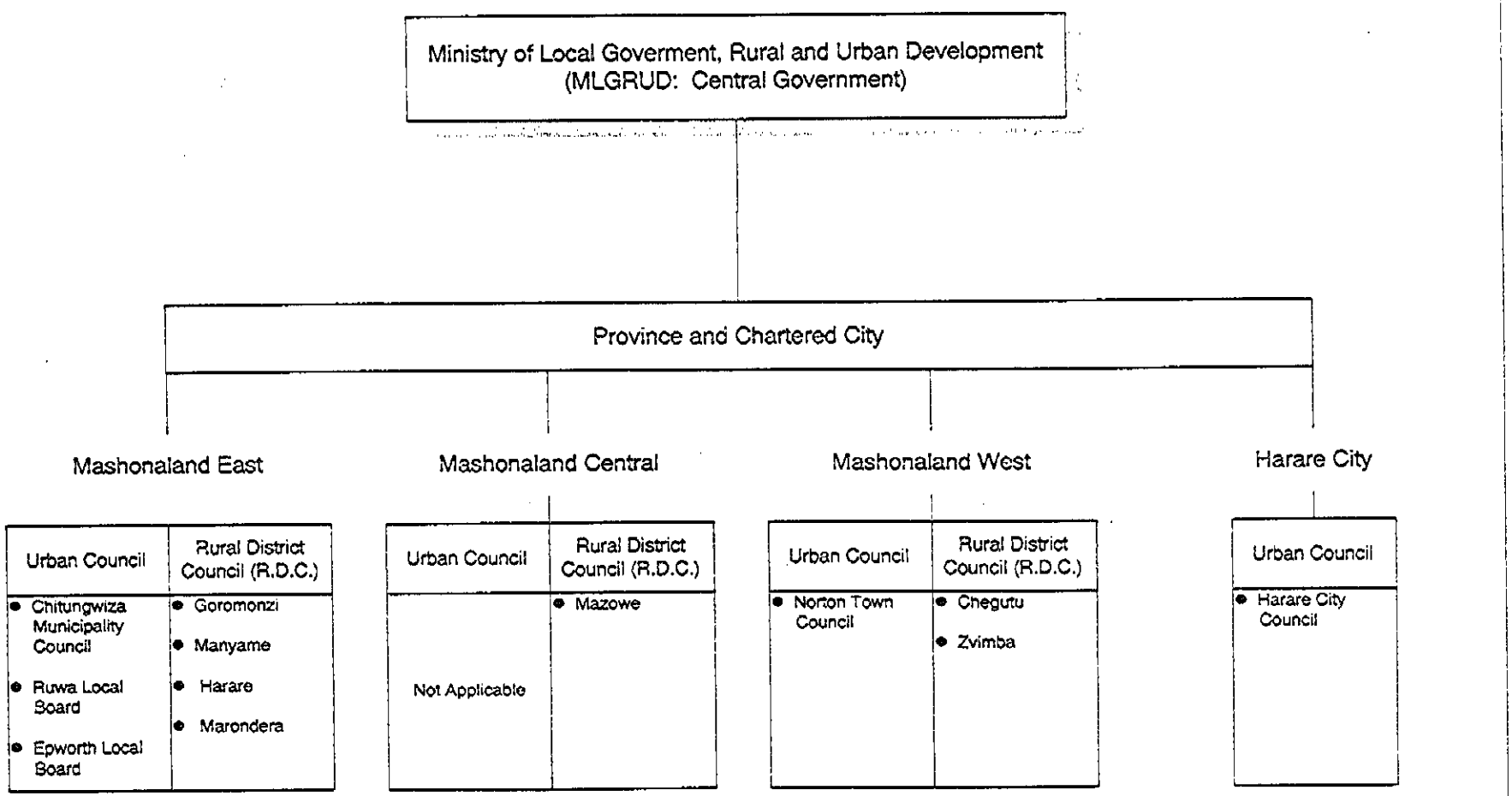


Figure 2.1.2 Local Administrative Composition in the Study Area

The local autonomous administrative units within the Study Area consist of five (5) urban councils and seven (7) rural district councils as of July 1996. The urban councils include City of Harare, the Municipality of Chitungwiza, the Town of Norton, and the Ruwa and Epworth Local Boards. Table 2.1.1 shows the local administration units by province/chartered city and their respective corresponding areas and present population. Following are the outline of the urban councils concerned:

(1) Harare City

The City of Harare is the capital city of Zimbabwe. It is situated in the upland region of the country at latitude 17.5° (S) and longitude 31° (E), and encompasses an area of some 560 km^2, with a 1992 population of 1,126,500. The first municipal authority was formed as a Board of Management in 1891. It was granted city status in 1935.

(2) Chitungwiza Municipality

The Municipality of Chitungwiza, currently the third largest in the country in terms of population, lies approximately 9 km south of the Harare City boundary. It was formed in 1978 by the amalgamation of three of Harare's former dormitory townships: Seke, Zengeza and St. Mary's. A town council was proclaimed in 1981 and since then a strong emphasis has been placed on attracting various industries and commercial developers to the town; this is in sharp contrast to the original purpose of the locality as a dormitory town for low-income workers employed in the capital city. Chitungwiza was proclaimed a municipality in February 1996 and is responsible for the civic affairs of about 400,000 people.

(3) Norton Town

The Town of Norton, some 40 km west of Harare City, was originally developed in the 1970s as a dormitory town for workers in Harare City. The urban area of Norton was administered until 1993 as part of the Norton-Selous District Council. A town board was instituted in 1993 to administer the some 19.5 km^2 granted town status. Norton, with a 1992 population of 20,000, is expected to rapidly develop as a result of its new status as a service centre for the Chegutu district.

Table 2.1.1 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)

(4) Ruwa Local Board

Some 8 km^2 of the Ruwa farming area was designated as a growth point in 1986. The centre is located in a large-scale commercial farming area along the Harare-Mutare Road and is about 23 km from Harare City. The area has been formally excised from the rural district council's authority subsequent to the formation of the Ruwa Local Board. The population in 1992 was about 1,500 and the majority of development has been undertaken by the private sector.

(5) Epworth Local Board

Some 34 km^2 of mission land in Epworth, located in the south-east of Harare City, was occupied by refugees in the 1970s. After independence, the area was taken over by the Ministry of Local Government, Rural and Urban Development. The infrastructure in the area was upgraded with financial assistance from USAID with the aim of attaining the standard of utilities in Harare City. Epworth was proclaimed as a Local Board in 1996. The 1992 population was enumerated at 62,600.

2.2 Physical Characteristics in the Study Area

2.2.1 Meteorology

The Department of Meteorological Services has been carrying out an intensive monitoring of meteorological and hydrological parameters throughout the country (details are referred to in Appendix 2.2).

Meteorological data of Harare City monitored at Belvedere Station during the part 30 years is summarised in Table 2.2.1.

Table 2.2.1 Monthly Meteorological Data of Harare City

Month	Jan.	Feb.	Mar.	Apr.	May.	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Total (Ave.)
Ave. Rainfall (mm)	186	173	96	38	7	2	2	3	6	40	89	181	823
Ave. Temp. (C)	20.0	19.8	19.4	18.7	15.9	13.6	13.6	15.6	19.0	21.3	20.8	20.4	18.2
Ave. Humidity (%)	77	79	72	67	61	59	51	47	45	46	61	72	61

As shown on the table, climate in the Study Area is very seasonal with three distinct, wet or dry, seasons. "Spring" is a hot and dry season from September to November and rainfall is

unlikely to occur. The average daily temperature is approximately 22°C ± 6°C. "Summer" is classified as the rainy season with hot and wet conditions from December to April. The average daily temperature is about 20°C ± 6°C. The remaining period of the year is a cold and dry season, so called as "Winter" in other parts of the world. The average temperature is approximately 16°C ± 6°C.

Mean total annual rainfall is approximately 820 mm in the Study Area with annual fluctuations ranging from 440 mm to 1,220 mm. During the summer season, approximately 80% of the total annual rainfall is observed.

Winds in Zimbabwe are generally from an easterly direction throughout the year, carrying moist air from the sea. Wind directions in Harare for the months of January, July and October show light winds over 4 knots which are commonly observed 50% to 80% of the time in any month of the year.

2.2.2 Topography and Geology

The Study Area is generally a gently undulating plateau. Most of the Study Area lies on an altitude ranging from 1,400 to 1,500 meters above sea level and the lowest altitude is approximately 1,300 meters.

The Study Area is generally underlain by Archaean age rocks forming a part of the Zimbabwe Basement Complex. The upper part of the Study Area is underlain by rocks of the Older Gneiss Complex containing relatively small inclusion of schistose rocks being comprised of meta-sediments and meta-volcanics of the Bulawayan Age, while a relatively small part of the upper extremity of the Study Area is underlain by granite.

The lower part of the Study Area including, Lake Manyame, is on the other hand, almost entirely underlain by granite which excludes a relatively large portion of the northern flank and a part of the north-western boundary. Rocks in the northern flank are mostly meta-sediments and meta-volcanics of the Bulawayan Age. Harare City, including its industrial area, lies on the outcrop and sub-outcrop of these rocks. A narrow belt of schistose is seen on the ridge of hills which form the abutment of Lake Manyame.

2.2.3 Hydrology and Hydrogeology

An extensive monitoring of hydrological parameters is carried out by the Department of Meteorological Services with a network of stations around the country. The hydrological Bureau of the Division of Water Development also maintains a network of river and groundwater flow monitoring stations.

There are six (6) tributaries in the Upper Manyame River Basin Area and four (4) lakes/dams. Raw water is being drawn from lakes/dams of Seke, Chivero and Manyame for water supply to Harare and Chegutu. In this river basin, there are also seven (7) sewage treatment plants. An outline of the rivers in the Study Area is shown in Table 2.2.2, while that of lakes/dams is shown in Table 2.2.3. The configuration of sub-river basins in the Study Area is shown in Figure 1.1.

Table 2.2.2 Outline of Rivers in the Study Area

River	Length (km)	Catchment Area (km^2)	Remarks
Manyame	131.0	3,930	Harava Dam, Seke Dam, Lake Chivero,
Gwebi	83.0	680	Marlborough WWTP
Muzururu	35.0	320	
Marimba	16.5	230	Crowborough WWTP
Mukuvisi	23.5	230	Firle WWTP
Nyatsime	56.0	590	Zengeza WWTP
Ruwa	24.0	180	Donnybrook WWTP, Ruwa WWTP

Table 2.2.3 Outline of Lakes and Dams

Name	Year of Construction	Storage Capacity (10^3m^3)	Max. Surface Area (ha)
Lake Manyame	1976	480,236	8,100
Lake Chivero	1952	247,181	2,630
Seke Dam	1929	3,380	110
Harava Dam	1972	9,026	215

The flow rate of the rivers fluctuates very seasonally. A large volume of river flow is normally observed during summer season (December to April), while the minimum flow occurs in winter, (May to August) wherein compensation water from the upstream dams is released.

The mean annual flow of Manyame River is approximately $304.7x10^6m^3$, while the total annual flow varies from $20.7x10^6m^3$ to $796.5x10^6m^3$. The Manyame River occupies as much as

80% of the total gauged flow, while the Mukuvisi and Marimba Rivers contribute to the rest of flow rate.

Abstraction and discharge from Lake Manyame account for about 60% of the total outflow, while 30% of the total outflow is estimated to be lost by evaporation. Upon completion of the downstream Darwendale Dam (Lake Manyame), the amount of water released from Lake Manyame has been somewhat reduced. Groundwater inflows and outflows are considered to be minimal in comparison with the surface flows.

2.2.4 Natural Environment and Ecology in the Study Area

The Study Area falls under Natural Region II definition as per agro-ecological classification of Zimbabwe, and is considered an intensive farming region. As a result of intensive agriculture and urban development, the natural environment has been modified throughout most of the Study Area.

The underlying granitic geology of most of the Study Area has given rise to light textured sandy soils except where basic rocks extending up the Mazowe valley to the northern edge of Harare have resulted in heavier textured, more clayey soils.

(1) Terrestrial flora

In broad vegetation terms, the Study Area falls into the miombo belt that occurs all over the Central African plateau between 800 m and 1,800 m above sea level and where annual rainfall is in the range 500 mm - 1,800 mm (Wild and Barbosa, 1967). A particular feature of the miombo woodlands is the bright coloured red, purple and green foliage of early spring. Most of the woody species flower before the rains.

With the relatively high rainfall in the Study Area, the dominant upland vegetation is similar in all soil types, *Brachystegia spiciformis - Julbernardia globiflora* woodlands and savannah woodlands. The largest trees in these deciduous woodlands are *B. spiciformis* and *J. globiflora* while grow up to about 13 m tall. Commonly associated species include *Combretum molle, Faurea saligna, Monotes glaber, Uapaca Kirkiana, Philiostigma thonningii* and *Pterocarpus rotundifolius. Julbernardia globiflora* regenerates faster than *B. spiciformis* and areas where this species is dominant often represent areas of secondary growth following cultivation. Common shrubs include the three species

Bauhinia petersiana, Lannea discolour and various *Grewia* species. The grass layer is usually sparse where the woodlands are well developed but denser where the canopy is more open. Typical species are *Hypparrhenia filipendula, Hyperthelia dissolute, Pogonarthria squarrosa* and *Brachiaria brizantha.* The flame lily *Gloriosa superba* may be conspicuous during the wet season. On the rocky hills (kopjes) a variety of other species not found on the deeper soils, such as *Brachystegia glaucescens* and *commiphora sp.* are common. Colourful aloes are also a feature of rocky outcrops and kopjes.

Scattered throughout the woodlands are large termitaria (anthills) usually covered with a dense thicket of woody vegetation which often contains, in addition to the typical woodland species, other species such as *Albizia amara, Cassia abbreviata* and *Ziziphus mucronata.*

In the northern part of the Study Area and near Melfort and Bromley there are areas where the water table is too high for the typical woodlands and a more open tree savannah occurs. The grassland is generally dominated by *Hypparrhenia sp.* with scattered *Parinari curatellifolia* trees up to 15 m tall.

The woodlands and savannah are dissected by seasonally wet grasslands (vleis), that develop into small stream as they pass down the catena and join together. The vleis are dominated by tall grasses such as *Hyparrhenia filipendula* and *Hyperthelia dissoluta* and although the streams themselves do not have a well developed riverine vegetation, as would be found at lower altitudes, trees such as *Syzygium guineense, Combretum erythorophyllum* and *Acacia karroo* are often found along the banks and reedbeds (*Phragmites sp.*) are common.

Relatively small areas of *Acacia* savannah also occur, usually in the vicinity of smaller streams, typical trees being *A. sieberana* and polyacantha.

(2) Terrestrial fauna

Before development took place, most of the large mammals found in Zimbabwe also occurred within the Manyame catchment, but agricultural and urban development have made the area unsuitable for the larger wild mammals except where fenced game parks have been established. Outside these game parks kudu, reedbuck, duiker, steenbuck,

antbears, naboons and monkeys still occur and also a range of smaller carnivores and omnivores such as civet, genets, mongooses, jackals, bushpigs hares and rodents. Many of these smaller animals are primarily nocturnal and seldom seen.

Although deforestation and agriculture have altered the natural environment, many of the 640 species of birds recorded in Zimbabwe can be found within the Study Area, both as resident species and migrants. Many species have adapted to development and Peregrine and Lanner falcons have been recorded nesting in central Harare on the high rise buildings. Little swifts and Palm swifts are also common in the city as well as house sparrows, which are not indigenous to Zimbabwe but are now found in all urban areas. One group of birds that has been particularly favoured by the development of dams are the water and wading birds. The larger impoundments and smaller farm dams and the overflow from the sewage works are all suitable habitats and the number and variety of birds at these sites can be striking.

Reptiles and amphibians are well represented in the Study Area and Broadley and Blake (1979) give 37 species of reptile recorded and another 25 of probable occurrence in Lakes McIlwaine (Chivero) and Robertson (Manyame) Recreational Parks, on the Manyame River. These include snakes, lizards and tortoises as well as monitor lizards. There is habitat for a number of fossorial amphibians and reptiles, such as burrowing frogs and amphisbaenids.

(3) Aquatic ecology

The eutrophication of the river system and Lake Chivero in particular has led to large amounts of algae and floating aquatic plants, particularly water hyacinth (*Eichornia crassipes),* water lettuce (*Salvinia molesta*), and water fern (*Azolla filiculoides*). The floating aquatic plants interfere with commercial fishing and recreational uses of Lake Chivero in particular. Methods of combating the water hyacinth have included spraying with chemicals and manual removal and more recently, biological control using a weevil, *Neochetina eichhorniae,* is showing promising results. Rooted macrophytes such as *Lagarosiphon major* are also very common in the lakes and these aquatic systems also have a diverse populations of aquatic fauna.

About 28 species of fish are known from the Upper Manyame, (Marshall, 1982) and Lakes Chivero and Manyame both support commercial fisheries as the eutrophic nature of the impoundments leads to high fish productivity.

A feature of the larger reservoirs is the very marked thermal stratification that occurs as the surface water warms during the summer causing two discrete layers to form. The lower layer remains colder but accumulates nutrients from the decay of sinking organic matter and becomes anaerobic. At the beginning of the cool season, stratification breaks down as the surface layer cools, the layers mix and trapped nutrients from the lower layer are released resulting in algal blooms. De-oxygenated water from the lower coming to the surface may also cause fish deaths as happened at Lake Chivero in March-April 1996.

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