JAPAN INTERNATIONAL COOPERATION AGENCY
THE UNITED REPUBLIC OF TANZANIA
MINISTRY OF WATER, ENERGY AND MINERALS

[illegible]

WATER [illegible]

[illegible]

MAIN REPORT

JUNE 1994

NIPPON [illegible] CO., LTD.
PACIFIC CONSULTANTS INTERNATIONAL

JAPAN INTERNATIONAL COOPERATION AGENCY

THE UNITED REPUBLIC OF TANZANIA
MINISTRY OF WATER , ENERGY AND MINERALS

STUDY
ON
WATER RESOURCES DEVELOPMENT
IN
THE RUVU RIVER BASIN

FINAL REPORT

VOLUME II

MAIN REPORT

JUNE 1994

NIPPON KOEI CO., LTD.

PACIFIC CONSULTANTS INTERNATIONAL

PREFACE

In response to a request from the Government of the United Republic of Tanzania, the Government of Japan decided to conduct a Master Plan Study on Water Resources Development in the Ruvu River Basin and entrusted the Study to the Japan International Cooperation Agency (JICA).

JICA sent to Tanzania a study team headed by Mr. Makoto Tsuda, Nippon Koei Co., Ltd., and composed of members from Nippon Koei Co., Ltd. and Pacific Consultants International, three times between February 1993 and June 1994.

The team held discussions with the officials concerned of the Government of the United Republic of Tanzania, 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 with to express my sincere appreciation to the officials concerned of the Government of the United Republic of Tanzania for their close cooperation extended to the team.

June 1994

Kensuke Yanagiya

Kensuke Yanagiya
President
Japan International Cooperation Agency

June 1994

Mr. Kensuke Yanagiya
President
Japan International Cooperation Agency
Tokyo, Japan

Dear Sir,

Letter of Transmittal

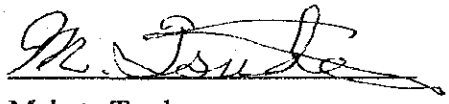
We are pleased to submit herewith the Final Report of the Study on Water Resources Development in the Ruvu River Basin in the United Republic of Tanzania.

The Report presents a master plan for water resources development comprising various projects for municipal water supply to Dar Es Salaam, agricultural development, electric power development and flood control, of which the municipal water supply is given the first priority in order to meet the water demand in Dar Es Salaam city by the year 2020. Based on the Study, two (2) development scenarios involving the provision of a few dams in the basin are proposed for not only municipal water supply, but also development in other sectors.

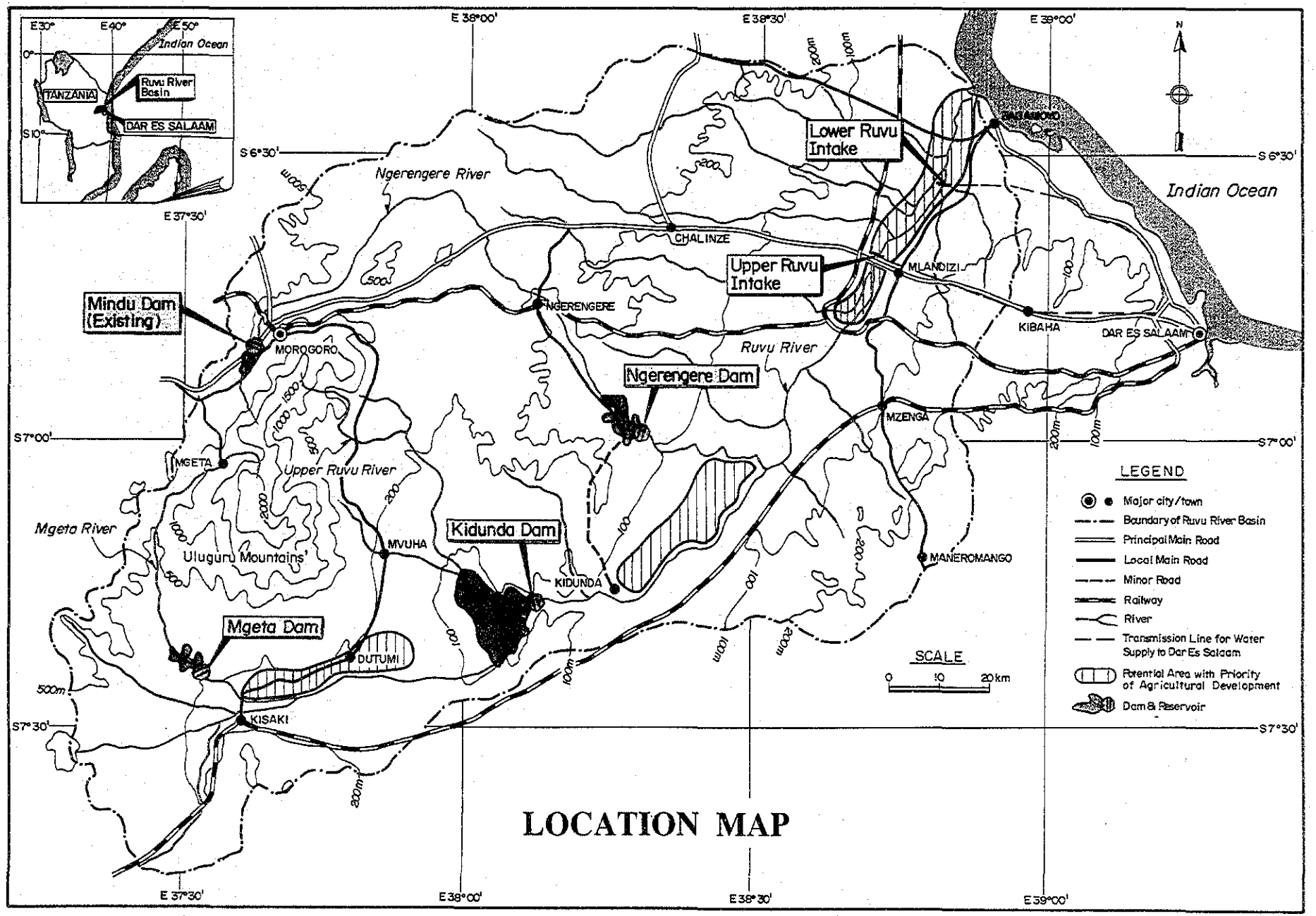
The Report consists of four (4) Volumes, the Executive Summary, Main Report, Supporting Report and Data Book. The Executive Summary presents main outputs of the Study. The Main Report covers all the study results including analysis of the respective disciplines. The Supporting Report gives additional and supporting information, and the Data Book provides data obtained from the field surveys and investigations.

We would like to express our heartfelt thanks to the personnel of your Agency, your Branch Office in Dar Es Salaam City, and the Embassy of Japan in Tanzania, and also to officials and individuals of the Government of Tanzania for the assistance and advice extended to the Study Team. We sincerely hope that the results of this Study will contribute to the national and regional development of the country.

Yours sincerely,



Makoto Tsuda
Team Leader
Water Resources Development in
the Ruvu River Basin



LOCATION MAP

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER I

INTRODUCTION

1.1 Background of the Study

On the basis of the Scope of Work (S/W) agreed upon between the Ministry of Water, Energy and Minerals (MWEM) of the Government of Tanzania and the Japan International Cooperation Agency (JICA) on 22 October 1992, the Study on Water Resources Development in the Ruvu River Basin (hereinafter referred to as "the Study") was carried out over 17 months since February 1993.

The Study period comprises the following three phases, each of which is divided into the field work period in Tanzania and home office work period in Japan:

Phase 1 : February to August 1993
Phase 2 : September 1993 to February 1994
Phase 3 : March to June 1994

The Study covers the entire Ruvu River basin and the Dar Es Salaam city. The main objectives of the Study are:

- To formulate the comprehensive master plan on water resources development in the entire Ruvu River basin covering an area of about 17,900 km^2, in which the first priority was placed on the municipal water supply to Dar Es Salaam towards the target year 2020, and

- To carry out the transfer of knowledge to the Tanzanian counterpart personnel dispatched by the Government of Tanzania by means of the on-the-job-training.

To fulfill the above S/W and objectives of the Study, JICA organized the JICA Study Team consisting of thirteen (13) disciplines. In addition, JICA maintained the JICA Advisory Committee during the Study period in order to support the works executed by the Study Team. The members of the JICA Advisory Committee for the Study are listed in Table 1.1, while those of the JICA Study Team are in Table 1.2.

1.2 Cooperation

During the field work period, the counterpart personnel were fully assigned to the Study by MWEM in compliance with the request by the Study Team as shown in Table 1.3. Especially, a lot of field investigation works including data collection in the respective disciplines involved in the Study, topographic survey, installation of new stream gauging stations and current metering thereat, sampling for water quality analysis and soil analysis were carried out in collaboration with the counterpart personnel.

In order to formulate the consistent master plan on the water resources development from viewpoint of development policy of every sector in Tanzania, the Government set up the Steering Committee immediately after the commencement of the Phase 1 Field Work. The Steering Committee was composed of the following governmental organizations:

- Ministry of Water, Energy and Minerals
- National Urban Water Authority
- Ministry of Agriculture
- Ministry of Tourism, National Resources and Environment
- Tanzania Electric Supply Company
- Ministry of Finance
- Ministry of Health
- Ministry of Community Development, Women Affairs and Children
- Planning Commission
- Regional Commissioner's Office, Coast Region
- Regional Commissioner's Office, Morogoro Region

The Study was proceeded keeping the close coordination with the Steering Committee during the Study period.

1.3 Work Progress

1.3.1 Phase 1 Work

The phase 1 Field Work was commenced in the early March 1993 and continued for about four (4) months up to the end of June 1993. On arrival of the Study Team at Dar Es Salaam, the Inception Report on the Study was submitted to the Ministry of Water, Energy and Minerals (MWEM) and the meeting was held on March 10th with the attendance of the concerned personnel of both Japanese and Tanzanian sides so as to discuss the content and policy of the Study described in the Inception Report. The Study Team commenced the regular field

investigation works immediately after the conclusion of the Minutes of Meeting on the Inception Report.

In the course of the Phase 1 Field Work, the heavy rainfall that took place in the Ruvu River basin at the end of April and from time to time thereafter hampered the smooth execution of the planned field survey and investigation works, although the reasonable progress was being made on every aspect of the field works until the middle of April. Due to the high river stage resulting from the heavy rainfall, the low-lying areas extending on both banks of the Ruvu River was submerged and a lot of swamp areas were formed in the basin. Nevertheless, all the field works scheduled in the Phase 1 Field Work were completed and those results were stated in the Progress Report (1) submitted to MWEM at the end of June 1993 and were fully utilized in preparing the Interim Report on the Study in the Phase 1 Home Office Work.

1.3.2 Phase 2 Work

In succession to the Phase 1 Home Office Work during which the Interim Report on the Study was prepared to describe the interim results thereof based on the results of the Phase 1 Field Work, the Phase 2 Field Work commenced on arrival of the members of the Study Team at Dar Es Salaam on 28th September 1993. Immediately after their arrival, the Interim Report was submitted to MWEM. The Steering Committee meeting on the Report was held on 12th October 1993, being attended by the members concerned of the both Japanese and Tanzanian sides, in order to discuss about the contents of the Interim Report.

During the Phase 2 Field Work, the scheduled field works were smoothly progressed under the favorable climate condition as compared with that in the previous Phase 1 Field Work. Consequently, the Study Team could reconnoiter the proposed Kidunda and Mgeta dam sites for the purpose of confirming the topographic and geological conditions as well as gathering the data and information relevant to these dam schemes, especially those on villages which may be submerged due to creation of the Kidunda reservoir.

In particular, it is clarified through the field survey that there are the on-going projects under the Selous Conservation Programme (SCP) in and around the planned Kidunda and Mgeta reservoir areas, which may have an intervention with those dam projects, in particular in case of the Kidunda dam. Hence, the Study Team attempted to collect the data and information on the on-going projects as much as possible.

The progress of the Phase 2 Field Work as well as the major findings and analyses results obtained from the field work were described in the progress Report (2) submitted to MWEM at the end of December 1993.

During the Phase 2 Field Work, as well as the case in the previous Phase 1 Field Work, the counterpart personnel were dispatched by the MWEM as required by the Study Team for the successful completion of the field works. Thus, most of the field works were carried out in collaboration with the counterpart personnel.

1.3.3 Composition of the Report

This Final Report comprises the following four volumes:

- Volume I : Executive Summary
- Volume II : Main Report
- Volume III : Supporting Report
- Volume IV : Data Book

The Executive Summary summarizes the Study results as well as the master plan for the water resources development in the Ruvu River basin, which has been set up in the course of the Study. The Main Report describes the master plan in more detail in addition to the study results of the Study in the respective disciplines related to the master plan. The Study results and the field investigations performed are presented in detail in the Supporting Report by discipline. The Data Book provides the topographic survey data, meteo-hydrological data and its analysis results, data on flood damage survey and data on soil analysis.

CHAPTER II

THE STUDY AREA

2.1 The Land

The United Republic of Tanzania is located in the middle-eastern part of the African Continent, which lies between 1° and 11° 45' South Latitude and between 29° 21' and 40° 25' East Longitude. The land of the country with a gross area of about 945,000 km^2 is bounded by the borders with Kenya and Uganda on the north, those with Rwanda, Burundi and Zaire on the west and those with Zambia, Malawi and Mozambique on the south, and faces to the Indian Ocean on the east.

The land of Tanzania is mostly composed of high land of more than 300 m in elevation except for the low-lying area along the Indian Ocean, and it is dissected by the rift valley running from north to south so that there exist a lot of lakes like Tanganika and Nyasa which are created thereby.

The Study Area covers the entire Ruvu River basin with a catchment area of about 17,900 km^2, and its neighboring Dar Es salaam city to which the municipal water is being supplied from the Ruvu River. The upper basin of the Ruvu River is administratively under the jurisdiction of the Morogoro Region, while the lower basin thereof under that of the Coast Region.

Except for the Uluguru Mountains area, the Study Area is mostly composed of the low-lying areas along the Ruvu River and slightly elevated hilly area with moderate undulation which extends behind the low-lying areas, and around which high land areas with 500 to 1,000 m in elevation spread to surround the hilly area forming the relatively sloped landscape.

The asphalt-paved Morogoro road connecting Dar Es Salaam city and Morogoro municipality which is a trunk road in the Study Area runs in the east to west direction, from which a lot of unpaved rural roads branch off. However, most of these rural roads are not passable during the wet season. In addition to the trunk road, the existing Tanzan railway along the Ruvu River, constructed by the aid of China, is also available as a transportation means in the wet season.

2.2 Socio-Economic Condition

2.2.1 National socio-economic condition

(1) General

About 25 million people lived on the Main Land in 1991, while about 1.6 million people in Dar Es Salaam, a capital of Tanzania.

The Revolutionary Party (CCM), which had been only a single party until the introduction of multiparty system has been keeping the place of the majority party since then. Grumbling over the federation of the Main Land and Zanzibar islands has increasingly taken place recently.

The GNP was 3,079 million US$ (120 US$ per capita) in 1989 and the annual average growth rate for the previous ten years was 3.8 percent (1.8 percent per capita).

Economy of Tanzania was liberalized, but increased import goods have pushed the price. The exchange rate reached nearly TSh. 500 per US$ at the end of 1993, about 100 percent declined in two years. The policy to mitigate the economic shock caused by the introduction of free market system has not been effective yet. The mainstay of the Tanzanian economy is agriculture. But the exports of commodity crops such as coffee, cotton and cashew nuts have been stagnant. The general basic socio-economic data are given in Table 2.1 and population of the Main Land and the regions is listed in Table 2.2.

(2) Economy

The annual GDP (total and per capita) of the Tanzania Main Land between 1980 and 1991 is given in Table 2.3, and the GDPs by kind of economic activities at current prices between 1982 and 1991 are given in Table 2.4.

In 1991, contribution to the total GDP of the agricultural sector reached 62.5 percent. Whereas manufacturing sector accounted for only 3.6 percent of the total GDP six years after the introduction of the Economic Recovery Plan (ERP).

With the help of steady growth of agriculture at annual growth rate of more than 4 percent for eight consecutive years up to 1991, the annual growth rates of GDP since 1984 have exceeded 3 percent except that in 1985. In the Study, the annual growth rate for the planning period is assumed at 3 percent on the constant price basis.

Approximately 60 percent of the GDP of Tanzania was shared by agriculture in 1991 as aforesaid. If it is supposed to grow at a rate of 3.5 percent annually, the rest would grow at a rate of 2.25 percent annually to achieve the overall annual growth rate of 3 percent.

Though the manufacturing industry sector has not contributed so much to the Tanzanian economy in terms of GDP, its contribution to the indirect tax revenue was 65.5% in 1991/92 fiscal year, and it provides more than 80 percent of salaried work force with respect to job opportunities in the formal economy. It has a bright scope in future as many manufactured goods are imported at present (textiles: 90%, beer: 40%, sugar: 35%, footwear: 95%, cooking oil: 70%, tyres except for bicycles: 50%, radios: 80%).

(3) National economic development plan

The long-term perspective plan (1981-2000) was implemented in the context of socialism and self-reliance. The target of average GDP growth rate was set at 6 percent.

Due to the unsatisfactory progress of the plan, the Government introduced the first ERP for three years in 1986. The second ERP covered the period from 1989/90 to 91/92, and the third ERP is going to start from July this year. The core of the plan was to introduce a system of free market economy with an intention to revive the national economy as a whole.

The first and second Priority Social Action Programmes (PSAP) are indispensable components of the ERPs to mitigate many unavoidable socio-economic strains to the poor, which will be accompanied by the economic reforms.

The recent Union Five-Year Development Plan is going to end at the end of June 1994. It had been initiated a year earlier than the first ERP in which a reassessment of some parts was called for.

2.2.2 Socio-economic condition of the Study Area

(1) General

About 610 thousand people lived in the Ruvu River basin in 1988. In terms of water use of the basin, about 1.3 million people living outside the basin were served by the basin water in the same year through piping systems.

(2) Economy

The annual GDP (total and per capita) of regions concerned with the Study Area between 1980 and 1991 are given in Table 2.3.

In 1991, an average per capita RGDP of the Morogoro Region, which was about 93 percent of that of the Main Land, was about one third of that of the Dar Es Salaam Region. The per capita RGDP of the Coast Region was less than 12 percent of that of the Dar Es Salaam Region.

The RGDP of Dar Es Salaam, of which agriculture does not contribute so much as other regions, accounts for 20 percent of the total GDP in 1991. Then, the RGDP of Dar Es Salaam is equal to half of the GDP except for that derived from agricultural sector. About 41 thousand persons were engaged in the manufacturing industries in Dar Es Salaam in 1987. Whereas the so-called informal sector provided jobs to about 316 thousand people in Dar Es Salaam in 1990 according to the "Tanzania, The Informal Sector, Bureau of Statistics, 1991".

There are 35 manufacturing industries in the basin. The number of work force totals around 4000. With advancement of privatization, the existing factories in the Morogoro Urban District owned solely by the Government or managed by it as a majority shareholder may boost their productivity if the resources are sufficiently available. Kibaha has industrial growth potential if public utilities become fully usable without any hindrance. There are no statistics available about informal sector in the basin, but besides fruit/vegetable growing and sale, charcoal making, transport and sale provide jobs to a considerable number of residents. It is estimated that about 22 thousands people are engaged in charcoal making and that 55 thousands people are involved in their sales throughout the Main Land. With the increase of urban population, the use of charcoal would naturally increase. In connection with consumption of fire woods and charcoal, finding a sustainable way of managing forests would be given priority in the immediate future, even though there is a prospect of having natural gas from the Songo Island to mitigate the tight energy supply situation.

(3) Socio-political situation

i) Administrative units

The structure of administration of the Main Land consists of five levels of hierarchy in terms of geographical units, namely region, district, division, ward and village. Administratively, the region and district have parallel structures. They are headed by both of a commissioner and a development director. Except planning, finance and manpower departments, all other departments are headed by an officer and/or engineer dispatched from the Ministries of the central Government.

The division is not given administrative importance though they give some geographic characteristics being in between units of the district and ward and no code numbers are allocated thereto.

The ward is the electoral unit of the national parliament, and the village has their elected local government. Some staff of the regional government are dispatched thereto to run their offices, for example, in case of ward water secretary for its water management.

There are five districts in the Ruvu River basin, namely the Morogoro Rural and Urban Districts of the Morogoro Region, and Bagamoyo, Kibaha and Kisalawe Districts of the Coast Region. The geographical boundary of the basin does not necessarily coincide with that of village. There are some cases that a boundary of two river systems is on low-lying flat plateau. Some villages in those areas have water sources in the both river basins.

The use of water source of the basin also takes place in its outside areas through existing two intake structures on the Ruvu River. Some residents along the trunk main pipelines in Bagamoyo and Kibaha Districts of the Coast Region and of major parts of the Dar Es Salaam Region are getting treated water. Plants on the irrigated plots or kitchen gardens and some livestock are also among the beneficiaries.

ii) Communities in the basin

The Waluguru and the Wazaramo are two predominant communities in the Ruvu River basin. The former, matrilineal and mostly Catholics, mainly live in the Uluguru Mountains area, as the name suggests. With the increase of community members, they have started to settle in the piedmonts of the mountains and the river terraces downward. The latter, patrilineal and mostly Moslems, are the residents of the areas nearer to the coast.

There are some smaller communities in the basin. They are locally concentrated. From the upper reach downward, there are the Wakutu in the fertile Mgeta plain, the Wakwavi in the Ngerengere River basin, and the Wakwere and Wadoe along the coast. They are agriculturists except for the Wakwavi in its origin.

The Wakwavi, which is sometimes called Baraguyu, is a descendant of the Masai people, which has a heritage as pastoralist. In Ngerengere, they are leading a sedentary life and they grow cereal and tuber, while taking care of their herds of cattle. The range lands of the community were used to be far wider than their present ones. As population has increased in the area, the creation of government livestock policies has made them change their pastoral way of life into more confined one. It threatens them with the problem of over-grazing, but gives

them a chance of sending their children to school, while it is another dilemma to their parents as school-going reduces practical training of pastoral production usage.

iii) Water supply

Total expenditure of the Dar Es Salaam water supply system operated by the NUWA in the fiscal year of 1991/1992 amounted to TShs. 3,389 million, which accounted for recurrent expenditure of 55.4% and depreciation costs of 44.6%.

If actual production of water is set at 180,000 m^3 per day, the unit cost of water produced by the NUWA would be TShs. 51.58 per m^3.

Even if all the water bills are fully collected at the present water rate, the amount would not cover the recurrent expenditure. The amount of the deficit would reach about 15 percent of the recurrent cost.

iv) Flood Damage

During the field work period, the Ruvu River basin was hit by a fairly big flood, but no house was washed away since all of them are built outside the floodplain.

If flood happens during the rainy season, the potential damage would occur on paddy fields where transplanted paddy is grown. The farmers can grow maize even after the field is hit by flood. Consequently, the net damage incurred would be only the costs of material and labour input therefor.

2.2.3 Present socio-economic conditions of Selembara ward in the planned Kidunda reservoir area

(1) General description

Major part of Selembara ward located upstream of the Kidunda dam site would be submerged when the planned dam is constructed at the site proposed by the Study. The ward consists of four villages, i.e., Magogoni, Kiganila, Bwilajuu and Bwila-chini. The Magogoni village is located on the right bank of the Ruvu River, while the next two ones on the left bank. The last extends on both banks.

In this area, the right bank of the Ruvu River is designated as a buffer zone of the Selous Game Reserve under the Selous Conservation Programme (SCP) which is discussed in the succeeding Section 2.9. The residents of Magogoni village and Vikonge area of Bwila-chini

village, where a hunting community exists, deem to be removed out of the present location in future whether or not the Kidunda dam project is implemented.

In case the Kidunda dam is constructed, the residents on the left bank would also need to be moved out of the present site where they have lived for some generations. In this area, the earliest settlers came to the Bwila-chini village area. Then, with the commencement of the Ujama movement in 1974, new immigrants are settled in a part of the Bwilajuu village. Now with the population growth within the Bwila-chini village, the village is about to be further divided, creating the new village called Kiburma.

The land use and economic activity in the ward are mostly agricultural. Bus services between the ward and Ngerengere via Kisange are available while the road condition permits it. On the other hand, communication within the ward across the river is done by canoes. Ambulance relies on them as a dispensary, which is located in the Magogoni village. A primary school is located in the Bwila-juu and Magogoni villages on the left bank and right bank sides of the Ruvu River, respectively.

As the area is infested with tse-tse flies, the residents cannot keep cattle except some goats. Pastoral community of Wakwavi has come down to stay in the Tunungwa and Kisange villages which are located on the left bank of the Ruvu River, some 20 km upstream of the Kiganila village. This fact exhibits that the surrounding Miombo forests are less infested with tse-tse flies.

(2) Land use and agriculture

The present land use and agricultural activity of the ward are given in Table 2.5. Although it is difficult to size the population figures with accuracy as seen in the Table which shows the different statistics of the population, it gives the general features of the activities in the ward.

Their agricultural activity has been extensive with a limited number of manpower with only hoes and machetes. An average unit production of maize, paddy and sorghum is around 3 tons per hectare.

In addition to the crops listed in the Table, they grow cassava and millet for their subsistence and tobacco as a cash crop. Besides, vegetable, beans, pumpkins are found in the kitchen gardens. Tobacco they grow is a local variety so that its market is limited. There is few papaya in the ward, which may prove the fact that the area is flood-prone during the rainy season. The flood marks are clearly seen on the house walls. In the area, fishing activity of human being has been competed with the wildlife predator such as crocodile.

Average annual income per household in 1991 ranges between TShs. 20,000 and 25,000 according to the report of the Selous Conservation Programme (SCP). Most of the houses are made of wattle and mud walls with thatched roofs. A house with four rooms made of wattle-mud walls without roof costs them about TShs. 52,000. Every house has a detached toilet, which costs them TShs. five thousand to build. There is a shallow well with a hand pump in each village, but the pumps are either malfunctioning or broken. A piece of burnt brick costs them TSh. 10, and cement block TSh. 15 per a piece. Transport cost of a bag of cement from Dar Es Salaam is about TShs. 400.

2.3 Geology

2.3.1 Geomorphology

The Study Area spreads from the Uluguru Mountains with an altitude of more than 2,000 m in the west to the coastal plain with an altitude of less than 200 m in the east. The Study Area can be divided into the following four topographic zones:

- Uluguru Mountains
- Highland around Morogoro municipality
- Elevated rolling hill
- Alluvial low-lying plain along the Ruvu River

The Uluguru Mountains rise abruptly out of the coastal plain and form a compact unit which is physically and geologically distinct from the surrounding hilly and low-lying plains. The highland around Morogoro municipality with an altitude of approximately 500 m above sea level, is formed by the Ngerengere and Wami Rivers. These lands are scattered and are composed of intrusive rocks and Precambrian rocks. Elevated rolling hill with an altitude ranging from 50 m up to 300 m above sea level is developed between the Ruvu and Wami Rivers and between the Ruvu River and Indian Ocean. These hills consist of the Mesozoic and Neogene sediments that are easily eroded forming gentle rolling hills. The Ruvu River forms the wide floodplains of 5 to 10 km wide. These floodplains consist of the Quaternary deposits.

2.3.2 Regional geology

The regional geological map of East Africa is shown in Fig. 2.1. The geology of the Study Area can be categorized into the following five major divisions:

- Precambrian rocks
- Karroo rocks
- Jurassic rocks
- Cretaceous rocks
- Tertiary and Quaternary rocks

Precambrian rocks mostly occur in the Uluguru Mountains and in the western part of the Ngerengere subbasin. These rocks are mainly meta-sedimentary rocks and can be divided into three major lithological groups, namely acid gneisses, granulate and crystalline limestone. They seem to have been thrust and uplifted by the upward movement of the basic gneisses, thus giving rise to distinct fault zone in the rocks.

The Karroo rocks occupy southeastern area of the Uluguru Mountains. The rocks consist mainly of sandstone, and shale deposited in shallow fresh to blackish water. Their ages may vary from Permian to Triassic.

Jurassic rocks occur in the eastern margin of the Uluguru Maintains and elevated rolling hills between the Ruvu and Wami Rivers. They consist of course sandstone, mudstone, and oolitic limestone deposited under the marine environment.

Cretaceous rocks lie in the elevated rolling hills. They consist of clay, shale, calcareous sandstone, sandy limestone and mudstone.

Sediments of Tertiary and Quaternary ages occur in the catchment area of the Ngerengere River near Morogoro municipality, and in the elevated rolling hills and floodplains along the Ruvu River and extend up to Dar Es Salaam. The tertiary deposits consist of sandy clay, clayey sand with minor lenses of pure sand or clay, gravel and calcareous fragment. The Quaternary deposits were formed in the fluvial and alluvial fan, being subject to the swampy condition during the wet season. They consist of clay, silt, sand and rarely gravel.

2.3.3 Fracture lineament identified by aerial photo interpretation

(1) Major fractures

The Study Area is located in the eastern part of the African Rift Valley, with simplified major faults along the Rift Valley in association with gravel and the tertiary to recent volcanics, stretching from the Red Sea to Mozambique. The Lake Victoria lies between the western and eastern branches. These major fractures strike in the North-South and NNE - SSW directions,

the same direction as the western rift. The geological structure of rocks and fractures is shown in Fig. 2.2. The main structure indicates the direction of North - South and East - West.

(2) Fracture lineament

The results of the aerial photo interpretation for the lower reaches of the Mgeta River are shown in Fig. 2.3. The area is located at the southern edge of the Uluguru Mountains. Geologically it is composed of granulate of Precambrian, carbonatate formed along the fractures, sediment rocks of Karroo and Alluvial deposit developed along the river. The interpreted fracture lineament in the area is assessed as follows:

i) Major fractures can be clearly identified on the aerial photographs. They can be plotted mainly in NNE - SSW or E - W directions. These lineament of fractures are classified as major faults in the existing geological maps. Especially, the fracture lineament running along the border between mountains on the right bank and alluvial plain of the Mgeta River are interpreted to be its lineament with about 30 km in length and 10 to 50 m in depth.

ii) Other fracture lineaments extend to 1 to 10 km in width, taking mainly three directions of N - S, NNW - SSE or ENE - WSW. The fracture of rocks extend in the same direction. The lineament running in the ENE - WSW direction was formed by the major fracture of E - W direction. The lineament of NNW - SSE direction runs in parallel with the East African Rift System.

2.3.4 Hydrogeology

To assess the ground water potential in the Study Area, it is divided into four zones (Zone A to Zone D) as shown in Fig. 2.4. In those zones, the following areas are assessed to have the potentials of the ground water resources development based on the geologic and hydrogeologic data made available so far:

No.	Zone	Geologic Formation of the Potential Area
1.	Zone A	Metamorphic limestone in the northeastern foot of the Uluguru Mountains (Sub-area VI)
2.	Zone A	Karroo formation and Quaternary deposits along the Mgeta and Ruvu valleys at south and east of the Uluguru Mountains (Sub-area VII)
3.	Zone A	Jurassic limestone in the Ngerengere area (Sub-area VIII)
4.	Zone C	Alluvium in the floodplain, present river channel and relict of stream channel
5.	Zone D	Quaternary deposit (Sub-zone D-4)

The locations of the above potential areas of ground water development are shown in Fig. 2.4. Although the water quality analysis carried out during the present field survey revealed that ground water at the Dutumi well is suitable for the drinking water, it appears that ground water in most of the Study Area is affected by saline water or of poor quality as long as the data in the boreholes show. In the implementation of the ground water development project, therefore, the investigation by electric resistivity survey, resistivity log and pumping tests and water quality analysis needs to be carefully executed.

2.4 Meteorology and Hydrology

2.4.1 Meteorology

The Study Area belongs to the tropical savanna climate zone. While rainfall occurs throughout a year in the Study Area, its amount is extremely variable and undependable. The mean monthly rainfall during the period of November to May is higher than that during June to October and these periods are generally referred to as the wet season and dry season, respectively. In the northeastern part of the Study Area, the mean monthly rainfall during March to May is higher than that during November to December.

Annual rainfall in the low-lying and hilly areas varies from 800 to 1,000 mm, while at the Uluguru Mountain foot it varies widely from 1,000 to 2,000 mm. Annual rainfall of more than 2,000 mm occurs in the high mountainous area of the Uluguru Mountains. Based on the rainfall data, an isohyetal map of mean annual rainfall in the Study Area was drown as shown in Fig. 2.5.

The seasonal pattern of meteorological parameters in the Study Area is shown in Table 2.6 and Fig. 2.6. Those annual values are summarized below:

Basin average rainfall	1,080 mm
Mean temperature	26°C
Average max. temperature	30°C
Average min. temperature	20°C
Relative humidity	62%
Wind velocity	1.4 m/sec
Sunshine	7 hrs/day
Potential evaporation	1,800 mm/year

2.4.2 Hydrology

The Study Team collected all the available data of monthly rainfall at 66 rain gauge stations, daily rainfall at 19 stations, meteorological data at 4 stations, hydrological data at 11 stream gauging stations and sediment data at 3 stations. To compare with the regional runoff characteristics in the Study Area, it is divided into 5 main subbasins as shown in Fig. 2.7. The annual average basin rainfalls for the whole Ruvu River basin and those subbasins are estimated as shown in Table 2.6 by the Thiessen polygon method based on annual rainfall data at the representative 19 rain gauge stations in the Study Area.

Through the analysis, the runoff coefficient for the entire Ruvu River basin is estimated to be about 12%, which is equivalent to approximately 2,100 million m^3 in annual yield of runoff. The regional runoff characteristics were clarified by the subbasin as follows:

(1) Upper Ruvu and Mgeta basin

Considering the conditions of rainfall, vegetation, topography and others in the basin, approximately 50 % of annual rainfall is expected to run off in the mountainous area. However, a large amount of water loss due to evaporation, infiltration, etc. would also take place in the floodplain with a catchment area of more than 1,500 km^2, which extend in altitude of 100 m to 200 m in the lower part of these basins. A runoff coefficient of less than 20 % is estimated, being equivalent to 1,600 million m^3 in the annual yield.

(2) Middle Ruvu basin

In the upper part of the confluence with the Mkulazi River, the runoff coefficient is not so large, being different from that of the Upper Ruvu and Mgeta basin mentioned above. Annual yield of water of 1,600 million m^3 is expected to take place at Mikura. However, at the floodplain in lower part of this basin, some of water loss may occur.

(3) Ngerengere basin

There is also floodplain in middle reach of the Ngerengere River. As the river is comparatively long with tender slope, a large amount of water loss is also expected to take place. Consequently, around 5 % of runoff coefficient is estimated for annual rainfall of less than 1,000 mm. Only annual yield of water of 140 million is expectable.

(4) Lower Ruvu basin

The runoff characteristic of the tributaries in the Lower Ruvu basin is quite similar to that of the Ngerengere basin. For the subbasin, a runoff coefficient of around 5% is estimated for the annual average basin rainfall of about 950 mm. Though a total catchment area of these tributaries is more than 6,000 km^2, only annual yield of water of about 250 million m^3 is expectable. Especially it is noted that in the dry season no water flow was observed in the rivers except the Ruvu mainstream.

In mainstream of the Ruvu, there are two bottlenecks, each at the Railway Bridge and the Morogoro Road Bridge, where the streamflow of the Ruvu River is constrained. Approximately 20 km long floodplain with around 10 km width extends along the Ruvu River between those bottlenecks. In the rainy season, due to the storage function in the floodplain, some of the flood peak is cut therein before flowing down into the lower reach. In the dry season, on the other hand, some of water loss also may take place therein. The annual runoff volume at the Railway Bridge is estimated at 2,300 million m^3, while that at the Morogoro Road Bridge is at 1,900 million m^3 which is less than that at the upstream bottleneck. Therefore, approximately 15 % of the annual runoff volume at the railway bridge may be lost in the section.

In the rainy season, the floodplain in the lower reach was inundated by flood water for 2 to 3 weeks. The flood occurs in April and May mostly every year and causes the problem for the local transportation in these areas.

In the dry season, there were no river flow in most of the tributaries of the Ruvu River except the Mgeta River, Ngerengere River and the tributaries which originate from the Uluguru Mountains. Especially, the tributaries in the Lower Ruvu basin completely dry up, even in the Mbiki and Mkombezi Rivers of which catchment areas are more than 800 km^2. Usually, there is no river flow in those tributaries for the period from July to October.

Concerning the Ruvu mainstream, there are two river routes in the lower reach of the Morogoro Road Bridge as shown in Fig. 2.7. In the rainy season, the river flow diverges approximately 7 km downstream of the bridge, and these two river flows again join approximately 2 km

downstream of the existing Lower Ruvu intake weir. According to the field investigation, the main route of the Ruvu River is the right side channel. In the dry season, the river flow does not diverge and all the river discharge from its upper reaches flows down into the right side channel. It was roughly estimated that the river flow starts to diverge when the river discharge is over 150 m^3/sec.

2.5 River System and Flood Problems

2.5.1 Ruvu River subbasins

The Ruvu River basin is located in the Coast and Morogoro Regions and lies between 6°- 05' and 7°- 45' South Latitude and between 37°- 15' and 39°- 00' East Longitude. It is divided into the following five main drainage systems as shown in Fig. 2.7:

- Mgeta basin including Msoro River basin,
- Ngerengere River basin,
- Upper Ruvu River basin and
- Middle Ruvu River basin
- Lower Ruvu River basin (Right and Left Bank)

Most of the basins are rolling hill areas overlooked by the Uluguru Mountains with the highest altitude of 2,634 m at the Kimtiandu hill.

2.5.2 Major rivers and their tributaries

(1) The Ruvu River

The Ruvu River originates in the Uluguru Mountains area with an altitude of about 1,920 m. It passes through the Karoo formations, gneisses and loosely compacted Jurassic rocks in succession, and finally emerges into quaternary alluvium. Then it discharges to northeast towards the Indian Ocean.

In the upper reach, its largest tributary is the Mfizigo River coming from the left bank side with a catchment area of 589 km^2. The other major tributaries in the upper reach are the Mvuha (525 km^2) on the right bank side and the Mkulazi (416 km^2) on the left bank side. In the lower reaches, large tributaries join to the Ruvu mainstream through Chalinze hills. These are the Kigogo (672 km^2), the Msua (899 km^2), the Mbiki (885 km^2) and the Mkombezi (885 km^2)

The river gradient is less than 0.025 %, 0.05 % and more than 10 % in the lower reach below Mafisi, the middle reach before joining the Ngerengere River and in the upper Uluguru Mountains area, respectively. The upper mountainous area of its catchment is densely populated, while the middle valley has few population and the lower reach is scattered by the seasonal settlement whose permanent houses are on the hill of the both banks.

(2) The Mgeta River

The Mgeta River is the largest tributary of the Ruvu River, originating in the central part of the Uluguru Mountains with an altitude of over 2,000 m. It passes through several formations of meta-sedimentary rocks in the hill. It runs toward north and then turns to west and south in the Uluguru Mountains. Thereafter it changes the flow direction towards southeast in the rather flat area facing the northern boundary of the Selous Game Reserve up to the confluence with the Ruvu River. Its total catchment area is measured at 3,903 km^2. The largest tributary of the Mgeta River is the Msaro on the right bank side, with a catchment area of 1,437 km^2. The other major tributaries are the Mbakan (357 km^2) and Mngazi (223 km^2) on the left bank side which also originate in the Uluguru Mountains.

The river gradient is rather steep as compared with that of the Ruvu, and it varies from less than 0.1 % in the Mgeta floodplain to 6% in the upper reach of the Mgeta stream gauging station (1HB2). The upper slopes of the Uluguru Mountains and the southeastern foothills are much populated, while few resident on the right bank. The lower reaches of the subbasin are rather flat and subject to frequent flooding in the rainy season. Often the flood overflows the natural bank, flowing into the adjoining Mvuha subbasin and creates a huge swamp area just upstream of the proposed Kidunda dam site during the wet season.

(3) The Ngerengere River

The Ngerengere River is the second largest tributary of the Ruvu River. Its headwater lies in the gneissic formation of the western area of the Uluguru Mountains with an altitude of about 1,600 m. It encircles its northern end in the shape of horse-shoe, and it flows down for about 30 miles through a narrow belt of alluvium and clayey deposits. After passing through a series of Jurassic formations, it again enters the alluvium before joining to the Ruvu River.

Its catchment area is measured at 2,856 km^2. Its largest tributary is the Kwazi on the left bank side with a catchment area of 257 km^2. There are many small tributaries flowing down from the northern part of the Uluguru Mountains. The river gradient is less than 0.2 % and more than 6 % in the lower to middle reaches and upper reach of existing Mindu dam, respectively.

Upstream of the Mindu dam, the irrigation project exists. In the middle reach of the river, sisal estate is still under operation. The northern slope of the Uluguru Mountains is densely populated.

The major rivers in each of the aforesaid five drainage systems which are identified based on the topographic maps at a scale of 1 to 50,000 are summarized in Fig. H.1 of Appendix-H of the Supporting Report.

2.5.3 Longitudinal profile of major rivers

Longitudinal profiles of major rivers with a length of more than 20 km, which were identified in the topographic maps at a scale of 1 to 50,000, are shown in Fig. H.2 of Appendix-H of the Supporting Report. According to these longitudinal profiles, most of the rivers have the gentle slope of less than 1 % up to an altitude of about 200 m to 500 m. The rivers meander tremendously by the large scale flood. This is proved through the comparison of the latest aerial photos and the topographic maps at a scale of 1 to 50,000.

2.5.4 Flood problems

In the Study Area, there were many sisal estates at the elevated land previously, but most of them are not functioning at present. Major commercial-based economic activities are concentrated in Morogoro municipality and other small towns in the Ruvu River basin. They are located in the elevated area. The areas which are likely to be submerged by flood are mainly those cultivated by peasants at small scale using rainfed mainly in the lower Ruvu floodplain and eastern part of the Uluguru Mountains. Peasants who cultivate the floodplains in the basin are well familiar with annual flooding and know how to reduce the flood damages through their experience. Small scale irrigation systems are being operated in small areas.

At present, the river training or flood protection works are less in the basin, apart from the national highway and railway bridges, intake structures and reservoir for water supply, and on-going irrigation project.

According to the hydraulic analysis, the flow capacity of the Ruvu River is about 150 m^3/sec at Kidunda, and 100 to 300 m^3/sec in the lower reaches of the Ruvu. If the flood of about 380 m^3/sec occurs at the Morogoro Road Bridge, several parts of the basin would be subject to flooding, forming swamp areas where no permanent residences exist. They are as follows:

1) Lower Ruvu Floodplain
   - area between Mafisi and existing railway bridge where the Msoro River runs in parallel with the Ruvu and there are several lakes such as Wongomori Lake.
   - area between existing Railway Bridge and Morogoro Road Bridge
   - downstream area of Morogoro Road Bridge up to river mouth including the area below high tide level and mangrove forest.

2) Kidunda Floodplain (Middle Ruvu area)
   area along the Ruvu between the proposed Kidunda dam site and the confluence of the Ruvu and Ngerengere Rivers

3) Mgeta Floodplain
   upstream area of the confluence of the Ruvu and Mgeta Rivers up to Kisaki

4) Ngerengere Floodplain
   area along the Ngerengere River between the proposed Ngerengere dam site and Ngerengere town

5) Morogoro Floodplain
   area along the Ngerengere River at north of Morogoro municipality up to existing Mindu dam.

2.6 Water Quality

The water quality analysis was carried out for water samples collected in the Ruvu River basin both in the dry and wet seasons of 1993. Locations of the water sampling sites are shown in Fig. 2.8.

2.6.1 Rainy season

The results of those water quality analyses are detailed in Appendix-F of the Supporting Report. As a result of the water quality analysis carried out in the rainy season in 1993, four water samples, which were taken upstream of the Ngerengere River, the Chalinze reservoir, the Lugoba of the Mkombezi River and the Dutumi well, were assessed to be suitable for the rural domestic water supply according to the Tanzania Temporary Standards. The remaining sixteen samples revealed high turbidity and/or high content of Cl, Fe and Mn. According to the USDA classification of irrigation water salinity and sodicity, the water samples at the Umbenazomozi bridge of the Msua River and Lugoba of the Mkombezi River were classified as high salinity water or very high salinity water and high sodium water.

Besides, most of water samples were highly contaminated by coliform, especially at the Dutumi new gauging station on the Mgeta River, the Morogoro Road Bridge and Darajam bridge across

the Ngerengere River, the Umbenazomozi bridge across the Msua River and the Yombo lined well. The total coliform was over 4,000/100 ml and fecal coliform was over 2,000/100 ml. It seems that at many places drainage and surface runoff lead to contamination of the water sources.

As a result of the physical, chemical and bacteriological tests, water to be exploited in the Ruvu River basin would have to be treated and/or disinfected before use for any domestic purposes. Most of water samples, excepting those sampled in the upstream reach of the Ruvu and Ngerengere Rivers and at the Dutumi well, are not so suitable for irrigation water with respect to the physical and chemical parameters such as electric conductivity, dissolved oxygen, chemical oxygen demand and sodium adsorption ratio.

2.6.2 Dry season

In the dry season, the physical parameters such as turbidity, SS and color levels were low. Most of the samples analyzed for physical and chemical parameters, excepting the samples taken in the major tributaries, were assessed to be suitable for the rural domestic water supply. The water samples at the Umbenazomozi bridge across the Msua River, Lugoba of the Mkombezi River and the Pangani reservoir were classified as very high salinity water. The water samples taken at the Darajam bridge as well as those at the Ngerengere and Mgeta bridges were classified as high sodium water or very high sodium water.

Most of the water samples were contaminated by coliform except one ground water sample at the Dutumi well. The water samples highly contaminated are those sampled from the Ngerengere River. It is considered that such a high contamination is caused by sewer from the neighboring towns including Morogoro municipality.

2.6.3 Comparison of water quality in rainy season and dry season

The streamflow of the Ruvu River and its tributaries in the dry season is considerably less as compared with that in the rainy season. At almost all locations where water was sampled during the field survey period, the physical parameters of water in the dry season such as turbidity, SS and colour were larger than those in the rainy season.

Generally, there was a tendency that the values of EC, CO_3, total hardness and salinity of small stream were higher than those of the river of larger streamflow in the both seasons. In the upper reaches of the Msua and Mkombezi Rivers and the Pangani reservoir, high EC values were always detected. It seems that the water quality of those area is affected by the specific geologic conditions.

Most of water samples showed that the river water became acidic in the dry season. EC values of all streamflows in the dry season increased in comparison with those in the rainy season and the increase rates of EC value were comparatively large in the downstream reach of Morogoro municipality on the Ngerengere River and on the Msua and Mkombezi Rivers. Concerning the ground water, EC values in the dry season reduced as compared with those in the rainy season, while those of the existing reservoir do not vary so much. Some chemical parameters such as Cl and Mg showed very high values on the Msua and Mkombezi Rivers as compared with those in the rainy season. In the downstream reaches of the Ngerengere River, content ratio of Na remarkably increased in the dry season. SAR also increased at most of the sampling locations except only one sample taken from the Msumbisi River.

Most of the water samples were contaminated by coliform except one ground water sample at the Dutumi well. It is considered that in the rainy season the water quality of the Study Area is remarkably affected by flood water and/or rain water. Especially this is seen on the physical and bacteriological parameters. As far as the water quality analyses carried out in the present field investigation show, the surface water of the basin needs to be treated for the purpose of the domestic use, especially for that in the wet season.

2.7 Existing Water Resources Facilities

2.7.1 Mindu dam

The municipal water for Morogoro, the second largest town in the Study Area, is being supplied from existing Mindu dam.

The Mindu dam is situated on the Ngerengere River, about 7 km southwest of Morogoro municipality. It was constructed for the purpose of the municipal water supply to Morogoro municipality.

In 1972, the Ministry of Water Development and Power carried out a feasibility study on Morogoro Town Water Supply covering a period up to the year 1995. The study examined various alternative sources of water to meet the future water demand therein. The alternative modes of water supply were as follows:

- Construction of Mindu dam
- Extension of the present system using the Morogoro River
- Development of tributaries of the Ngerengere River

- Draw-off from the Ngerengere River (at Konga)
- Supply from the Mlali River
- Ground water supply

As a result of the study, construction of the Mindu dam was selected as the best alternative. The project has inherent problems but it had advantages and was more substantial alternative than the other modes. The Mindu dam was completed in 1985. Main features of the dam are shown in Table 2.7.

Also the project considered the second stage construction, which includes heightening of the dam by 2.5 m to get additional storage reservoir capacity to meet the future water demand and cope with siltation in the reservoir.

As explained in Appendix-E of the Supporting Report, the municipal water demand in Morogoro in the year 2020 is forecast at 0.95 m^3/sec or 82,373 m^3/day. The balance of water demand and water supply for the Morogoro municipality is shown in Fig. 2.9. As seen in the Figure, the water deficit is forecast to take place in the year 2017, even though the reservoir storage capacity of the Mindu dam is to be augmented through heightening of existing dam as originally planned.

2.7.2 Intake facilities on the Ruvu mainstream for water supply to Dar Es Salaam

There exist two intake structures on the lower reach of the Ruvu, which are an component of the Upper and Lower Ruvu schemes for municipal water supply to the Dar Es Salaam city. At present, these schemes are functioning as the major water supply facilities for the city.

The main features of these facilities are discussed in more detail in the succeeding Chapter IV in relation to the water demand forecast for the Dar Es Salaam water supply system.

2.7.3 Existing irrigation system

Irrigation and drainage systems exist in the lower Ruvu and western slope of the Uluguru Mountains. Irrigation water amount supplied to sisal and other estates is negligible small because of scale-down of their production. The farmers in the middle and upper Ruvu areas rely on unstable rainfall.

Existing irrigation methods in the basin are broadly divided into two types, namely, modern irrigation by pumping in the low-lying area and traditional irrigation in the mountainous areas.

(1) Modern irrigation and drainage system in the Lower Ruvu valley

Modern irrigation method using pumps with flood protection dike system was introduced to Kivungwi area in middle 1960's establishing NAFCO farm of 750 hectares under the Chinese assistance. In early 1970's pumping irrigation schemes, namely the Ruvu national service rice irrigation and the Makurunge projects, were constructed by the Government. Private company, the Matusita farm, attempted a pumping irrigation farming just upstream of the Makurunge scheme in 1980's. However, at present, the Makurunge and the Matusita farms are abandoned and cultivation in the Ruvu national service rice irrigation project is suspended since 1989. Cultivated land area in NAFCO farm is also reduced to some 150 hectares in 1988/89 crop season.

Since 1987 the Bagamoyo Irrigation Development Project (BIDP) has been operated on an experimental basis of 8 hectares with joint effort of the Tanzanian Government and JICA. The aim of the experimental farm is training of farmers in irrigated paddy farming. At present, a total of 70 farmers have been trained. In 1992/93 crop season, 17 farmers were selected from approximately 300 applicants for the training.

In addition, Kigongoni prison farm possesses small scale irrigation area of 20 hectares by gravity system utilizing their own reservoir on a tributary of the Ruvu River. Irrigated cultivation is not practiced in other existing private farms and PAC Masuguru farm. Villagers along the river course also cultivate paddy supplying supplemental water manually from ponds scattered in the floodplain.

(2) Traditional irrigation and drainage in the Uluguru West

Irrigation in this area has been voluntarily commenced by the local people since 1960's. There exist 68 traditional unlined irrigation canal systems with total length of 170 km in the Mgeta division. These systems irrigate some 2,000 hectares of vegetable farms in the dry season. Each farmer owns 0.18 to 0.24 hectares of farm plot and cultivates vegetables throughout the year.

Irrigation canals, connected with the perennial streams, convey irrigation water to each farm plot running along contour lines and crossing gullies of 2.5 km long on an average. Canals are maintained and operated by farmer's users groups. However, their maintenance activities are limited to minor works such as canal reexcavation after the rainy season, protection of intakes and rehabilitation of leakage portions of canals with stones and clay due to lack of budget, proper material and technical skills.

2.8 Natural Conservation Area

In the Study Area, there are one national park (Mikumi National Park), one game reserve (Selous Game Reserve) and many forest reserves.

2.8.1 Mikumi National Park

The Mikumi National Park lies in the most western part of the Ruvu River basin, occupying the uppermost area of the Mgeta, Rudete, Msegere and Msoro Rivers. But the park boundary is not clear in some part of the Study Area. The Mikumi National Park gazetted in 1964 with an area of 3,230 km^2 is the fifth largest park and the nearest to Dar Es Salaam of those in Tanzania. The Park contains a spectacular concentration and variety of wildlife. The Mgeta River floodplains are of horseshoe-shaped hills, and are the feeding grounds of large herds of buffalo and wandering groups of elephant. The wooded fringes of the plains harbor many wildebeest, zebra, impala, baboon, warthog, jackal, etc. Most of the Park portion located in the Ruvu River basin is covered by Miombo woodland, a home of the black rhino (*Diceros bicornis*), the pangani black-and-white colobus monkeys (*Colobus angolensis*), the leopard (*Panthera pardus*) and many bird species including the guinea fowl (*Numida mitrata*), the lilac-breasted roller (*Coracias caudata*) and the European roller (*Coracias garrulus*), vultures and marabou storks.

2.8.2 Selous Game Reserve

The Selous Game Reserve is situated in the southwest corner of the basin, covering an area of the right bank side of the Mgeta River, downstream of Kisaki. This is one of the largest wildlife areas left in the world. The Reserve, established in 1922, occupies a total area of about 50,000 km^2 or 6% of the national land area. Altitudes of the Reserve range from 110 to 1,250 m. The Reserve is divided into four sectors. Animal viewing, boating, fishing and camping are restricted to the northern sector which borders the Mikumi National Park. The ecosystem of the Selous Game Reserve is rich and diverse. It, for instance, contains more than 2,000 species of plant and over 30 species of animals. Due to its unique ecological importance, the Reserve was listed by the Untied Nations as a "World Heritage Site" in 1982. The very small portion of the northern Selous Game Reserve is situated inside the Ruvu River basin and it is mainly of open grassland and/or open woodland. A great part of this area is an extension of the Lake Tagalala Area, an important area for rhinoceros and cheater. Other important animal species which inhabit the area include impala (*Aepyceros melampus*), buffalo (*Syncerus caffer*), wildebeest (*Connochaetes taurinus*), zebra (*Equus burchelli*) and elephant (*Loxodonta africana*). With the assistance of the Federal Republic of Germany, the conservation program

for the Reserve is on-going involving the local communities in terms of the wildlife management as described in the succeeding Section 2.9.

2.8.3 Forest Reserves

There are many forest reserves with various scales in the Study Area. These are mostly located in the eastern part of the Ruvu River basin and around the Uluguru Mountains area in the western part of the Study Area. They are important sites in terms of both animal and plant bio-diversity even if their primary purpose is different, e.g. water catchment, fuelwood. The largest forest reserve is the Mkulazi Forest Reserve which is located on the north of the confluence of the Ruvu and Mgeta Rivers with an area of some 69,000 ha., followed by the Ruvu North, Ruvu South, Uluguru North, Uluguru South and Morogoro Fuel Forest Reserves. These forest reserves are national forests and are managed by the Forestry Division of the Ministry of Tourism, Natural Resources and Environment.

2.9 Selous Conservation Programme (SCP)

It is identified that in and around the both Kidunda and Mgeta reservoir areas there are activities undertaken by the Selous Conservation Programme (SCP) under the Ministry of Tourism, National Resources and Environment, which include introduction of the community wildlife management (CWM) in the buffer zone bordering the Selous Game Reserve. Especially, the Kidunda dam project is likely to have an intervention with the planning area established by the SPC project to a significant extent, depending on a scale of the reservoir.

The SCP contemplates to demarcate the village area adjacent to the reserve area applying the following land classification:

- Residential area,
- Area for agriculture,
- Communal wildlife utilization area,
- Area for fuel woods,
- Area for future expansion, and
- Forest reserve area.

The land use plan worked out by the SCP project office in and around the proposed Kidunda and Mgeta reservoir areas are shown in Figs. 2.10 and 2.11, respectively. The areas likely to be submerged by creation of those dam projects under the present development scale are measured based on the planning maps provided by the SCP project office as follows:

The SCP's planning area likely to be submerged by the Kidunda Dam/Reservoir

No.	Land Use Planned by the SCP	Kidunda Dam		
		Total Planning Area by the SCP : Ta	Area to be Submerged by the Reservoir	
		(km^2)	(km^2)*	Ratio to Ta (%)
1	Residential area	10	6.6	66
2	Area for agriculture	39	28.3	73
3	Communal wildlife utilization area	162	13.9	9
4	Area for fuel wood	49	7.2	15
5	Area for future expansion	41	2.8	7
	Total	301	58.8	20

Note: * ; Area at the dam crest level

The SCP's planning area likely to be submerged by the Mgeta Dam/Reservoir

No.	Land Use Planned by the SCP	Mgeta Dam		
		Total Planning Area by the SCP : Ta	Area to be Submerged by the Mgeta Reservoir	
		(km^2)	(km^2)*	Ratio to Ta (%)
1	Residential area	35	0.0	0.0
2	Area for agriculture	250	0.2	0.1
3	Communal wildlife utilization area	310	5.8	1.9
4	Area for fuel wood	60	0.2	0.3
5	Area for future expansion	95	1.2	1.3
6	Miombo wood land	120	1.0	0.8
	Total	870	8.4	1.0

Note: * ; Area at the dam crest level

In view of the conceivable implication of the conservation of wildlife in the Selous Game Reserve, the detailed environmental impact assessment study on the Kidunda dam is recommended to be carried out after completion of the Study in the framework of the prefeasibility study, in particular focusing on the assessment of influence on the ecosystem of the Selous Game Reserve, to be caused by construction of the Kidunda dam project.

CHAPTER III

HYDROLOGICAL ANALYSIS

3.1 Rainfall Analysis

3.1.1 Average rainfall in the Ruvu River basin

The Study Team collected all the available data of monthly rainfall at 66 rain gauge stations during the field survey period. The locations of these stations are shown in Fig 3.1 and the annual mean monthly rainfall data are summarized in Table 3.1.

Correlation coefficients of monthly rainfall among the rain gauge stations were calculated. Every station has correlation coefficient of more than 75 % with it's neighboring station. Especially, high correlation coefficients of more than 95 % were derived in the two stations around Morogoro and Ngerengere.

(1) Rainfall in the Ruvu River basin

Considering location and data availability of the aforesaid rain gauge stations, 19 stations were selected to estimate the basin average rainfall. Using mean monthly rainfall and the Thiessen polygon shown in Fig. 3.2, the annual average rainfall in the Ruvu River basin was estimated to be about 1,080 mm/year as shown in Table 3.2.

(2) Rainfall in the unit basin

The Ruvu River basin was divided into 21 unit basins as shown in Fig. 3.3 for the purpose of clarifying the regional runoff characteristics. The mean monthly rainfall in each of the unit basins was estimated using the same procedure as summarized in Table 3.3.

(3) Rainfall in the catchment area covered by stream gauging station

The mean monthly rainfall in the catchment covered by each stream gauging station was also estimated using the same procedure. The results are summarized in Table 3.4 and Fig. 3.4.

3.1.2 Frequency analysis

Based on the daily rainfall data at the 19 key stations, the frequency analysis on the following values was carried out:

- Annual rainfall (probability of non-exceedance)
- Maximum 24 hour rainfall (probability of exceedance)
- Maximum 3 days rainfall (probability of exceedance)
- Consecutive non-rainy days (less than 0.1 mm/day, probability of exceedance)
- Consecutive non-rainy days (less than 0.5 mm/day, probability of exceedance)

The results are summarized in Appendix-C of the Supporting Report.

3.2 Runoff Analysis

There existed more than 20 stream gauging stations in the Ruvu River basin. Considering their location and scale of catchment area, the Study Team collected available hydrological data at the selected 11 stream gauging stations which are shown in Table 3.5 and Fig. 3.1.

3.2.1 Construction of rating curve

Based on the discharge measurement data and river cross section data, the stage-discharge rating curve (H-Q curve) at those 11 stream gauging stations were constructed. These are compiled in Appendix-C of the Supporting Report.

It was confirmed that the discharge measurement data at 1H8 did not include the river flow passing though the 10 culverts installed in the right bank of the Morogoro Road Bridge. It means that the rating curve of 1H8 shows only discharge flowing through the Morogoro Road Bridge. Therefore, when the river water level is so high, it is necessary to consider the discharge passing through the culverts for the high flow analysis. Using the available hydrological data and considering the section and elevation of the culverts, the relation between gauging height at 1H8 and total discharge passing through the culverts was roughly estimated. The equation was worked out as shown below:

$$Q = -8.23 + (H-6.00) \times 154.34 \quad (\text{if } Q<0 \text{ then } Q=0)$$

where Q : Total culvert discharge (m^3/sec)
H : Stage height at 1H8 (m)

Using the above equation and mean daily stage height, the river discharges for the high river stages were calculated.

3.2.2 Estimate of long-term runoff

Using the stage-discharge rating curve, the long-term daily water levels were converted into the mean daily discharges. The results are shown in Table 3.6 and Fig. 3.5 and summarized below:

Station Code	Catchment Area (km^2)	Mean Discharge (m^3/sec)	Annual Runoff Depth (mm/year)	Annual Rainfall (mm/year)	Runoff Coefficient
1H2	12,488	74.7	189	1,132	16.7%
1H3	6,697	57.8	272	1,291	21.1%
1H5	420	18.5	1,388	2,620	53.0%
1H8	15,190	61.1	127	1,099	11.5%
1H8*	15,190*	65.1*	135*	1,099*	12.3%*
1H10	5,870	50.2	269	1,342	20.1%
1HA1A	2,840	4.3	48	970	5.0%
1HA5	1,646	3.9	74	986	7.5%
1HA15	2,370	4.7	63	974	6.5%
1HB1	963	6.3	207	1,080	19.2%
1HB2	101	2.5	768	1,333	57.6%
1HC2	251	9.0	1,131	2,057	55.0%

Note: * ; Include the culvert discharge.

The relationship between catchment area and runoff is shown in Fig. 3.6.

The mean daily discharge of 90% and 95% firmness at the stream gauging stations 1H8, 1H10 and 1HA1A were estimated by the series method as shown below:

Station Code	90% firmness (m^3/sec)	95% firmness (m^3/sec)	No. of Year of complete data
1H8	11.0	9.1	21
1H10	10.4	8.6	8
1HA1A	0.07	0.02	7

3.2.3 Frequency analysis

Based on the long-term discharge data derived through the runoff analysis, the frequency analysis was carried out for the following items, and the results are shown in Table 3.7.

- Annual mean discharge (probability of non-exceedance)
- Annual minimum discharge (probability of non-exceedance)
- Annual maximum discharge (probability of exceedance)

3.2.4 Low flow analysis

(1) Design of low flow analysis model

Based on the monthly rainfall and discharge and using the Tank Model method, the low flow analysis models for the stream gauging stations 1H5, 1H8, 1H10 and 1HA1A were constructed as shown in Fig. 3.7. The comparison between the observed discharge data and the simulated discharge data at 1H8 was made as shown in Fig. 3.8. The results of the comparison for the other stations are compiled in Appendix-C of the Supporting Report.

(2) Low flow analysis for prospective dams

Applying monthly rainfall data to the Tank Model, the mean monthly runoffs at the following prospective dam sites were estimated for the period of 40 years from 1950 to 1989. The results are shown in Appendix-C of the Supporting Report and summarized in Table 3.8.

Name	Catchment Area (Km^2)	Used Model
1. Rudete	246.8	Tank Model for 1H5
2. Ngerengere	2,809.3	Tank Model for 1HA1A
3. Mkombezi	602.9	Tank Model for 1HA1A
4. Mgeta	938.7	Tank Model for 1H5
5. Kidunda	5,760.9	Tank Model for 1H10

3.2.5 High flow analysis

The Ruvu River basin was divided into 21 unit basins for establishment of high flow analysis model as shown in Fig. 3.3. The daily rainfall data for each of the 21 unit basins were worked out using the Thiessen polygon method as shown in Fig. 3.2.

A high flow analysis model was made using the Storage Function Model as shown in Fig. 3.9 and daily rainfall data. The coefficients of the Model were determined based on the observed floods in 1968, 1973 and 1974. Although the 1979 flood is the biggest one at 1H8 during the observation period, it was not used since the rainfall and discharge data were not sufficiently available for the analysis. The comparison between observed discharge and simulated discharge at 1H8 was made as shown in Fig. 3.10. The results of the comparison for other stations are shown in Appendix-C of the Supporting Report.

Based on the daily rainfall pattern in 1974, the flooding patterns at 1H10 and 1H8 for each of the return periods of 5, 10, 20, 50, 100 and 200 year were derived as shown in Fig. 3.11.

Regarding the flood of 5-year return period which is adopted as the design flood for the flood control works required for the agricultural development projects in the lower Ruvu, the effect of the flood control by the planned Kidunda dam was examined securing the flood control space between the Normal High Water Level (NHWL) and Surcharge Water Level (SWL) of the reservoir. The NHWL of the Kidunda dam is optimized to be EL. 89.0 as discussed in the succeeding Chapter VII. The surcharge volumes of the Kidunda reservoir required to regulate the spillout discharge therefrom were estimated for three cases as shown below:

Case No.	Maximum spillout discharge from the Kidunda dam (m^3/sec)	Required surcharge volume of the Kidunda Reservoir (Million m^3)	Peak discharge at 1H8 (m^3/sec)	Remark
Case 1	-	-	610	(without flood control by the Kidunda Dam)
Case 2	100	483	250	(with flood control by the Kidunda Dam)
Case 3	150	308	300	(- do -)
Case 4	200	203	350	(- do -)

As seen in the above, the peak discharge of the 5-year probable flood at 1H8 can be diminished to 300 m^3/sec in case the Kidunda dam is planned to have a flood control space of about 310 million m^3.

The peak flood discharges at proposed dam sites for each of 5, 10, 20, 50 100 and 200-year return periods were estimated by means of the Storage Function Model. The results are shown in Table 3.9. The hydrographs at the dam sites for each of 20, 50 and 100-year return periods were also derived as shown Fig. 3.13.

3.3 Sediment Analysis

During the Phase 2 Field Work, the Study Team collected the suspended sediment data at following sites:

Name of River (Location)	Observation Period	Catchment Area (km^2)
Ruvu (1H8, Morogoro Road Bridge)	from 1958 to 1986	15,190
Ruvu (1H10, Mikula)	from 1970 to 1977	5,870
Kikundi	from 1978 to 1979	4.4

Based on the suspended sediment data, a relation between mean daily discharge and suspended sediment was analyzed as shown in Fig. 3.14. The equation was derived as shown below:

No.	Name of River (Location)	Catchment Area (km^2)	Rating Formula of Suspended Sediment Load
1	Ruvu (1H8, Morogoro Road Bridge)	15,190.0	$Qs = 33.06 \times Q^{1.424}$
2	Ruvu (1H10, Mikula)	5,870.0	$Qs = 61.30 \times Q^{1.281}$
3	Kikundi	4.4	$Qs = 232.65 \times Q^{2.066}$

Note
Variables in above rating formula of suspended load
Qs : Daily transport of suspended load in ton/day
Q : Mean daily discharge in m^3/sec

Using those equation and mean daily discharge data at 1H8 and 1H10, the long-term sediment transport was estimated. The results are summarized in Table 3.10. The sediment transport was derived to be approximately 200 m^3/km^2/year and 400 m^3/km^2/year at 1H8 and 1H10, respectively. However, sampling period of those sediment data are a little bit old, considering

the change of the condition in the basin. Furthermore, the number of the suspended sediment load data are insufficient for the sedimentation study. Therefore, it is essential to carry out intensive water sampling for the suspended load analysis in the next study stage in order to estimate the sediment yield rate with accuracy.

CHAPTER IV

MUNICIPAL WATER DEMAND FORECAST FOR DAR ES SALAAM CITY

4.1 Present Situation of Municipal Water Supply System

4.1.1 General description of existing water supply system

The water supply system for Dar Es Salaam city is owned and run by NUWA (National Urban Water Authority), while the rural water supply system in the surrounding rural area of the city is run by RWSD, being of very small scale. At present, the Dar Es Salaam water supply system run by NUWA comprises the following (3) three systems:

Existing Water Supply System for Dar Es Salaam City

Name of Water Supply System	Design Capacity of Existing Water Treatment Plant	
	(m^3/day)	(m^3/sec)
1) Lower Ruvu scheme	182,000	2.11
2) Upper Ruvu scheme	82,000	0.95
3) Mtoni scheme	9,000	0.10
Total	27,300	3.16

The main features of the above three schemes are listed in Table 4.1. Out of these, the water source of the Lower and Upper Ruvu schemes is the Ruvu River. The intake structures of these schemes are located on the Ruvu River about 18 km and 40 km upstream of the river mouth, respectively. The river water off-taken at these sites is conveyed to Dar Es Salaam city through the separate two trunk transmission mains with a length of some 50 km after purification. Locations of existing these two schemes are schematically shown in Fig. 4.1.

On the way of the transmission mains to Dar Es Salaam, some amount of conveyed water is being off-taken to be supplied to the areas along the transmission mains. The major towns served by the off-taken water are Kibaha, a capital of the Coast Region, and Bagamoyo. In view of the water consumption, the characteristics of these areas are that some of water supplied is used for agricultural production such as irrigation, horticulture, animal husbandry, poultry farming, etc. Thus, the Dar Es Salaam water supply system run by NUWA covers the areas along the transmission mains as well as the city area of Dar Es Salaam.

4.1.2 Upper Ruvu scheme

The Upper Ruvu scheme was constructed in 1959, its capacity being increased in stages after then. The intake structure is located just downstream of the Morogoro Road Bridge crossing the Ruvu River. The treatment plant is located at Mlandizi about 7 Km distant from the intake site. After treatment, the treated water is conveyed to the Kimara Reservoir through the transmission pipelines. At present, the whole facilities including intake, treatment plant and pumping stations are in good condition after the recent rehabilitation completed by Italian financing in 1992.

The newly constructed intake structure is designed to have the maximum intake capacity of 210,000 m^3/day (2.4 m^3/sec) which is more than twice the present capacity of the treatment plant of 82,000 m^3/day. The raw water pumping station and some components of the treatment plant are also designed to enable expansion of the present capacity in future. The 50 km long transmission pipeline connected to the Kimara reservoir consists of 2 or 3 parallel pipes depending on the location. The pipes are made of steel or of fiberglass reinforced one (FRP) of which diameters vary from 500 to 900 mm. A lot of illegal taps were found to be installed on the steel pipe portion. This transmission lines supply water to Mlandizi town, Kibamba town, Kibaha ward of DSM and villages situated along the pipeline.

The Kimara Reservoir with a total storage capacity of 31,800 m^3 is provided along the Morogoro road in the fringe of the city. Usually, the water stored in the reservoir was supplied to the service area at about 5 a.m. and quitted usually between 9 and 10 a.m. when the tank dries up.

4.1.3 Lower Ruvu scheme

The Lower Ruvu scheme was constructed between 1975 and 1976. The intake structure is located on the Ruvu River 22 km downstream of the Upper Ruvu intake or 18 km upstream of the river mouth. A weir is provided on the river in order to keep the minimum level of the raw water well.

The intake structure has three (3) openings, one for low water level and the other for high water level, with a design capacity of 386,000 m^3/day which is equivalent to about 2.1 times that of the existing treatment plant (182,000 m^3/day). The water passing through the intake structure is transmitted to the low lifting pumping station which accommodates 4 low lift pumps. Besides, it has a space to install one additional pump for the purpose of the future expansion of the capacity. The current operating capacity of the pumping station is 191,000 m^3/day.

Although the existing treatment plant was designed to have a capacity of 182,000 m^3/day as mentioned above, the current production reached about 207,500 m^3/day exceeding the capacity. This is because the water by-passes the rapid sand filters which are currently out of order. This results in production of the water with high turbidity. After the sand filters are rehabilitated, the production would drop to the nominal capacity of 182,000 m^3/day.

The high lift pumping station is equipped with 4 pumps, which has a space for one additional pump for future expansion of the capacity. The transmission main of a 55 km long prestressed concrete pipe of 1,350 mm in diameter conveys the treated water to the University Reservoir. The water conveyed by the transmission main is being extracted at 17 different places, on the way to the University Reservoir, to be supplied to Bagamoyo town, Bunju, Kunduchi, Mbweni and Goba wards of DSM, a part of Kawe ward and other villages situated along the transmission main.

The University Reservoir with a total storage capacity of 45,400 m^3 is located in the northwestern part of the city. The water of the reservoir is supplied mainly to the lower zone of the city.

4.1.4 Mtoni scheme

The intake structure of the Mtoni scheme is located on the Kizinga River which drains the southern area of Dar Es Salaam city. The treatment plant with a design capacity of 9,000 m^3/day is provided beside the river bank. The average production rate is about 6,000 m^3/day according to the report on the Urban Sector Engineering Project, but it drops to 1,500 m^3/day from time to time during the dry season. The water is directly conveyed to the distribution network of the city by pumping. Since this scheme was constructed in 1949, most of the main components such as the plant and the pumping station need rehabilitation.

4.2 Latest Water Consumption in Service Area of NUWA

4.2.1 Water supply in 1990

The present Dar Es Salaam water supply system is characterized by an overall shortage of water supply and uneven distribution of the water supply in the city. According to the data on latest water consumption collected and analyzed through the "Study on Rehabilitation of Dar Es Salaam Water Supply by JICA (1991)", the production of treated water in 1990 was as follows:

Production of Treated Water by Scheme in 1990

	Water Supply Scheme of NUWA for DSM			
	Lower Ruvu	Upper Ruvu	Mtoni	Total
Supply of treated water (m^3/day)	207,500	82,000	6,800	296,300
(Ratio to total supply)	(70.0 %)	(27.7 %)	(2.3 %)	(100 %)

As seen in the above table, the Lower and Upper Ruvu schemes share a large part of the total production of treated water supplied to the service area of NUWA. The above total supply of the treated water in 1990 is divided into the consumption in the two areas, namely area along the water transmission mains of the Lower and upper Ruvu schemes and area covered by the distribution network in Dar Es salaam city as shown below ;

Service Area	Consumption (m^3/day)	Leakage/Wastage (m^3/day)	Total (m^3/day)
- Area along Transmission Mains	-	-	102,900
- Area Covered by Distribution Network of Dar Es Salaam City	67,673	125,727	193,400
Total			296,300

The above table exhibits that about 35 % of the total production of treated water (296,300 m^3/day) was supplied to the areas along the transmission mains of the Lower and Upper Ruvu schemes and that the water leakage ratio in the distribution system of Dar Es Salaam city reached 35% of the net supply (193,400 m^3/day). The sectorial consumptions in the distribution system in 1992 are summarized in Table 4.2. On the other hand, it has to be noted that the above consumption does not reveal the real water demand since the water consumption was suppressed in some areas of the Dar Es Salaam City due to the insufficient water pressure in the distribution pipes.

The hourly variation of the supply from the reservoirs and the Mtoni plant is shown in Fig 4.2. As seen in the Figure, the hourly supply from the University Reservoir of the Lower Ruvu scheme does not vary so much during the 24 hours, varying between 6,000 m^3/hour and 7,000 m^3/hour except for a few hours in the morning. This means that the reservoir does not meet the water demand of the service area which comprises the lower zone of DSM, as the supply is far less than the demand. While, the operation of the Kimara Reservoir was intermitted, usually limited to the morning time between 5 a.m. and 10 a.m. This was because the reservoir could

receive only 18,410 m^3/day from the Upper Ruvu scheme according to the aforesaid previous JICA study. Thus, it is obvious that most of the areas covered by the distribution network is subject to the shortage of the municipal water.

4.2.2 Present situation of distribution system in Dar Es Salaam city

The present aggravated situation of existing distribution system is attributable to the irregular extension works undertaken since 1950's. About 30% of the distribution pipes have been used for more than 30 years. The total length of the pipes is about 800 km. However, in many areas of the city the secondary and tertiary networks are not sufficiently installed due to the insufficient funds allocated therefor.

The extent of encrustation of network pipes in 1990 was investigated by the previous study. The pipes of 200 mm in diameter and less at various places suffered from deposits consisting mainly of silt and crust. It was observed that a flow area of these pipes had been reduced from the original one by about 50%. The main cause of the occurrence of silt deposit was lack of filtration in the treatment plant of the Lower Ruvu scheme.

The previous study also undertook field tests for estimation of water leakage in the network. *The leakage ratio was measured to range from 35% to 50% in some areas. The major reasons* for the water loss were:

- Leakage from pipes, pipe connections, valves and service connections,
- Absence of water meters that did not encourage anyone to check the water loss,
- Illegal connections, and
- Lack of maintenance of the network.

4.2.3 Sectoral water consumption in distribution network of Dar Es Salaam city

(1) Domestic water consumption

According to the data and information collected from NUWA, there are about 70,000 registered connections in the city. Only 2,000 connections are metered, of which about 40% are functioning. Concerning the domestic water supply, the connections to the distribution system are classified into the following three (3) types;

- House connection : Within the housing unit, a number of taps are available for water use in kitchen, toilet, bathroom, etc.

- Yard connection : Only one or two taps within the house premise are available. Usually taps are located at the back of the house in the yard, from which water is taken and hand-carried by bucket and containers to inside of the house.

- No connection : This type has no water connection within the house or house premise. Residents have to go to water kiosks or standpipes or to their neighbors to fetch water in buckets.

It was estimated through the previous JICA study that the total number of the connections was around 308,270, of which the house connection, yard connection and no connection shared about 30 %, 24 % and 45 %, respectively. Further, it estimated the total number of population served in 1990 at 1,335,028 persons. The average water consumption per capita is calculated at about 96.0 litters/day, while that in the house connection showed a comparatively high rate of 204 litters/day as tabulated below:

Domestic Water Consumption by Type of Connection in DSM Distribution Network

Consumer by Type of Connection (liters/day)	Water Consumed in m^3/day (Ratio)	Population Served (Ratio)	Water Consumption Per Capita (liters/person)
- House Connection	87,537 (69 %)	428,851 (32%)	204.1
- Yard Connection	27,648 (21 %)	315,482 (24%)	87.6
- No Connection (Kiosk/Standpipe)	12,995 (10 %)	590,695 (44%)	22.0
Total	128,180 (100 %)	1,335,028 (100%)	96.0

(2) Water consumption in other sectors

The water consumption in other sectors in 1990 were estimated as follows:

Sector	Total Connections (Nos.)	Water Consumption (m^3/day)
- Industrial sector	475	4,612
- Commercial sector	4,902	6,282
- Institutional and others	1,141	5,335

4.2.4 Water consumption along transmission mains

For the service areas along the trunk transmission mains, NUWA established branch offices and started registration of the connection in 1990. The population served is estimated to be around 109,000 based on the data collected at village level.

The per capita consumption in the domestic sector is little known on the area. Herein assumed is that the average daily consumption per capita in 1990 was the same as that in the distribution network of DSM (96 litters). Consequently, the domestic water consumption in 1990 is estimated at about 10,464 m^3/day.

Based on the data on registered numbers of industrial, commercial, institutional and agricultural consumers as well as their consumption which were collected through the field survey, the water consumption in other sectors than the domestic sector in areas along the transmission mains is derived to be 30,375 m^3/day as shown in Table 4.3.

4.3 Expansion and Rehabilitation Plan of the Dar Es Salaam Water Supply System

Since 1976, no further expansion of the water supply capacity has been carried out. The Urban Sector Engineering Project considers that it is the most feasible to expand the treatment plant of the Lower Ruvu scheme to the extent corresponding to the maximum capacity of the existing transmission main. The major projects planned so far are as follows;

1) Improvement and rehabilitation of the Upper Ruvu scheme and the Dar Es Salaam distribution system. This project is the second stage of that described in the foregoing Subsection 4.1.2, which was implemented under the Italian financial assistance, including:

- Transmission main ; Replacement of the 4 km long old main pipes of 750 mm in diameter between the Mlandizi treatment plant and the Kimara Reservoir with cast iron (CI) pipes of 900 mm and 750 mm in diameter. Rehabilitation of feeder and main appurtenances between Kibaha and Kimara.

- Distribution main ; five (5) distribution main of 600 mm in diameter in a total length of 20.3 km.

2) Rehabilitation of the Lower Ruvu scheme, the Mtoni scheme, and the distribution network. These works were studied by JICA in 1990 and 1991.

- Improvement of the Lower Ruvu scheme including repair of chlorinating system, construction of additional intake, minor repair of clarifiers
- Repair of the Mtoni scheme
- Leakage control measures including installation of meters
- Cleaning of about 650 km long pipelines in the distribution system
- Replacement of 90 km long service pipes of small diameter in the city center
- Installation of 38 km additional primary mains of 200 mm to 900 mm in diameter in Oyster Bay, Kinondoni, Temeke, Kurasini, Kigamboni and Mbagala.
- Installation of 46 km long secondary pipes of 100 mm to 150 mm in diameter in Tabata, Yombo, Ukonga, Mbezi and Kigamboni.

3) Expansion of the Lower Ruvu treatment plant.
The study on the expansion of the existing Lower Ruvu scheme as well as rehabilitation of distribution system in Dar Es Salaam city is going to commence under the finance of the African Development Bank (AFDB) within year 1994.

It is expected that the present design water supply capacity (182,000 m^3/day or 2.11 m^3/sec) of the Lower Ruvu scheme is increased to 1.5 times the present one (273,000 m^3/day or 3.16 m^3/sec) or more through implementation of the aforesaid expansion project. As well, the present high rate of leakage and waste in the service area is expected to be much improved through realization of the aforesaid projects.

4.4 Municipal Water Demand Forecast

4.4.1 Procedures adopted

The water demand forecast in the Dar Es Salaam water supply system was made for the target year 2020 and the intermediate years at interval of five (5) year dividing the service area into the two areas; namely the area covered by the distribution network and area along the transmission mains.

The gross water demand comprises domestic, industrial, commercial and institutional demand as well as leakage and wastage. The domestic water demand which constitutes a large part of the gross one is derived through the multiplication of the population served and the averaged

per capita demand. By summing up the sectorial demands, the gross water demand is calculated by the following formula on an average daily basis:

$$\text{Average daily water demand} = \frac{\text{Daily gross water demand}}{1 - \text{Leakage/Wastage ratio(\%)} / 100}$$

The daily maximum demand is assumed to be constant at 125 % of the average daily demand throughout the period up to the year 2020, adopting the daily peak factor of 1.25 obtained through the previous study for the Dar Es Salaam water supply system. The water demand forecast was made adopting the year 1990 as the base year.

4.4.2 Water demand by sector

The sectorial water demand in the Dar Es Salaam water supply system was made as mentioned below:

(1) Domestic demand forecast

The service area of the Dar Es salaam water supply system lies in the two (2) Regions; namely the Dar Es Salaam Region (06) and Coast Region (07). The population forecast for these Regions was made for the years up to 2020 in the course of the Study.

The population served in the distribution network is predicted to increase from 1,358 thousand in 1990 to 5,491 thousand in 2020 at annual growth rates varying from 4.4 % to 4.9 % as shown in Table 4.4. The average daily water demand per capita in the distribution network is projected dividing the consumers into the two categories, namely house connection and other type of connections (yard connection and no connection). The per capita water demands in the both categories are predicted to increase in proportion to the annual increase rates of per capita GDP (1.8 %). On the other hand, it is assumed that the per capita water demand of the house connection would not exceed 300 lpcd with reference to those in capitals of other developing countries. As a result, the total domestic demand in the distribution network in the year 2020 is estimated 634,215 m^3/day as shown in Table 4.4.

The population in area along the transmission mains is forecast to increase from 109 thousand in 1990 to 312 thousand in 2020, while the per capita water demand therein is forecast to increase at the rates of the per capita GDP. The domestic water demand in area along the transmission mains in the year 2020 comes to 51.152 m^3/day.

(2) Water Demand in other sectors

Except for the agricultural demand, those in other sectors are assumed to increase at the same annual growth rates as those of the GDP, ie., 3 % between 1990 and 2000, and it is assumed at 1.5 % between 2000 and 2020.

With regard to the agricultural water demand, NUWA intends to apply higher water tariff to the users to reduce the water consumption for the purpose. Taking into account the water shortage likely to take place in near future due to the increasing water demand in Dar Es Salaam city, it is strongly hoped that the water source for the agricultural production is replaced by other one including ground water. In the present water demand forecast, it is assumed that the agricultural demand along the transmission main is constant until the year 2020.

(3) Water leakage and wastage ratio

The water leakage within the distribution network was estimated to be 35% of the daily average demand in the previous study for year 1990. In addition, the study assumed that the leakage ratio would decrease to 20 % with the rehabilitation of the distribution system. While, the distribution leakage and wastage level in the area along the trunk transmission mains in 1990 was calculated at high ratio over 50 % based on the gross consumption of each sector and the gross supply to the area. In the present water demand forecast, the water leakage and wastage ratio in the area is assumed to decrease to 20 % in the target year 2020.

(4) Municipal water demand in 2020

Tables 4.5 and 4.6 show the water demand in the distribution network of Dar Es Salaam city and the area along the transmission mains, respectively.

Through the above assumptions and procedures, the gross demand in the whole service area in the year 2020 was estimated at about 970 thousand m^3/day or 11.2 m^3/sec on an average daily basis as shown in Table 4.6, while the daily maximum demand at about 1,211 thousand m^3/day or 14.0 m^3/sec.

CHAPTER V

POTENTIAL OF AGRICULTURAL DEVELOPMENT

5.1. Present Condition

5.1.1 Soil

(1) Soil survey

A total of 25 sampling pits including auger holes were dug in the selected priority areas in order to examine the suitability of soils in the basin for the purpose of agricultural development. The soil profile observation was made for major items applying the standard of national soil service of Tanzania. Location of pits and auger hole sites are given in Fig 5.1. In parallel with the soil profile observation, soil sampling was performed at each soil depth. A total of 118 soil samples were collected and they were laboratory-tested for ten (10) items. In addition to the aforesaid soil survey, the water quality analysis was also made for seven (7) samples collected from those test pits and rivers to clarify the saline condition.

(2) Characteristics of soils

a. Lower Ruvu Valley
This area is dominated by alluvial clayey soils transported by the tributaries of the Ruvu River. The depth of the top soils and effective soils are good enough for agriculture. The soil reaction is weak and suitable for most crops. The electrical conductivity is low and this indicates that soils are almost free from salinity problem. Sodium adsorption ratio is also as low as 6, implying absence of sodicity hazard. The cation exchangeable capacity ranges from medium to very high. This indicates that the soil is very fertile and suitable for rice cultivation.

b. Middle Ruvu Valley
The soil survey for this area was not carried out due to flooding and heavy rain at the time of sampling. According to the geological map prepared by FAO, report No. 1316, the areas outside both right and left banks of the valley are covered by alluvium and clayey deposits.

c. Upper Ruvu Valley (Mgeta Plain)
The soil texture of the upper part of this area is sand, sandy clay and sandy clay loam whereas the lower part of this area is covered by clay and clayey loam. Except for some

northern part of the Gombo village, PH and EC values are low and S.A.R. values are generally medium. These soil characteristics indicate that the soils are suitable for most crops. Salinity and sodicity problems are also absent. Soil fertility is high especially in the lower part of the area.

The soil in the northern part of the Gombo village shows that sodium adsorption rate is over 12 at many places. Therefore the area covering approximately 1,700 hectares should be excluded from the priority area for agricultural development.

5.1.2 Present land use

(1) Present land use in the Ruvu River basin

The total area of the Ruvu River basin is about 17,900 km^2, of which arable land area accounts for 1,800 km^2 or about 10 % of the total area. The rest of 16,900 km^2 comprises forest, steep slope area, floodplain, water body, road and public compounds. The present land use in the Ruvu River basin is summarized as follows:

Land Classified	Area (Km^2)
Entire area	17,900
Forest	4,000
- forest reserve	2,800
- forest non-reserve	1,200
Steep slope area	1,200
Drainage area	11,600
- floodplain	9,800
- arable land	1,800
Town, village, road, etc.	900

The principal types of vegetation in the basin are; (a) Mangrove forest of about 2 km^2 at the mouth of the Ruvu River, (b) Thicket scattered over the entire basin up to 600 m in altitude, (c) Woodland of about 14,200 km^2 or 80 % of the basin area, (d) Tropical evergreen and semi-deciduous forest along the river streams, and also in places above 1,000 m where annual rainfall exceeds 1,000 mm, (e) Mountain forest and mountain heath-land with altitude of more than 1,000 m

5.1.3 Present cropping pattern

Owing to the relatively mild climate, various kind of crops such as wheat, maize, paddy, cassava, vegetables, orange, coffee banana, pineapple, etc. have been introduced in the Langali areas, western side of the Uluguru Mountains, Bwakira-chini area in the Mgeta Plain, and Mkuyuni area in the upper Ruvu. Whereas, in the lower basin between the Ruvu station and Bagamoyo areas, a few kind of crops such as paddy, maize, cassava are cultivated in the floodplain with the traditional farming practices at a small scale. In the Ruvu River basin, the current cropping calendars prevailing in Langali, Bwakira-chini, Mkuyuni and Bagamoyo are illustrated in Fig. 5.2.

5.1.4 Present farming practices

Peasant cultivation techniques are manual with simple hoe. In general, animal power and tractors are not suited to small scale farming in the basin. Large scale farming of paddy is practiced in the Ruvu Rice Farm Ltd. (NAFCO RUVU) with an extent of 750 ha under surface irrigation system by pumped water in the lower Ruvu. The present farming practices with regard to the major crops such as cassava, maize and paddy are summarized as follows:

(1) Cassava

Planting of cassava takes place in October to November or February to April with rain. Propagation of cassava is made by means of stem cutting.

(2) Maize

Maize cultivation is mainly made in small holdings, more often as a mixed stand entirely under rainfed conditions except for the Ruvu floodplain where the extent of crop grown and the sowing time are dependent on the flooding condition.

(3) Paddy

Small Scale Farming : Nearly all of the paddy is sown directly in the field after plowing, which is usually done in the dry period. Germination depends largely on available moisture and the water level in the field. There is no control over this factor in the floodplain at present. In the floodplain, sowing takes place during January and February, before the flooding becomes a threat. Paddy is often inter-planted with maize and is harvested in June when the flood begins to recede.

Large-Scale Farming : Before sowing, the land is plowed once, harrowed twice and leveled. These operations are performed between September and December. Sowing commences in February. The direct sowing is made by using seed drills mounted on wheeled tractor.

Chemical control of pest and diseases is applied, and hand weeding is also practiced to avoid the other weed generation and the wild rice which are not controlled by the herbicides.

Fertilizer used are tiple super phosphate (TSP) at a rate of 125 kg/ha every two years, two splits of urea after germination and booting stage and nitrogen at a rate of 100 kg/ha. Harvesting of paddy is done by using combine harvesters and commences in June to August, depending on the planting times and planted areas.

5.1.5 Crop yield and production

Farmers of the Coast Region are primarily subsistence producers. Cash crops including cashew, sesame, cotton and citrus are produced in addition to the subsistence crops. The Morogoro Region is one of the major suppliers of fruits and vegetables to the Morogoro municipality and Dar Es Salaam city. Sisal, the major cash and export crop, is grown in large-scale plantations. Coffee and cotton are grown by smallholders at a limited scale. Major food crops comprise maize, paddy rice, cassava, sesame, etc.

No reliable statistical data on crop yield and production are available in the Ruvu River basin. Crop production and unit yield of the major crops were estimated on the basis of the data provided by the Ward and District Extension Offices, information collected from the village offices and local farmers and the field data obtained from the field investigation. The average production of major crops for the period from 1985/86 to 1990/91 in the both regions including outside area of the Study Area and unit yield and production of major crops in the Ruvu River basin are estimated as follows:

Average Production and unit yield

	Cassava	Maize	Paddy	Cashew	Sesame	Cotton	Sisal
Production (Unit 1,000 tons)							
Coast	202.4	19.1	34.9	4.1	0.5	2.5	-
Morogoro	69.3	115.8	92.7	-	4.6	No Data	456.4
Ruvu Basin	24.4	66.5	31.4	-		11.6	-
Unit Yield (ton/ha)							
Ruvu Basin	2.3	1.4	2.5	-	-	1.6	-
National Ave.	2.25	1.42	1.5	-	-	0.5	-

5.1.6 Irrigation and drainage system

(1) Existing irrigation system

Irrigation and drainage systems are used in very limited areas such as estates, lower Ruvu area and western slope of the Uluguru Mountains (Uluguru West). Irrigation water amount supplied to sisal and other estates is negligible small because of scale-down of their production. The farmers in the middle and upper Ruvu areas rely on unstable rainfall.

Existing irrigation methods in the basin are broadly divided into two types, namely modern irrigation by pumping in the low-lying area and traditional irrigation in the mountainous area.

(a) Modern irrigation and drainage system in the Lower Ruvu Valley
There are 17 numbers of existing, abandoned and proposed agricultural development project/farms between the Ruvu town and the Ruvu River mouth. Irrigation farming has been attempted in some projects/farms. The list of these projects/farms and their locations are shown in Table 5.1. Following table shows a summary of the existing and potential areas of agricultural development in the lower Ruvu.

	Area		Irrigated Area		
Ownership	Potential (ha)	Planted (ha)	Designed (ha)	Actual (ha)	Future plan (ha)
Public	9,300	3,900	1,045	197	2,400
Private	7,550	30	-	-	220
Village	2,400	2,400	-	-	2,400
Total	19,250	6,330	1,045	197	5,020

(b) Traditional irrigation and drainage in the Uluguru Mountain West
Irrigation in this area was voluntarily commenced by the local people in 1960's. There exist 68 traditional unlined irrigation canal systems with total length of 170 km in the Mgeta Division. These systems irrigate some 2,000 hectares of vegetable farms in the dry season.

(2) Water right

The water right registered for agricultural purposes totals 43 with a gross water amount of 4.5 m^3/sec as listed in Table 5.2. The total amount dose not necessarily coincide with the

agricultural water requirement. For the proper management of the water resources, registration system and registered water amount should be reviewed and adjusted.

5.1.7 Livestock production

Tables 5.3 and 5.4 show the data on the livestock grazing in the Ruvu River basin in Bagamoyo and Kibaha Districts. The annual increase rate of number of cattle in the basin is lower than that in the entire Bagamoyo District which is equivalent to 2.8 %. Table 5.5 shows the livestock grazing in the Morogoro Rural District in the 1984 census. Kingolwira, Melela, Mlali, Kidugalo and Tununguo villages are producing a large number of cattle. These villages are well known as the traditionally cattle producing villages in the Morogoro Rural District by means of the grazing method enforced by Masai people.

A total of 22 dips and 6 veterinary centers exist in the Coast Region, of which only two dips are in operation at present. Other 20 dips and all 6 veterinary centers require rehabilitation. In the Morogoro Region, no veterinary and bull centers exist.

5.1.8 Forest

Table 5.6 shows a tendency of the forest production in the Districts in the Ruvu River basin for the period from 1985/86 to 1991/92. The trees in the vicinity of Dar Es Salaam had been eliminated by timber and charcoal traders. However, the Districts in the Coast Region will continue to be a major source of charcoal, firewood and house building poles for Dar Es Salaam. The charcoal and firewood production records in the Coast Region show a tendency that the producing areas move from Kibaha area to the accessible forested areas in the Bagamoyo and Kisarawe Districts in and around the Study Area. A lot of forest reserves and forested areas are in need of afforestation.

The Regional Natural Resource Office of the Morogoro Region has its own tree seedling nursery. This office supplied the tree seedlings to the villages and Wards in its jurisdiction for the period from 1981/82 to 1988/89. In 1989/90, this service was stopped due to lack of fund, and the seedling was restarted in 1992/93, but apparently the supply of seedling is inadequate to meet the present requirement of the villagers and reserves.

5.1.9 Fishery

The fishery in Tanzania is still in a primitive stage without improved pisciculture, being mainly of catching fish from natural water bodies. In 1988, the marine fish catch in Indian Ocean occupied only 47,300 tons, accounting for only 13.9% of total catch of 340,300 tons.

In the Ruvu River basin, the freshwater fishery at a commercial scale is made at the Mindu dam in the upper basin and at the Morogoro Road Bridge in the lower basin. The fishery in these areas is also at a primitive level without storage and marketing facilities. Fishery office in the Morogoro Region controls the fish catch in the Mindu dam reservoir, but no production data were available. A hatchery center was once established in the vicinity of Morogoro municipality in 1980's. However, no expected results were obtained. The Government has an intention to reestablish the center.

5.2 Prospective Agricultural Development Plan

5.2.1 Basic concept for agricultural development

Taking into consideration the National Development Programme, the national irrigation policy and agricultural condition in the basin, the agricultural development plan was formulated on the basis of the following concepts:

i) Development of potential area to the maximum extent
ii) Development for increasing agricultural diversification
iii) Supporting to smallholder scheme
iv) Rehabilitation of existing scheme
v) Introduction of private fund to new development scheme
vi) Introduction of gravity irrigation system

5.2.2 Assessment of land resources

The potential areas in terms of land resources are preliminarily selected on the basis of the previous studies by FAO and French Mission, topographic maps at a scale of 1/50,000, reconnaissance survey along the river, the results of soil analysis and study on environmental conditions.

The area and locations of potential irrigable areas preliminarily selected are tabulated below and illustrated in Fig. 5.3.