Table of Contents

Appendices

List of Tables

List of Figures

Glossary

Abbreviations

AfDB	:	African Development Bank
B/C	:	B C ratio or B by C
CFL	:	Cistern Flush Latrine
CTC	:	Communal Toilet Committee
CWP	:	Communal Water Points
CWPC	:	Communal Water Points Committee
DHS	:	Demographic and Health Survey
E.C.	:	Electric Conductivity
EIA	:	Environmental Impact Assessment
EIRR	:	Economic Internal Rate of Return
EPLF	:	Eritrean People Liberation Front
EU	:	European Union
FIRR	:	Financial Internal Rate of Return
FRP	:	Fiberglass Reinforced Pipe
GDP	:	Gross Domestic Product
GOJ	:	Government of Japan
GTZ	:	German Technical Agency
HMSU	:	Hydrometeorological Information Unit
HRD	:	Human Resource Development
IDRC	:	Institute of Development Research of Canada
IEE	:	Initial Environment Examination
IFAD	:	International Fund for Agricultural Development
JICA	:	Japan International Cooperation Agency
MIS	:	Management Information System
MoA	:	Ministry of Agriculture
MoH	:	Ministry of Health
MoLG	:	Ministry of Local Government
MoLWE	:	Ministry of Land, Water and Environment
NGO(s)	:	Non-Governmental Organization
NPV	:	net present value
NUEW	:	National Union of Eritrean Women
NUEY	:	National Union of Eritrean Youth
O&M	:	Operation and Maintenance
PFL	:	Pour Flush Latrine
PHC	:	Primary Health Care
RAD	:	Regional Affairs Department
S/W	:	Scope of Work
UNDP	:	United Nations Development Programme
UNICEF	:	United Nations International Children's Emergency Fund
US$	:	U.S. Dollars
UTM	:	Universal Transversal Mecator

VIP	:	Ventilated Improved Pit Latrine
WD	:	Water Department, MoLWE
WID	:	Women in Development
WLU	:	Water Law Unit
WQPU	:	Water Quality Pollution Unit
WRD	:	Water Resources Department
WRDU	:	Water Resources Development Unit, MoLWE
WRID	:	Water Resources Information Division, MoLWE
WRIU	:	Water Resource Information Unit
WRUMD	:	Water Resource Use Management Division, MoLWE
WSA	:	Water Supply and Sewerage Authority / Water Supply Authority
WSC	:	Water and Sanitation Committee
WSS	:	Water Supply Service
WSSO	:	Water Supply Service Office

Tigrigna Words used in the Report

Adi	:	Village
Kebabi	:	Lowest administrative unit comprising of group of villages
Baito	:	Traditional village assembly
Megabia	:	Elected democratic legislative body at Kebabi level
Ne'us Zoba	:	Sub-Region
Zoba	:	Region

Units and Measures

a	:	Annum
asl	:	Above sea level
av.	:	Average
bgl	:	below ground level
G.d.h	:	German degree of hardness
ha	:	Hectare(s)
hr	:	Hour(s)
in	:	Inch(es)
kg	:	Kilogram(s)
km	:	Kilometer(s)
km^2	:	Square kilometer(s)
kwh	:	kilowatt hours
l	:	Liter(s)
lit	:	Liter(s)
l/c/d	:	Liter(s) per capita per day
m	:	Meter(s)
m^2	:	Square meter(s)
m^3	:	Cubic meter(s)
mg/l	:	Milligram per liter
µS/cm	:	Micro Siemens per centimeter
micro S/cm	:	Micro Siemens per centimeter
min	:	Minute(s)
mm	:	Millimeter(s)
mon	:	month
msl	:	Mean Sea Level
MCM	:	Million cubic meter(s)
mv	:	Milli-volt(s)
Nfa	:	Nakfa
Ohm-m	:	Ohm meter(s)
Ωm	:	Ohm meter(s)
s	:	Second(s)
sec	:	Second(s)
US$	:	US Dollar
yr	:	Year(s)
¥	:	Japanese Yen
℃	:	Degree centigrade
%	:	Percent
”	:	Inch(es)

CHAPTER 1 INTRODUCTION

1.1 Background

Eritrea gained its independence on 24 May 1991, after 30 years of debilitating war. This war has hampered the country's development in all aspects. During the war, almost no development took place regarding water supply facilities both in urban and rural areas. Furthermore, many facilities were damaged severely. As a result, water delivery in the urban water supply systems, other than Asmara, is very low. It is envisaged that rapid increases in the population, inclusive of returnees from Ethiopia and Sudan, will put even more pressure on present water supply conditions.

Since independence, many donor countries/international organizations have extended assistance to Eritrea in the field of improvement of existing water supply facilities and sanitary education. In response to the request of the Eritrean Government, Japan also has come forward with the offer of technical assistance. A Preparatory Study Team was sent to Eritrea in April 1997, in order to formulate the Scope of Works with the Ministry of Mines, Energy and Water Resources for the project titled "The Study on Groundwater Development and Water Supply for Seven Towns in Southern Region of Eritrea" (refer to Appendix-A). Later, in August, the Japan International Cooperation Agency (JICA), the official agency responsible for technical cooperation programs, sent a Study Team consisting of twelve (12) members headed by Mr. KUME Takao.

1.2 The Study

The objectives of the Study are:

(1) to evaluate potential of water resources, focusing on groundwater,

(2) to formulate a development plan for water supply and sanitation,

(3) to conduct a feasibility study for a water supply project, and

(4) to pursue technology transfer to counterpart personnel in the course of the Study.

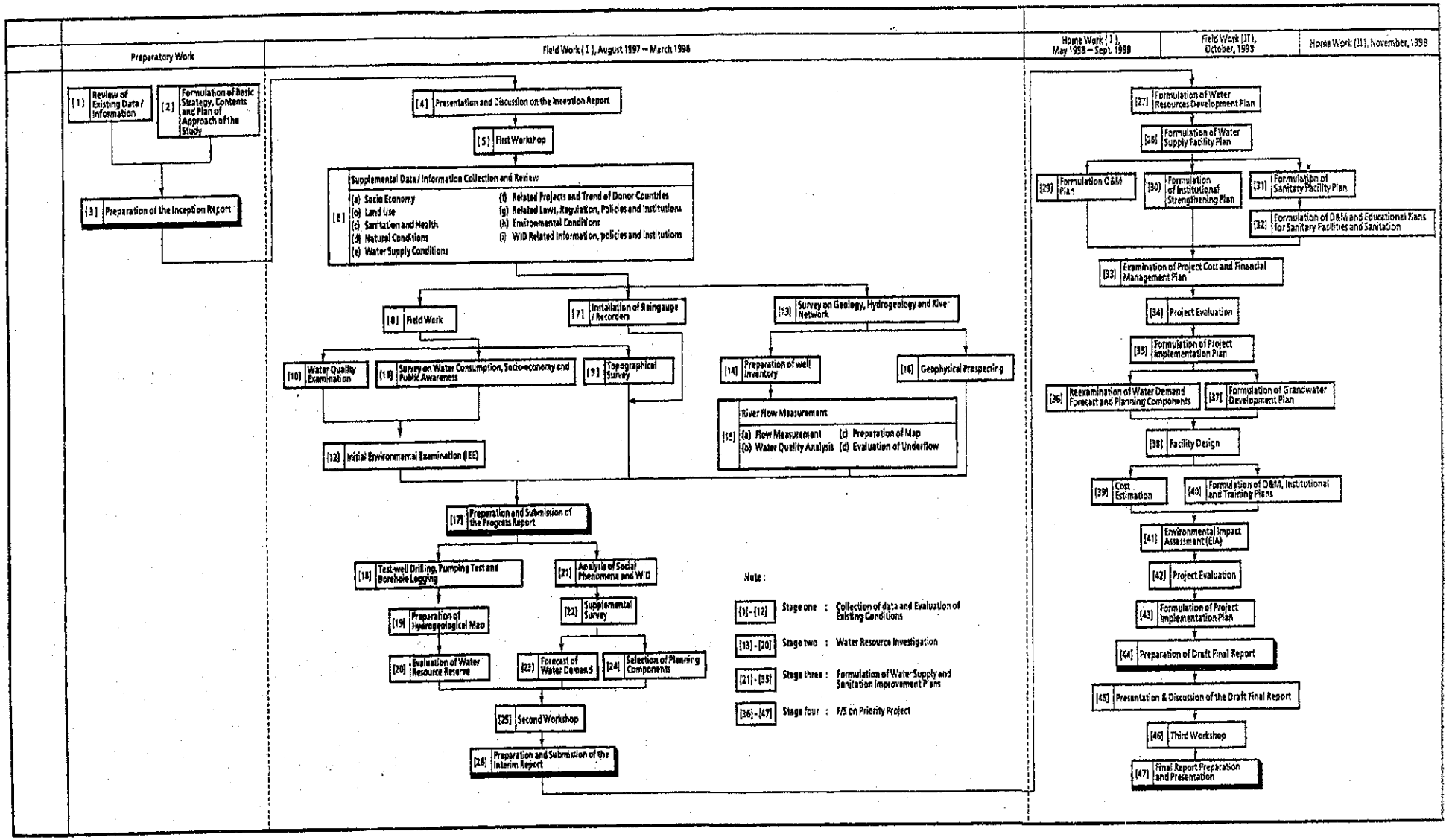
The Study covers the following 7 towns in the Debub Region (please refer to the Location Map):

- Debarwa, Mendefera, Adiquala, (along the Route 3)
- Dekemhare, Segeneiti, Adi Keyih, and Senafe. (along the Route 1)

The Study consists of Preparatory Work, Field Work (I), Home Work (I), Field Work (II), and Home Work (II). Further, the Study is divided into four stages strategically; Stage one for "Collection of Data and Evaluation of Existing Conditions", Stage two for "Water Resources Investigation", Stage three for "Formulation of Water Supply and Sanitation Improvement Plans" and Stage four for "Feasibility Study for the Priority Project". The work flow chart, together with the said staging, is shown in Figure 1.1.1.

The Study commenced on 27 August 1997. At the very beginning, an Inception Report was submitted to the Water Resources Department (WRD), the counterpart agency for the Study. Through the subsequence discussions, it was agreed that the Study Team would prepare another Inception Report after an initial field survey. The second Inception Report (Inception Report-II) was submitted to WRD at the end of September. The Inception Report-II was consisted of an understanding of the Study Area, preliminary findings, a summary report on the first workshop, and the following study plan.

Figure 1.1.1 Work Flow Chart



The Team, in close cooperation with WRD's counterparts, carried out their studies, surveys, and analyses on a continuous basis. And on the occasion of the completion of Stage one works, the progress of the study by each expert was summarized and reported as the Progress Report at the beginning of December 1997. Continuously, the field works were conducted uninterruptedly and completed by the beginning of February 1998. Immediately, the results of field works as well as the socio-economical survey results were examined and analyzed comprehensively. On this occasion, all of the results on surveys, studies and analyses were rearranged and reported as Interim Report, together with a basic strategy on the following planning and design works. The Interim Report consists of a summary, main text with appendices, and associated separate volumes of "Field Investigation Report" and "Socio-economic Survey Report".

On 20 May 1998, the Study was resumed as the Home Work (I). Major themes of the work were 1) formulation of the Water Supply Development Programs for the short, middle and long terms and 2) Feasibility Study (F/S) for the priority Project. Through the study for around four (4) months, the development programs were formulated and arranged as the Draft Final Report together with the results of F/S on the priority Project. The Report was submitted to WRD in the early November 1998. At the beginning of January 1999, the Draft Final Report was finalized taking the comments from the several agencies concerned in Eritrea into the consideration, and the Final Report was submitted to the Government of Eritrea immediately.

CHAPTER 2 OVERVIEW OF ERITREA

2.1 Overview of the Country

2.1.1 Geographical Setting

Eritrea covers an area of 124,320 km^2, and is bordered by the Red Sea to the north and northeast, Sudan to the north and northwest, Ethiopia to the south and southwest and Djibouti on the far south-eastern corner. Despite being a relatively small country, it has varied geographic and climatological regions, glaringly manifested in the three main physical features of the country, viz, the central highlands, the Western Lowlands and the Easter Lowlands running parallel to the Red Sea.

2.1.2 Historical Background

Historically, Eritrea was occupied by successive colonial rulers first by the Turks, followed by the Italians and British and finally by the Ethiopians. It emerged as a sovereign state in 1991, after three decades of bitter struggle with the Ethiopians. Following an internationally-supervised national referendum, Eritrea proclaimed its *de jure* independence in May 1993. For the period 1993 up to the year 2000, the country is expected to be governed by a transitional arrangement coinciding with the process of constitutional development.

Elections for a national assembly were held in early 1997, whose mandate, among other things, will be to oversee the transition to multi-party state. The ruling People's Front for Democracy and Justice (PFDJ), views multi-partiism as only one of a series of developments which would strengthen the democratic orientation of the country. These developments consist of: National Unity, Active Participation of the People, People Centered Development, Social Justice, Self-Reliance, and Strong links between People and the Leadership.

All the above six principles are consistent with the method in which the liberation struggle itself was fought, and form a solid basis to handle the challenges to come. It is commitment to these principles that has constantly kept the role of women at the forefront of development efforts. Women comprise 21 percent of the National Assembly, 13 percent of all Ministerial positions, and 50 percent of all members of the Constitutional Commission.

Further, such development principles have also guided the passage of key reform legislations, most importantly the Land Reform Act, which entitles all Eritreans the right to inherit/use land, and the passage of the Proclamation for the Establishment of Regional Administration, and the introduction of the National Currency (the Nakfa).

2.1.3 Population

In Eritrea, no census has been carried to date, nor are there reliable and time series data and information on the socio-economic aspects of the country. For this reason, data and figures quoted in this report are estimates drawn from unofficial sources and are meant to provide the broad contextual framework for this study.

Estimates put the country's population at around 3.5 million. The number of Eritreans living abroad

range between 700,000 to 1,000,000. The population is culturally and linguistically diverse, consisting of nine ethnic groups namely: Afar, Bilen, Hedarib, Kunama, Nara, Rashaida, Saho, Tigrigna and Tigre.

In 1995, a Demographic and Health Survey (DHS) was conducted for the first time in the country by the National Statistics Office that, covers a sample of 25 households in each urban cluster and 35 households in each rural cluster. Accordingly, 53 percent of the population are females and 47 percent males. The average household size is about 4.2 for both rural and urban areas and there are large number of population in the younger age groups than in the older age groups.

2.1.4 Administrative Structure of the Government

The Constitution of Eritrea unambiguously provides that Eritrea is a unitary state. The Government of the State of Eritrea is made up of 17 ministries, most of whom are represented at the regions, and six regional administrations. Detailed elaboration of what decentralized regional administration means within the sprit of Proclamation 86/96, is provided in Appendix A, Chapter 2). The main functions of the central level ministries and regional administrations are also elaborated because it has direct bearing on the implementation of water and related projects both during the construction stage and latter on its management.

In short, Ministries at the center are responsible for policy matters and for developing guidelines and procedures for program development and implementation, while the Regional Administration is vested with the responsibility of program/project implementation.

2.2 National Development Plan

2.2.1 General

The three decades of armed struggle for national liberation was solely based on self-reliance and sufficiency without any external assistance whatsoever. Even today, the cardinal strategy for national development and economic and social transformation of the country is based on the principle of "Self-reliance and People's Participation", particularly via community organization.

However, self-reliance and popular participation cannot be replicated as in the days of the struggle where it was adopted as a survival strategy in a non-market and non-moneytized economic environment. Hence, in its attempt to ensure that economic and social rehabilitation and reconstruction takes place in a liberal market led economic environment, the Government prepared the Macro-Policy Directives and various by-laws which define and articulate what the country will be after 20 years, what the development objectives are the medium-term and long term, and the strategy to be adopted in the implementation of the development objectives. The strategy is laying due emphasis and reliance on people's participation in all developmental endeavor.

2.2.2 Development Policies and Plans

In its broad context, the development policy of the Government, from which its development plans and programs are derived, are based on the following basic principles:

(1) Ownership of policies and programs: that policies and programs should not be based on the influence

of external factors or donors, but should be drawn on the basis of the felt needs and aspirations of the Eritrean people.

(2) Participatory politics: which involves the active participation of all the people in general and the beneficiary target groups in particular.

(3) Good economic management: lean, efficient and accountable Government civil service, and efficiency in the delivery of services one is entrusted with.

(4) Human resource development: involves giving priority to education and much energy and resources need to be devoted to build and up-grade the human resource potential.

(5) Physical infrastructure: considered as a key factor for success and need to be attended with utmost urgency because the pitifully underdeveloped infrastructure hampers capital and resource flow

The national development plan could be characterized by a series of separate but coordinated short term sectoral programs prepared by ministries. Accordingly, in the coming years, the Government intends to strengthen the agricultural sector especially export oriented cash crop production and/or agricultural products that serve as raw material for domestic manufacturing industries. The task of jump-starting the agricultural sector has already started in earnest by volunteer campaigners who will be engaged in a massive soil and water conservation works in potentially arable areas. Thousands of hectares of previously fallow land has been farmed by mechanized means especially in the Debub Region.

Another potential sector which is expected to play a meaningful role in the national economy is the marine resource of the country. Presently, the country is reaping only 5,000 tons of marine products against an estimated 70,000 tons of sustainable yield. The Government has already started implementing its programs of releasing this huge potential resource.

The construction sector will continue to dominate the economy of the country for years to come. Already big residential and other construction projects have been completed and currently there are a number of other projects like ports, dams, roads and electricity that are being built and/or planned to be built.

In 1996 alone investment (both local and foreign private) in the manufacturing sector amounted to US$ 37 million. This coupled with the on-going privatization program of formerly Government owned industries will undoubtedly contribute towards the improvement of the country's trade balance.

In the tourism sector, the past years were devoted to preparation of master plan and familiarization of the tourist potential of the country to investors.

It is believed that the new national currency introduced in December 1997 will, among other things, enable it to redress its fiscal deficit, enhance national savings and pursue its own fiscal and monetary policies for its national development.

With regards to water sector policies and programs, the Ministry of Land, Water and Environment (MoLWE) and the various Departments under it are still in their establishment stage and as such have not yet started implementing the Water Sector Policy and Strategy elaborated in section 2.3.5. below. However, in the remaining months of 1998, their action plan includes activities related to the organization of offices and filling of vacant posts; to conduct national water resource studies on the basis of catchment

areas; see the smooth promulgation of the draft National Water Law; carry out and finalize the "Sector Study on National Water Resource and Irrigation Potential"; consider and monitor development of the technology for sea water desalination and ensure its use in the islands and along the Red Sea off-shore areas; implementation of its human resource development plan, viz, provision of on-the-job and off-the job internal and external training; and supervise and monitor on-gong projects and ensuring their proper implementation.

2.2.3 Economic Growth

There are various parameters for measuring the economic growth of a country. One of the most common is the GDP of a country. Eritrea's GDP which was estimated to be in the range of Nfa 1.9 billion in 1992, has grown to Nfa 2.7 billion in 1997. This means that the country registered GDP growth between 7-9% for the years. When judged from the low development stage the country started, this figure is quite high; however considering the war ravaged economy and the poor living condition of the people the growth could be negligible.

Except for 1994, the contribution of the agricultural sector to GDP is low due to erratic rainfall and stochastic weather conditions. However, this was compensated by the estimated growth rate of 14% for the other sectors of the economy, viz., construction, transport and communications, trade and services finance and tourism, etc.

Loans for investment are also an index for economic development. In 1997, about 30% of GDP was spent for capital expenditures. During the same period, about 400 investors requested for license with a capital of about Nfa 2 billion. Private sector borrowing from banks grew from its low level of Nfa 45 million in 1993 to Nfa 699 million in 1996 representing annual average increase of Nfa 230 million per year. However, it is reported that banks have far greater lending capacity than the level of private sector borrowing.

The value of capital goods imports increased from Nfa 55 million in 1992 to Nfa 1.1 billion in 1996. Construction sector took the lion's share of 33 percent for the period under consideration.

Prices have been kept stable since 1993, and in fact prices of essential commodities decreased from 11% in 1995 to 4% in 1996. It is expected that the figure for 1997 would remain the same as that of 1996. Two conditions explain this low rate of inflation in Eritrea - growth in production of goods and service and growth in volume of imports. For example, despite the bad harvest and termination of food-aid as of 1996, prices of food items got stabilized due to the importation of the country's food requirements.

Since 1993, the Eritrean economy is characterized by unfavorable balance of trade and imbalances in Government expenditures and revenue. In 1996, total Government revenue was Nfa 1.4 billion while total expenditure amounted to Nfa 2.7 billion. The deficit was financed by internal borrowing (Nfa 843 million) and foreign grants and credit (Nfa 508 million). This apparent large deficit was due to several factors including: the need for the Government to undertake huge program of rehabilitation and reconstruction of the ruined social and physical infrastructures, implement its program of demobilization of ex-fighters and reintegration of returnees from neighboring countries, and finally compensate the families of martyred fighters. Available statistics for 1966, indicate that imports amounted to Nfa 3.6 billion while the value of exports were a negligible Nfa 700 million. The deficit was covered from two

sources: income from services and remittances from Eritreans who live abroad. The latter amounted to US$ 240 million and its contribution to the country's development could not be underscored. In terms of the composition of imports, the share of intermediate goods and raw materials from the total value of imports was Nfa 55 million in 1992, and rose to Nfa 1.1 billion in 1996. The share of the construction industry in capital and intermediate goods imports amounts to about 33 percent.

Currently, the Ministry of Health (MoH) is operating 20 hospitals, 43 health centers and 136 health stations, most of which are Government owned (MoH, 1995). More over, the last few years have seen an expansion of the water and sanitation program as a strategy to control diarrhea diseases; expansion of immunization program for children under five and expectant mothers aimed at improving the health status of mothers and children; the provision of health services for nominal fees to the majority of the population; and the training of traditional birth attendants.

Training of human power needed to staff health institutions is being carried out at a reasonable pace. A large number of nurses, midwives and health assistants have been trained and upgraded.

2.2.4 Women in Development

(1) The status of women in Eritrea

The Constitution of Eritrea accords equal treatment for women for the acquisition of property especially land as that of men. In order to ensure the sustained political participation of women, it is provided that women members must occupy 20 percent of the seats in the national assembly, 17 percent in the region and 10 percent in the village.

(2) Women's legal and economic status

a) Concerning marriage and family: such as, women can enter marriage freely and are accorded equal rights as men; marriage is based on the free consent of both partners; prohibition of bride price and dowry; kidnapping for marriage is illegal; legal age for marriage is 18; followers of Islam have, however, the choice to adhere to the Sharia Law.

b) Revision of the penal code: death penalty commuted to life imprisonment for pregnant convicted women, or those having children under the age of three; abortion if permitted on specific cases; rape is a criminal offence with a maximum sentence of 15 years; and slavery and pornography are punishable offences.

c) Economic policy concerning women

The Macro-Policy Document of the Government reiterates that in order to enhance the decisive role of women in the socioeconomic, political, and cultural transformation of the country, the following measures will be taken:

- implementation of awareness and sensitization programs;
- enhance the awareness of society to upheld equal rights of women and change all laws that are detrimental to women's status;
- expand participation of women in education and economic activities and employment;
- introduce appropriate labor savings technologies to reduce the drudgery of women in the household and other activities (water, fuel,, wood, child centers, etc.); and

- improve and expand child care services.

d) The National Union of Eritrean Women

The National Union of Eritrean Women (NUEW) was formed in 1979 in the liberated areas of the country. Not only has it greatly contributed to the armed liberation of the country (for women used to comprise about 30 percent of the fighting force); it has also greatly contributed to the political emancipation and social development of women from its the inception to the present time. For example, women currently occupy 45 percent of the seats in the village assembly. In brief, it is the considered opinion of many writers on women in Eritrea, that the sustenance of the active and detrimental role that Eritrean women played in the armed struggle and their present active participation in the political and socioeconomic arena is attributed to the relentless effort of the Union.

2.3 Water and Sanitation Sector

2.3.1 Water Supply and Sanitary Conditions

Eritrea is located in an extension of the persistently dry region of the African Sahel belt. Thus water, even in normal years is mostly in short supply which forces most Eritreans to resort to ground water sources.

Sanitation is also a problem in that only a handful of the households have access to sanitary facilities. More specifically more than half of the urban households defecate in the open and virtually an insignificant number have sanitary facilities in the rural areas. The situation is exacerbated by the shortage of water in the country as whole.

Most of whatever water and sanitation facilities exist in the country date back to the Italian period. They were concentrated in urban areas and designed mainly to serve colonial administrations and export-oriented cash-crop production. Despite the growing population, very little improvements have been done to them during the British and Ethiopian occupations. The Ethiopian administration limited improvements to urban water and sanitation facilities which directly benefited colonial and military purposes.

During the three decades of armed struggle, the Eritrean People Liberation Front (EPLF) introduced water supply development programs in the liberated areas in the mid 1970's by digging bore holes and rehabilitating existing ones.

Access to safe drinking water is very low in Eritrea. UNICEF sources indicate that only 7 percent in rural areas and 44 percent in urban areas are estimated to have safe water supply. Access to safe water in urban areas may in fact be lower than indicated because deterioration in the existing old systems could exacerbate the situation. In addition, if access is considered as 'within 500 m of the household', access falls to about 15 percent among urban dwellers (UNICEF, 1994).

At the same time, existing water supply equipment is deteriorating very rapidly from age and over use. Pipelines are very old and require high level of maintenance, resulting in losses due to leakage and breakage reaching as high as 30 percent to 50 percent. Disrepair and malfunctioning continue to plague existing system for a variety of reasons most importantly due to the lack of material, financial and

manpower capacity in WRD. At both the urban and rural community level, there is absence of trained maintenance teams or token sense of ownership or responsibility. Women are underrepresented in water management committees, even though they are the major users and managers of water in the house and so have the greatest interest in how this precious resource is managed.

Household access to sanitation facilities is also inadequate in Eritrea. According to UNICEF sources, it is at less than 1 percent in rural areas and 48 percent in urban areas. In the absence of latrines, defecation in the open becomes the norm. However, existing facilities are reportedly clean, odorless and well-maintained.

Only Asmara and a small part of Massawa, Keren and Asseb have piped sewerage. About 40 percent of Asmara dwellers, for example, do not have excreta disposal system, according to a survey undertaken by Asmara Health Department in 1988 (quoted from UNICEF, 1994). Whatever initiatives that were taken, in the past, to ameliorate the situation, did not succeed largely due to the low income level of the residents. In other towns, the situation is considerably worse. Many open water wells in towns lack fixed water lifting devises, parapets, and drainage aprons, apparently due to shortage of finance and materials. Buckets, pots, jerrycans, etc. for carrying and storing water are usually source of contamination of water.

2.3.2 Water Laws, Policies and Regulations

This section will deal with existing water laws and regulation to be followed by a presentation of the comprehensive draft water law which is being revised and commented upon by concerned ministries and agencies within the Government, and which will replaced the existing one.

Regarding water quality, there are no statutory water or waste water standards operative in Eritrea. Water pollution levels are rising, especially in the urban areas, where sewerage is affecting groundwater quality. Some traditional practices such as animals drinking from the same source as people and bush toilets exacerbate the decline in the quality of water sources.

Some aspects of the Transitional Civil Law of Eritrea, and local tradition, customs and practices which pertain to water are highlighted below.

The Provisional Civil Code of the State of Eritrea, which is the also the Civil Code of Ethiopia, stipulates that waterways, lakes and canals and underground accumulations form part of the public domain. With regards to ownership and use, it empowers the community to have priority in the usage of all running and still water, but it gives the competent authority controlling and protection responsibilities. Even though it specifies that water collected in man-made reservoirs or basins to be private property, it does not preclude the powers of administrative authorities from making special laws and administrative regulations, whether of a general nature or local applications. With regards to prohibited works, it prescribes that whosoever is entitled to use a well, spring or other water, whether running or still, may object to the construction of any work such as a sewer or latrine, capable of polluting the water used by him. He may require any work done in disregard of his rights to be destroyed. The law gives priority for the domestic use of water at the expense of irrigation, for example, and allows private distribution of water if granted permission by the competent authorities. With regards to drainage, the owner of the land can construct such works with minimum damage to neighboring lands and properties. In like manner, due considerations and regards will be made when laying pipes. In laying pipes, land on which buildings are

erected or gardens or yards pertaining to such buildings should be avoided as far as possible. Concerning underground water, the law clearly spells out that all underground accumulations of water and rivers shall form part of the public domain. No person without permission is allowed to construct on his land a bore-hole exceeding one hundred meters in depth.

2.3.3 The Draft Water and Sanitation Law of Eritrea

The Water Resources Department, drafted the Eritrean Water Supply and Sanitation Law in June 1997. It is currently being reviewed by all government departments, and it is expected that the law will be proclaimed within a relatively short period of time, and be followed by the draft legislation covering water quality standards for drinking water, irrigation water and waste water effluents.

The objectives of this draft law are:

- to promote the provision of clean and sufficient water for domestic purposes to all persons;
- to allow for the orderly development and use of water for purposes other than domestic use, such as public, commercial and industrial use;
- to control pollution and promote safe storage, treatment, discharge and disposal of waste which may pollute water or otherwise harm the environment and human health.

The draft law envisages the establishment of Water and Sewerage Authorities (WSA) the functions of which, inter alia, include:

- the provision of water supply services for domestic, public commercial, industrial, recreation, environmental and other beneficial uses;
- to manage the water resources entrusted to it; and
- to provide and manage sewerage services;

In the exercise of its functions, a WSA is envisaged to dispense its services in the following manner:

- in the most viable and beneficial manner to the Eritrean people;
- efficiently and economically;
- in a socially and environmentally sound manner; and
- in consultation with appropriate public authorities and relevant community groups.

The draft law also enumerates the powers of the Minister including his power of delegation and also specifies the powers and prerogatives of the WSA as follows:

- no water works shall be started without its permit, but it can discontinue such works by giving prior notice;
- declare water related works completed;
- permit water connections from its works;
- supply water by measures subject to its terms and conditions, and test such measuring appliances, or restrict, prohibit and regulate the supply of water power to erect fire hydrants and standpipes;
- issue waste discharge permits; and operate, construct and regulate sewerage works;
- approve sewerage works for new buildings and declare sewerage works completed;
- issue permits for construction of private sewerage system and allocation and relocation of waste and

sewerage disposal sites, as well as enter into trade waste agreement with private persons;

- declare an area as prohibited for waste and sewerage disposal;
- enter private lands for the purpose of reading, removing or repairing of meters or other water works and repairs with minimum damage to property, and in the wake where damage occurs pay compensations;
- own land and works acquired or constructed on behalf of the Authority;
- protect and declare land adjacent to water works and water sources;
- determine water rates, charges and fees; and
- give due considerations to local laws and customs; water rights, water allocation policies, etc.

2.3.4 Water Sub-sector Policies and Strategies

In January 1997, the WRD brought out a draft National Water Policy that can "spearhead equitable, economically viable and environmentally sustainable development" for the country. Its prime objectives are to integrate the management of water resources across the various sectors in a holistic and sustainable manner and to develop capacity throughout the water sector among others.

- provision of safe, adequate and accessible water supply for all;
- improved coverage of appropriate sanitation in both urban and rural areas;
- integrated management and fair allocation of the available water resources to meet the needs of all sectors of the population;
- assessment, conservation, regulated utilization and quality protection (i.e., maintenance or enhancement) of all water resources, and also the mitigation of water-related hazards; and
- economically and environmentally sound and sustainable water development, according to a prioritized schedule.

In the implementation of these policies, the WRD or the Water Department (WD) of MoLWE, will adhere to the following strategies:

- planning and programming: coordination of all institutions that are involved in water and sanitation projects and activities by promoting bottom-up and top-down planning approaches;
- encourage private sector participation in the provision of water and sanitation services;
- develop the required institutional and human capacity for integrated management of water and sanitation systems by in-built training systems and promoting self-reliance;
- enhance community participation, empowerment and ownership;
- prepare a national water resources master plan including Management Information System (MIS);
- develop the water law, by-laws, regulation and administrative guidelines for water users; and
- enhance the operation and maintenance capabilities by employing new technologies and appropriate tariffs.

2.3.5 International Cooperation

There are 17 completed water-related projects funded by donors at the time of writing of this report (see Table 2.3.1). Seven of these are studies and surveys while the rest are construction programs. There is

one recently constructed dam in Adiquala, financed by a Swiss NGO at the cost of 5.2 million Nfa. The rest are studies related to water point inventory, rural water and sanitation studies and the water resource potential of the country. Donors include UNICEF, the German Government through its agencies - GTZ and KfW, the European Union, Italy, Belgium, IDRC Canada, IFAD, and NGOs (EIAC, ECS, SUKE and CAFOD). Some of these are part of the Eritrean Rehabilitation and Reconstruction Program like the EU's assistance for drilling 50 boreholes. Others are emergency measures like the KfW and Italian funded projects for Massawa and the rest are normal development programs.

Presently, water related projects and programs funded by donors are the following:

- GTZ: are involved in water and sanitation projects in the Western the Lowlands of Eritrea in the towns of Agordat, Barentu, Tessenei, Haykota, Omahajer and Tokombia.
- KFW: are active in digging 170 boreholes to supply community water supply and sanitation in Gash Barka Region. Additionally, they have funded the construction of the new Massawa water supply system which involves supplying water for the main port town of the country from some 40 km distance.
- SDR (Swiss Disaster Relief): are involved in water supply projects in Anseba Region.
- UNICEF: Through IFAD fund are involved in water and sanitation Projects in Ghinda and Shieb-Wadi-Labka in the North-Eastern Coastal Region.
- European Community (EU): involved in digging some 40 boreholes as part of the Eritrean Reconstruction and Rehabilitation Program and in the National Rural Water Irrigation and Sanitation study.
- World Bank: has availed credit fund for the Government, amounting to US$ 5.5 million to be implemented by the Eritrean Community Development Fund (ECDF). The project involves: the construction of drinking water points for 150 communities (representing about 3.6 percent of the population) of which hand dug wells comprise of 51 percent, bore-holes 25 percent, piped water supply 16 percent, roof catchment and ponds 8 percent and water and sanitation facilities for schools, communities, health facilities and market places.

Table 2.3.1 Related Water Project Funded By Donors

No	Puroject Name	Implementing Institution	Donor	Project Contents	Period	Progress	Funds	Funds (000' of Birr)	
							Local Curr. (000' NFA)	Forigen Curr. (US$)	Total(NFA)
1	National Water Point Inventory Study	WRD	UNICEF	Inventory of all water points in the country	1993/94	Completed	NA	NA	NA
2	Keren Water Supply	WRD	UNICEF	Water Supply project M/P and F/S for Keren	NA	Completed	NA	NA	NA
3	Massawa WSP Rehabilitation Phase 2	WRD	GSE/ Italy/ EIAC	Reparation of existing water network for Massawa	1995/96	Completed	1,919.10	8,640	10,559
4	Massawa WSP(immediate measures)	WRD	GSE/Italy	Chlorine disinfection, reparation of reservoir, delivery facility for Massawa	1995/96	Completed	1,627.00	10,908	12,535
5	Massawa WSP Feasibility study	WRD	KFW	Hydro-geological Survey for Massawa	1995/96	Completed	NA	2,743	2,743
6	Construction of 50 boreholes	WRD	GSE/EU	Driling 50 boreholes for 28,500 peaple, 30 village for Gash-Baraka area	1994/97	Under Implementation	179	11,730	11,909
7	ERIWESP	WRD	GSE/UNDP/ UNICEF	Development plan of water supply for rural area including O&M program	1995/96	Completed	1,220	377	1,597
8	Water Resources Potential Study	WRD	EU	Survey volume of water resource analysis & planning	1996/98	Under Implementation	NA	32,400	32,400
9	Zoba Gash-Barka WS Feasibility Study	WRD	GSE/KWF	Water supply project F/S for Zoba Gash Baraka	1996	Under Implementation	194	3,113	3,307
10	Sheib-Wadilabka WS Programme	WRD	GSE/IFAD/ UNICEF	Chlorine disinfection, construction of reservoir, delivery facility	1996/97	Under Implementation	794	81,866	82,660
11	Hagaz WS Project	WRD	GSE/COMMP ART	Water Supply Project for 19,000 families in Hagaz	1995/96	Under Implementation	471	3,429	3,900
12	Ginda Water Supply	WRD	GSE/Italy	Extention of water network for Ginda and sanitary education	1995/97	Plan Stage	950	5,256	6,206
13	Adiquala Water Supply Project	WRD	GSE/SUKE	EarthDam, Well Construction	1996/97	Implemented	608	6,954	7,562
14	Six towns WS & rehabilitation project (Agordat,Tesseney,Barentu,Omhager,Tokombia&Haikota)	WRD	GTZ	Water supply project for 75% the towns' residents	1994	Under Implementation	NA	44,949	44,949
15	Forto Mogorieb WS Project	WRD	GSE/CAFOD	Water supply project for returnee from Sudan	1996/97	Under Implementation	210	1,097	1,307
16	Mekerka & Dekishehay WS Project	WRD	GSE/Belgium Gov.	Water supply project for Mekerka and Dekishehay	1996/97	Plan Stage	416	2,330	2,746
17	Water Allocation and Princing Study	WRD	GSE/IDRC	Estimation of water demand, establishment of water fee, selection of water resources	1996/97	Implemented	25	536	561

CHAPTER 3 THE STUDY AREA: THE DEBUB REGION

3.1 Natural Conditions

3.1.1 Physical Setting

One of six regions, the Debub region is bounded on its northwest border by the Gash Barka region, northeast by the northeastern Red Sea region, north by Makelay and south by Ethiopia. The region is located in the central highland and has a total area of about 8,349km^2. The region is full of steep walled canyons, rolling hills and valleys. The topography becomes flatter with scattered hills and undulations as we move to the western part of the region. The elevation ranges between 1500m and 2400m asl. Except some parts in the eastern side, the seven target sub-regions (out of twelve) are bounded by two main roads from Asmara and situated mainly in the watershed of the Mereb river.

3.1.2 Hydrometeorology

The meteorological data are collected mainly by two organizations, namely, Water Resource Department (WRD) and Ministry of Agriculture (MOA). There are two first class meteorological stations in the region; one is in Tsorona, maintained by WRD and the other one is in Mendefera, maintained by MOA. Apart from the two, WRD has 15 stations at present and MOA has 17 stations. These stations are equipped with only rain gauges and/or maximum-minimum thermometers.

The topographical variations make the climatic pattern of the country very different according to the regions. The Debub region is a part of the highlands which has a warm to cool semi-arid climate. The mean annual maximum temperature is around 27°C in May and mean minimum temperature falls down to 3.5°C in December to January. The average monthly values of meteorological parameters collected in Mendefera station are presented in Table 3.1.1.

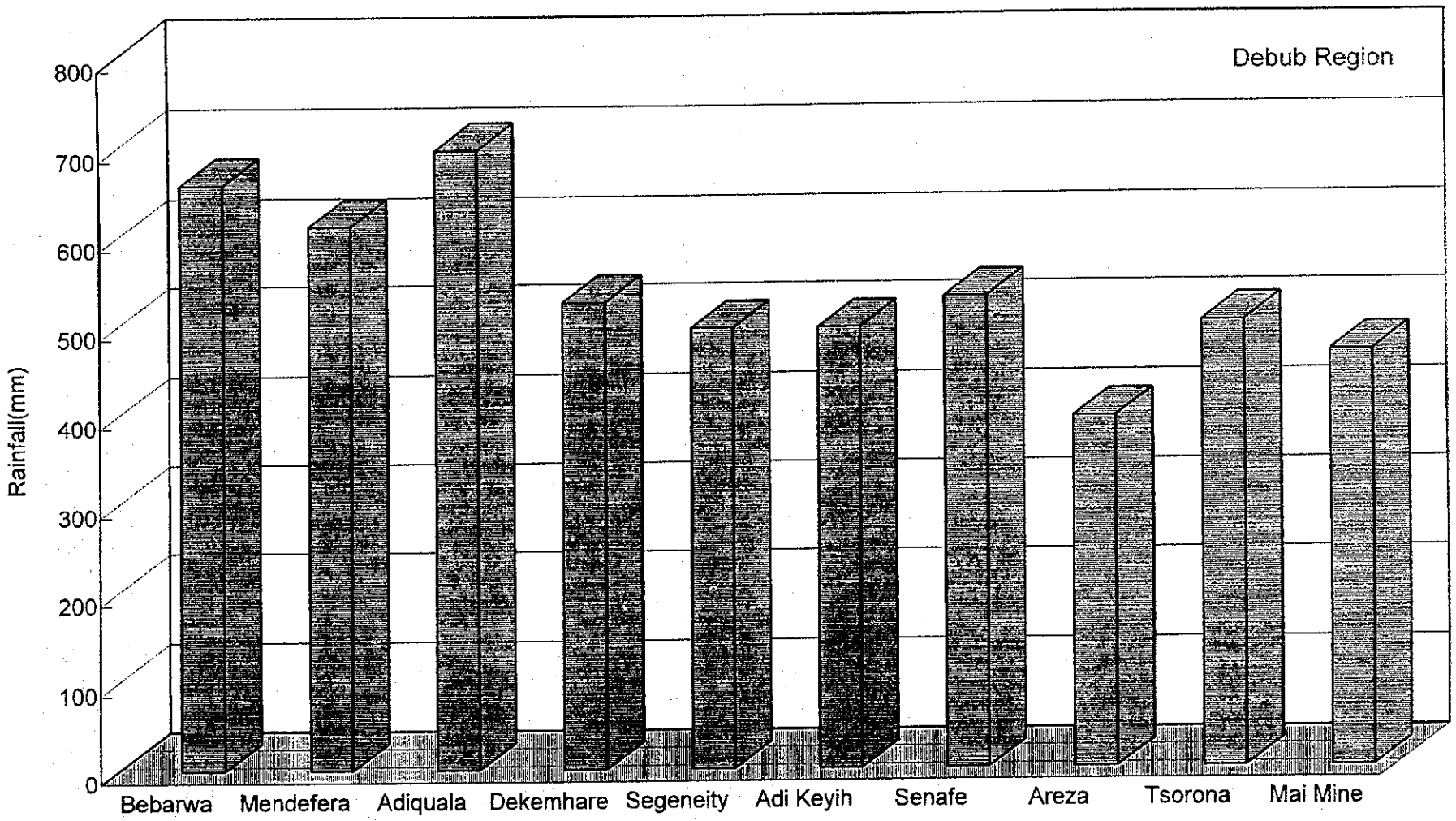
Table 3.1.1 Meteorological Data

Month	Temp (°C)	R.H. (%)	Windspeed (m/sec)	Pan Evapo. (mm/day)	Sunshine (hr/day)
Jan	16.3	75	1.5	5.4	10.8
Feb	17.3	68	1.6	6.7	10.4
Mar	20.7	59	1.7	7.0	10.7
Apr	19.2	70	1.8	7.5	11.1
May	19.3	65	2.0	6.0	12.3
Jun	19.1	64	1.9	5.4	11.2
Jul	15.5	98	1.8	5.6	8.8
Aug	15.4	95	1.8	4.6	7.2
Sep	17.1	78	1.7	5.1	9.7
Oct	16.9	86	2.1	6.3	11.4
Nov	16.3	89	1.4	5.5	10.6
Dec	15.6	83	1.3	5.5	10.7

Data source: Sector Study Report (ref. FAO), MOA and WRD

The average annual rainfall in the region varies from 393mm in Arcza to about 696mm in Adiquala. In general, the main rainy season extends from June to September with minor rains in April to May. Highest rainfall occurs during the months of July and August. Figure 3.1.1 shows the average annual rainfall pattern of the Debub Region.

Figure 3.1.1 Average Annual Rainfall of Debub Region



The hydrology of this region is governed by the Mereb River and its tributaries. All watercourses are ephemeral streams and flow only intermittently during defined periods of the year, in the form of flash floods of short duration. The upper middle part of the region (Debarwa) is drained by the Mereb itself and by two of its main tributaries named the Gual Mereb and the Gala. The lower eastern part i.e. the western parts of Segeneiti and Adi Keyih are drained by two main streams, namely the Ruba Mai Serao and the Ruba Heddemti. The western part of Senafe is drained by Mai Segla and Ruba Hadadum. The eastern part of the region is drained by the Ali Ghede, Hadas and Leghede Rivers to the Red Sea. The drainage of the western part, i.e. Areza, Kudo Bur and Mai Mine sub-regions, is facilitate by Ruba Mai Ambesa, Ruba Ubel and by Ruba Ketina rivers. A drainage network including the Study Area is presented in Figure 3.1.2.

There are many micro-dams in the region, which are constructed on small streams, mainly for agricultural and livestock and/or artificial recharge purposes. However, water scarcity always exists in the region. An effective surface water development plan has yet to be formulated. The main source of domestic water supply is groundwater. Therefore, there are bore-holes, dug-wells and hand pumps in each town or village to serve the purpose of providing water.

3.1.3 Hydrogeology

(1) Nation-wide geology

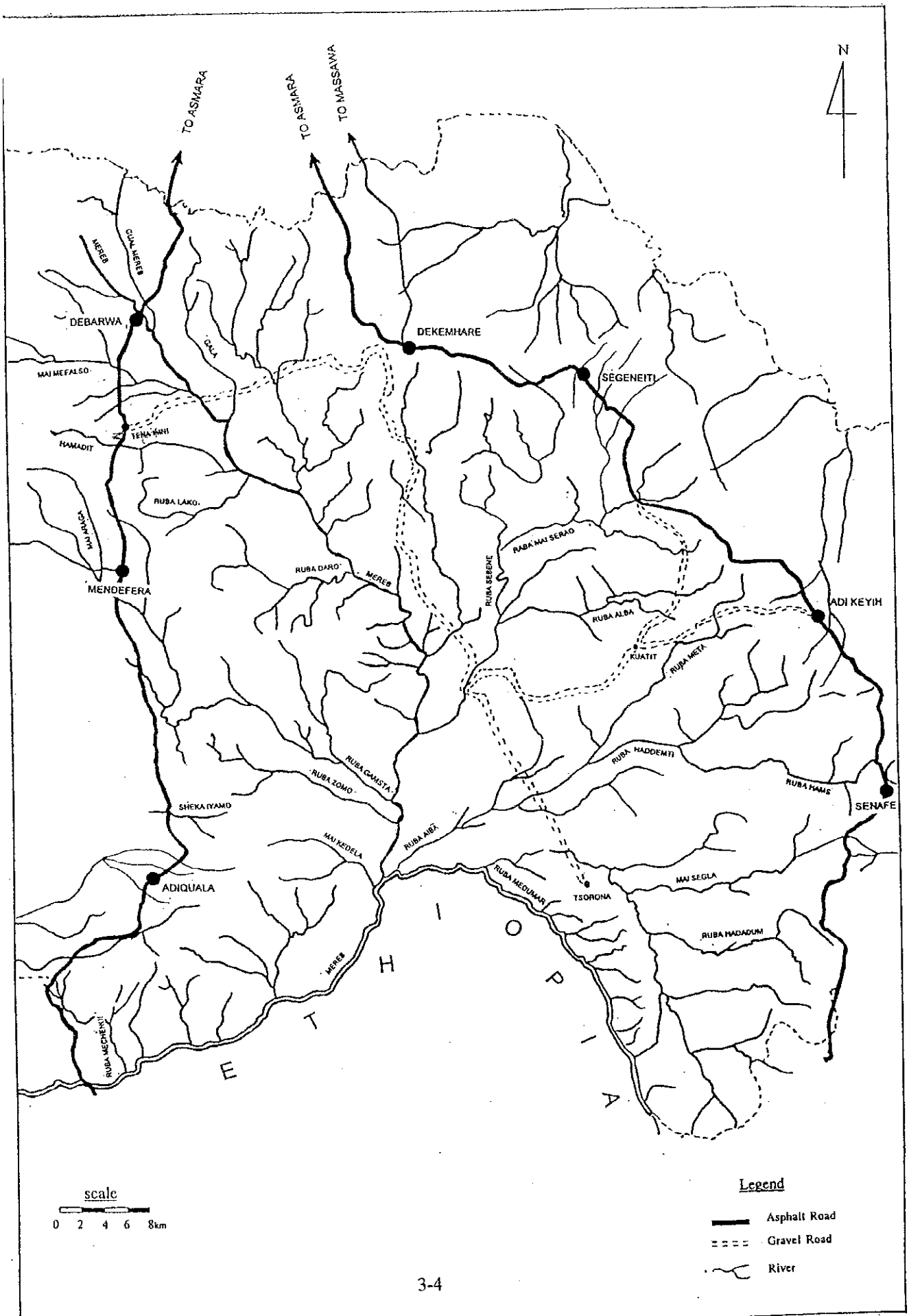
The knowledge of the geological events, of an area, is quite important in evaluating its groundwater resources. The geological events in the East Africa, inclusive of Eritrea, are summarized as follows:

1) Precambrian era: Formation of the crystalline basement complex and its associated intrusives,
2) Paleozoic era: Peneplanation of the surface of the basement complex and deposition of sedimentary rocks,
3) Jurassic era: Transgression regression of the Mesozoic sea, which formed lower sandstone, Adigrat sandstone and Antalo limestone due to subsidence towards the Indian Sea,
4) Upper Eocene-Miocene period: Great uplift forming domes, great cracks and overflows of lava (trap volcanics) and formation of East African rift system,
5) Miocene period: Formation of upper sandstone, and
6) Quaternary period: Formation of alluvials, eluvials and colluvials.

Generally, the geological environment of Eritrea is made up of Precambrian basement rocks, high to low grade metamorphic rocks and associated intrusives, which are overlain unconformably by predominantly Mesozoic sedimentary rocks and Tertiary to Quaternary volcanics and sedimentary rocks, as shown in Fig.3.1.3. The geology of the country consists of the following:

1) Various low-high grade basement rocks, metamorphic rocks and associated intrusives are exposed over more than 60 % of the surface of the country. The Precambrian basement rocks of Eritrea can be subdivided into four tectonic blocks or segments; the Barka Terrain in the north-western part of the country, the Hagar Terrain in the central part, the Nakfa Terrain in the central-eastern part and the Danakil Terrain in the southern part. The sequence is cut in places by late tectonic granites.

Figure 3.1.2 Drainage Network



Team original

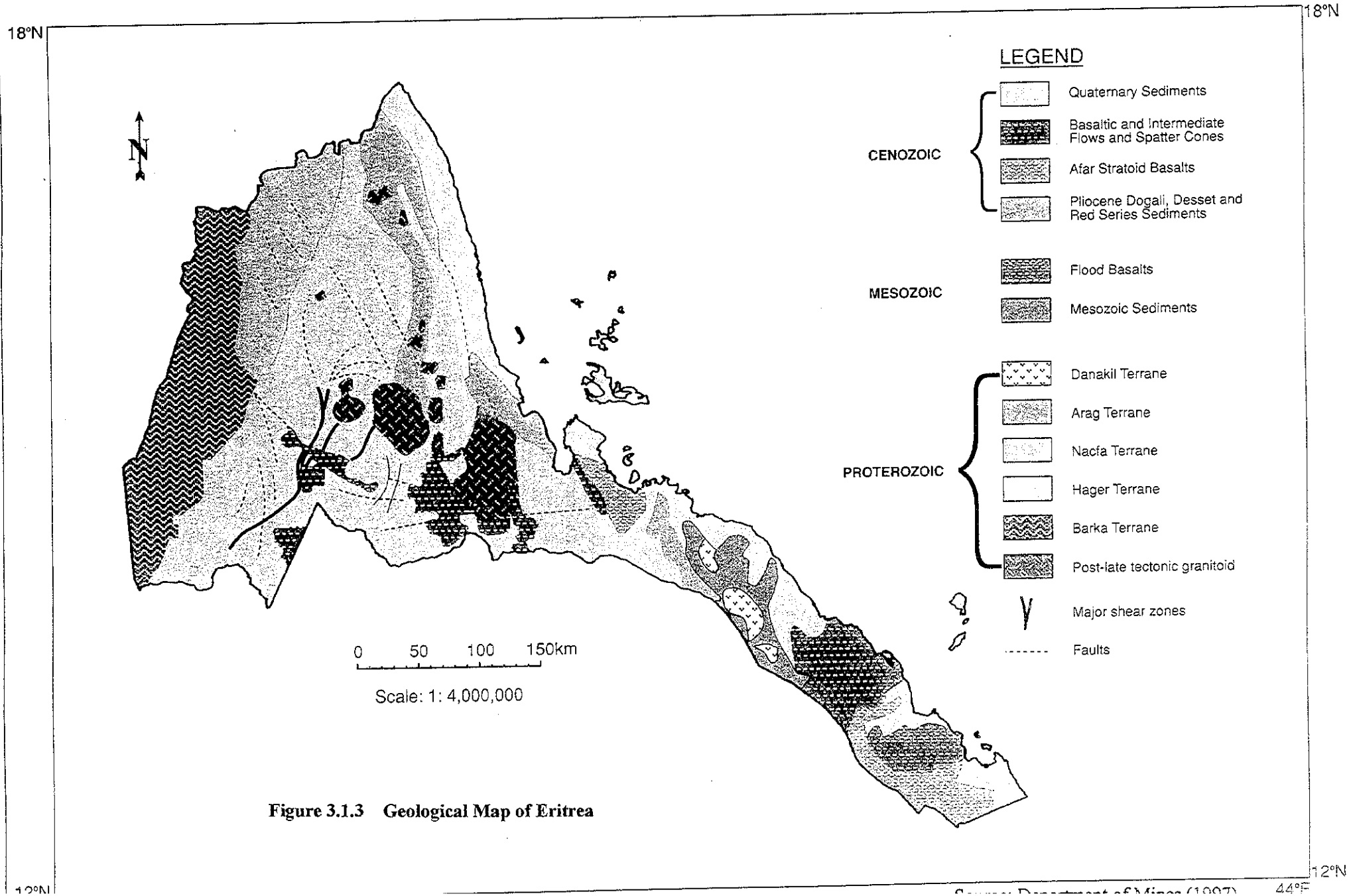


Figure 3.1.3 Geological Map of Eritrea

2) Tertiary and Quaternary volcanics occupies 15 % of the surface. The plateau-forming Tertiary basalts, also called trap volcanics, are exposed over a wide range in the highlands. The Tertiary basalts are predominantly olivine basalts with intercalation of intermediate lavas and tuffs. The trachytes occasionally form domes, which are specially widespread in the Senafe area. The trachytes rest on the Mesozoic Adigrat sandstone in most cases.
3) Consolidated to unconsolidated sediments occupy 25 % of the surface. The alluvial sediments cover plains and are found in river or stream channels. The fluvial sediments mainly occupy weathered lateritic crusts of the basements. The colluvial sediments are at the foot of fault scarps and mountains and consist of clays, fine-coarse sands, gravels and boulders.

(2) Geology in Debub Region

Debub Region is located in the central eastern segment, the Nakfa Terrain, which is bounded by the Adobha Abiy valley in the Northwest and by the Red Sea escarpment to the east. The Nakfa Terrain is made up of calc-alkaline volcanic and volcanoclastic rocks conformably overlain by a metasedimentary sequence of chlorite schists, grits and polemic conglomerates with occasional pelitic sericite schists and carbonates. The metavolcanic rocks are intruded by variably deformed plutonic to hypabyssal calc-alkaline bodies. The sequence is cut in places by late tectonic granites and is also transected by several narrow shear zones sub-parallel to the regional strike.

The late tectonic granites are distributed in the central part of the Region. The granites are exposed in Dekemhare and Segeneiti. The granites are originally massive porphyritic and have quartz veins, but the granites are intensively fractured, jointed and deeply weathered and hence have a very high secondary porosity and permeability.

The Adigrat sandstone is exposed in the surroundings of Adi Keyih, Senafe and the isolated scarps of Hazemo Plain as shown Figure 3.1.4. The thickness of the sandstone distributes towards the south from Dekemhare and Segeneiti and ranges from several 10s to several 100s of meters in Ethiopia. The thickness increases from the eastern and western mountains in the Study Area towards the central part of the lowlands. The sandstone is white-brown colored and very hard. The sandstone is well jointed with minor shale intercalations and is usually cliff forming due to intensive erosion.

The plateau-forming Tertiary basalts, also called trap volcanics, are exposed over a wide range in the western part of the Region. The Tertiary basalts are predominantly olivine basalts with intercalation of intermediate lavas and tuffs. Their thickness ranges from 70m to 300m and the maximum thickness is about 600m between Asmara and Mendefera. The Tertiary basalts rest directly on the Precambrian metamorphic rocks or the Adigrat Sandstone. The basalts are dominated by flood flows and the thickness of the individual flow ranges from less than 10 to 30m.

The Tertiary trachytes are usually stratified and are less common than the Tertiary basalts. The trachytes occasionally form domes, which are especially widespread in the Senafe area. The trachytes rest or protrude the Mesozoic Adigrat sandstone in most cases. The trachytes in the Senafe area are fine grained, compact and serve as aquicludes and barriers to groundwater flow.

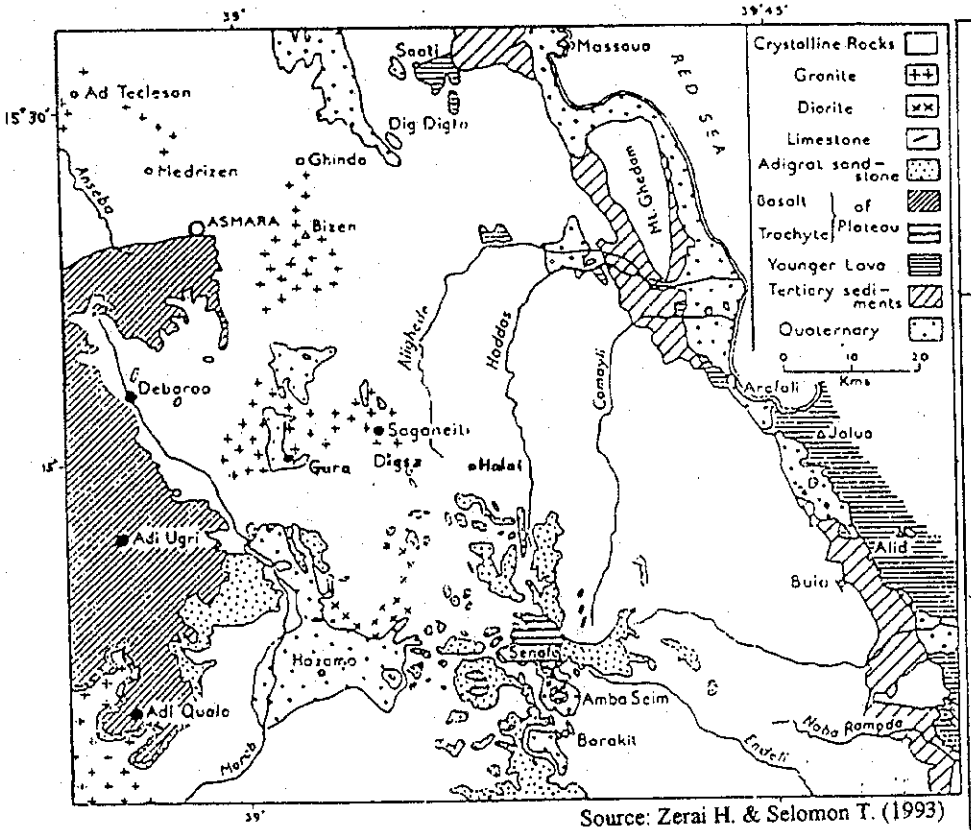


Figure 3.1.4 (a) Geological Map of Central Eritrea

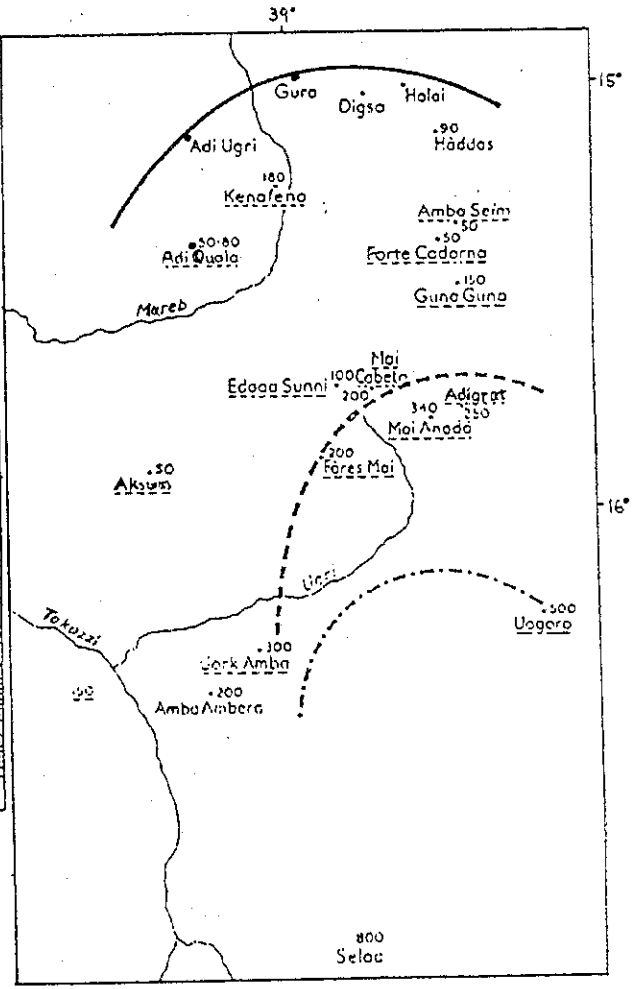


Figure 3.1.4 (b) Thickness of Adigrat Sandstone

Source: Zerai H. & Selomon T. (1993)

The alluvial sediments cover flood plains, and are found in river or stream channels in this Region. The alluvials sediments are distributed in the Hazemo Plain in the central part of the Region. The alluvial sediments in the plains are made of alternating layers of fine-coarse sediments. The alluvials in the plains which derived from mainly granites and coarse-grained metamorphic rocks are composed of coarse materials. The alluvial sediments along the river or stream channels are shallow and vary from place to place depending on the grain sizes, sorting and thickness, pertaining to the river course stages.

The fluvial sediments mainly occupy weathered lateritic crusts of the basements. The colluvial sediments are at the foot of fault scarps and mountains and consist of clays, fine-coarse sands, gravels and boulders.

(3) Aquifer systems

In contrast to surface water, the groundwater of the Region is more abundant. Although it occurs in all geological formations, useful quantities and qualities may not be everywhere. The main hydrogeologic units are the following:

1) Basement rocks, metamorphic and intrusive rocks with localized low-moderate permeability along fractured and weathered zones,
2) Volcanic rocks (mainly basalts) with fracture and fissure permeability, and
3) Unconsolidated sediments with various inter-granular permeability.

The characteristics of groundwater resources in the Study Area are summarized as follows:

a) Fissured aquifers of basements

i) Granites: (a-i as a symbol in Hydrogeological Map)

The yield of the granites varies from place to place depending on the density and spacing of the fractures and the amount of recharge. The yield is usually 1 – 3 *l /sec* and rarely approaches 7 lit/*sec*. The depth of groundwater ranges from 10 to 50 m.

ii) Metamorphic rocks (slates, phyllites, schists, meta-volcanics): a-ii a-iii

Although the rocks have generally small permeability, localized groundwater occurs in the weathered part, which is 10 to 50 m in thickness. The yield is generally of fair productivity ranging 1.0 to 2.0 lit/sec but sometimes shows quite high productivity beyond 10 lit/sec. The meta-volcanics can have better yields than the meta-sediments generally, but the highest yield was recorded in weathered schist.

b) Fissured aquifers of the sedimentary rocks

i) Adigrat sandstone: b-i

There is little hydrogeological information of the sandstone in Eritrea, few boreholes indicate shallow groundwater up to 40m with approx. 2-3 lit/sec of yield. Max. yield shall be around 5.0 lit/sec.

ii) Paleozoic sedimentary rocks: b-ii

There also be little hydrogeological information on this aquifer. Because of their hard rock qualities,

fissures in them are mostly small and discontinuous. The yield is generally less than 1.0 lit/sec.

c) Fissured and jointed aquifers of volcanics (basalts and trachytes)

i) Basalts: c-i

The basalts have moderate permeability and also moderate productivity. The compact scoriaceous and clay layers serve as aquitards and aquicludes, and hence the groundwater may be confined and semi-confined and occurs at a depth of 7 to 100m. Usually the yield is less than 2.0 lit/sec and rarely approaches 5.0 lit/sec.

ii) Trachytes: c-ii

The trachytes are specially widespread in the Senafe area where they intrude the Adigrat sandstone and form isolated mountains like Amba Seim. The trachytes usually serve as aquicludes and barriers to groundwater flow.

d) Intergranular aquifers of sediments

i) Alluvial sediments: d-i

The alluvial sediments which derived from porphyritic metamorphic and intrusive rocks have high porosity and permeability. The alluvial sediments along river or stream channels form shallow aquifers. Generally the aquifer has high water productivity but the ones distributing in the Study are fair to low productivity because of their small development scale.

ii) Colluvial sediments: d-ii

The colluvial sediments are highly recharged by flood runoff and rainfall. They are wide spread in the western low lands and along the coastal low land, but nothing in the Region. These sediments have little influence as direct rainfall recharge to be regarded as potential aquifers. But are of important ground water reservoir units when related to such big river flood plains as Barlsa Gosh and wadis from the escarpments.

e) Aquitard and aquiclude AqC

As mentioned above, most of the geological units distributing in the area are classified into any aquifer systems, some are good and some are fair though. However, as noted already, the trachytic volcanics are used to be classified into an aquitard or an aquiclude because of their quite low permeability, as well as the fresh and massive portions of basalt lava. Then, some special geological units are usually divided into aquitard/aquiclude group: those are Charts (Paleozoic), alkaline intrusives (Tertiary), and Hornfels of Precambrian metamorphics.

Thus, hydrogeological condition of every target tows was rearranged and summarized into a hydrogeological map of 1:50,000 scale. The scale is approximately because the base-map was drawn from the aerial-photo interpretation. Hydrogeological map of each town is attached in Appendix-C of each volume.

3.2 Socio-economic Conditions

3.2.1 Area and Population

Debub Region is one of the six regions of Eritrea and has a total area of about 8,349 km^2. Most of the region is in the highlands with a temperate climate. There are 11 sub regions called Neus Zobas with 212 village administrations called Kebabis (the lowest administrative units) which in turn have 884 villages (Adi) under them (Appendix A, Table 3.1). In this section, the word **Zoba** will be used alternatively with "Region" or "Regional"; the term **Ne'us Zoba** will be used alternatively with "Sub-Region" or "Sub-Regional" and the word **Adi** or **Kebabi** will be used to refer to a village or group of villages which form the lowest administrative unit. The word **Megabya** will be used instead of "village assembly" and **Baito** will be used to refer to an elected democratic legislative body at Zoba or national level.

Basic data and information on population for the region as well as for the seven towns are derived from the Ministry of Local Government (MoLG), which is the best source for planning figures for the purpose of the present study. Accordingly, the total population of the region is 702,500 and comprises about one fourth of the entire population of the country, with a population density of about 84 persons per km^2. The urban population including that of the seven towns is roughly 17% that of the region and consists of 193,022 households with an average household size of 3.6 (Appendix A, Table 3.2).

The majority of the inhabitants of this Zoba are from the Christian Tigrigna ethnic group who comprise more than 63% of the total population. The Saho and Tigre ethnic groups who profess Islam roughly constitute 6% and 1% respectively (Appendix A, Table 3.3 & 3.4). It is estimated that the population of Debub Zoba is comprised of 53% females and 47% males (DHS, 1995). A larger number of the population of both sexes is in the younger age group.

Overall, due to the three decades of war and recurrent drought, people from the surrounding rural areas have been flocking to these towns to seek shelter and employment. Additionally, Debub Zoba is attracting quite a large number of returnees from Ethiopia, the Sudan, Saudi Arabia and other countries in Europe and America.

One piece of evidence for this phenomenon is the reported unfulfilled demand for urban land in all the towns of Debub Zoba. The favorable climate also contributes to the desire of many people to settle in the Zoba. As a consequence, the population is growing at a rapid rate that could contribute to urban unemployment and poverty.

3.2.2 Organizational Structures of Debub Region Administration

(1) Debub Zoba

Proclamation no. 86/96 which allows for decentralized regional administration also sets out the structures of the sub-national levels or units. The three bodies of the regional administration, viz., the Zoba Administration (Executive), the "Baito"(Legislative) and the Courts (Judiciary) are represented at the region level. Under Administration, there is the Executive Office and under him the three main sectoral branches, viz., Economic Development, Social Services and Infrastructure Development. Under the Economic Division there are branches responsible for industry and trade, mines and energy, tourism,

finance, investment and license, agriculture, marine resources, land and environment. Under the Social Division are branches responsible for education, health, labor and social welfare and refugee/returnee affairs. The branches under the Infrastructure Department: are engineering or technical and project administration and management, transport, communications and water resources. Supporting units, such as, internal administration, police and public relations, statistics, etc. are under the Head of the Executive Office (Appendix A, Chart 3.1).

(2) Nues-Zobas

Towns like Mendefera and Adi Keyih have the status of Neus-Zoba as indicated in Chart 3.2 Appendix A. Here, we find Head of the Executive Office, who runs the day-to-day affairs of the Neus Zoba including that of administration and police and Kebabi affairs. Of the three main development branches that are provided at the region level, only economic development and social services exist. Infrastructure development including project administration and follow-up is under the head of the executive officer, where water and sanitation units are found. The staff composition in the water and sanitation offices comprise of one head of the unit who coordinates all the other staff, viz., plumbers, pump attendants, and sales staff. Their number varies with the size of the towns.

(3) Town administrations

With regards to town administration, the towns of Mendefera and Adi Keyih have sub-zone status while the rest have town administration status (Appendix A, Table 3.6 and Chart 3.3). The former are also the main towns of the sub-zone in which they are located. In the structure of towns like Debarwa, Adiquala, Segeneiti and Senafe, there is the town administrator who is assisted by the Head of the Executive Office. There are two main departments: that of infrastructure development and administration. Water supply and sanitation is under the former with personnel responsible for motor pumps, sales and plumbers. Their number varies with the size of the town.

(4) Human resources of Debub Region and town administrations

As described above, Zoba Administrations have been vested with the responsibilities of implementing development programs, projects and activities in their respective Zobas. However, this would require to allocate skilled and experienced manpower which could take a long time to fulfil (Appendix A, Table 3.5).

Overall, at the time of writing, all the planned manpower and staffing as indicated in the organizational framework have not been placed. The shortage is more serious for towns that have Neus-Zoba status like Mendefera and Adi Keyih. This is partly due to the fact that placement of personnel has not been completed yet and, in fact, the status of some towns is being revised by the national committee responsible for restructuring.

3.2.3 Economic and Social Development

(1) Economic condition and infrastructure development

Most of the inhabitants of this region live in the rural area and derive their livelihood from agriculture: cultivating cereals, pulses and vegetables as well as cattle rearing and dairy farms. Aside from the civil servants in government institutions, urban people are mostly petty-traders, daily workers and small shop

owners. Some towns like Dekemhare and Debarwa are rapidly growing into important industrial zones, attracting investors in the manufacturing and service sectors. The area is also reputed to be rich in minerals and substantial mining exploration activity is taking place.

All Ne'us Zobas in the region are connected with all weather roads almost all villages could be reached by feeder roads. As such, the inter-urban transport system is quite good and many villages are accessible by land transport, even though there is no regular transport leading to them.

According to the Zoba Administrator and the Head of the Executive Office, final preparations have been completed to build the following all weather roads in Debub Zoba:

- Maereba – Tekelebi - Mai Aini (already under construction)
- Dekemhare – Mai Aini – Tsorena
- Nefasit – Dekemhare – Tera Emni – Mendefera – Barentu
- Mendefera – Mai Aini – Adi Keyih
- Mendefera – Mai Mine

Additionally, the Government intends to implement the following agricultural development projects in 1998 with the active collaboration of the community.

- Tselema plains (about 8-10 km. from Debarwa on the Mendefera road)
- Hazemo plains (south of Dekemhare and west of Adi Keyih and Senafe)
- Semegaina plains (South east of Senafe)
- Major agricultural development programs in the vicinity of 73 micro dams in the region
- Establishment of a dairy and poultry complex at Tera Imni some 12 km on the Debarwa
- Mendefera road which will provide extension assistance and distribute selected breeds to the farmers of the Debub Region.

These and a host of other related activities in the region will, among other things, lead to more access to markets and schooling with clear implications for increased demand for utilities like water. Almost all the towns in the Zoba have electricity and electrification has even begun in some rural villages. Towns like Dekemhare and Mendefera are linked with a digital telephone service, and it is expected that the other towns will have similar service in 1998 or by the end of 1999.

(2) Education and health infrastructures

a) Education

Sources from the Debub Zoba Social Department indicate that in the region as a whole, there are 200 schools (137 primary, 56 junior secondary and 7 senior secondary schools). Out of these, 73 of them (35%) are located in the seven towns under study. In each of these towns, there is only one senior secondary school that serves quite a large student population. The gross enrolment ratio for the 5-24 age group in the region is 38%, with male/female region ratio of 58:42 (Appendix A, Table 3.7). Debub region accounts for 34 percent of all primary school enrolment in the country and 25 percent and 20 percent of enrolment in the junior and senior levels respectively. The plan is to reach a sustainable enrollment ratio of 80% by the year 2015 for the primary level. One of the main obstacles in the expansion of education in the region is cited as finding a sufficient number of

teachers.

b) Health

With regards to health facilities in the region as a whole, there are 36 clinics, 9 health centers and 2 mini-hospitals with 60 beds, each type of facility serving 15,000; 53,000 and 106,000 people respectively. The number of health personnel and the people they serve is indicated in (Appendix A, Table 3.8).

In terms of other basic health indicators: the infant mortality rate is 135 per 1,000 live birth; under five mortality rate 170 per 1,000 live births; maternal mortality rate 590 per 100,000; fertility rate of 5 per child bearing woman; and 55% of children fully immunized. The causes of morbidity in the region are malaria, diarrhoea, ART, intestinal parasites and respiratory diseases, while the main causes of hospitalization are diarrhoea diseases, severe malaria, TB and malnutrition.

c) Water

Water supply schemes in the towns, not only in the Debub Region but throughout the whole country, were developed during the Italian regime. During the subsequent regimes, misrule and neglect caused irreparable damage to water and other infrastructure. This, coupled with recurrent drought and war, caused wells and other water sources to dry up resulting in inconvenience, ill-health and morbidity of the society, especially that of children and woman. Shortage of piped water forces people to use water directly taken from the rivers, ponds, pools and open dug-wells. This state of affairs give rise to a high incidence of water-borne and related diseases.

d) Social affairs

In the Zoba, there are 28,000 children who are orphans (whose fathers or mothers are dead or both parents are dead) living with close relatives and/or guardians who are given some money for their maintenance by the Government. There are some 17,000 demobilized fighters, mostly working in farms and as traders. Quite a number of these are unemployed. To the extent that these towns were military garrisons during the era of the war of liberation, invariably the female population is much greater than males and consequently about 41% of households are headed by women. In all towns, there are a number of community associations related to religious holidays in which individual members take turns to provide food and drinks for their association members. These associations are community self-help groups with the aim of assisting members during marriage, burial and other social events.

3.2.4 Current Situation of Seven Towns: Survey Result and Analysis

In the seven towns as a whole, there are substantial number of women headed households ranging from 39% in Debarwa, Mendefera and Dekemhare to a high of 48% in Adi Keyih. Several factors could explain this phenomenon, mainly the fact that many males participated in the war for liberation, some left the country in search of security and gainful employment and still others are migrant workers in other parts of the country.

The sample frame for establishments for all towns was a total of 59 out of which hotels, restaurants, institutions and shops account for 12 each and for that of factories 11.

The average situation of hotels and restaurants with regards to number of rooms and seats, and occupancy rates and turnover (Appendix A, Table 3.9). To the extent that the since the survey result indicates that hotels, shops and restaurants each have an average of not more than three workers, it can be concluded that they are one man owned and family operated small business enterprises.

In as far as shops and restaurants each have an average of not more than three workers, it can be concluded that they are one man owned and family operated small business establishments. In terms of employment therefore, there are far more workers in Government offices, followed by health and education. When employment is dis-aggregated by gender, there are more female workers in non-household institutions than males (Appendix A, Table 3.10).

The survey tried to find out the condition of energy/electricity service in the towns. Table 3.11 in Appendix A, shows that almost all establishments/institutions have their own generators with capacities ranging from 6 to 29 kw. Except shops and hotels, all of them experience power failure. Institutions reportedly face power failure up to 27% of the time.

There are women's organizations in all the sampled non-household establishments: 50% of interviewed hotels, 67% of restaurants, 75% of institutions, etc reported that there are women's organizations (Appendix A, Table 3.12). In terms of the existence of specific organizations, however, the response shows that very few of the traditional organizations exist, while the more formal and national ones exist in almost all establishments (more so in institutions and factories and less in shops). On the average, the number of members in these organizations is reported to be as high as 25 in factories and only 1 and 2 in shops, hotels and restaurants.

From all sources, the average daily consumption ranges from as low as 2.53 M^3 for restaurants to 21.95 M^3 for factories. The fact that the consumption for hotels and restaurants is lower than for that of shops could entail not only the apparent shortage of water but also the implications on sanitary condition of these establishments as a whole. On the average, 46 percent of water source for all the establishments in all the seven towns is from piped water source of the town administrations. Water from river contributes 30 percent followed by water tanker 18 percent (Appendix A, Table 3.13).

Taking water consumption as proxy indicator of income level, on the whole, the lower income group of households' average daily consumption from piped water system greater during the dry season than during the rainy season, and vise versa. The opposite is also true in that the higher income group's consumption during the dry season is less than their consumption during the rainy season (Appendix A, Table 3.14). This could be explained by the fact that lower income households compliment their water consumption from rain water during the rainy seasons, while the higher income group may not bother to do so. Moreover, comparing the daily average water consumption of households shows the relative availability of water in the seven towns. Thus, Adiquala, Debarwa and Mendefera consumption stands at 37.8, 34.5 and 31.6 respectively. Despite the apparent availability of water in Senafe, it has the lowest per capita consumption of 12.9. This could be due to the old age and high leakage of the pipe system.

3.3 Water Supply and Sanitation

3.3.1 Water Supply

There are many water supply modes in the Debub region. Main modes are individual connection like house connection and yard connection, communal water point, water wagon and water vender by donkey.

Main water supply facilities were constructed during the Italian regime. It seems that there was no major maintenance of the water supply system during the last six decades including the civil war time of nearly 30 years. Therefore these facilities were obsolete and damaged at present.

People living outside town seek for drinking water in streams and puddles and fetch water usually with 20-litter plastic container. However these streams and puddles were usually dried up in the dry season. On the other hand, people living in the town make use of wells. Main water sources for drinking in the towns are groundwater of the tube wells or dug wells and recharged water of dug wells at the down stream of the dam. Although many wells were dug in and around the town, all of them were not used effectively. Some wells were constructed and capped soon because some had no pumps or others stopped operation because of luck of spare parts.

Water is transmitted from wells to the reservoir by pumps or to customers directly by water wagons or donkeys. It is common water is sold by venders in and outside towns.

Reservoirs are installed at the higher location and potable water is distributed to customers by pipeline without disinfection. Most of the reservoirs are ground type made of concrete or masonry and there are few elevated reservoirs made of steel.

The main modes of water supply services in the towns are piped supply to individual connections and public connections (communal water point), and water wagon supplies. The residents of the towns, due to scarce water supply, are forced to fetch water from unprotected traditional sources which inevitably have implications for their health. In the dry season, even the near-by traditional sources dry up and water is fetched from distant sources. Mothers are obligated to leave their children unattended and school children are forced to miss classes. Moreover, the inadequacy of water supply restricts domestic and personal hygiene habits of the society.

As mentioned above, water supply schemes were developed about 60 years ago. During the subsequent regimes, misrule and neglect caused irreparable damage to water supply and other infrastructure. No major maintenance activities and the 30-year civil war also damaged water supply facilities. This, coupled with recurrent drought and war, caused wells and other water sources to dry up, resulted inconvenience, ill health and morbidity of the society especially that of the children and women. The major factors contributing to the critical problems of the water supply are as follows:

- inadequate sources of water supply from wells,
- unsafe water quality of the impoundment,
- limited and dilapidated piped distribution systems,
- unacceptable high leakage rate,
- inadequate capacity of balancing reservoirs, and

- inadequate number of public communal water points.

To alleviate the present critical water shortage problem in the towns, efforts have been made for the last four to five years by WRD and the town administrations. By them, wells have been drilled, water meters changed, house connections increased, communal water points constructed, water tankers provided, pumps and generators changed, etc. On the other hand, in spite of all the efforts undertaken, the water shortage problem has been exacerbated by the following reasons:

- influx of people from the surrounding villages,
- influx of non-Eritreans who come to seek jobs,
- returnees settling in the towns,
- the fact that all these towns are market centers which are expanding year by year,
- domestic water being shared for many house connection,
- domestic water being shared for small to big scale industries,
- water being shared for watering animals and trees (which is encouraged by the government),
- operation and maintenance problems, such as lack of spare parts, skilled technicians, etc., and
- small and large investments that are being attracted to these towns.

3.3.2 Sanitation

The Debub region was area of focus for infrastructure development fifty years back during Italian Colony. During this period sanitation facilities and well organized sanitation management systems were set up under the Municipalities. After the Italians specially during 30 years of Ethiopian colony Eritrea in general being turned to war zone neither development work was undertaken nor the existing infrastructures were maintained. As a result during independence Eritrea was left with infrastructures which are deteriorated beyond repair and the Municipalities without qualified personnel. The sewerage system lacking enough wastewater for self cleansing was blocked and in some cases the sewer pipes were removed. Public places were either without public latrines nor with unhygienic latrines. Schools specially government schools were either without water points and latrines or with broken water points and out of function latrine. Hospitals and clinics did not have hygienic sanitation facilities. Private sanitation facilities particularly household latrine coverage in this region is very low for a town.

After independence all the Town administrations in the Debub region being set up in a new form have to deal in all aspect of development programs from scratch. With regard to sanitation The town administrations are putting some effort to improve the sanitation facilities. Some of the towns are trying to rehabilitate the existing sewerage systems, though not appropriate provided simple dump trucks for refuse collection and disposal, and also constructed public latrines. New regulations with regard to sanitation improvement are also set-up. The Town administrations however have a lot of constraints in carrying out the development programs. The main constraints of the Town administrations though are:

- Lack of experienced personnel who could make development and budget program on priority basis, implement programs etc.
- Lack of skilled personnel for operation and maintenance
- Lack of budget

The present sanitation condition of the region in general is in poor level hence, it requires quite a lot of

improvement with regard to public and private sanitation facilities, operation and maintenance and capacity building. To improve the hygiene and health condition of the inhabitants however, the development program should also embraces the society awareness to sanitation and hygiene which is achieved by hygiene education programs.

3.4 Environmental Conditions

Eritrea has inherited a degraded natural environment due to colonization and 30 years of war. During this time, the natural forests have been reduced from an estimated 30% of the total land area to a little more than 2%. This was mainly due to logging for timber, firewood, charcoal and poles, and clearing for agricultural land, uncontrolled grazing, worsening climate and extensive soil erosion.

The vegetation includes *Acacia tortilis, Acacia seyal and Acacia abyssinica on rocky and steep sites.* Along the rivers, *Faidherbia albida, Balanites aegyptiaca* and *Ziziphusphus spina-christi* forms the limited wood land forest. Apart from these, some man-made plantations have been established in the highlands, dominated by *Eucalyptus cladocalyx.* On the other hand, a long history of cultivation, grazing and fuel-wood/timber harvesting has caused land degradation, erosion and depleted vegetation. However, government has designated some areas as Permanent closures and Temporary closures in order to save the forest wealth from the human intervention all over the country. In Debub region there are two Patmanent closures consisting of 6,300ha. Both of them are in Adiquala sub-region. There are also seven Temporary closures covering 435ha in the region.

Historical records indicate that Eritrea was rich in wildlife. Varied wildlife species were widespread over the country. However, the present wildlife condition is not very much known, because a wildlife survey has yet to be done. But it is clear that their number has drastically decreased because of wars, successive droughts and forest destruction. These forced wild animals to die or to migrate to neighboring countries. According to the officials of Ministry of Agriculture (MOA), the main species of wildlife in the region that may be present are Leopard, Baboon, Fox, Jackle, Squirrel and Monkey. It was also reported the numbers of variety of birds are increasing year by year.

The chemical quality of existing surface water sources is generally good but physical quality is very poor, mostly due to high levels of turbidity. In case of groundwater, some towns have problems of hardness, otherwise, it is reported as good. However, during the rainy season, presence of bacteria is a common phenomena and this causes water borne diseases. It should be noted that as a part of the study, 70 samples from the seven target towns were collected and analyzed. According to the results, 29 samples were found contaminated which is not usual and believed to be due to the rainfall which caused inflow of runoff from various unclean areas into the sample source.

Household solid waste management is very poor in the region. Most of the towns lack transportation facilities and designated dumping sites. Sewage system is a big problem in all of the towns (except Mendefera). There are houses which even do not have any septic tank. Improper sanitation system is the main cause for the water contamination.

Although at present factory waste is not creating a problem due to its small volume, it might be a problem if the increasing trend of factory establishment continues in the future.

There are three historically importance places in the Study area. Two (Gobo Methara and Belau Kelao)

of them are located in Senafe and another one (Hish-Male) is in Adi Keyih.

CHAPTER 4 CURRENT SITUATION

4.1 Natural Condition

4.1.1 Topography, Geology and Hydrogeology

(1) Topography

Topo-map of 1:100,000 scale made by USSR, near around Dekemhare, is shown as Figure 4.1.1. It is a little difficult to understand the situation from the map but the town is located on the saddle which forms the northern edge of fairly wide and quite flat alluvial basin opening toward south. And further north of the town is surrounded by cliffs with steep slopes opening toward north, dissected by drainages to the Red Sea.

The alluvial basin prolongs almost N-S direction, and an abandoned airstrip exists at central-western part of the plain. The north of the basin is limited by the saddle mentioned above, the west and the east of the basin are also bounded by low but rather steep small mountains. A drainage called Mai Edaga flows down to south, along the center of the valley. The stream is called as Ruba Adi Harm or Ruba Adi Golgol too, at its upper stream positions. The average elevation of the town is around 2,050m, and the elevation of basin bottom is ranging from 1,950 to 1,900m. In the flat plain, there is a remnant of army camp with a clogged borehole besides the abandoned airstrip.

(2) Geology

Basically, the area is underlain by Precambrian basement. The basement in this area is a granite phase but divided into two units: a normal granite group and a marginal phase granite. Geological map of the area is presented as Figure 4.1.2. Normal phase granites are exposed in the eastern and western parts of the area, which are weathered heavily in most of the case. Marginal phase granites are exposed in the northern and southern parts, having rather hard rock quality and toughness to weathering.

The southern part of the Dekemhare town is a fairly wide and flat plain, lying in between residual hill ranges consisted of granites. Alluvial sediments, with an average thickness of 10 – 20m, are observed along the Mai Edaga and neighboring Ruba Koraro basin. Reportedly, the alluvial sediments are lake deposits, derived mainly from the weathering of granites. Other alluvial deposits are developed on the bottom of deep valley, at fur north of the town as shown in the figure.

According to the lithology of the borehole BH-16 (in the Inventory, but BH NO.6 drilled under the Sector Study), located at almost center of the alluvial basin, these sediments are composed of fine to medium sand accumulated to the depth of 11m, overlying the weathered zone of gneissic granites up to 28m, and massive granite to the bottom of the hole (49m). This borehole did not produce water.

(3) Hydrogeology

Hydrogeological situation of Dekemhare site was arranged and presented as Hydrogeological Map, attached in the Report (Appendix-C).

Figure 4.1.1 Topographic Map -Dekemhare-

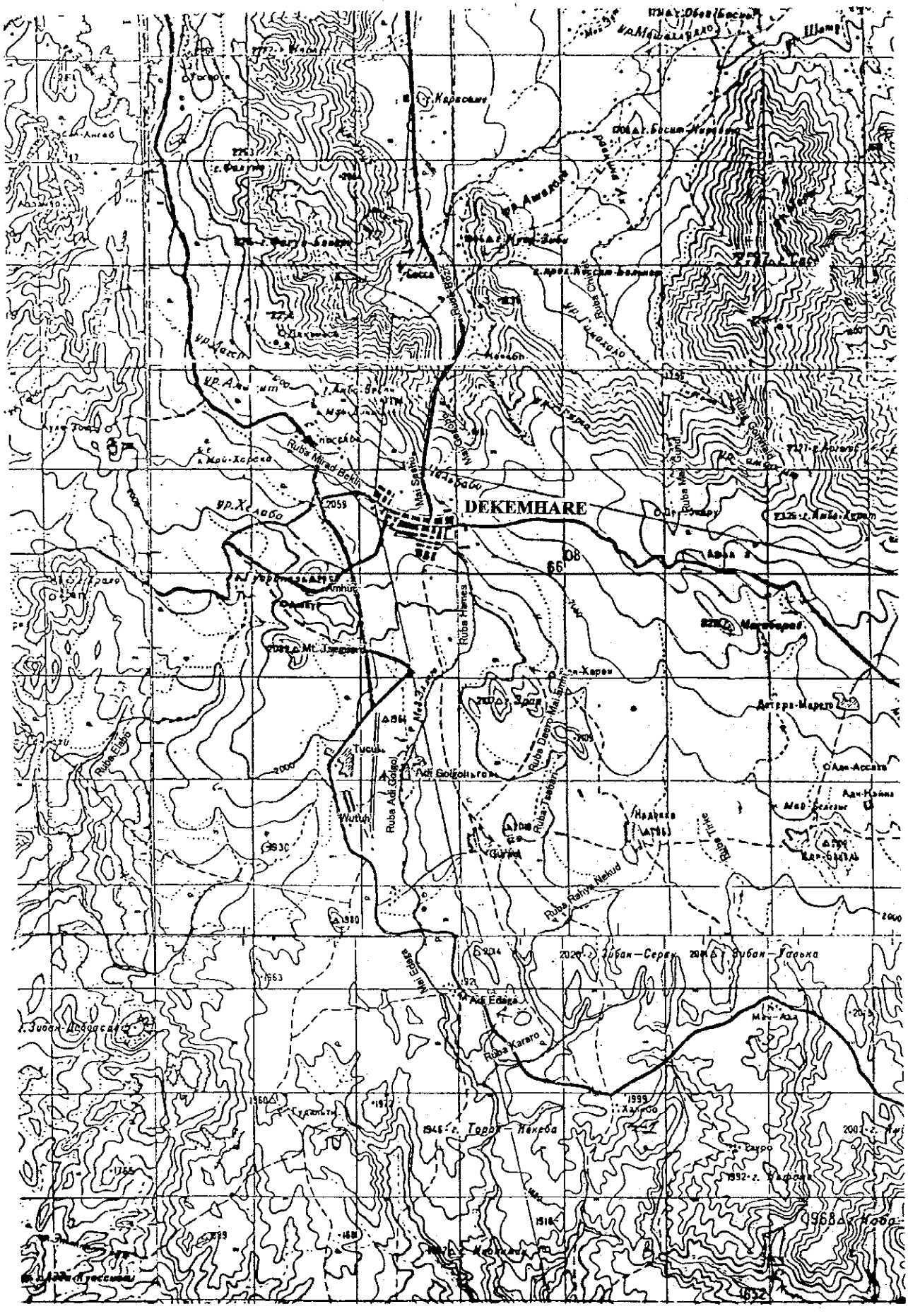
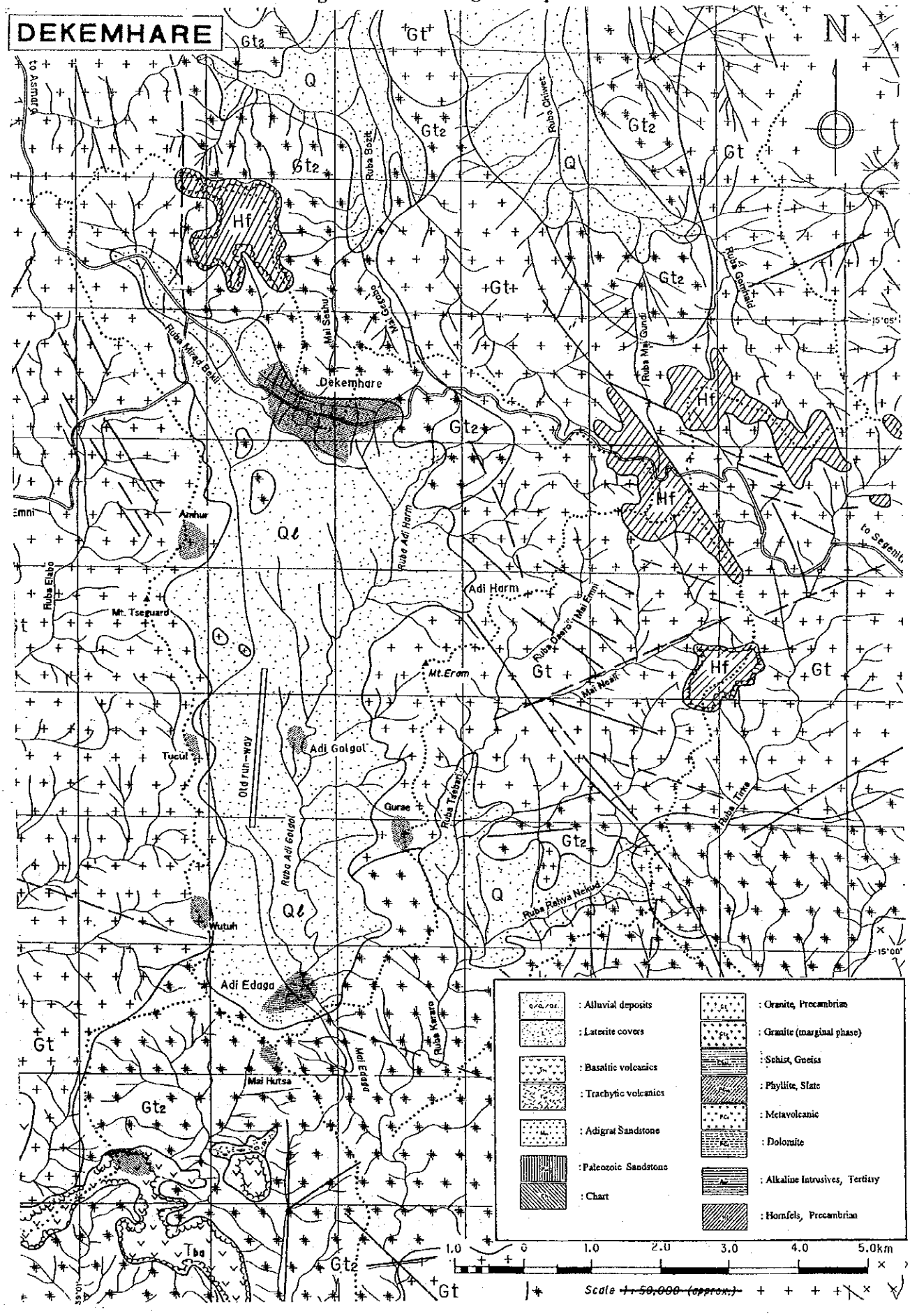


Figure 4.1.2 Geological Map



As shown in the topo-map and in the Hydrogeological Map more clearly, Dekemhare town is stand up on just the watershed for the Red Sea and for the Mereb catchment areas. Almost one third of the area shown in the topo-map, the north and northwest of the town, is the catchment of the Red Sea. The remaining major area is included in the Mereb catchment area, and it can be divided into several sub-basins such as the Adi Golgol, Ruba Koraro, Ruba Elabo sub-basins, etc. Those sub-basins are limited by sub-watershed composed of fresh granite cores.

Since the area is underlain, throughout ate area, by granitic basement, the major aquifer system of the site is a fissured aquifer of basement, granite type: a-i. Exception is an intergranular type aquifer (alluvial deposits: d-i). The alluvial aquifers distribute in the area as shown in the Hydrogeological Map, overlying the said granitic aquifer. Aquicludes (AqC) consisted of Hornfels and basaltic lava scatter in the area, forming table-mountains because of their hard rock quality.

Fissured aquifer in granite is reported to have low water productivity. In fact, BH-16 yielded no water. However, existing boreholes of BH-14 and 19, and Test Wells drilled under the Study (DEK-1 and 2) also, showed more than 4.0 lit/sec, maximum 8.0 lit/sec of yield. These facts suggest that the granitic aquifers in this area, in particular overlain by the alluvial deposits, have moderate to high productivity.

4.1.2 Meteorology and Hydrology

(1) Meteorology

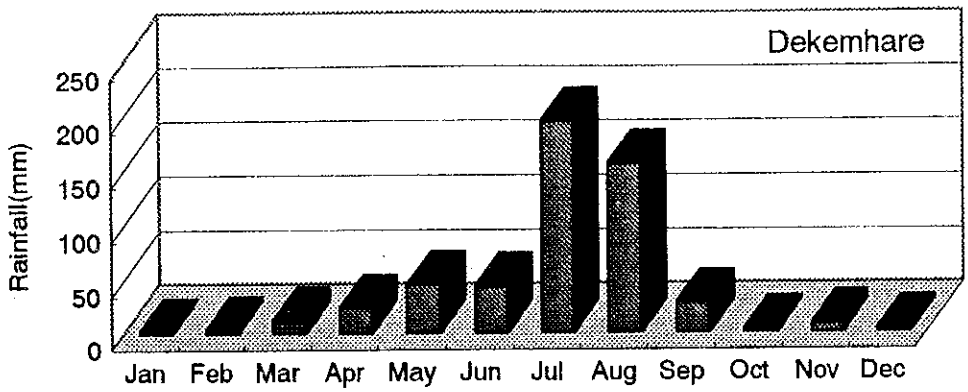
The meteorological data for this sub-region is substituted by the data of Mendefera, the regional head quarter. Only rainfall data in this sub-region is recorded by MOA and WRD. Review of data reveals that annual average temperature varies between 15 and 21°C. Evaporation is higher in April, 7.5mm/day, whereas, low in August 4.6mm/day. Records also show that annual average rainfall is about 524mm, and as in other sub-regions, most of them occur during two months of July and August. But in October 1997, unusual rainfall was recorded. The monthly total was found as 99.0mm, with a daily maximum of 40.0mm. The meteorological data are presented in Table 4.1.1, and monthly rainfall pattern is presented in Figure 4.1.3.

Table 4.1.1 Meteorological Data

Month	Temperature (°C)	R.H. (%)	Windspeed (m/sec)	Pan Evapo. (mm/day)	Sunshine (hr/day)	Rainfall (mm)
Jan	16.3	75	1.5	5.4	10.8	2.3
Feb	17.3	68	1.6	6.7	10.4	3.7
Mar	20.7	59	1.7	7.0	10.7	11.7
Apr	19.2	70	1.8	7.5	11.1	23.9
May	19.3	65	2.0	6.0	12.3	44.8
Jun	19.1	64	1.9	5.4	11.2	43.7
Jul	15.5	98	1.8	5.6	8.8	195.1
Aug	15.4	95	1.8	4.6	7.2	156.0
Sep	17.1	78	1.7	5.1	9.7	27.8
Oct	16.9	86	2.1	6.3	11.4	3.3
Nov	16.3	89	1.4	5.5	10.6	8.4
Dec	15.6	83	1.3	5.5	10.7	3.4
					Total	**524.1**

Data source: Sector Study Report (ref. FAO), MoA and WRD

Figure 4.1.3 Monthly Rainfall Pattern



(2) Hydrology

The main sources of surface water may be considered as Mai Edaga, Ruba Koraro and Mai Elabo. So far, no development attempt has been made in these rivers though, there are dam-sites around Adi Nefas. Another source of surface water is micro dams. In Dekemhare there are about 9 micro dams mainly used for livestock and irrigation. As in the other areas of the region, most of the dams are suffering from sedimentation problem. A list of the existing micro dams is presented in Table 4.1.2.

Table 4.1.2 List of Existing Micro Dams

Sl. No.	Village Name	Const. Year	Agency	Capacity (cum)	Remarks
1	Enda Deko	1993	SIM	100,000	Silted
2	Mai-Aron	1993	MoA	24, 000	Silted
3	Derco	1996	MoA	380,000	RGC
4	Kilowelie	1996	MoA	700,000	RGC
5	Zeban-Una	1988	LWF	200,000	H.S.
6	Taakia	1994	LWF	20,500	Silted
7	Geza-Gobo	1994	LWF	200,000	Silted
8	Zuban Angeb	1996	MoA	500,000	RGC
9	Adi Golgol	1979	MoA	300,000	C.S.

Source: MoA
SIM: Sudanese International Mission, LWF: Lutherian World Fund,
RGC: Relatively good condition, H.S: Highly silted, C.S: Completely silted

4.1.3 Hydrogeological Investigation and Groundwater Monitoring

(1) Hydrogeological investigation

To identify the water resources available for each target township, to evaluate the potential of those water resources, and to obtain basic data needed to formulate a water resources development plan, a series of hydrogeological surveys were conducted. To minimize the survey period and to maximize the outputs of the survey, the hydrogeological survey must be conducted systematically, from the wider area to the

local; extensive to intensive; and general to special. Thus, the hydrogeological surveys in this Study flew as follows:

1) Regional geological study:

To grasp the geological conditions/structures of the area and to select the following geophysical prospecting site(s), through a review of existing data/information, aerial-photo interpretation, and an actual field reconnaissance survey.

2) Geophysical prospecting:

To analyze the resistivity structure of the ground and interpret the geological/hydrogeological relations, to select the most suitable drilling point for test or observation well(s), through VLF-EM, horizontal geoelectric sounding (HS), and/or vertical geoelectric sounding (VES).

3) Test well drilling:

To obtain exact geological/hydrogeological information of the site and to know the aquifer potential through well drilling, borehole logging, pumping test, and water quality analysis. Further, to get data on time-series groundwater level fluctuations through setting automatic water level recorders into the wells.

4) Total analysis:

To analyze the geological and hydrogeological conditions of the target areas, to identify the available and suitable water resources, and to evaluate their resource potential for long-term development, through comprehensive analysis, examination and consideration of the results of the above mentioned field surveys.

The details and results of each investigation work were already reported as "Field Investigation Report", as a separated volume of the Interim Report, and quite roughly but the work volumes and results of them are summarized and presented in Appendix-C, excepting the parts explained in the following clauses.

(2) Groundwater monitoring

After completion of the Test Well drillings, an automatic water level recorder was installed in DEK-1 and 2. The measurements on both wells were commenced on March 8, but the measurements were disturbed immediately. Only one well, the recorder in DEK-2 could be recovered on March 11, and since that, it is still continuing the observation. The records until June 10 were withdrawn and analyzed (the records are attached in Appendix).

The groundwater monitoring period since early March to early June corresponds to the end of a dry season through the beginning of a rainy season. That means, the water level comes down to the lowest level in a year and just starts recovering, as a general tendency. While, the actual water level recorded shows almost constant drawdown but within very small range, from 13.60 m to 13.70 m below ground level for this three months. It suggests the water level around 13.70 m bgl is the lowest water level in a year, the yearly fluctuating is not so much because of the vast extension and storativity of the aquifer, and the effective recharging has not yet occurred at the early June in this area. In any rate, it is too early to make a conclusion on the groundwater hydrograph and aquifer condition. One year of continuous monitoring shall be required to make severe examination on groundwater hydrograph.

4.1.4 Water Resources

(1) Existing water resources

Many boreholes and dug wells exist along Mai Adi Harm and Mai Adi Golgol, in particular along its upstream. All of existing wells, both boreholes and dug-wells, were checked and arranged into Well Inventory associated with their location map. These are attached in Appendix-C, and only a copy of the location map is presented here as Figure 4.1.4. As the Inventory said, and as shown in the figure, there are as much as 28 wells in total, 4 of dug-wells and remaining 24 of boreholes.

Current public water sources of the town are those three of boreholes near or in the town and two boreholes in the alluvial plain. Among those, the former three wells (BH-4, 8, and 10 in the Inventory) are used for the sources of pipe-born water, installed with a motor pump. And the later two wells (BH-14, 19) are also installed with a motor pump but water is delivered through water tankers.

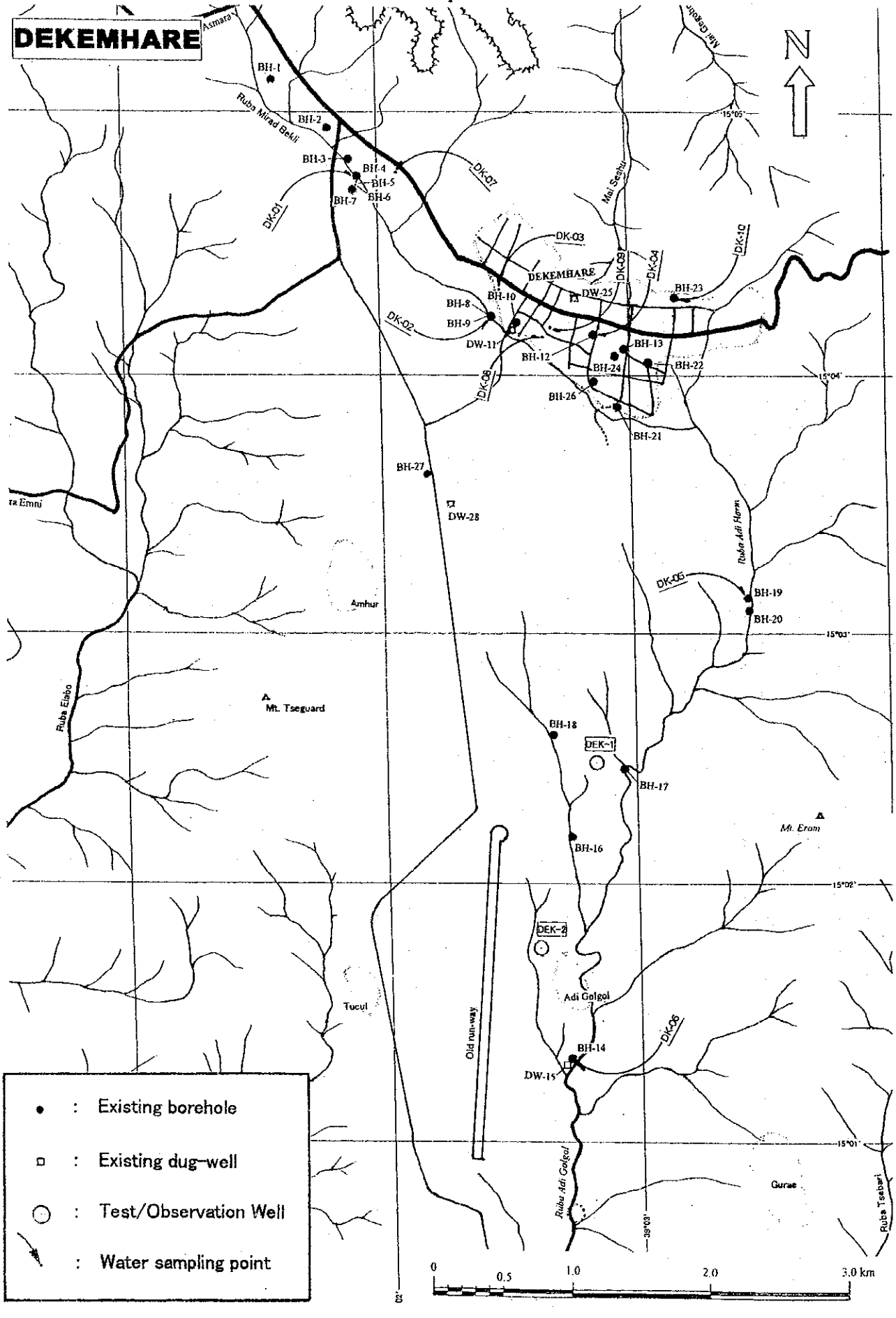
Besides those public water sources, one dug (DW-11) and one borehole (BH-16) are dry, 4 boreholes (BH-5, 6, 7, and 9) are capped, and 5 boreholes (BH- 2, 3, 17, 18, and 20) are out of use now through miscellaneous reasons. Thus, remaining 3 dug-wells and 9 boreholes are still working and serving for mainly domestic water use. Among 9 available boreholes, 5 boreholes are equipped with a hand-pump, and others are installed with a motor pump. While for a dug-well, only DW-25 dug in a Catholic church is equipped with a motor pump. It is a noteworthy that BH-12 drilled in an elementary school has a pump driven by a solar battery system.

At around 9 km south of Dekemhare town, there is a small village named Adi Edaga. Rather wide alluvial plain extending in the south of Dekemhare is ended at immediately downstream of this village. Here, the widely extended lake deposits are constricted by the granitic, and the underflow of Mai Edaga comes up as a surface-flow again. The situation suggests the wide lake deposits, and also upper part of the granitic aquifer, are enclosed by the fresh basement forming a kind of natural underground dam. The tail flow of Mai Edaga shall be a natural intake of the underground dam.

(2) Test wells

Two Test Wells were drilled, both were in the fairly wide alluvial plain, east of abandoned runway. Code name DEK-1 was drilled at around 2km upstream from the village of Adi Golgol, and DEK-2 was drilled adjacent to the village, as shown in Figure 4.1.4. Planned depths of both were 80m but revised to 53m and 60m respectively, because of very hard rock formation. Followings are rough conditions of these two holes, and the formal lithological logs are attached in Appendix-C, as same as other boreholes.

Figure 4.1.4 Location Map of Water Resources



DEK-1

0 – 22.0m	Alluvial deposits, muddy to coarse sand, many quartz and plagioclase granular, brownish gray.
22.0 – 35.0m	Sand, granite origin tough and coarse sand consisted of quarts, plagioclase, feldspar and biotite, light gray.
35.0 – 52.0m	Weathered granite, strongly weathered, light gray.
52.0 – 53.0m	Granite, very hard, light gray.

DEK-2

0 – 22.0m	Alluvial deposits, mostly medium to coarse sand consisted of quarts, plagioclase and alkali-feldspar, granite boulders at the bottom, brownish gray.
22.0 – 35.0m	Sand, granite origin tough and coarse sand, partly medium size, light brown.
35.0 – 44.0m	Aplite, dyke rock (?), hard, greenish to dark gray.
44.0 – 60.0m	Granite, slightly weathered in upper 9m, very hard lower than 53m, pinkish gray.

At DEK-1, groundwater was touched at the depth of 13.6m. During the drilling work, a condition of groundwater yield was hardly known because mud water was used for drilling. Based on the logging, screen was set at the span from 23.0 to 47.0m of the depth. Water yield was increased to around 2.0 lit/sec through the development, but it was increased further through the preliminary pumping. It means the development time was not sufficient. In accordance with the results of step draw-down test, constant discharge test at the pumping rate of 4.0 lit/sec was conducted for 48 hours. Transmissivity obtained through the constant discharge test was around 100 m^2/day.

Groundwater table detected at DEK-2 was 12.2m. Drilling method of the well was changed to DTH at the depth of 21m where hard granite boulders encountered. Immediately after this depth, rather much water was yielded, around 7 lit/sec by air-lift. Screen was installed at the span from 24.0 to 54.0m of depth. Step draw-down test consisted of five pumping steps of 3, 4, 5, 7 and 9 lit/sec was performed after development and preliminary test. As a result, 7 lit/sec was decided as the pumping rate for constant discharge test, and the test was done. Transmissivity of the aquifer, obtained through the test, was 206.1 m^2/day.

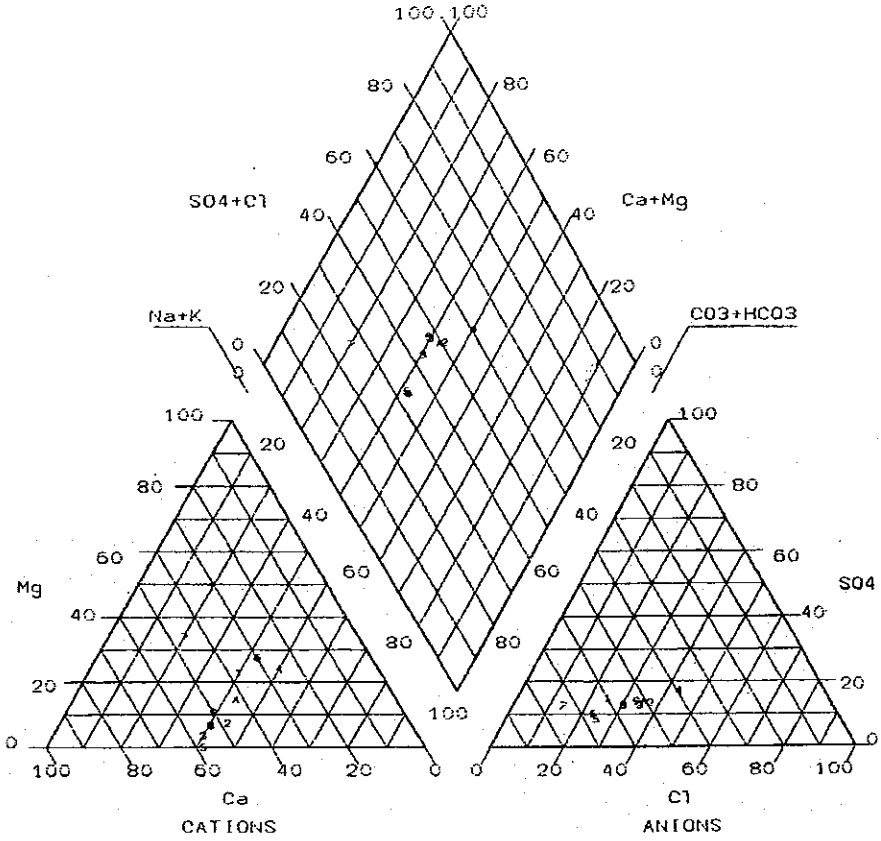
4.1.5 Water Quality

In order to know the water quality of current water supply system, samples from ten points were collected, and their physical, chemical and bacteriological qualities were analyzed in the laboratory of WRD. The samples include the main source of water, vicinity of the main source, dug-well, public fountain, house connections, etc. The location of the sampling points is presented in Figure 4.1.4, together with all water sources.

It was reported that the water quality of this sub-region is generally good. However, the results of the analyses show that only one sample (DK-06, BH-14 in the Inventory) was found to be contaminated with *faecal coliform bacteria*, two samples (DK-04 and DK10) were found with higher EC value and higher value of nitrogenous compound. It is noteworthy to mention that findings of contaminated water may be due to the intrusion of overland flow from the surrounding areas to the sample source as a result of unusual rainfall during or at the time sampling. The results of the analysis are presented as Table 4.1.3,

and arranged as Piper Diagram as shown below (Figure 4.1.5).

Figure 4.1.5 Water Quality of Dekemhare Area



Label	Seq.No	Sample Identification
1	1	DK-1
2	2	DK-2
3	3	DK-3
4	4	DK-4
5	5	DK-5
6	6	DK-6
7	7	DK-7
8	8	DK-8
9	9	DK-9
A	10	DK-10

Table 4.1.3. Water Quality in Dekemhare

I.Physical Quality

Date Sampled 21/10/97

Date Analysed 22/10/97

II. Bacteriological Quality

T.C.B = Total Coliform Bacteria

F.C.B = Faecal Coliform bacteria

Well	Description	EC	pH	Temp	Odor	Taste	Turb.	Color	T.C.B		F.C.B		Remarks
Ident		us/cm		°c			NTU		count/100ml,35°c		count/100ml,44.5°c		
DK-01	BH,Motorized,Bloko	676	7.1	23.0	agreeable	agreeable	<5	clear		0		0	Safe
DK-02	BH,Motorized,Asail	980	7.0	21.3	agreeable	agreeable	<5	clear		0		0	Safe
DK-03	Main reservoir 340cu.m	926	7.0	22.2	agreeable	agreeable	<5	clear		0		0	Safe
DK-04	BH,Erdi-Awet School	1980	6.9	24.4	agreeable	salty	<5	clear		0		0	Safe
DK-05	BH,Ruba Adi Harm	684	6.6	24.3	agreeable	agreeable	<5	clear		0		0	Safe
DK-06	BH,Adi golgol	635	7.0	21.2	agreeable	agreeable	<5	clear		10		4	contaminated
DK-07	HDW,Private,Hadamu	477	6.8	21.1	agreeable	agreeable	<5	clear		0		0	Safe
DK-08	Consumer's Tap	898	7.1	19.7	agreeable	agreeable	<5	clear		0		0	Safe
DK-09	Consumer's Tap	922	7.1	22.5	agreeable	agreeable	<5	clear		0		0	Safe
DK-10	HDW, miss.school	1290	6.8	24.5	agreeable	salty	<5	clear		0		0	Safe

III. Chemical Quality

Date Sampled 21/10/97

Date Analysed 07/11/97

Well	Description	Ca	Mg	Na	K	Fe	Mn	HCO3	SO4	Cl	NO3	N-NH3	NO2	F	Hard.
Ident		mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	*G.d.h
DK-01	BH,Motorized,Bloko	72	27	87	2.6	0.06	0.1	342	67	84	5.8	0.25	0.04	0.98	16.3
DK-02	BH,Motorized,Asail	94	9	99	2.2	0.22	0.1	332	72	148	22.1	0.20	0.03	0.98	15.2
DK-03	Main reservoir 340cu.m	104	4	84	2.2	0.01	0.0	317	61	124	19.9	0.27	0.02	0.93	15.4
DK-04	BH,Erdi-Awet School	96	55	215	3.1	0.02	0.0	405	140	260	97.4	0.85	0.07	0.46	26.1
DK-05	BH,Ruba Adi Harm	75	0	61	2.2	0.00	0.2	300	30	66	0.0	0.13	0.01	0.61	10.5
DK-06	BH,Adi golgol	48	27	78	1.3	0.10	0.1	273	33	56	14.6	0.09	0.14	0.90	13.0
DK-07	HDW,Private,Hadamu	49	22	24	1.8	0.03	0.0	185	25	20	25.2	0.06	0.81	0.67	11.9
DK-08	Consumer's Tap	102	8	89	1.8	0.04	0.1	332	59	104	21.3	0.11	0.04	0.88	16.1
DK-09	Consumer's Tap	99	13	88	2.6	0.02	0.0	322	68	120	43.0	0.20	0.02	1.06	16.8
DK-10	HDW, miss.school	109	23	127	3.1	0.05	0.0	322	71	132	51.8	0.40	0.03	1.41	20.6

*G.d.h = German degree of hardness,1G.d.h = 17.9mg/l hardness as CaCO3

* Note: HDW = hand dug well