GROUNDWATER DEVELOPMENT STUDY IN THE SOUTHWESTERN REGION OF THE REPUBLIC OF MADAGASCAR

(PHASE II)

FINAL REPORT
VOLUME II
SUMMARY REPORT

KOKUSAI KOGYO CO., LTD. TOKYO
ALMEC CORPORATION Inc. TOKYO

JAPAN INTERNATIONAL COOPERATION AGENCY

DEPARTMENT OF WATER
MINISTRY OF ENERGY AND MINES
REPUBLIC OF MADAGASCAR

GROUNDWATER DEVELOPMENT STUDY IN THE SOUTH-WESTERN REGION OF THE REPUBLIC OF MADAGASCAR

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KOKUSAI KOGYO Co., Ltd., TOKYO
SANYU CONSULTANTS Inc., TOKYO

Preface

In response to a request from the Government of the Republic of Madagascar, the Government of Japan decided to conduct a Study on the Project of Groundwater Development in the South - Western Region (Phase II) and entrusted the study to the Japan International Cooperation Agency (JICA).

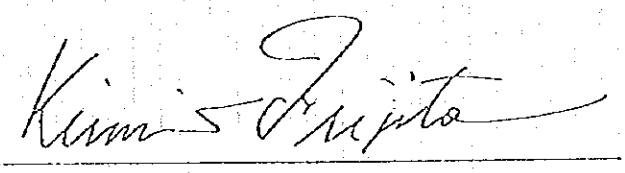
JICA sent to Madagascar a study team headed by Mr. Kunio Fujiwara, Kokusai Kogyo Co., Ltd. and composed of members of Kokusai Kogyo Co.,Ltd. and Sanyu Consultants Inc., on two occasions between April 1995 and June 1996.

The team held discussions with the officials concerned of the Government of Madagascar, and conducted field surveys at the Study Area. After the team returned to Japan, further studies were made and the present report was prepared.

I hope that this report will contribute to the promotion of the project and to the enhancement of friendly relations between our two countries.

I wish to express my sincere appreciation to the officials concerned of the Government of the Republic of Madagascar for the close cooperation they extended to the team.

August, 1996



Kimio Fujita
President,
Japan International Cooperation Agency

August 1996

Mr. Kimio Fujita
President,
Japan International Cooperation Agency

Letter of Transmittal

Dear Sir,

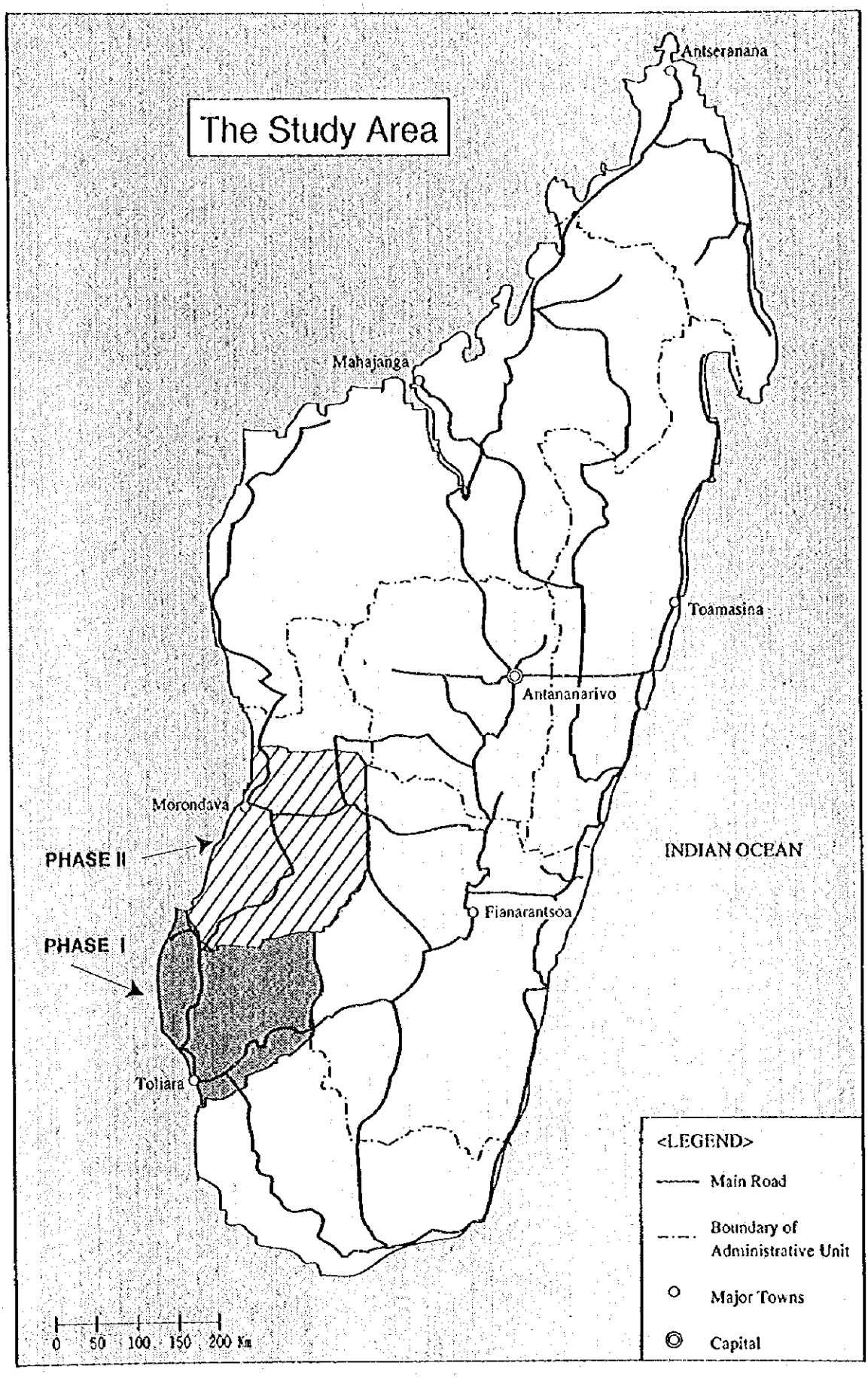
We are pleased to submit to you the development study report on the Groundwater Development Project in the South-Western Region (Phase II), in the Republic of Madagascar.
The report contains: study results on the socio-economic condition of the area; an evaluation of groundwater resources; a groundwater development plan, accompanied by the appropriate water supply facilities plan; and an operation and maintenance plan.

The final report consists of four separate volumes : Summary, Main and Supporting reports, and Data Book. The Summary Report states concisely all the study results. The Main Report describes the results of the study with analysis, and is accompanied by a hydrogeological map. The Supporting Report contains the study method and materials produced through the process of analysis and others. The Data Book contains the raw and processed field survey records, and the processed reference materials collected.

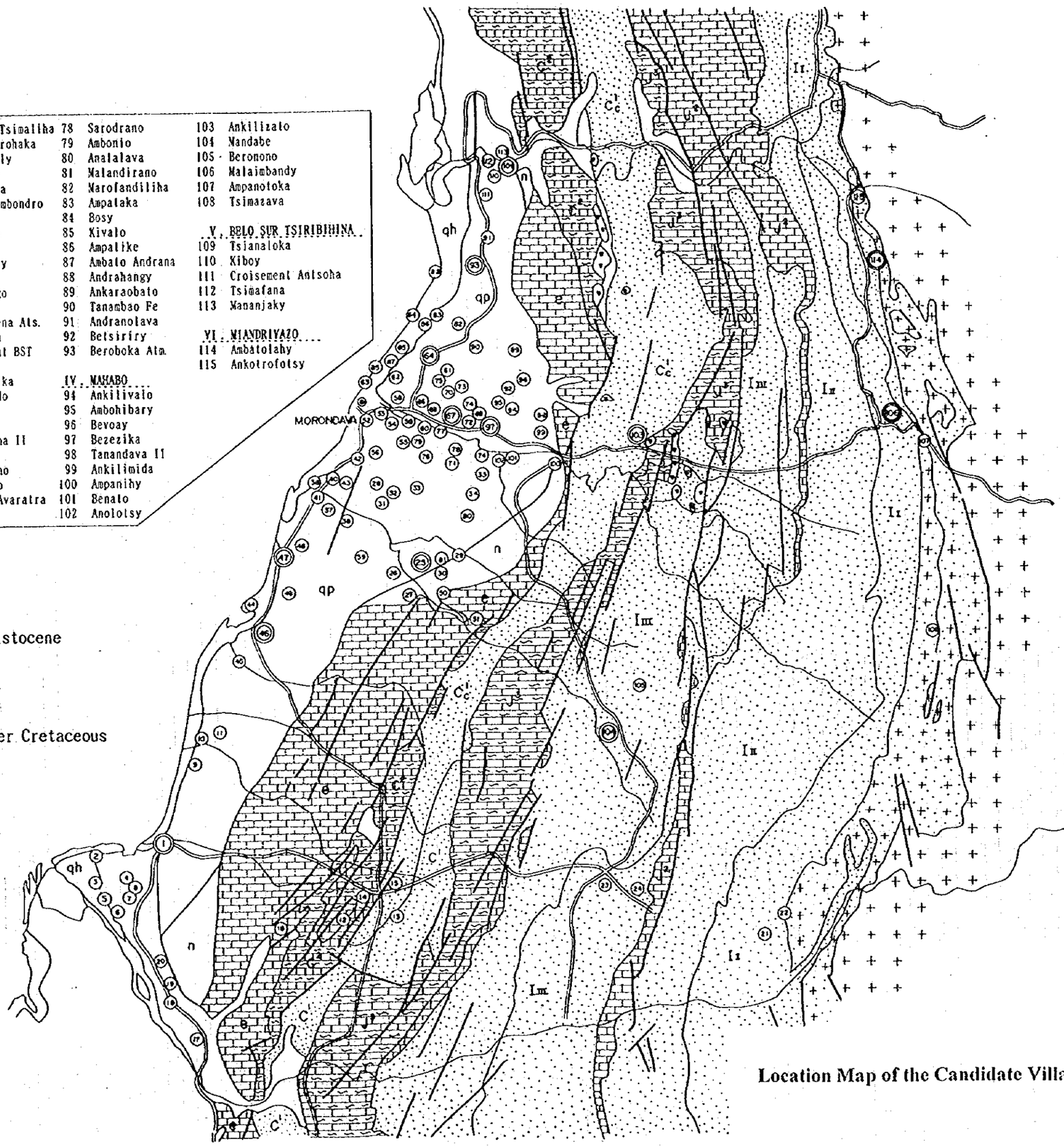
We are confident that the implementation of the proposed groundwater development scheme will greatly contribute to improved water supply conditions in the South-Western Region of the Republic of Madagascar.
Lastly, we would like to take this opportunity to express our sincere gratitude to your agency and the Japanese Embassy in Madagascar for their kind guidance and encouragement. We also wish to express our heartfelt thanks to the concerned authorities of the Government of Madagascar, especially to the Ministry of Energy and Mines, for the close cooperation and assistance extended to us during the study period.

Very truly yours,

Kunio Fujiwara
Team Leader
The Team for the Study on
Groundwater Development in the
South-Western Region of Madagascar
(Phase II)


The Study Area
Antseranana
Mahajanga
Toamasina
Antananarivo
Morondava
PHASE II
PHASE I
INDIAN OCEAN
Fianarantsoa
Toliara
0 50 100 150 200 Km
<LEGEND>
Main Road
Boundary of Administrative Unit
Major Towns
Capital

I. MANJA		**III. MORONDAVA**		51	Lavaravy Tsimaliha	78	Sarodrano	103	Ankilizato
1	Andranopasy I	25	Befasy	52	Antsakamirohaka	79	Ambonio	104	Nandabe
2	Andranopasy II	26	Antevamena	53	Androvakely	80	Analalava	105	Beronono
3	Antaly	27	Mitsitiky	54	Androvabe	81	Malandirano	106	Malaimbandy
4	Darika	28	Andranovorisosotra	55	Ampananiha	82	Marofandiliha	107	Ampanotoka
5	Befamonty	29	Ankitatamahavelo	56	Antseranambondro	83	Ampataka	108	Tsimazava
6	Ambatobe	30	Bekininy Soarano	57	Tanambao	84	Bosy		
7	Nositonga	31	Beleo	58	Bemanonga	85	Kivalo	**V. BELO SUR TSIRIBIHINA**	
8	Nosibe	32	Anadabo	59	Marovoay	86	Ampalike	109	Tsianaloka
9	Ankoba	33	Misokotsa	60	Tandrokosy	87	Ambato Andrana	110	Kiboy
10	Antseranandaka N.	34	Croise. Besotroka	61	Bekonazy	88	Andrahangy	111	Croisement Antsoha
11	Tsaramandroso	35	Amanga	62	Bevoliengo	89	Ankaraobato	112	Tsimafana
12	Songary	36	Namakia	63	Kimony	90	Tanambao Fe	113	Mananjaky
13	Piste de Bedo	37	Voloe	64	Andranomena Ats.	91	Andranolava		
14	Tanambahiny	38	Benasy	65	Tanandava	92	Betsiriry	**VI. MIANDRIVAZO**	
15	Miary	39	Antsamaka	66	Croisement BST	93	Beroboka Atm.	114	Ambatolahy
16	Ambivy I	40	Manomentimay	67	Analaiva			115	Ankotrofotsy
17	Ambivy II	41	Farateny	68	Betsipotika	**IV. MAHABO**			
18	Ambahia	42	Ianadabo	69	Amboloando	94	Ankilivalo		
19	Besatrohaka	43	Andrananja	70	Ampandra	95	Ambohibary		
20	Marolafika Atm.	44	Belo Sur Mer	71	Besonjo	96	Bevoay		
		45	Ankilifolo	72	Antevamena II	97	Bezezika		
II. BEROROHA		46	Marofihitsa	73	Belobaka	98	Tanandava II		
21	Ambalavato Nord	47	Ambararata	74	Tsinjorano	99	Ankilimida		
22	Andranomena	48	Ankevo	75	Betsinefo	100	Ampanihy		
23	Marerano	49	Ambivy	76	Laijoby Avaratra	101	Benato		
24	Ambondrobe	50	Bevantaza	77	Ambinda	102	Anolotsy		



qh	Holocene	qp	Pleistocene
n	Neogene (Pliocene-Miocene)		
e	Eocene		
c²	Upper Cretaceous	c¹	Lower Cretaceous
j³	Upper Jurassic		
j²	Middle Jurassic		
I m	Upper Isalo Group		
I a	Middle Isalo Group		
I c	Lower Isalo Group		
	Substratum(Anté-Jurassique) Basement Complex(per-Jurassic)		

10km 0 10 20 30 40 50 km

Location Map of the Candidate Villages

TABLE OF CONTENTS

1. INTRODUCTION

1.1 General

This is the Final Report on the "Groundwater Development Study in the South-Western Region of the Republic of Madagascar (Phase II)", covering an area of about 39,000 km² situated between the two rivers of Tsiribihina and Mangoky. The Study Area involves 115 candidate villages for the implementation of the water supply project.

The Phase I Study was conducted by the joint study team of the Japan International Cooperation Agency (JICA) and the MIEM, Ministry of Industry, Energy and Mines (present name MEM), during a two-year period (1990 to 1992), and covered the southern half of the proposed study area, that is, the southern area of the Mangoky River. Based on the study results, the rural water supply project was formulated, and the Japan's Grant Aid Program was extended for the construction of water supply facilities in 50 selected villages during the 1993 to 1995 period.

The Study for the Phase II project was carried out in accordance with the "Scope of Work" agreed upon by the MEM and the JICA in December 1994. The Study commenced at the end of March 1995, and terminated with the submission of this Final Report in July, 1996. Similar to the study of Phase I, a joint study team of JICA and MEM was organized, and the field survey was conducted in the period from April to December 1995.

The study work in Madagascar was divided into two stages. The first stage extended from April to August and dealt with the categorization of the villages from the viewpoint of socio-economical conditions and groundwater potential. The second stage, from September to December, comprised test drilling, detailed socio-economic survey and the project formulation, including the implementation of the pilot project with the villagers' participation.

After further analysis in Japan, a hydrogeological map of the Study Area was prepared and groundwater development plan for each of the proposed villages was established. Also, the Phase II project was formulated accompanied by the facility design for the categorized villages. The period from January to March 1996 was used for above analysis and arrangement as well as preparation of the Draft Final Report.

Discussions on the Draft Final Report were held in June 1996 between the MEM and JICA mission. Taking into account the MEM's comments on the Draft Final Report, this Final Report was prepared and presented to the Government of Madagascar from JICA through diplomatic channel in August 1996.

1.2 Outline of the Project

1.2.1 Background of the Project

Madagascar is a developing agricultural country with cultivation of crops and raising of livestock as its main industry; agriculture employs 80% of the population and provides 80% of the exports.

In Madagascar, a public investment plan, which succeeded the third 5-year plan (1986-1990), is currently in progress, emphasizing on the following points:

- Improvement of the sanitary environment
- Mitigation of impoverished conditions
- Activation and development of rural economy.

The execution strategy focuses on rural development, particularly on the improvement of living standards in rural areas, which concerns over 75% of the total national population.

The improvement of water supply services is believed to be one of the most important factors to achieve this objective, however, the service coverage in rural areas did not exceed 12% in 1991, whereas the service coverage in urban area was about 70%. The south-western region of Madagascar, where annual precipitation is limited to 400 ~ 1,000 mm, has particularly suffered long from severe water supply shortages - service coverage in rural areas is only 2.6%, which is far smaller than the national average.

In order to upgrade such conditions, the Government of Madagascar made a request in 1987 to the Government of Japan for technical and financial assistance for groundwater development in the south-western region, that is the area between Onilahy river and Tsiribihina river.

In response to this request, the Japanese Government sent a JICA study team and a study was conducted from September 1989 to July 1991. After the study, the water supply project was implemented in the prioritized 50 villages between January 1993 and January 1995 under Japan's Grant Aid Program, based on the study results and also in response to the request from the Government of Madagascar for financial assistance. However, the Study and the Project implementation were limited to the southern half of the requested area, that is, between the Onilahy and Mangoky Rivers, because the area concerned was too large and water supply by groundwater development was considered uncertain at the time of the first request.

When the construction works on the 50 water supply systems were near completion, the Government of Madagascar made a new request to the Government of Japan for the execution of the same study in the northern half of the area. In response, the Government of Japan decided to, again, send a JICA study team to conduct a study.

Both governments of Madagascar and Japan recognized this study as the "Phase II Groundwater Development Study in the South-Western Region of Madagascar (the Study)".

1.2.2 Objectives of the Study

The objectives of the Study are the following four points:

1) To evaluate the groundwater development potential of the area concerned (including preparation of the hydrogeological map)

2) To formulate the water supply plan for the candidate villages in the survey area, setting the target year at 2005, as well as to upgrade the rural standard of living in the south-western region of Madagascar through the establishment of public water supply systems

3) To formulate a sustainable operation and maintenance plan for water supply facilities, and to encourage the commitment of the inhabitants, particularly women, to participate in operation and maintenance and in keeping a sanitary environment, and

4) To transfer technology to the counterpart personnel during the course of the Study.

1.2.3 Study Area

The "Study Area" covers about 39,000 km² and is bordered by the Tsiribihina River to the north and the Mangoky River to the south. Until October 1995, there were 6 prefectures (FIVONDRONAM-POKONTANY) involved in the area: Belo-sur-Tsiribihina, Miandrivazo, Morondava, Mahabo, Manja and Beroroha. Some of them, however, are only partially included in the Study Area: the southern parts of Belo-sur-Tsiribihina and Miandrivazo until the Tsiribihina River, and the northern part of Beroroha until the Mangoky River. 115 villages (FOKONTANY) distributed in the Study Area were surveyed.

In October 1995, through a new national policy for the simplification of local administration, the Study Area was divided into 4 Departments, that is, the 3 departments of Belo-sur-Tsiribihina, Mahabo and Manja of the Menabe region (FARITANY), and the Department of Beroroha, of the Atsimo Andrefana region. Further, the 115 candidate villages became parts of Communes (KAOMININA).

1.2.4 Study Team

The Study was executed by a joint study team composed of JICA Study Team members and MEM personnel. JICA organized a study team consisting of a team leader and 10 members specialized in various fields. The team leader, Mr. Kunio Fujiwara, was responsible for maintaining a close liaison between JICA and MEM and other relevant agencies of the Republic of Madagascar in this Study. As a groundwater development

specialist, he was also responsible for formulating the development plan and for monitoring and managing of the progress of the Study.

MEM organized the counterpart study team headed by Mr. Aubert Robinirina, Director of the Water Department of MEM. For a smooth conduct of the Study and an effective transfer of the technology applied in this Study, the field representative, Mr. Marcel Rakotomavo, and other 9 counterpart personnel were assigned for the first stage field survey with the addition of 30 workers for the second stage field survey.

1.2.5 Scope of the Study

The Study period is divided into 3 stages, and the Scope of the Study by stages agreed upon between the JICA and MEM are as follows:

Stage I: Understanding and analysis on present conditions

1. *Collection and analysis of existing data and information on:*
   a. Natural conditions, including:
      (a) meteorological conditions
      (b) geological and topographical conditions
      (c) hydrological and hydrogeological conditions
   b. Social and economic conditions
   c. Conditions of health and hygiene
   d. Environmental conditions
   e. Laws, regulations and policies on water resource development, and water supply services
   f. Existing water supply services, including:
      (a) water sources
      (b) water supply system and facilities
      (c) water quality
      (d) coverage and level of services
      (e) water use
      (f) organisations for operation and maintenance
   g. Institutional aspects of project implementation and monitoring
   h. Ongoing and planned projects relevant to the Study
   i. Other related data and information

2. Preliminary survey on actual conditions of water resources through:

a. Geological reconnaissance

b. Hydrological investigation including salt-water intrusion

c. Water quality tests on existing wells and surface water

d. Hydrogeological observation on:

(a) well inventory and production capacity

(b) well levelling

(c) groundwater level

(d) water flow

3. Survey on actual conditions of water supply services and related aspects, such as:

a. Existing water supply facilities with emphasis on the conditions of operation and maintenance

b. Condition of water use by household

c. Sanitary conditions such as toilets and other form of waste water disposal

d. People's awareness on health and hygiene and their willingness to pay for better water supply services

e. Education on health and hygiene at schools and public health centres

4. Identification of potential areas for groundwater development and plan for detailed field survey

a. Identification of high potential areas for groundwater development

b. Selection of areas for detailed field survey

c. Plan for test drilling, including appropriate methodology

d. Initial Environmental Examination (IEE)

Stage II: Analysis and Evaluation of Groundwater Resource Potential

1. Detailed field survey in potential areas and analysis of obtained data

a. Geological survey

b. Groundwater levelling

c. Water quality analysis

d. Geophysical survey

e. Test drilling and pumping test

f. Others

2. Analysis and Evaluation on Groundwater and other water resources potential

a. Topographical and geological analysis

b. Hydrological and water balance analysis

c. Evaluation on groundwater potential

d. Evaluation on surface water potential

3. Water Demand Projection and Allocation

a. Forecast of water demand

b. Water allocation

4. Pilot Project to encourage Inhabitants' Participation

a. Pilot facility construction (hand pump wells)

b. Technology transfer for facility maintenance

c. To encourage the inhabitants to carry out autonomous maintenance

d. To educate the villagers on sanitation

e. To encourage women's participation

f. Monitoring of Project

Stage III: Formulation of Water Supply Plan

1. Formulation of basic policies and strategies of water supply services

a. Target coverage rate in terms of number of population served

b. Target level of services in terms of accessibility

c. Target level of water quality and quantity

d. Choice of technology

2. Water supply plan with emphasis on sustainability

a. Plan for water source including combination of existing and new water sources

b. Plan for rehabilitation of existing facilities

c. Preliminary design of water supply facilities

d. Operation and maintenance plan including maintenance education program.

3. Cost Estimation

4. Monitoring plan of groundwater level and water quality

5. Evaluation

a. Financial plan and evaluation

b. Institutional and technical evaluation

c. Socio-economic evaluation

d. Environmental Impact Assessment

6. Prioritization of projects

7. Formulation of Implementation Program

The reports to be prepared during the course of the Study are as follows:

- Progress Report in English and Summary in French, at the end of Stage I (August 1995)

- Interim Report in English and Summary in French, at the end of Stage II (December 1995)

- Draft Final Report at the end of Stage III (May 1996), which consists of:

  Main Report in English and French

  Summary Report in English and French

  Supporting Report in English

  Data Book in English

- Final Report achieved within 1 month after receiving the comments on the Draft Final Report from MEM, and made of the same volumes of the Draft Final Report. The Final Report will be sent from JICA to MEM through diplomatic channel.

1.3 Study Description

1.3.1 Study Schedule

The duration of the Study was 16 months from March 1995 to July 1996 as shown in the work schedule (Fig. 1.1) and the flow chart (Fig. 1.2). The stages of the Study are as follows:

1) Preparatory work in Japan:

15 days around the end of March 1995

2) Study in Madagascar:

About 8 months from April to December 1995. This Study was divided into 2 stages:

2)-1 1st field survey stage: April - August

2)-2 2nd field survey stage: September - December

3) Study in Japan:

Two months and a half from January to March 1996. A one-month counterpart training program in Japan was incorporated in this period.

4) Explanation and Discussion on the Draft Final Report:

Three weeks in June 1996.

Workshop on operation and maintenance is to be incorporated in this period.

5) Preparation and Presentation of the Final Report:

The reports are to be sent to the Government of Madagascar from JICA through diplomatic channel in August 1996.

1.3.2 Technology Applied

The following technologies have been applied in this Study:

(1) Methods of hydrogeological investigation

(Stage 1 Survey)

- Aerial photograph interpretation (topography and geological structure)

- Geological field reconnaissance

- Geophysical survey (Electric resistivity sounding and trial use of electromagnetic method)

- Review on existing drilling data (lithology and pumping test)

- Inspection and interview survey on groundwater use

-Preparation of preliminary hydrogeological map

(Stage 2 survey)

- Test drilling and geophysical logging

- Pumping test to determine the hydraulic parameters of aquifers

- Water quality analysis on chemical components

- Improvement of the preliminary hydrogeological map based on the results of test drilling

(2) Method of hydrological survey

- Collection and analysis on meteorological data
- Discharge measurement of river water flow (dry season)

(3) Evaluation survey for the Phase-I Project

- Inspection on the water supply system
- Interview with the villagers on operation and maintenance

(4) Socio-economic survey

(Stage 1 Survey)

- Interview with the administrative staff of the villages
- Inspection of sanitary environment, water use, etc., in the villages
- Preparation of village inventory and assessment for their categorization

(Stage 2 Survey)

- Interview survey on household economy
- Economic analysis according to various methods
- Review and rearrangement of village categorization

(5) Pilot Project for case study on O/M of facilities and life style improvement

- Formulation of Water Associations
- Enlightenment of inhabitants on such matters as sanitation, women's status and others through discussions with villagers
- Hand pump installation to the drilled wells and concrete base construction using two different methods, that is, construction by the villagers themselves, and construction by the Study Team, and then to compare the two different methods of villagers' participation.
- Monitoring on water use in the pilot project, functioning of water associations and condition of facilities operation and maintenance. Also, comparison was made between the two methods of villagers' participation.

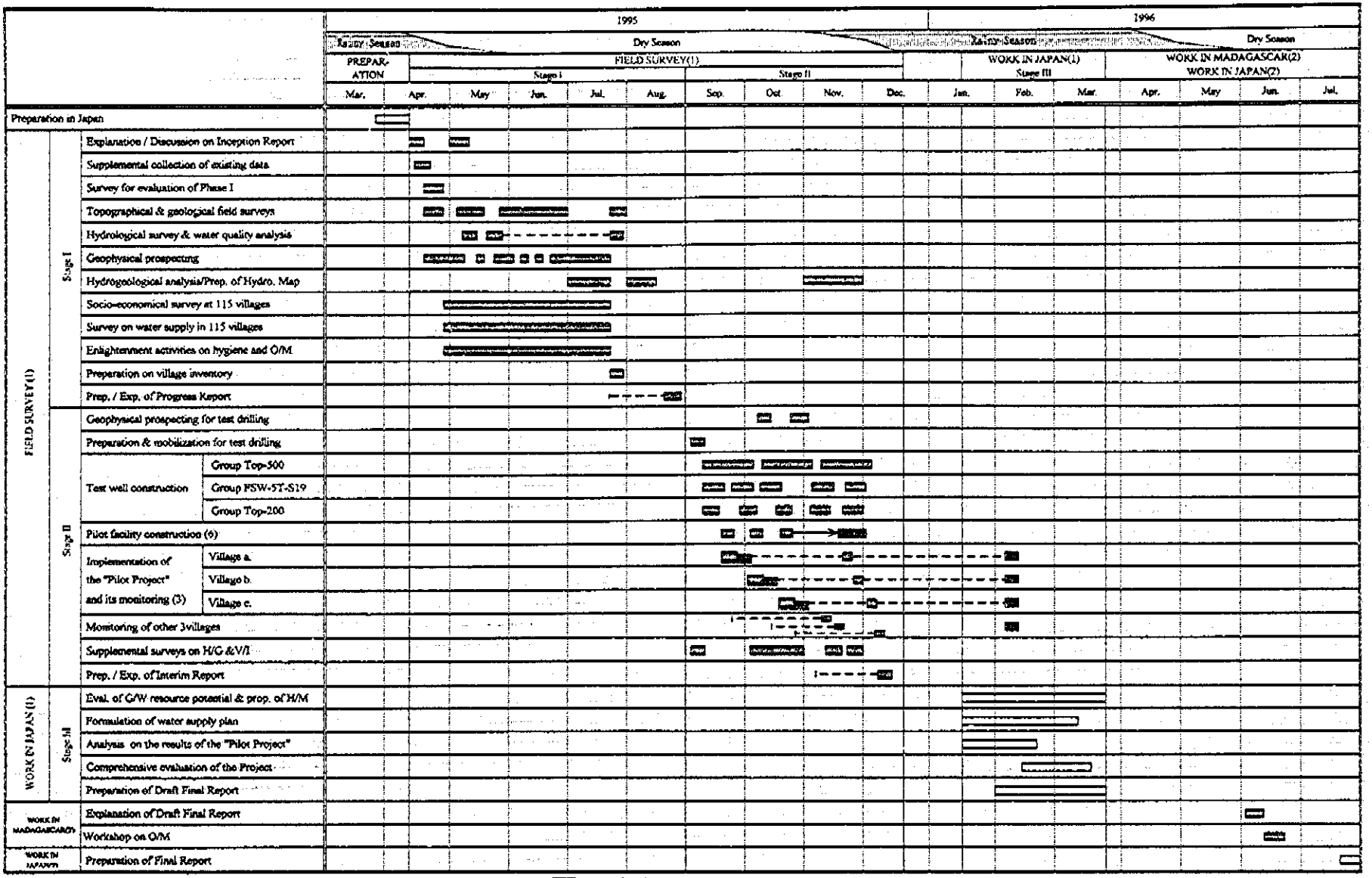


Fig. 1.1 WORK SCHEDULE

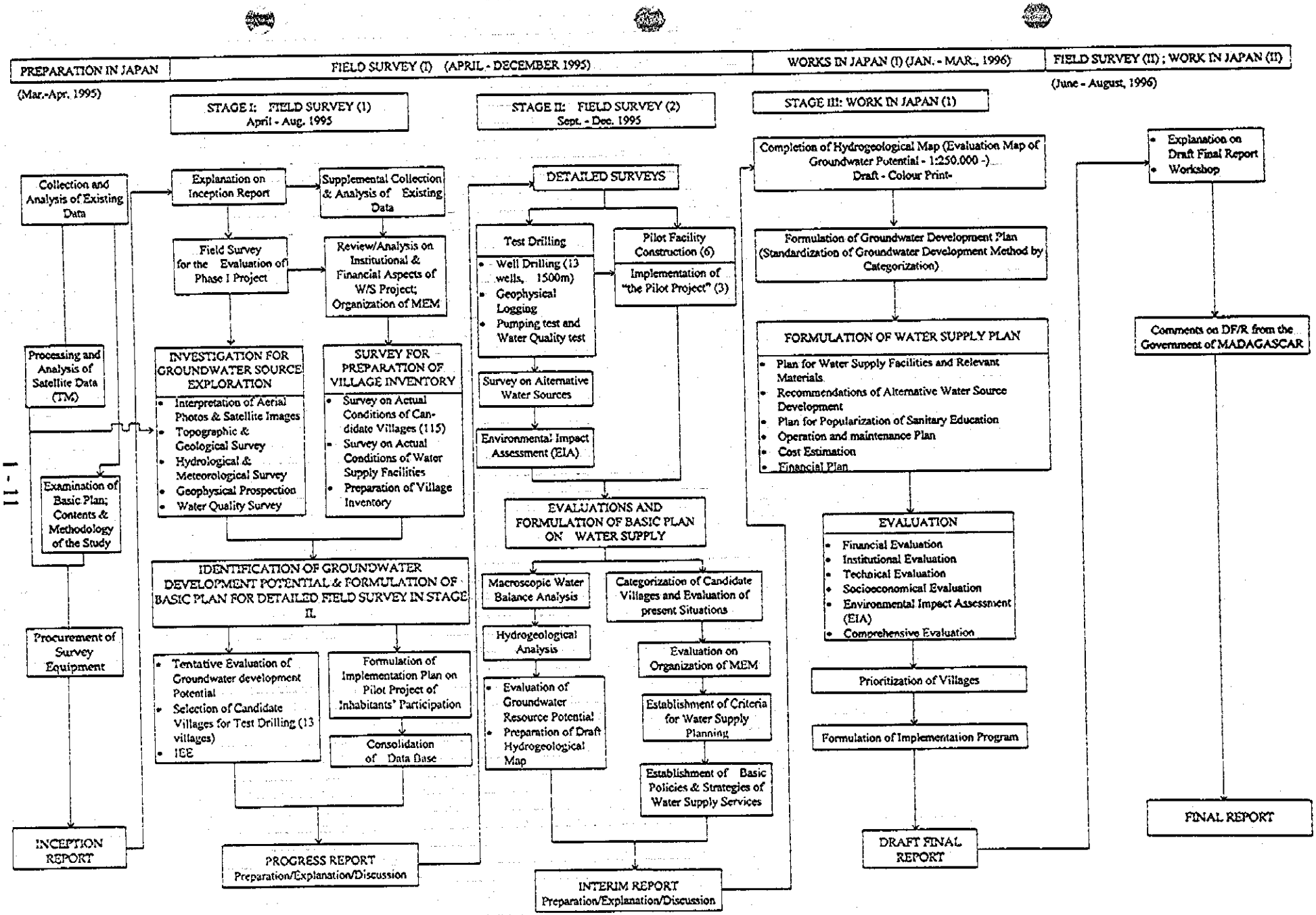


Fig. 1.2 THE FLOW CHART OF THE GROUNDWATER DEVELOPMENT STUDY IN THE SOUTH-WESTERN REGION OF MADAGASCAR

2. GENERAL CONDITION OF THE STUDY AREA

2.1 Natural Condition

2.1.1 Topography

Topographic feature of the area is characterized by coastal plains in the western area, a hilly area in the central part and a mountainous area in the eastern part, which extend in a northeast-southwest direction arching eastward.

The coastal plain, popularly called the Morondava plain, is wide and long, extending along the coast line and arching eastward. Two big deltas, the Mangoky delta on the southern margin and the Tsiribihina delta on the northern margin, form part of this plain.

The plain is composed of sand dunes and swampy areas, consisting mainly of alluvial deposits in the coastal part, and a dried plain of Pliocene and Pleistocene sediments. The width of this plain is around 50 kilometres at the center, becoming narrower toward the north and south (20 kilometres wide). The total area is approximately 6,000 km².

The hills in the central part are composed mainly of the Bemaraha-Tangorombohitr'i Makay massifs (about 225 km long and 350 to 1,035 m high), the Ankilizato massif (about 125 km long and 400 to 510 m high), and the massif and limestone plateau of Manja (approx. 125 km long, and 150 to 560 m high). These massifs and plateau extend in the northeast-southwest direction, arching eastward. They are separated by the Besabora intramountain basin (a wide valley of the Morondava River), the Maharivo River and the branches of the Tsiribihina and Mangoky Rivers. In general, these massifs form a continuous mountain chain or cuesta with a steep cliff on the eastside and a gently inclined westward slope.

The mountainous area of the eastern part of the Study Area is the western edge of the "Central Highland of Madagascar" and extends in the northeast-southwest direction, arching eastward. These mountains consist mainly of Precambrian basement rocks similar to the major central highland, and is separated from the Bemaraha-Tangorombohitr'i Makay massifs by a wide valley formed by the Sakeny and Matsiatra rivers (the Betsiriry intramountain basin).

2.1.2 Climate

The average annual maximum and minimum temperature in the coastal area are about 30° C and 11° C, respectively, while those of hilly and mountainous areas are about 33° C and 18° C. The difference between the maximum and minimum temperature is about 11° C in the coastal area and about 15° C in the hilly and mountainous areas. In general, the period

from May to September is called winter, and from October to February is summer.

Fig. 2.1 and 2.2 show the general climatic conditions such as monthly rainfall, monthly maximum, minimum and average temperatures, mean monthly relative humidity, sunshine hours and potential evaporation at Morombe and Morondava stations.

The Study Area has a five-month rainy season from November to March, and a seven-month dry season from April to October. Annual rainfall varies from 600-800 mm (south-west coastal plain) to 1400 mm (north-east mountainous area).

The monthly sunshine hours presented in the tables are the one decade average value of the 1980's. The average daily sunshine hours by month ranges from 8.56 (Feb.) to 10.50 (Nov.) in Morondava, and from 9.10 (Feb.) to 10.66 (Nov.) in Morombe.

2.1.3 Geology and Geological Structure

(1) Stratigraphy

The stratigraphy of the concerned area is presented in Fig. 2.3. Since the established stratigraphy through former geological surveys slightly differs from each other, these stratigraphic classification are also presented in the same figure for reference.

The Precambrian System is composed of hard metamorphic rocks and plutonic rocks and exposed in a limited area at the eastern margin of the Study Area. The Sakoa and Sakamena Groups of the Carboniferous and Permian periods, respectively, are in unconformable or fault contact with the Precambrian System. Of the two groups, the Sakoa Group begins with a basal tillite and is mainly composed of continental deposits, while the Sakamena Group is composed of continental deposits associated with lagoon sediments and marine deposits, indicating that the sedimentary environment changed during the sedimentation of the group.

Of the Jurassic System, the parts composed mainly of continental deposits are collectively called Isalo Group and gradually shifts into the underlying Sakamena Group. The Lower and Middle Isalo Groups consist mainly of arkose sandstone which is low in solidity and exhibit cross-bedding and conglomerate, but the Upper Isalo Group shows mixed facies of continental and marine origins. The marine Lower Jurassic System shows the contemporaneous and heterogeneous facies of the Upper Isalo Group and is composed mainly of limestone and calcareous sandstone, containing sandstone of continental origin at a considerable rate. The marine Upper Jurassic System is composed of marl (Ankilizato marl), marly limestone and alternating facies of limestone and marl.

The Cretaceous System is divided into the upper and lower subsystems, and no large time gap is inferred between the lower subsystem and the Jurassic System. The Lower

Cretaceous System begins with limestone, but is thin. The Upper Cretaceous System occupies the main part of the Cretaceous System and is composed of thick continental sandstone overlain by alternating facies of limestone and marl. The Upper Cretaceous System is interbedded with several basalt beds. Since the strata contacts with basalt beds is generally affected by thermal alteration, the basalt beds are considered to be sheets intruded into the Upper Cretaceous System. The Cretaceous System in the area is unconformably overlain by the Eocene Series.

The lower section of the Eocene Series is composed mainly of limestone and marly limestone being distributed in almost whole Study Area. The Middle and Upper Eocene Series consist of limestone, marly limestone, marl, marly sandstone, sandstone, etc.

The Eocene Series are unconformably overlain by the Neogene System.

The Neogene System is also widely distributed in the area, and is partially exposed in the eastern margin of the Morondava plain. The marine calcareous sediments probably of the Miocene, and continental facies of sandstone probably of the Pliocene are exposed sporadically.

The Quaternary System is composed of sand beds forming new and old sand-dunes, fluviatile deposits and clayey deposits including salty mud and sand in the seashore area. Although the existing geological maps have classified sandy veneer beds and rocks as members of the Quaternary System and showed their distributions, the beds and rocks were regarded as surface covering materials and excluded from the hydrogeological map and stratigraphic table prepared in the Study. In particular, the Morondava plain is widely covered by sandy veneer beds and rocks, and geological information of underground is limited to a few areas of Mahabo and Analaiva areas. In this Study, electrical resistivity sounding and test drillings were conducted, and they revealed that the main part of the Morondava plain was formed during the Pleistocene Period and was composed of sandy and muddy materials of marine and continental deposits.

(2) Geological Structure

The geological structure of this region is given in the four cross sections of Fig. 5.2 and Fig. 5.3, and is summarized below.

The upper boundary of the Precambrian basement, widely exposed in the mountainous area of the western ridge of the Central High Land of Madagascar, steeply inclines westward and is overlain by Palaeozoic and younger strata of 5,000 - 10,000 meters thick in total. Generally speaking, these strata gently dip westward (1° to 5°), and the zonal structure is disturbed by several fault systems. The area is characterized by existence of following 3 major fault systems.

The first fault system is composed of a group of N-S and NNW-SSE faults developed

in echelon at the western margin of the Precambrian basement. Since the displacements by this fault system are limited within the Precambrian basement and the Carboniferous Sakoa and Permian-Triassic Sakamena Groups, it is considered that the main activities of the fault system took place in the Palaeozoic Period.

The second fault system is the L'Ilovo-Vohitelo fault which runs through the central part of the Study Area in the direction of NNE-SSW at the southern part and in NNW-SSE at the northern part. The displacement by this fault system reaches up to the Upper Jurassic system.

The third fault system is a group of faults running in the direction of NNE-SSW and NE-SW at the western half of the hilly area. The displacement by this fault system reaches up to the Upper Eocene. The east-west alternating dip-slip faults have formed many horsts and grabens.

In the Study Area many dykes, sheets, necks and stocks of basaltic to gabbroic rocks are present and hot springs have occurred in connection with their volcanic activities. The volcanic activities may belong to the two geologic periods of the Pre-Eocene and the Post-Eocene. In general, the lithologic character of stock-type rocks is gabbroic basalt to gabbro, and its distribution is restricted in the Upper Jurassic System and the Cretaceous System. The distribution of necks and stocks is generally controlled by the third fault system of NNE-SSW and NE-SW directions mentioned above. The basalt dykes are intruded in the NW-SE, NNE-SSW and N-S directions with a width of several meters and an elongation of several kilometres to 35 km. Of the basalt dykes, the dyke of NW-SE direction intrudes all of the geological formations except the alluvial deposits, and is accompanied by hot springs.

2.1.4 Land Use and Vegetation

The land use and vegetation coverage was analyzed for the total area of about 39,000 km² by compiling a natural color image using LANDSAT TM data.

The land use classification was made by the characteristics of color on the natural color image through the digital image processing, image interpretation and by referring to the existing land use map.

The cultivated land in the Study Area, including fallow, is very limited occupying about 210 km², which is only 0.5 % of the total area.

The vegetation coverage pattern in this area is quite different in accordance with the topographic feature.

In the coastal plain, the forest coverage is nearly 70 %, which is led to good condition for groundwater recharge.

The forest area situated between Andranomena and Morofandilia has been under the management of an American voluntary group since 1983 as a water resource conservation forest.

The hilly area in the central part of the Study Area is characterized by the coverage of grasslands partially accompanied by short bushes. More than 80 % is occupied by this type of vegetation, and sporadic small forests are present sporadically and along the rivers.

The mountainous area at the eastern part is predominated by grasslands and barren land. The forest coverage is limited to the narrow area along rivers. Since the retention capacity is usually small in the grasslands or bareland, the portion of direct run-off from precipitation becomes larger resulting in flooding of the lower reaches, and a low groundwater recharge.

The classified vegetation coverage by automatic classification of the natural colour image is given below.

Table 2.1 Vegetation Coverage (Land Use) of the Study Area

Land Use	Area (Km^2)	Portion (%)
Dense forests	4,572	11.7
Sparse forests	4,412	11.3
Mangrove forests	352	0.9
Bush and grass	15,560	39.7
Grassland	12,604	32.9
Paddy field	166	0.4
Farmland including fallow	36	0.1
Plantation	13	(0.03)
Bareland	920	2.3
Swamp	170	0.4
Water body	374	1.0
Not interpreted due to clouds	4	(0)
Total	39,183 Km^2	

2.2 Socio-economic Situation of the Study Area

The local administration system has been recently revised to a new system in accordance with the national decentralization policy in Madagascar. While Fivondronana, a middle unit of local authority, remains the same just being renamed as Departemanta, ex-Faritany, an upper unit of local authority, was divided into several Faritanys, and several Firaisanas, lower units of local authority, were unified into Kaominina (Commune). Fokontany (village), a minimum administrative unit was abolished, as far as the official administration unit is concerned. In the whole nation, 6 ex-Faritanys (Antananarivo, Antsiranana, Mahajanga, Toamasina, Fianarantsoa and Toliara) are converted into 29 new Faritanys.

As a result of the new local administration system, the administrative coverage under which the study area is commanded was slightly changed. The Study area, bordered by the Tsiribihina River in the North and the Mangoky River in the South, now belongs to 2 Faritanys (Menabe and Atsimo-Andrefana) instead of Toliara ex-Faritany. The portion of the Study Area in Faritany Menabe includes 5 Departemantas (Morondava, Manja, Mahabo, Belo-Tsiribihina and Miandrivazo) with 46 Kaomininas, and the area in Faritany Atsimo-Andrefana includes 1 Departemanta (Beroroha) with 4 Kaomininas. The new administration coverage in the Study Area is shown in Table 2.2.

Although the new decentralized local administration system has been started, villages remain as the smallest communities under the leadership of unofficially nominated presidents, even if they are not presently official administrative units, implying that the development of groundwater should be planned at the village level.

2.2.1 Population

The population of the Study Area is estimated at 298,948 based on the 1993 population census, as shown below. Since a part of Belo Tshiribihina (40 %) and Miandrivazo (65 %), located to the north of the BeloTshiribihina River, is not included in the Study Area, the total population in the Study Area is estimated at 242,842 in 1992.

The population density in the Study Area is estimated at approximately 6.23 persons per square km. According to an estimate by the World Bank, the population growth rate in Madagascar was 3.03 % per annum in 1990, and it is projected that it will increase to 3.21 % per annum by 2000. However, since the population growth rate is much higher in urban areas than rural areas, the growth rate in the rural area presumably falls between 2.5 % and 3.0 %.

2.2.2 Regional Economic Characteristics

The major industry in the Study Area is agriculture except for some coastal areas, and a majority of cash income derives from agriculture. It is estimated that half of agricultural production is domestically consumed, and the rest is locally marketed to traders. Since access to markets has been poorly developed and the farmers have no means of transportation except for rudimentary vehicles, they are exploited by traders with better transportation who go to the farmers and offer lower prices. Consequently, farmers in the Study Area receive very little cash income for their produce.

Although some agro-industries such as the sugar factory in Betsipotika, rum brewery in Bezezika, tobacco factory in Malaimbandy and the salt farm in Belo-sur-mer employ wage labours, the number is limited relative to the whole regional economy.

In some villages and the coastal areas, fishery is active. However, the catches are sold only in a local market, and are not transported to big markets such as Antananarivo due to the absence of freezing storage facilities.

With its tropical beaches and its extraordinary landscape, the coastal areas such as Morondava and Belo-sur-mer capture a considerable number of tourists. However, the employment opportunities are limited to only a few specific areas.

Thus, the Study Area remains one of the poorest regions in Madagascar. According to the latest data, GDP per capita in Madagascar is estimated at FMG 532.3 thousand in 1993, which is equivalent to US$ 133.1 per capita at the current exchange rate. Meanwhile, the socio-economic survey in Chapter 6 reports that the cash income per household per annum in the Study Area is estimated at only FMG 587.8 thousand. The figure indicates that when the agricultural production for domestic consumption is also counted as non-cash income, the production is FMG 1175.6 thousand per household per annum. Consequently, the production per capita per annum in the Study Area is estimated at FMG 195.9 thousand, which is extremely low compared with the national average.

2.2.3 Infrastructure

The road network is poorly developed and has deteriorated over the past decade, with additional damage having been inflicted by Cyclone Geralda in 1994. A considerable number of dirt roads and farm feeder roads in the Study Area are impassable during rainy season. In particular, the access from Morondava to Manja is impossible due to several impassable rivers during the rainy season.

The telecommunication network in the Study Area is also limited, and communication between the Study Area and Antananarivo is very hard due to the lack of lines, which hampers economic activities in the area. A wireless communication network in case of

emergency is only available at police stations and other local government agencies.

JIRAMA (the state-owned company for electricity and water supply) is in charge of providing water and electricity services to major towns such as Morondava, Mahabo, Manja and so forth. However, the rural areas are not electrified except for the nearest villages in Morondava.

2.2.4 Tribal and Religious Issues

The people of Madagascar are of mixed African and Malay ancestry. Their forebears migrated across the Indian Ocean and intermingled with coastal Africans. Although Malagasy contains many African words, it is fundamentally a Malay-Indonesian language. It is widely believed that there are 18 ethnic groups in Madagascar. In the Study Area, Sakalava is the major ethnic group, followed by Antandroy, Betsileo, Antaisaka, Bara, Vezo, Mahafany and Antanosy. A majority of villages in the Study Area are composed of a single ethnic group, whereas several ethnic groups coexist in some villages. While traditional religion prevails among Sakalava and Antandroy, other ethnic groups mainly are Christian, including Protestant and Catholic.

2.2.5 Education

Although primary school enrollment in Madagascar is now universal in urban areas, and the adult literacy in urban areas was measured by UNICEF at approximately 80%, the people in the study area are still poorly educated except in big towns such as Morondava. The 1993 population census reported that the average adult literacy rate and the primary school enrollment rate in the Study Area were only 26.8% and 42.8%, respectively, as shown below. These low figures are due to the difficult access to primary schools and the fact that children are an important labour force for farming and are, therefore, often forced to stay home.

Adult Literacy and Primary School Enrollment in the Study Area

Name of Departemanta	Adult Literacy Rate (%)	Primary School Enrollment Rate (%)
Morondava	50.1	61.9
Mahabo	20.2	36.6
Belo Tshiribihina	29.5	48.8
Mianzrivazo	19.7	39.8
Manja	16.3	29.1
Beroroha	21.6	36.6
Total	26.8	42.8

Source: 1993 Population Census

2.2.6 Women's Activities

As is often the case with the traditional society in developing countries, women's position in the Study Area is relatively low compared with women in urban areas. The fact is that women in the Study Area seldom run for village presidency and fetching water is regarded as women's work. Although there are women's association in some villages, their activities are not so active.

2.2.7 Sanitary Environment and Health

Health conditions in Madagascar are poor, with disease and mortality patterns typical of countries at the early stages of epidemiological transition. In the Morondava area, the government hospitals are available only in major towns and some populated villages. Although there are a number of medical facilities named health care centers, the facilities have only a few medical assistants instead of a doctor. Due to the bad quality of water, the waterborne diseases such as diarrhea prevail in the Study Area, and hygiene habits such as boiling water before drinking have been poorly taught.

Table 2.2 Comparison between Old and New Administrative Units

A. Faritany Menabe		
Departemanta	Kaominina	Firaisana ao anatiny
Morondava	CU Morondava	Morondava,
	Analaiva	Analaiva
	Befatsy	Befatsy, Lavaravy-Tsiamalika
	Bemanonga	Bemanonga, Androvabe, Marofandili
	Belo-Amorondriaka	Belo Amorondriaka, Manomelimay.
Manja	Manja	Manja
	Beharona	Beharona
	Ankiliabo	Ankiliabo
	Andranopasy	Andranopasy
	Soaserana	Soaserana
	Anosibe-Sakalava	Anosibe-Sakalava
Mahabo	CU Mahabo	Mahabo
	Ankilivalo	Ankilivalo
	Ampanihy	Ampanihy
	Analamitsivalana	Analamitsivalana
	Befotaka	Befotaka
	Ankilizato	Ankilizato
	Mandabe	Mandabe
	Beronono	Beronono
	Malaimbandy	Malaimbandy
	Tsimazava	Tsimazava
Belo-Tsiribihina	CU Belo-Tsiribihina	Belo
	Tsimafana	Tsimafana
	Tsaraotana	Tsaraotana
	Masoarivo	Masoarivo
	Ankiroroka	Ankirorokaa
	Manambolo/Andimaky	Manambolo-Andimaky
	Ankalalobe	Ankalalobe
	Ambiky/Ankalalobe	Ambiky-Anakalalobe
	Berevo	Berevo
	Belinta-Soaserana	Belinta-Soaserana
	Beroboka	Beroboka
	Ambolimena	Ambolimena
	Bemarivo/Ankirondro	Bemarivo-Ankirondro
	Antsoha	Antsoha
Miandrivazo	CU Miandrivazo	Miandrivazo
	Bemahatazana	Bemahatazana
	Ampanihy	Ampanihy
	Anosimena	Anosimena
	Isalo	Isalo, Analambidy
	Belolo	Belolo
	Ankotrofotsy	Ankotrofotsy
	Ambatolahy	Ambatolahy
	Soaserana Anteramena	Soaserana-Anteramena
	Manandaza	Manandaza
	Manambina	Manambina
B. Faritany SUD-OUEST		
Beroroha	CU Beroroha	Beroroha
	Fanjakana	Fanjakana
	Behitsatsy	Behitsatsy
	Marerano	Marerano

Station : MORONDAVA Latitude : 20° 17' S Longitude : 41° 19' E Altitude : 7m

YEAR	ITEM	UNIT	JAN.	FEB.	MAR.	APR.	MAY	JUN.	JUL.	AUG.	SEP.	OCT.	NOV.	DEC.
1961-90	RAIN	(mm)	241.6	200.2	89.5	14.8	11.4	2.4	2.3	2.2	3.6	11.9	20.6	163.3
	TEMP.	Max.	31.9	31.8	32.2	31.8	30.4	29.0	28.7	29.1	29.7	30.7	31.6	31.9
		Min.	23.4	23.2	22.6	20.5	17.0	14.5	14.3	15.3	17.6	20.1	21.6	22.9
		Ave.	27.6	27.5	27.4	26.1	23.7	21.7	21.5	22.2	23.6	25.4	26.6	27.4
	HUN.	(%)	80.0	82.0	81.0	79.0	77.0	74.0	74.0	74.0	76.0	76.0	75.0	78.0
	SUN.	(h & 1/10h)	267.9	239.9	286.6	288.4	301.2	287.5	295.7	308.5	296.5	320.3	315.1	282.0
		(h & 24h/M)	8.9	8.6	9.2	9.6	9.7	9.6	9.5	10.0	9.9	10.3	10.5	9.1
	EVAP.	(mm/M)	143.7	143.7	139.5	124.8	90.0	63.9	64.7	74.9	92.5	127.1	125.0	139.5

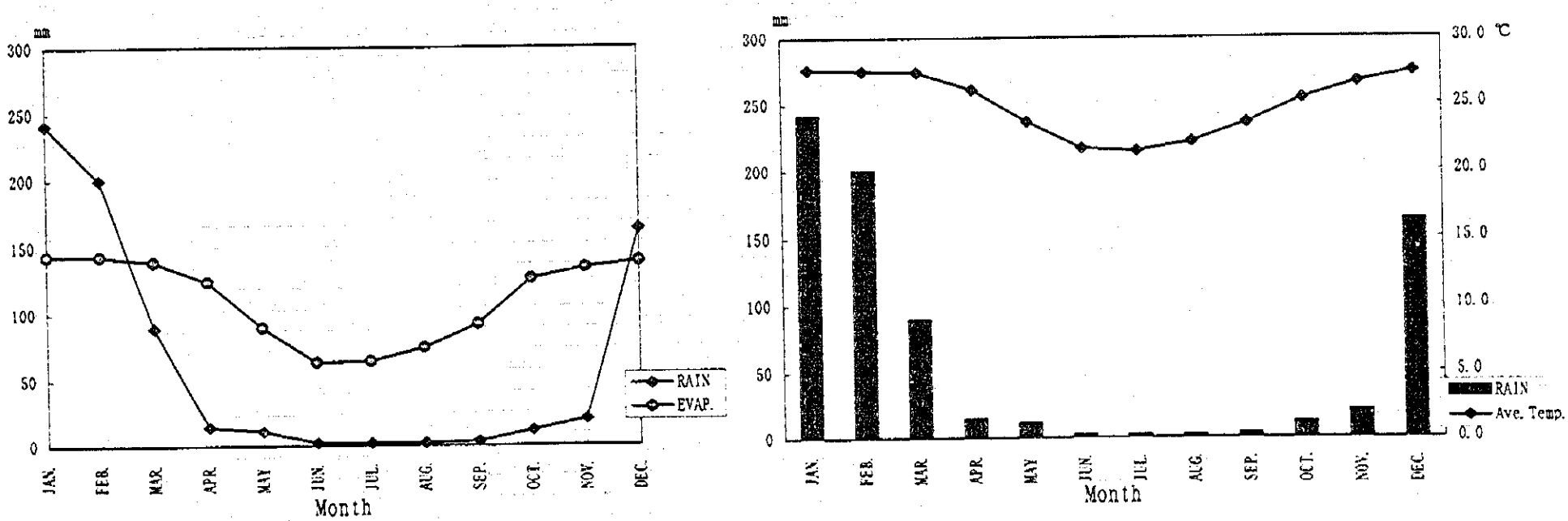


Fig. 2.1 General Climatic Condition (Morondava)

Station : MORONBE Latitude : 20° 45' S Longitude : 43° 22' E Altitude : 4m

YEAR	ITEM	UNIT	JAN.	FEB.	MAR.	APR.	MAY	JUN.	JUL.	AUG.	SEP.	OCT.	NOV.	DEC.
1961-90	RAIN	(mm)	119.4	128.7	51.7	9.9	11.6	4.3	2.0	2.8	2.6	12.6	18.3	108.8
	TEMP.	Max.	31.7	31.6	32.0	30.9	29.3	27.6	27.5	28.1	28.8	29.7	30.6	31.2
		Min.	22.9	22.9	21.8	19.7	16.5	14.2	14.0	14.6	16.2	18.5	20.2	22.1
		Ave.	26.8	27.2	26.9	25.3	22.9	20.9	20.7	21.4	22.5	24.1	25.4	26.6
	HUN.	(%)	80.0	81.0	78.0	77.0	76.0	75.0	74.0	74.0	76.0	76.0	77.0	80.0
	SUN.	(h & 1/10h)	292.9	254.8	299.6	292.5	303.9	289.6	298.3	316.5	306.6	317.8	319.7	297.7
		(h & 24h/M)	9.5	9.1	9.7	9.8	9.8	9.7	9.6	10.2	10.2	10.3	10.7	9.6
	EVAP.	(mm/M)	135.0	139.5	135.0	114.3	83.5	59.9	60.8	70.1	82.4	109.7	130.0	135.0

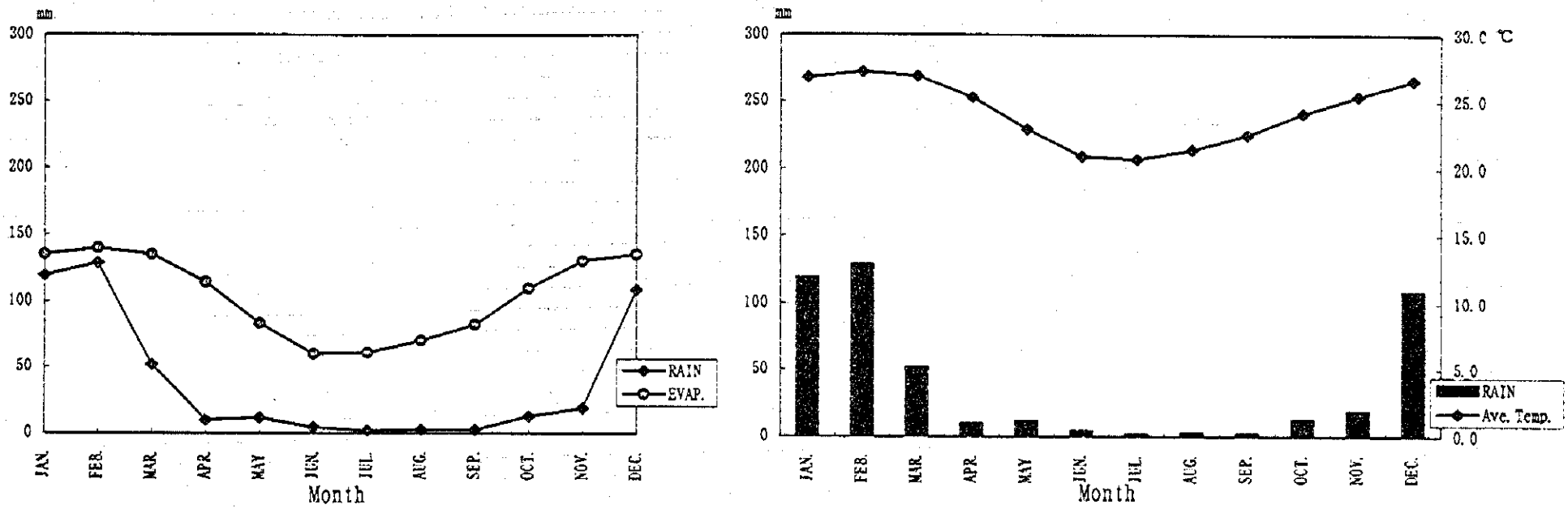


Fig. 2.2 General Climatic Condition (Moronbe)

Fig. 2.3 Stratigraphic Classificaton

Geological Time				Geological Map	1/1, 000, 000 Madagascar (1965)	1/500, 000 Morondava (1969)	1/500, 000 Ampanihy (1970)	1/250, 000 Phase I Study (1991)	
Quaternary	Alluvium				a , d	a , d^1	a , d^1	a	d
	Pleistocene				ac , d^1	ac , d^2	ac, cc, d^2, d^3	f	
Tertiar	Neogene	Pliocene			n^1	P^1	N^1	N	N^1
		Miocene			m	m	m		
	Paleogene	Oligocene							
		Eocene	Ludian		e	e^2	e^3	Emtu	
			Ledian						
			Lutetian			e^1	e^2	El	
			Ypresian						
		Paleocene					e^1		
Mesozoic	Cretaceous	Upper	Maestrichtain		C^2	C^{9-8}	C^{9-8}	Cu	
			Campanian						
			Santonian			C^7	C^{7-3}		
			Coniacian						
			Turonian		C^1	C^{6-3}		Cmtl	
			Cenomanian						
		Lower	Albian			C^1			
			Aptian						
			Neocomian			C_v			
	Jurassic	Upper	Tithonian		J^3	J^{8-5}	J^8	Ju	
			Kimmeridgian						
			Oxfordian		$I_{III}^{\triangle}$	J^{4-2}	J^4		$I_{III}^{4\triangle}$
		Middle	Callovian		J^2	J^1	J_1^1	Jm	
			Bathonian			J_{I-II} / J_{III-IV}	J_{I-IV} / I_{III}^4		
			Bajocian		I_{III}^4	I_{III}			
		Lower	Aalenian		(j^1)	I_{II}	I_{II}		I_{II}^4
			Lias		I_{II}^4	I_I	I_I		I_I^4
	Triasic				K^2	(Sakamena G.) $K^6 \sim K^4$	(Sakamena G.) K^4, K^3	PJu	
Paleozoic	Permian				K^{1b}	(Sakoa G.) $K^1 \sim K^3$	(Sakoa G.) K^2, K^1	PJl	
	Cabaniferous								
Igneous rock (Basalt)		Post Eocene			β^2	β^3	β^3	β^2	
		Pre Eocene			β^1	$\beta^1 \cdot \beta^2$	$\beta^1 \cdot \beta^2$	β^1	

(Isalo Group)

4 Continental facies sediments
△ Mixed facies sediments

3. WATER SUPPLY SECTOR

3.1 Political Strategy on Water Supply

In Madagascar, the national water supply strategy is formulated by the Water and Sanitation Committee (CNEA, Comité National de l'Eau et de l'Assainissement) under the Ministry in charge of Planning, and the coordination, orientation and follow-up of all activities related to this sector. In particular, the CNEA, by means of a restraint unit, prepares the document on national strategy for water and sanitation approved by the government in May 1995. This document stipulates the high priority of water and sanitation.

3.1.1 Global Objectives (by 2010)

To reach a 50% water supply coverage and a 35% sanitary service coverage by implementing the following measures:

- to reinforce the contribution of water sector to the improvement of public health by providing a sufficient volume of water of satisfactory quality, and improving environmental sanitation.

- to reinforce the contribution of water sector to socio-economic development by promoting the participation of the NGOs and private sector, improving coordination and follow-up, and ensuring the control of water in order to preserve the environment.

3.1.2 Operational Objectives

- *Middle-term objectives (2005-2010):*

  - Urban areas: to provide with water supply facilities to the towns that are not yet supplied, and to raise the sanitary service coverage up to 60%;

  - Rural areas: to raise the present water supply level up to 50%, and sanitary services up to 30%.

- *Short-term objectives (1997-2000):*

  - Urban areas: faced with the increasing urban concentration, to ensure the protection of water resources and preservation of the environment;

  - Rural areas: to provide the population with water of good quality.

- *For the time being (1995-1997):* to prepare the settling of various reforms planned in the 'Sectorial Strategy and Action Plan for Water and Sanitation (SSPA)', that is:

  - to redefine the role and attributions of the different contributors;

  - to stimulate the dynamism and initiative of the nation (skills and know-how);

  - to spur community participation at every stage of development of the sector.

3.2 Implementation Plan of Policies and Strategies

3.2.1 Key-Ministries

In order to improve technical coordination of actions undertaken in the water sector, the implementation of sectorial strategy shall be planned with the cooperation of key-ministries so as to achieve such actions in cooperative and systematic manner.

The SSPA shall be carried out with :

- the ministry in charge of water sector, that is, the Ministry of Energy and Mines that will lead the sub-sector of water through the Department of Water with the assistance of the Ministry in charge of rural development and all contributors of either the public or the private sector, NGOs, etc.. The responsible Ministry will be the technical counterpart of the different contributors, and will be responsible of implementation planning of the sectorial policy and strategy.

- the ministry in charge of urban development through its Department of Urban Planning that will lead the sanitation sub-sector with the support of the Ministry of Health, and the present and future contributors.

3.2.2 Present Contributors to the Sector

The organisms working with the CNEA are:

- On one hand, the ministerial departments and decentralized entities with responsibilities related to this sector:

  * Departments in charge of :
    - Planning,
    - Financing,
    - Interior affairs and Decentralization,
    - Energy and Water
    - Agriculture and Rural Development,
    - Meteorology and Hydrology,
    - Public Works and Urban Development,
    - Health
    - Population,
    - Research,
    - Environment, and

  * Decentralized administrative units.

- On the other hand, the following public organisms:
  - JIRAMA

- Operation "Water Supply in South" (OAES)
- Operation "Micro-implementation"
- Operation "Micro-Hydraulics"
- National Office for Environment (ONE)
- National Research Center for Environment (CNRE)

Besides these above organizations, there are other contributing entities such as:

- NGOs
- Enterprises in charge of studies and/or works, semi-private or private, national or international.
- Water vendors in urban areas and areas with very poor water services.

In addition, it is planned that a Public Establishment with Industrial and Commercial Characteristics (EPIC) is to undertake the operation and maintenance of the rural water supply in near future, under the control of the Ministry of Energy and Mines.

3.3 Administrative Organization and Service Coverage

3.3.1 Urban Water Supply

JIRAMA (Jiro sy Rano Malagasy), a state-owned company of Madagascar under the control of MEM, is in charge of urban water supply and electricity services mainly in urban areas. The company is financially independent from the governmental budget, and provides water supply services to 1) six major cities such as Antananarivo and Antsirabe and 2) major regional towns with populations of more than 2000. In the Study Area, for instance, JIRAMA extends its services to Morondava, Mahabo, Manja and so forth.

In addition, there are some cases that the decentralized administrative units play a central role to provide water supply services to major regional towns. According to the annual report 1993-1994 of CNEA, the number of cities and towns with water supply services under JIRAMA was 65 in 1991, while the number of cities and towns covered by local authorities was 45.

These 110 cities contain 70% of the urban population, that is, nearly 2 million people are covered by water supply services, 30% of which have house connections and 70% communal faucets.

In addition, there are other 122 cities and towns which are categorized as urban areas with a total population of about 846 thousand people. Fifteen of the 122 are chief towns of Fivondronampokontany. However, these towns are not covered by water supply services.

Consequently, the supply service coverage for urban area is 70%.

3.3.2 Rural Water Supply

The rural water supply in Madagascar has been provided by the public sector and the private sector (mostly NGO). The Department of Water under MEM is mainly in charge of the rural water supply, supported by the overseas development assistance. The following governmental organizations are also providing services to the rural areas.

1) Ministry of Welfare supplies water for the promotion of health

2) Department of Infrastructure of the Ministry of Agriculture supplies water for integrated rural development

As for the service coverage of the rural water supply for 76.7% of total population, reliable information has not been established, because of the different understandings on the definition of the water supply for the rural area. Some data even includes dug wells without protection as one type of the supply system, in spite of the bacteria contaminated water, while such wells are excluded as a supply source in other data.

According to the data provided by the DINIKA report, 12% of the rural population (9,300,000) is supplied with varying systems: public faucets, wells with or without pumps, boreholes with working hand pumps, rainpools, springs, etc.. If the rural water supply is severely defined as supplying safe and potable water, this mentioned 12% may presumably become smaller.

3.4 Water Supply Condition in the Study Area

3.4.1 Functional and Non Functional Water Supply Systems

95% of the middle to large size villages in the Study Area have at one time possessed a water supply system, for instance shallow boreholes (10-15 m) equipped with hand pump, deep boreholes (15-60 m) with motorized pump and elevated tanks and distribution system, that were provided by a USAID project in 1965.

However, all of these water supply systems, except hand pump wells in the village of Marofandilia, were broken within 3 to 5 years after construction mainly because of very poor operation and maintenance. The hand pump wells of this village have been periodically repaired by an American voluntary group. Another problem was that most of the wells were progressively abandoned by villagers because the water pumped was salty, thus villagers gradually lost their motivation for proper operation and maintenance of wells.

3.4.2 Water Sources for Domestic Use

The existing water sources of the concerned villages are dug wells, rivers, ponds,

boreholes and irrigation channels. The type of the water source by village is tabulated in Table 4.1, and the number of villages using these sources as a main water source are as follows.

-Dug well :53 villages (41 in the dry season)

-Spring :14 villages

-River :13 villages

-Irrigation Channel :5 villages

-Pond :4 villages

-Borehole :1 village

3.4.3 Water Consumption rate

The amount of water consumed for domestic use is generally very small ranging from 2 to 22 liters per capita per day, with an average of about 7 to 8 ℓ/c/d.

3.4.4 Water Quality of Existing Water Sources

93 water samples were collected from the existing water sources for domestic use and analyzed on the basis of the WHO standards using test kits owned by MEM (DREL 2,000 type). A test laboratory was established at Morondava, and the analysis work was performed by an employed analyst under the supervision of a MEM's analyst and a JICA Study Team member.

In this Study, 31 items of each sample were examined, comprising of physical and chemical components, toxins and bacteria. The water quality standards, items and methods used in this analysis, and the results are presented in Supporting Report.

Of the 93 source points, 80 are regarded as not potable or not recommended for drinking. The major undesirable elements detected were Hexavalent Chromium (Cr^{6+}), Chlorine (Cl_2) and Nitrate (NO_3). In addition, Zinc (Zn), Fluoride (F-) and Copper (Cu) were found in some areas, and are undesirable elements, too. Coliform organisms were detected at nearly 30% of the water sources, and the EC (electric conductivity) indicates generally high salinity levels in the coastal area.

More than 40 villages suffer from waterborne diseases caused mainly by drinking water. These villages are located along the coastal area where the EC is relatively high. The relationship between high EC areas and locations with high onset rates of waterborne diseases is given in the Supporting Report.

4. CATEGORIZATION OF CANDIDATE VILLAGES

4.1 Criteria and Procedure for Categorization

In order to decide the development priority for the 115 candidate villages in the Study Area, the categorization of the villages were made through following 3 steps.

Pre-screening is carried out as the first step. This concerns accessibility by 1) four-wheel drive vehicles, assessing the accessibility to villages for survey, and by 2) well drilling machines, assessing the accessibility to villages for well construction. As shown in Table 4.1 (1~4), 25 candidate villages are not accessible or were not found in the expected locations, and that 9 candidate villages are not accessible by well drilling machines. Consequently, it was concluded that 81 candidate villages remained for further categorization and prioritization.

The second step is the categorization of all the accessible candidate villages regarding water requirement, where the water requirement of each village is assessed in terms of the kind of existing water sources and the observers' evaluation in the inventory survey. As a result, the villages have been classified into Category A (absolute shortage of water), Category B (shortage of water) and Category C (no shortage of water). This is also tabulated in Table 4.1.

The third step is the categorization of all the accessible villages to assess their socio-economic capacities, where the economic capacities of each village are precisely assessed in terms of economic, social and institutional capacities which are evaluated in the inventory survey. As a result, the villages have been classified into Category A (higher economic capacity), Category B (average economic capacity) and Category C (lower economic capacity). This classification is presented in the right hand column of Table 4.1.

Paying special attention to the combination of the categorizations by water requirement and socio-economic capacity, the accessible villages were categorized into AA, AB, BA, BB, AC, CA, BC, CB and CC. The inventory data as well as the data from the population census 1993 and the socio-economic survey were employed as the basis for the categorization and prioritization.

Table 4.1 Accessibility and Categorization of the Village (1/4)

Village		Population	Accessibility		Existing Water Source	Distance to Water Source	Categorization	
No.	Name		4WD	Drilling Machine	Type		Necessity of Water Development	Economic Capacity for O & M
1	Andranopasy I	623	Possible but poor in wet season	Possible at present	Dug well	50 m	B	A
2	Andranopasy II	226	Possible but poor in wet season	Need for partial reform of road	Dug well	700 m	A	C
3	Antaly	327	Possible but poor in wet season	Need for partial reform of road	Pit on the riverbed	1,200 m	A	B
4	Darika	327	Possible but poor in wet season	Need for partial reform of road	Dug well	300 m	A	C
5	Befamonty	450	Possible but poor in wet season	Need for partial reform of road	Dug well	900 m	A	A
6	Ambatobe	220	Possible but poor in wet season	Need for partial reform of road	River	1,500 m	A	C
7	Nositonga	260	Possible but poor in wet season	Need for partial reform of road	Dug well	200 m	A	B
8	Nosibe	600	Possible but poor in wet season	Need for partial reform of road	River	600 m	A	B
9	Ankoba	410	Possible but poor in wet season	Need for partial reform of road	Spring	600 m	A	A
10	Antseranandaka N.	342	Possible but poor in wet season	Need for partial reform of road	Dug well	100 m	A	B
11	Tsaramandroso	237	Possible but poor in wet season	Need for partial reform of road	Dug well	1,000 m	A	C
12	Songary	36	Possible but poor in wet season	Need for whole reform	Spring	500 m	—	—
13	Piste de Bedo	—	No existence	—	—	—	—	—
14	Tanambahiny	131	Possible but poor in wet season	Possible at present	Pit on the riverbed	300 m	B	C
15	Miary	365	Possible but poor in wet season	Possible at present	Canal from spring	700 m	B	B
16	Ambivy I	130	Possible but poor in wet season	Possible at present	Pit on the riverbed	600 m	A	B
17	Ambivy II	500	Possible but poor in wet season	Possible at present	River	300 m	A	B
18	Ambahia	200	Possible but poor in wet season	Need for partial reform of road	Dug well	0 m	B	B
19	Besatrohaka	210	Possible but poor in wet season	Need for partial reform of road	Sallow pit	0 m	A	C
20	Marolafika Atm.	500	Possible but poor in wet season	Need for partial reform of road	Sallow pit	50 m	A	B
21	Ambalavato Nord	Not available	No access	No access	Not available information	—	—	—
22	Andranomena	Not available	No access	No access	Not available information	—	—	—
23	Marerano	1,100	Possible but poor in wet season	Need for partial reform of road	Dug well	200 m	A	A
24	Ambondrobe	Not available	No access	No access	Not available information	—	—	—
25	Befasy	2,000	Possible but poor in wet season	Possible at present	Protected dug well	0 m	A	A
26	Antevamena	360	Possible but poor in wet season	Need for partial reform of road	River	400 m	A	B
27	Mitsitiky	340	Possible but poor in wet season	Need for partial reform of road	Dug well	300 m	A	B
28	Andranovorisosotra	40	Possible but poor in wet season	Need for partial reform of road	Dug well	300 m	A	C
29	Ankitatamahavelo	190	Possible but poor in wet season	Need for partial reform of road	Borehole	500 m	A	C

Table 4.1 Accessibility and Categorization of the Village (2/4)

Village		Population	Accessibility		Existing Water Source Type	Distance to Water Source	Categorization	
No.	Name		4WD	Drilling Machine			Necessity of Water Development	Economic Capacity for O & M
30	Bekininy Soarano	400	Possible but poor in wet season	Need for partial reform of road	Dug well	30 m	A	C
31	Beleo	800	Possible but poor in wet season	Need for partial reform of road	Canal	50 m	A	A
32	Anadabo	36	Possible but poor in wet season	Need for partial reform of road	Protected dug well	400 m	C	C
33	Misokotsa	800	Possible but poor in wet season	Need for partial reform of road	Protected dug well	0 m	B	B
34	Croise. Besotroka	200	Possible but poor in wet season	Possible at present	Dug well	10,000 m	A	B
35	Amanga	400	Possible but poor in wet season	Possible at present	Dug well	300 m	A	C
36	Namakia	400	Possible but poor in wet season	Need for partial reform of road	Dug well	300 m	B	B
37	Voloe	144	Possible but poor in wet season	Need for whole reform	Dug well	500 m	—	—
38	Benasy	180	Possible but poor in wet season	Need for whole reform	Dug well	500 m	—	—
39	Antsamaka	150	Possible but poor in wet season	Need for partial reform of road	Pond	1,000 m	A	B
40	Manomentimay	436	Possible but poor in wet season	Possible at present	Protected dug well	300 m	B	A
41	Farateny	250	Possible but poor in wet season	Possible at present	Dug well	0 m	A	B
42	Ianadabo	Not available	No access	No access	Not available information	—	—	—
43	Andrananja	70	Possible but poor in wet season	Need for partial reform of road	Dug well	400 m	A	C
44	Belo Sur Mer	1,100	Possible but poor in wet season	Need for whole reform	Dug well	0 m	—	—
45	Ankilifolo	400	Possible but poor in wet season	Need for whole reform	Dug well	500 m	—	—
46	Marofihitsa	750	Possible but poor in wet season	Possible at present	Protected dug well	0 m	A	A
47	Ambararata	500	Possible but poor in wet season	Possible at present	Protected dug well	100 m	B	B
48	Ankevo	300	Possible but poor in wet season	Possible at present	Protected dug well	0 m	B	B
49	Ambivy	—	No existence	—	—	—	—	—
50	Bevantaza	150	Possible but poor in wet season	Need for partial reform of road	Protected dug well	0 m	B	C
51	Lavaravy Tsimaliha	Not available	No access	No access	Not available information	—	—	—
52	Antsakamirohaka	1,600	Possible	Need for partial reform of road	Protected dug well	0 m	B	A
53	Androvakely	550	Possible	Need for partial reform of road	Dug well	0 m	B	A
54	Androvabe	Not available	No access	No access	Not available information	—	—	—
55	Ampananiha	420	Possible	Need for partial reform of road	Dug well	150 m	A	B
56	Antseranambondro	60	Possible	Need for partial reform of road	Pond	800 m	A	C
57	Tanambao	Not available	No access	No access	Not available information	—	—	—
58	Bemanonga	1,250	Possible	Possible at present	Protected dug well	500 m	B	A

Table 4.1 Accessibility and Categorization of the Village (3/4)

Village		Population	Accessibility		Existing Water Source Type	Distance to Water Source	Categorization	
No.	Name		4WD	Drilling Machine			Necessity of Water Development	Economic Capacity for O & M
59	Marovoay	1,247	Possible	Possible at present	Dug well	0 m	B	A
60	Tandrokosy	238	Possible but poor in wet season	Possible at present	Canal	150 m	A	B
61	Bekonazy	40	Possible	Possible at present	Dug well	0 m	A	C
62	Bevoliengo	100	Possible	Need for whole reform	Pond	500 m	—	—
63	Kimony	Not available	No access	No access	Not available information	—	—	—
64	Andranomena Ats.	210	Possible	Possible at present	River	200 m	A	B
65	Tanandava	250	Possible	Possible at present	Sallow pit	100 m	A	C
66	Croisement BST	204	Possible	Possible at present	Protected dug well	300 m	B	B
67	Analaiva	1,520	Possible	Possible at present	Dug well	0 m	A	A
68	Betsipotika	120	Possible	Possible at present	Dug well	0 m	A	B
69	Amboloando	150	Possible	Possible at present	Sallow pit	400 m	A	C
70	Ampandra	600	Possible	Possible at present	Protected dug well	0 m	B	B
71	Besonjo	—	No existence	—	—	—	—	—
72	Antevamena II	100	Possible	Possible at present	Dug well	0 m	B	C
73	Belobaka	250	Possible	Need for whole reform	Dug well	0 m	—	—
74	Tsinjorano	450	Possible	Possible at present	Protected dug well	0 m	B	B
75	Betsinefo	—	No existence	—	—	—	—	—
76	Laijoby Avaratra	150	Possible	Possible at present	Dug well	500 m	A	B
77	Ambinda	—	No existence	—	—	—	—	—
78	Sarodrano	—	No existence	—	—	—	—	—
79	Ambonio	270	Possible	Possible at present	Dug well	0 m	A	C
80	Analalava	300	Possible	Possible at present	Dug well	0 m	A	C
81	Malandirano	400	Possible	Need for partial reform of road	Protected dug well	100 m	B	B
82	Marofandiliha	370	Possible	Possible at present	Hand pump	0 m	B	A
83	Ampataka	695	Possible	Need for partial reform of road	Pond	200 m	A	B
84	Bosy	Not available	No access	No access	Not available information	—	—	—
85	Kivalo	Not available	No access	No access	Not available information	—	—	—
86	Ampatike	Not available	No access	No access	Not available information	—	—	—
87	Ambato Andrana	Not available	No access	No access	Not available information	—	—	—

Table 4.1 Accessibility and Categorization of the Village (4/4)

Village		Population	Accessibility		Existing Water Source Type	Distance to Water Source	Categorization	
No.	Name		4WD	Drilling Machine			Necessity of Water Development	Economic Capacity for O & M
88	Andrahangy	Not available	No access	No access	Not available information	—	—	—
89	Ankaracbato	800	Possible	Need for partial reform of road	Protected dug well	0 m	B	A
90	Tanambao Fe	—	No existence	—	—	—	—	—
91	Andranolava	—	No existence	—	—	—	—	—
92	Betsiriry	650	Possible	Need for whole reform	Sallow pit	0 m	—	—
93	Beroboka Atm	783	Possible	Possible at present	River	200 m	A	A
94	Ankilivalo	2,960	Possible	Possible at present	Protected dug well	0 m	B	A
95	Ambohibary	300	Possible	Need for partial reform of road	Sallow pit	300 m	A	C
96	Bevoay	521	Possible	Need for whole reform	Dug well	0 m	—	—
97	Bezezika	855	Possible	Possible at present	River	500 m	A	A
98	Tanandava II	Not available	No access	No access	Not available information	—	—	—
99	Ankilimida	600	Possible	Possible at present	Dug well	300 m	A	A
100	Ampanihy	742	Possible but poor in wet season	Need for partial reform of road	Sallow pit	300 m	A	B
101	Benato	500	Possible but poor in wet season	Need for partial reform of road	Pond	800 m	A	B
102	Anolotsy	300	Possible but poor in wet season	Need for partial reform of road	Dug well	200 m	A	B
103	Ankilizato	4,200	Possible	Possible at present	River & Water vender	50 m	A	A
104	Mandabe	2,000	Possible	Possible at present	Canal & Water vender	100 m	A	A
105	Beronono	Not available	No access	No access	Not available information	—	—	—
106	Malaimbandy	7,000	Possible	Possible at present	River & Water vender	1,000 m	A	A
107	Ampanotoka	900	Possible but poor in wet season	Need for partial reform of road	Sallow pit	300 m	A	A
108	Tsimazava	Not available	No access	No access	Not available information	—	—	—
109	Tsianaloka	1,000	Possible	Possible at present	Pond	400 m	A	A
110	Kiboy	930	Possible	Possible at present	Pond	300 m	A	A
111	Croisement Antsoha	—	Abandoned	—	—	—	—	—
112	Tsimafana	1,500	Possible	Possible at present	Dug well	100 m	B	A
113	Mananjaky	1,170	Possible	Need for partial reform of road	Protected dug well	0 m	B	A
114	Ambatolahy	800	Possible	Possible at present	River & Water vender	800 m	A	A
115	Ankotrofotsy	908	Possible	Possible at present	River	100 m	A	A

5. SURVEY FOR GROUNDWATER DEVELOPMENT

5.1 Hydrology

Fig. 5.1 represents the outline of the precipitation in the Study Area, and the results of discharge measurement.

5.2 Hydrogeology

In order to evaluate the groundwater resource potential in the Study Area, a hydrogeological map (1/250,000) was prepared, accompanied by the hydrogeological cross sections and vertical sections. The map represents the groundwater development potential by area based on the comprehensive analysis of existing relevant data and materials, satellite image and aerial photographs, geological and hydrogeological field surveys, geophysical prospecting, test drilling and pumping test, water quality analysis, and macroscopic water balance analysis.

As shown in this hydrogeological map, the potential for groundwater development in the Study Area is generally high, except some portion of the particular lithological or topographical conditions.

The groundwater potential in the Study Area is expected to be sufficient in capacity not only to supplement water supply shortages but also to meet the demand for the development of local agricultural or industrial activities, particularly on the Morondava plain.

The Study Area is situated in the Morondava groundwater basin that is enclosed by the seashore of the Mozambique Channel in the west, the Tsiribihina and Mangoky rivers in the north and south and the western edge of the Central High Land of Madagascar in the east.

The geological structure of the groundwater basin is presented in the regional geological cross sections (Fig. 5.2, 5.3) and vertical sections (Fig. 5.4).

Macroscopic water balance analysis by the major groundwater basin was conducted and the results tabulated in the following Table 5.1.

Table 5.1

Basin	Area (km²)	Daily Groundwater Development Potential by basin (m³/day)	Daily Groundwater Development Potential by km² (m³/km²/day)
Morondava Plain	6,006	5,689,932	947
Andranomena River basin	882	499,151	566
Morondava River Basin (1)	667	170,983	253
Morondava River Basin (2)	3,885	850,229	219
Sakeny River Basin	2,183	443,808	203
Maharivo River Basin (1)	602	106,085	176
Maharivo River Basin (2)	2,299	411,565	179
Kirindy River basin	1,050	301,927	288
Maintapaka River Basin (1)	397	123,884	312
Maintapaka River Basin (2)	364	102,487	282
Mangoky River Basin (1)	1,301	490,816	377
Mangoky River Basin (2)	3,173	1,347,004	424

The test drilling and pumping tests were conducted in order to confirm the lithological formation and aquifer characteristics, and the results are listed in Tables 5.2 and 5.3.

Table 5.2 Result of Test Drilling Wells

No.	Village	Drilling Depth (m)	Well Depth (m)	Static Water Level (m)	Dynamic Water Level (m)	Draw Down (m)	Total Screen length (m)	Pumping Rate (ℓ/min.)	Specific Capacity (ℓ/min./m)	Transmissibility T=1.22Sc (ℓ/min.)	EC (25) (μs/cm)
109	Tsianaloka	73	71.67	17.180	-	-	60.00	-	-	-	5,230
		22	20.82	13.175	14.490	1.315	3.95	69	52.5	64.1	2,335
93	Beroboka Atm.	75	75.00	6.220	12.230	6.010	23.70	500	83.2	101.5	650
64	Andranomena A.	78	74.00	+1.800	1.530	3.330	27.65	402	120.7	147.3	846
67	Analaiva	73	70.90	3.700	4.810	1.110	35.55	715	644.1	785.8	214
97	Bezezika	48	41.75	7.802	8.640	0.838	23.70	930	1,109.8	1,354.0	210
25	Befasy	63	63.00	5.570	9.980	4.410	39.50	560	127.0	154.9	364
47	Ambararata	73	72.00	2.950	5.210	2.260	35.55	767	339.4	414.1	751
46	Marofihitsa	87	73.50	4.500	-	-	51.35	480	-	-	18,890
		38	37.20	4.120	4.480	0.360	19.75	524	1,455.6	1,775.8	6,840
1	Andranopasy I	30	29.50	7.160	12.485	5.325	15.80	137	25.7	31.4	2,000
103	Ankilizato	170	170.00	22.080	-	-	36.00	300	-	-	2,150
104	Mandabe	103	44.00	9.800	13.900	4.100	21.00	320	78.0	95.2	324
106	Malaimbandy	-	-	-	-	-	-	-	-	-	-
114	Ambatolahy	96	93.00	13.410	24.270	10.860	21.00	350	32.2	39.3	343

Table 5.3 Result of Pumping Test Analysis

No.	Village	Transmissibility (m^2/day)				Specific Capacity	T=1.22Sc
		Jacob	Theis	Recovery	Average		
						(m^3/day/m)	(m^2/day)
109	Tsianaloka	–	–	106.00	106.00	75.60	92.23
93	Beroboka Atm.	–	–	34.70	34.70	119.81	146.17
64	Andranomena A.	–	–	–	–	173.81	212.05
67	Analaiva	–	–	897.00	897.00	927.50	1,131.55
97	Bezezika	–	–	1,256.00	1,256.00	1,598.11	1,949.69
25	Befasy	–	–	1,109.00	1,109.00	182.88	223.11
47	Ambararata	–	–	898.00	898.00	488.74	596.26
46	Marofihitsa	–	–	738.00	738.00	2,096.06	2,557.19
1	Andranopasy I	–	–	347.00	347.00	37.01	45.15
103	Ankilizato	1.33	3.17	1.07	1.86	2.63	3.21
104	Mandabe	68.70	229.00	109.00	135.50	112.32	137.03
106	Malaimbandy	–	–	–	–	–	–
114	Ambatolahy	19.20	29.18	19.20	22.50	46.37	56.57

Station météorologique

Meteorologic Station

763.8 Pluviométrie annuelle moyenne (mm)

Mean Annual Rainfall (mm)

---700--- Isohyètes (mm)

Rainfall Contour Line (mm)

Bassin fluvial

River Basin

Débit de base (m³/sec)

Base Flow (m³/sec)

(1) Plaine de Morondava
Morondava Plain

(2) Delta de Mangoky
Mangoky delta

(3) Delta de Tsiribihina
Tsiribihina Delta

(4) Bassin du fleuve Tsiribihina
Tsiribihina River Basin

(5) Bassin du fleuve Andranomena
Andranomena River Basin

(6) Bassin du fleuve Morondava
Morondava River Basin

(7) Bassin de la rivière Sakény
Sakeny River Basin

(8) Bassin du fleuve Maharivo
Maharivo River Basin

(9) Bassin du fleuve Kirindy
Kirindy River Basin

(10) Bassin du fleuve Maintapaka
Maintapaka River Basin

(11) Bassin de la rivière Mangoky
Mangoky River Basin

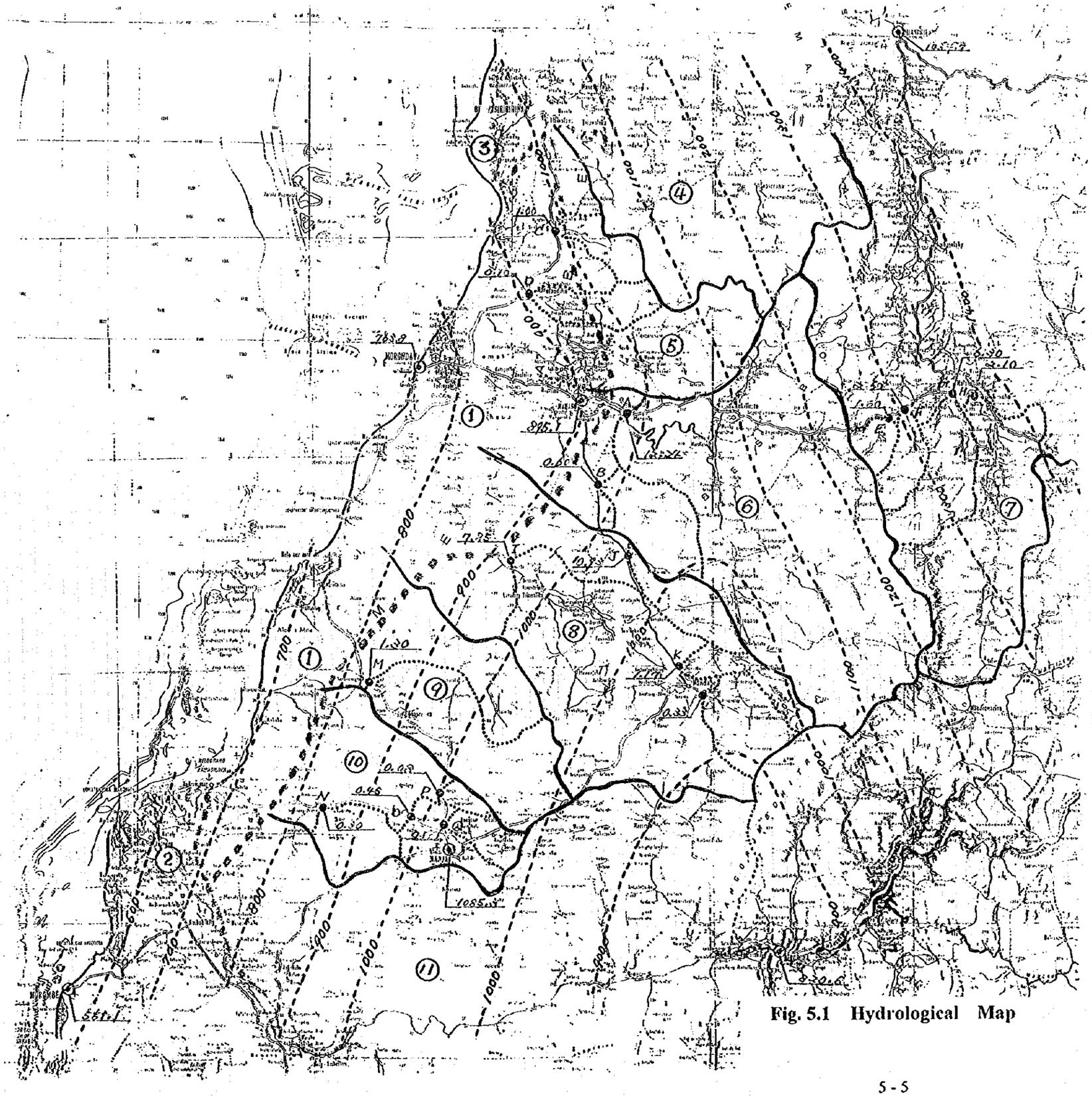
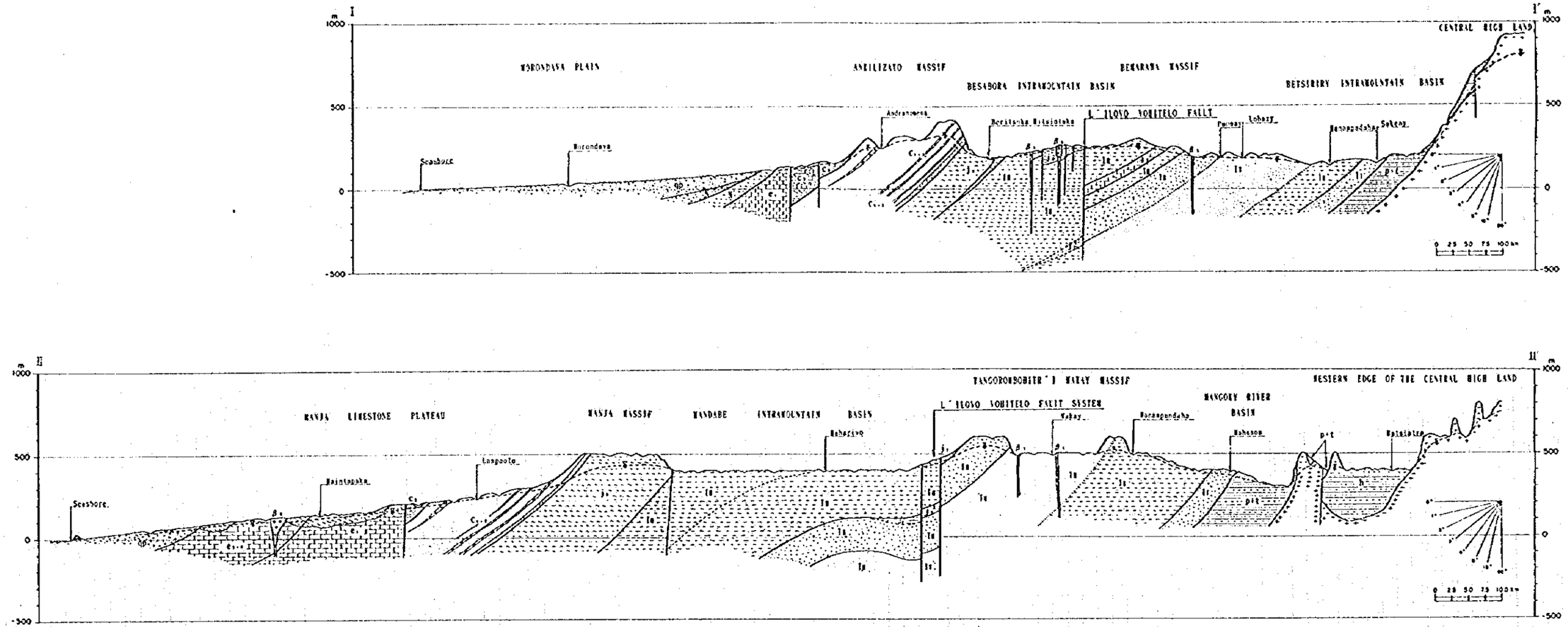


Fig. 5.1 Hydrological Map



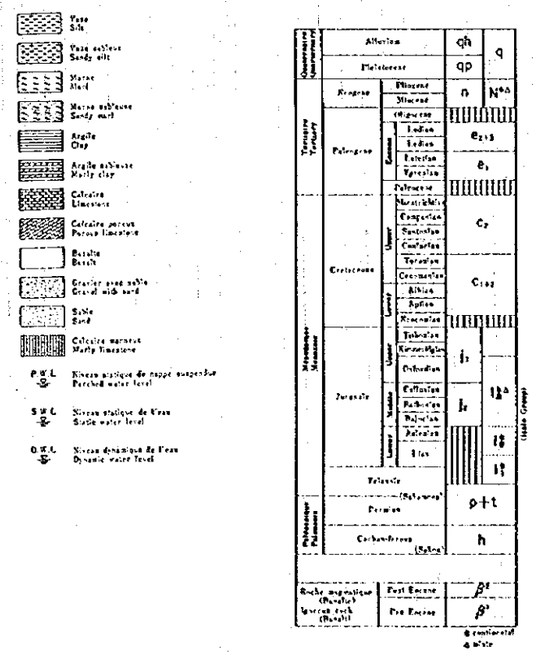
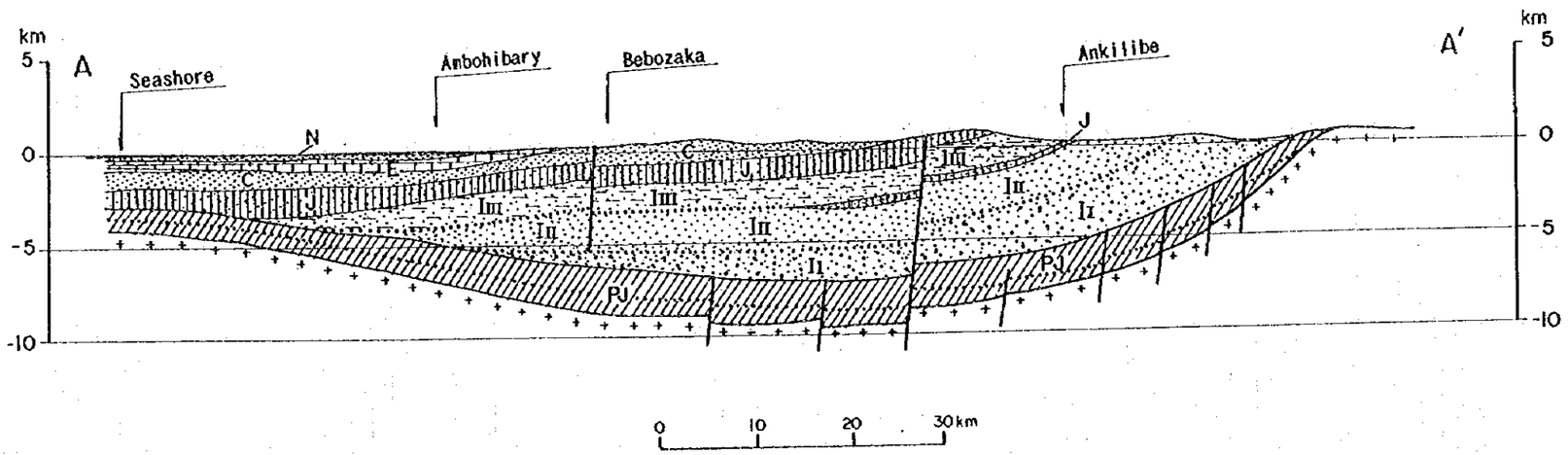
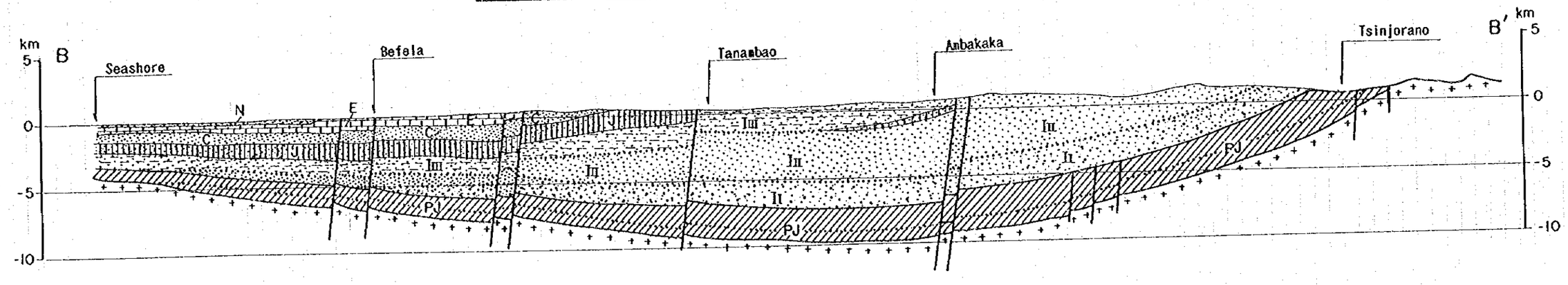


Fig. 5.2 Regional Geological Cross Section

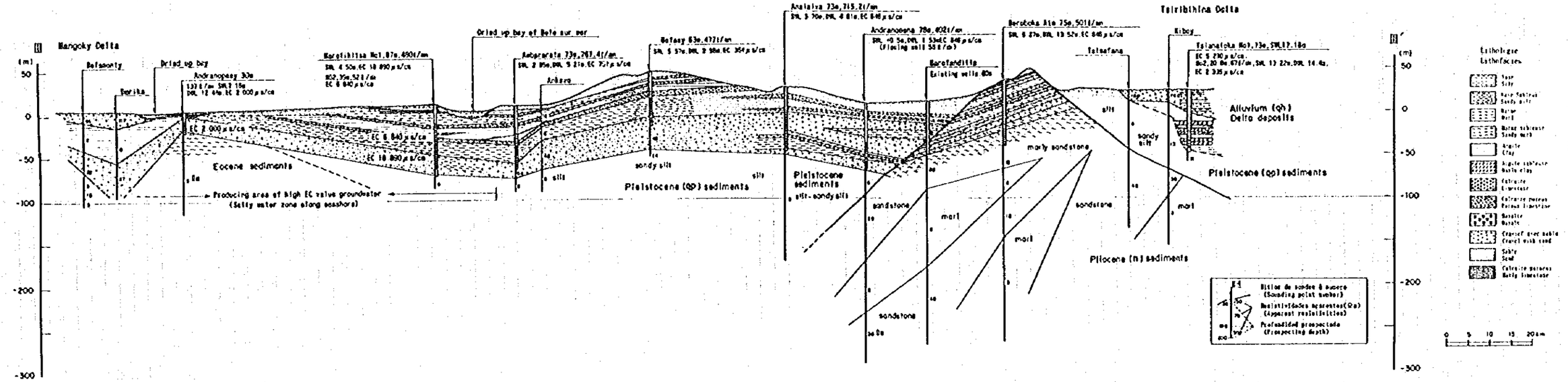




N Neogene
E Eocene
C Cretaceous
J Jurassic
Im Upper Isalo
Ii Middle Isalo
Ir Lower Isalo
PJ Sakamena Sakoa Pre-Jurassic
Pre-Cambrian

After "Géologie de Madagascar" (partially modified)

Fig.5.3 Hydrogeological Cross Section



Coupe hydrogéologique verticale de la plaine de Morondava
Hydrogeological Vertical Section of the Morondava Plain

Fig.5.4 Hydrogeological Vertical Section of the Morondava Plain

6. SURVEY FOR DETAILED SOCIO-ECONOMY

6.1 Overall Socio-economic Survey

The overall socio-economic survey was conducted in the previous stage of the Study in order to obtain basic socio-economic data for the project evaluation. The basic method employed was direct interviews held with 60 households randomly sampled in 30 selected villages. The list of the surveyed villages is as per Table 6.1. The survey was conducted on various socio-economic indicators: *1)* basic profiles, *2)* revenue and expenditure, *3)* water requirement and *4)* sanitation and medical services. The major findings of the survey are as follows.

The basic profile includes the number of family members, adult literacy, and primary school enrollment. The number of family members ranges from 3 to 13, and the average is approximately 6.0 persons. The average adult literacy rate is 25.6 % in Malagasy, and the average primary school enrollment is 38.6 %, indicating that the education level of the Study Area is much lower than the national average of Madagascar.

The level of the economy is measured by three criteria. The first criterion is the cash revenue per household per annum. The average of the samples is FMG 587.8 thousand per household per annum. A major part of this amount derives from the cash income from the marketing of agricultural products. The adjusted average income per capita per annum of FMG 195.9 thousand, after counting the same amount of non-cash income and being divided by the average size of a family of 6.0, is much lower than the average GDP per capita FMG of 532.3 thousand in Madagascar.

The second criterion is the expenditure per household per annum. It is observed that 95.6% of all the annual expenditure is for the daily necessities, and very little is invested on farming to improve agricultural productivity. It clearly shows that the Study Area remains a subsistence economy.

The third criterion is the cash balance per household per annum. The sample households with positive cash balances were only 11.7 %, and the average amount of the balances was only FMG 55,200 per annum. The balance, if any, is usually not invested on farm improvements but saved for future purchases of cattle.

In order to estimate the cash income level of all the accessible villages, the correlation between the level of cash income and population was analysed, as shown in Figure 6.1. The result shows that the level of cash income highly correlates to population with the correlation coefficient (R) of 0.7577.

In connection with the kind of existing water sources, 23.3 % of the sample households answered that their water source was inadequate, such as rivers, canals and ponds. As regards to the amount of water available, the average amount of water shortage, which is expressed in the form of the difference between the necessary amount of water and the actual amount of water available, is estimated at 35.5 liters per household per day, indicating that there are difficulties to meet the consumption demand for water, especially during dry seasons.

As for the quality of water, 45.0 % of sample households complains that the quality of water is poor, 35.0 % of them have responded that it is fair, and only 20.0 % regarded the quality as good. However, it is often the case that villagers evaluate the quality of water only in terms of its taste.

The average distance to the nearest water sources is 350 m, which forces villagers to be inconvenienced by fetching water. The maximum distance to an existing water source is 1 km. In summary, the statistics show that the development of water resources is urgently needed in the Study Area in every aspect.

The onset rates of the major waterborne diseases such as diarrhea, typhoid, amibiasis, hepatitis and other parasitic diseases were collected to obtain the information for the disease impact analysis in the economic evaluation. For example, the average onset rate of diarrhea, one of the major waterborne diseases, is an alarming 73.3 %, indicating that the poor quality of water in the Study Area causes the diarrhea.

The access to hospitals with doctors is very poor with the average distance to the nearest hospital being 10.5 km. Even if hospitals are accessible, there is no sufficient amount of medicines available, further, villagers cannot afford to buy medicines that are available. The sanitary education in the Study Area is lax. The data shows that only 23.4 % of the sample households responded that sanitary education had been conducted by some official organizations.

6.2 Survey on the Villages for the Pilot Project

In the latter stage of the Study, a more precise socio-economic survey was conducted in the 6 villages of the pilot project (Ambararata, Andranomena, Analaiva, Beroboka Sud, Bezezika and Tsianaloka). The objective of this specific survey is to collect the statistically meaningful information on the willingness to pay and the affordability to pay for the operation and maintenance of the facilities.

The willingness to pay (hereinafter referred to as WTP) is a maximum amount of operation and maintenance fee which villagers are willing to pay without sacrificing present expenditure. On the other hand, the affordability to pay (hereinafter referred to

as ATP) is the minimum amount which villagers are capable of paying with sacrificing present expenditure.

Direct interviews were conducted for the survey. In order to obtain statistically meaningful data, 15 sample households each, totaling 90 samples, were interviewed. The interviews were conducted individually so interviewees could not be influenced by other interviewees.

Table 6.2, Figure 6.2 and Figure 6.3 summarize the statistical data for the willingness to pay and the affordability to pay in the 6 pilot project villages. The mean ATP of the whole group of villages were estimated as shown below as well as the 95% interval of the mean.

Mean and 95% Interval of ATP in 6 Pilot project Villages

Unit: FMG per household per month

Name of Village	Minimum Mean	Mean ATP	Maximum Mean
Ambararata	484.85	1033.33	1581.81
Andranomena	863.05	1166.67	1470.29
Analaiva	486.20	866.67	1247.14
Beroboka Sud	507.90	966.67	1425.44
Bezezika	563.62	970.00	1376.38
Tsianaloka	596.53	1016.67	1436.81

It could be observed that while the mean ATP of the sample households ranges from FMG 866.7 to FMG 1166.67 per household per month, it is 95% probable that in the whole group of villages the mean ATP would range from FMG 484.85 at minimum to FMG 1581.81 at maximum per household per month. In other words, it is highly probable that the mean ATP exists at a certain point between FMG 484.85 and FMG 1581.81. Thus, it can be safely concluded that that villagers can pay at least about FMG 500 per household per month as the operation and maintenance fee for water supply facilities.

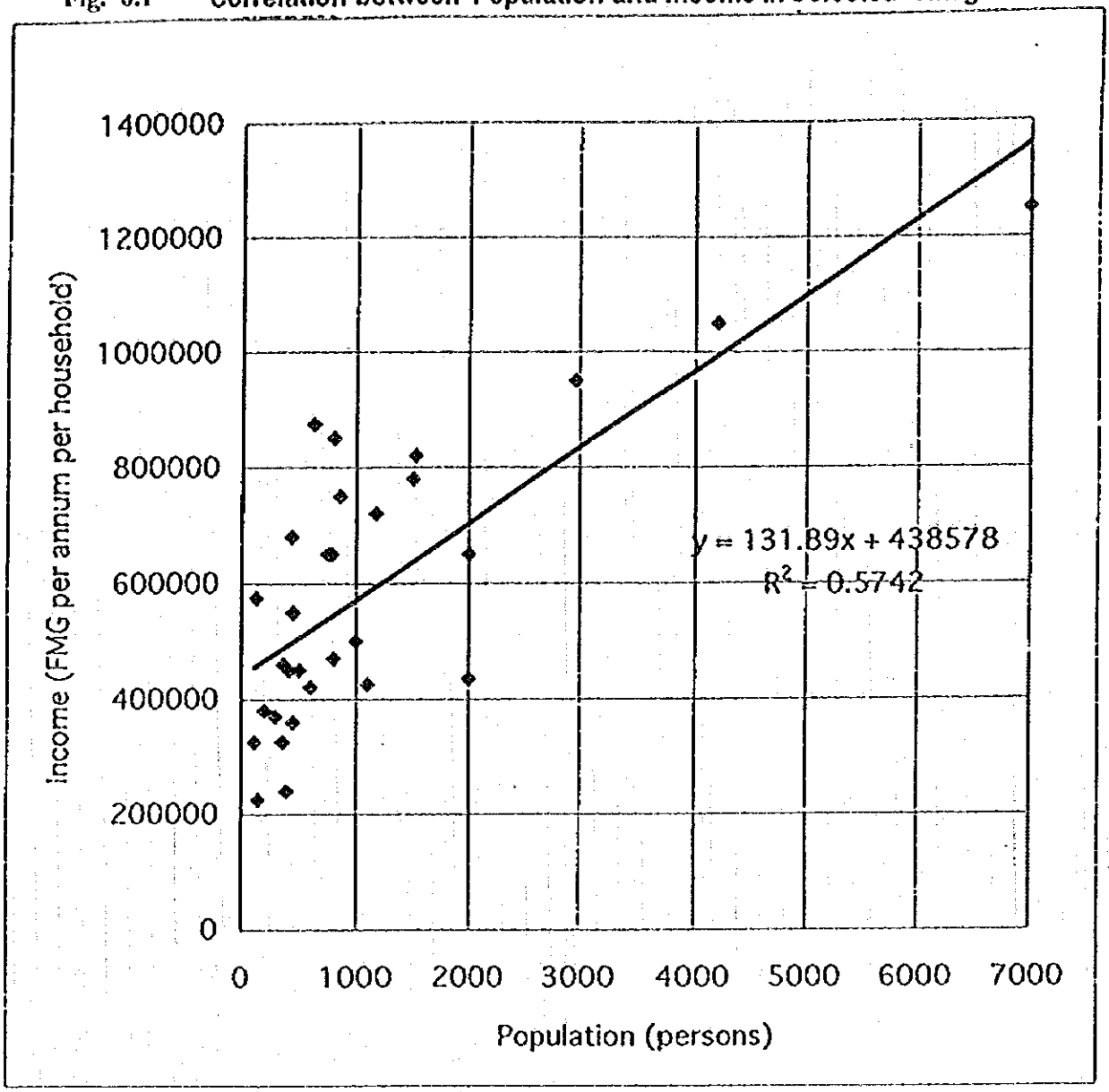
Table 6.1 Correlation between Population and Income in Selected Villages

No.	Fivondronana	Firaisana	Village	Population	Income
1	Manja	Andranopasy	Andranopasy I	623	875000
5	Manja	Andranopasy	Bafamonty	450	550000
15	Manja	Manja	Miary	365	325000
16	Manja	Ankiliabo	Ambivy I	130	575000
25	Morondava	Befasy	Befasy	2000	650000
33	Morondava	Befasy	Misokotsa	800	470000
35	Morondava	Laijoby	Amanga	400	240000
40	Morondava	Manomentinay	Manomentinay	436	680000
44	Morondava	Belo-Sur-Mer	Belo-Sur-Mer	1100	425000
46	Morondava	Belo-Sur-Mer	Marofihitsa	750	650000
47	Morondava	Belo-Sur-Mer	Ambararata	500	450000
48	Morondava	Belo-Sur-Mer	Ankebo	300	370000
64	Morondava	Bemanonga	Andranomena Sud	414	450000
66	Morondava	Bemanonga	Croisement (BST)	204	380000
67	Morondava	Analaiva	Analaiva	1520	820000
68	Morondava	Analaiva	Betsipotika	120	325000
69	Morondava	Analaiva	Amboloando	150	225000
70	Morondava	Analaiva	Ampandra	600	420000
74	Morondava	Analaiva	Tsinjorano	450	360000
82	Morondava	Marofandiliha	Marofandiliha	370	460000
93	Morondava	Marofandiliha	Boraboka Sud	783	650000
94	Mahabo	Ankilivalo	Ankilivalo	2960	950000
97	Mahabo	Ankilivalo	Bezezika	855	750000
103	Mahabo	Ankilizato	Ankilizato	4200	1050000
104	Mahabo	Mandabe	Mandabe	2000	435000
106	Mahabo	Malaimbandy	Malaimbandy	7000	1250000
109	Belo sur Tsiribihina	Tsianaloka	Tsianaloka	1000	500000
112	Belo sur Tsiribihina	Tsimafana	Tsimafana	1500	780000
113	Belo sur Tsiribihina	Tsimafana	Mananjaky	1170	720000
114	Miandrivazo	Ambatolahy	Ambatolahy	800	850000

Table 6.2 Stastical Summary for WTP and ATP in Pilot Project Villages

Stastical Items	Ambararata		Andranomena		Analaiva	
	WTP	ATP	WTP	ATP	WTP	ATP
Mean	2000.00	1033.33	2433.33	1166.67	2066.67	866.67
95% Confidence Interval	1009.26	548.48	685.20	303.62	1426.79	380.47
Standard Error	470.56	255.73	319.47	141.56	665.24	177.39
Median	1000.00	500.00	2000.00	1000.00	1000.00	500.00
Mode	1000.00	500.00	2000.00	1000.00	500.00	250.00
Standard Deviation	1822.48	990.43	1237.32	548.27	2576.45	687.04
Variation	3321428.57	980952.38	1530952.38	300595.24	6638095.24	472023.81
Range	5500.00	2750.00	4000.00	2000.00	9500.00	1750.00
Minimum	500.00	250.00	1000.00	500.00	500.00	250.00
Maximum	6000.00	3000.00	5000.00	2500.00	10000.00	2000.00
Number of Samples	15	15	15	15	15	15
Stastistical Items	Beloboka Sud		Bezezika		Tsianaloka	
	WTP	ATP	WTP	ATP	WTP	ATP
Mean	1966.67	966.67	2166.67	970.00	2066.67	1016.67
95% Confidence Interval	932.94	458.77	794.73	406.38	766.32	420.14
Standard Error	434.98	213.90	370.54	189.47	357.29	195.89
Median	1500.00	500.00	2000.00	500.00	2000.00	1000.00
Mode	500.00	500.00	2000.00	500.00	2000.00	1000.00
Standard Deviation	1684.66	828.44	1435.10	733.83	1383.79	758.68
Variation	2838095.24	686309.52	2059523.81	538500.00	1914880.95	575595.24
Range	4500.00	2250.00	4500.00	2250.00	4500.00	2750.00
Minimum	500.00	250.00	500.00	250.00	500.00	250.00
Maximum	5000.00	2500.00	5000.00	2500.00	5000.00	3000.00
Number of Samples	15	15	15	15	15	15

Fig. 6.1 Correlation between Population and Income in Selected Villages



Revolution Stastics		Revolution Analysis			
R	0.7577	Y=aX+b	Coefficient	Standard Error	t Value
R2	0.5742	b Value	438577.7832	38619.7235	11.3563
Revised R2	0.5589	a Value	131.8900	21.4656	6.1443

Fig. 6.2 Estimated WTP based on 95% Confidence Interval

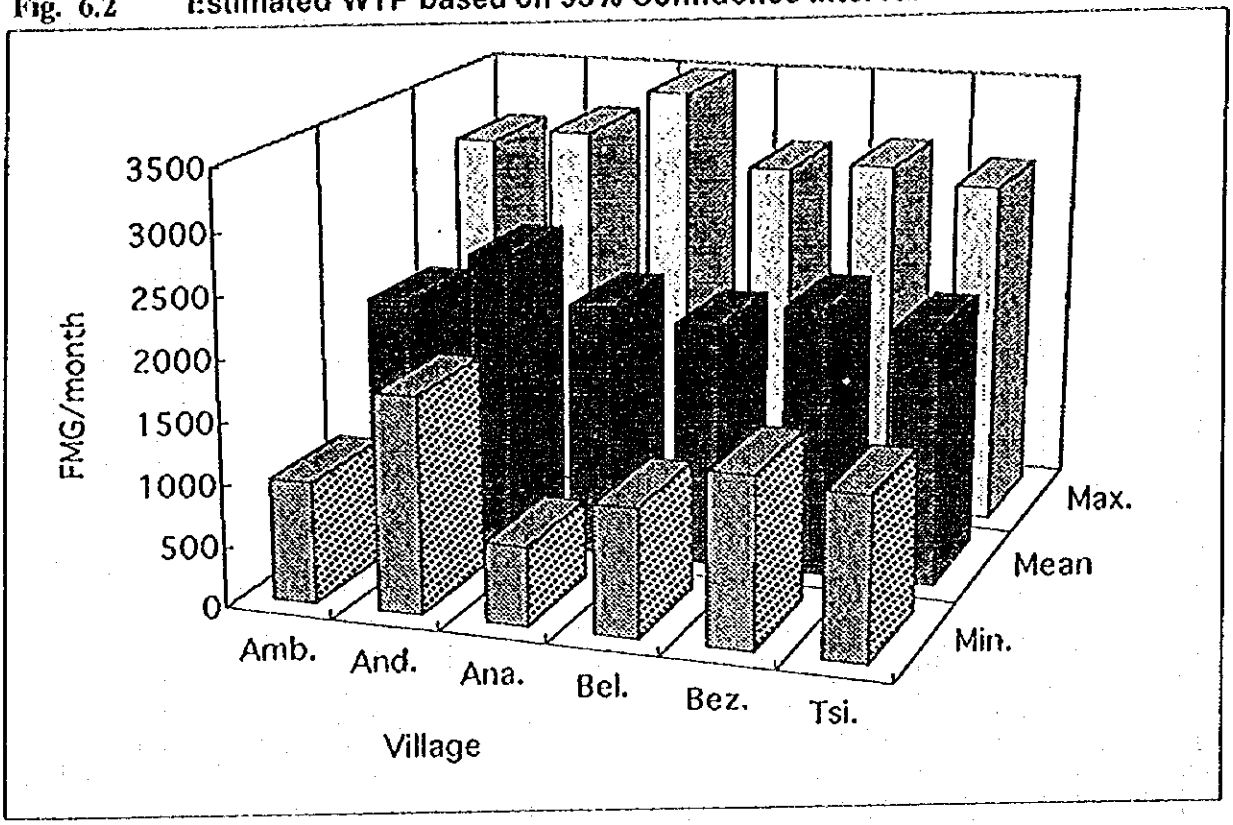
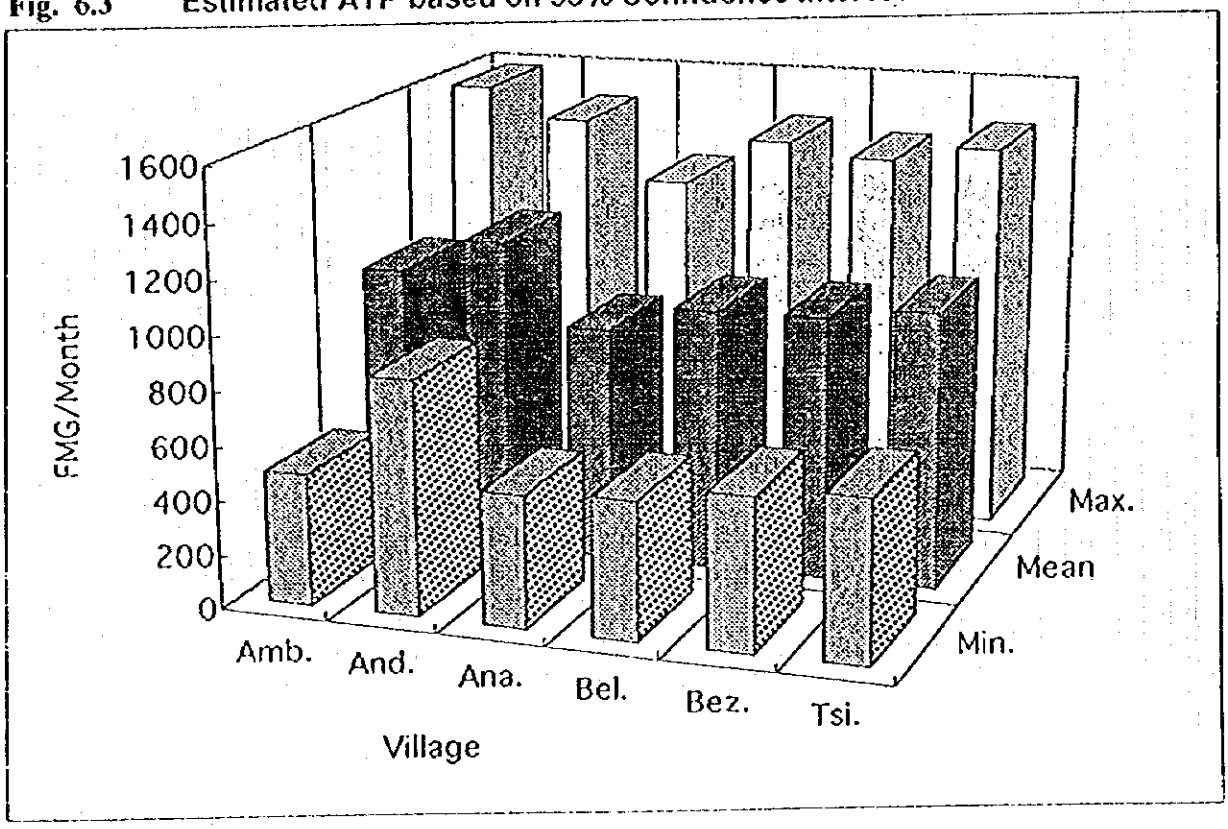


Fig. 6.3 Estimated ATP based on 95% Confidence Interval



7. EVALUATION SURVEY ON PHASE - I PROJECT

The purpose of the evaluation survey on the Phase I Project was to draw lessons from the following for the Phase II Study:

- Whether the type and scale of the supply facility is appropriate, especially for the villages where water supply facilities have never existed.
- Whether the willingness to pay for the supply services has been fully established in this area.
- Whether the water association established in each of the project implemented village is functioning adequately (technically and administratively).
- Whether the sanitary environment as well as the sense of sanitation have been improved by the service of potable water supply.
- Whether the regional office of MEM and the local authorities have extended sufficient facility maintenance services.
- Whether the women's social status has improved in this area through participation of water associations as administrative members.

7.1 Existing Condition of the Phase I Project Facilities

In the Phase I Project area, that is the southern half of the proposed project area, 50 sets of water supply facilities were constructed in the selected 50 villages from 1993 to 1995 under the Japan's grant aid program.

The facilities constructed are :

- 2 or 3 borehole wells in each village with a hand pump in 12 villages, and
- Simple water supply systems comprising of a borehole well with motorized pump, generator house, distribution tank, branch type distribution pipeline, and communal faucets in 38 villages.

Of the 50 villages, 28 villages were visited during the early stage of the Study in order to observe the facilities in operation, functioning of the water association, and how the facilities are being maintained.

The apparent operation and maintenance condition of each village is tabulated in Table 7.1, and the typical findings are as follows:

a) The general trend of water use indicates little increase in the water consumption rate. In many of the villages, the inhabitants seem to prefer to consume smaller amounts of

water and thus make smaller payments rather than the amount they would like to use. Whereas the supply systems are designed to distribute 20 liters per capita per day by 6-hours pumping, the majority of motor pumps are operated only 1 to 2 hours a day, in order to save the cost of diesel. This means that the average daily supply amount per person is limited to only 3 to 7 ℓ/c/d, resulting in little improvement in water use, so far as quantity is concerned.

b) The technology transfer on how to operate the diesel engine generator to the person in charge of daily facility operation has been done well, and there is little problem with the facility operation, so far as the technical aspects of the daily operation are concerned.

c) With regard to the facility maintenance, however, some problems have appeared a short time after the facility construction. For example, damaged taps or broken down hand pumps have not been immediately repaired due to the difficulty in obtaining parts, and probably due to the old habit of fetching water from distant water sources, therefore, they do not mind collecting water from further taps or wells so long as the remaining taps or wells are present in the village.

d) The maintenance services from the Toliara regional office of MEM or from the local authorities are not adequate. The periodical patrol service of the MEM Toliara office has not been extended to cover the whole Project area.
Moreover, countermeasures are not taken immediately, ignoring the request of the villagers for the inspection or repair of the troubled parts. This is due to a lack of man - power and budget of MEM for O/M.

e) In some of the villages, the water supply operation was suspended during the rainy season because there was plenty of water in the streams and ponds nearby.
Many inhabitants preferred to use water as before refusing the burden for operation costs, thus operation of supply facilities was forced to be suspended during the rainy season. This fact suggests that the sense of sanitation has not been fully established in these areas, due to lack of continuous efforts on extension activities.

f) Women's participation in the management of water associations is believed to be very effective in the improvement of the status of women. Based on this, vigorous efforts to enlighten women were done during the course of the study and the construction period. However, only 4 of the 28 water associations have female executive members. Such a low female participation as executive members was simply explained by the fact there were "no requests for candidacy from women".

7.2 Lessons for Phase II Study

Taking due consideration of the findings in the Phase I Project, special attention was paid to improving the study methodology and approach especially for the Pilot Project and the detailed socio-economic survey of the Phase II Study. Also, in formulation of the Phase II Project, the type of supply facility was determined while carefully considering low-cost and easy maintenance. The following lessons are applied to the Phase II Study.

1) The willingness to pay and the amount the villagers are able to pay, declared by the villagers before implementation of the project, are not always the same after provision of the water supply facility. The actual ability to pay was surveyed through a detailed socio-economic survey. Trials on the establishment of the willingness to pay were made through repeated discussions with the villagers in the Pilot Project.

   The importance of safe water use even in the rainy season was emphasized in these discussions.

2) Through the village inventory survey and the Pilot Project, women's participation in the water supply management was strongly suggested from the viewpoints of better management, and improvement of women's social status.

3) In order to achieve independent operation by the villagers, and to make maintenance easier and the costs lower, the hand pump well facilities have been planned for all villages with a population smaller than 800. Also, solar powered systems are planned to be introduced in the villages where fuel supply is difficult.

4) A reinforcement of the maintenance service organization of MEM, including the establishment of a Morondava branch office, has been strongly suggested to MEM.

Table 7.1 Condition of Water Supply in Phase I Project Area

Name of Village (Population 1995)		Facility type and Number of H/P wells or Communal faucets		Condition of the facilities, as of May 1995			Remarks
				NO. of damaged wells or faucets	Generator operation hours per day	Water charge collection rate (%)	
Ambalamoa	1,180	M/S	6F	3F	0	0	Totally not working caused by battery exhaustion
Tsianihy	1,630	M/S	10F	0	4～5	100	Fairly good O/M
Namatoa	880	M/S	6F	3F	2～3	80	Damaged faucets are left unrepaired
Mangolovolo	1,760	M/S	10F	2F	2	70～80	No money collection during rainy season
Andranomanintsy	1,650	M/S	10F	3F	1(2h/2d)	60～70	Very short operation period
Analamisampy	890	H/P	3W	1W	—	100	No spare parts for damaged pump
Antseva	940	H/P	3W	0	—	100	Fairly good
Ankatrakatora	540	H/P	2W	0	—	100	Fairly good
Ambondro	1,170	H/P	3W	3W	—	0	No countermeasures until the last well stopped working
Andranohinary	2,070	M/S	12F	0	1～2	100	Comparatively good
Sakaraha	4,510	M/S	18F 26F	0 10	Zone(1) 1.5 Zone(2) 2	75 100	(1) Fairly good (2) Frequent tap damages
Ankazoabo	3,440	M/S	24F	2F	3	90	No saving for maintenance cost due to small charge of FMG1000
Belitsaka	1,510	M/S	8F		1(2h/2d)	100	Small amount of water is equally shared
Ampasikibo	2,290	M/S	12F	2F	3.5	100	Fairly good
Namaboha	1,730	M/S	10F	0	1.5	75	Partial supply
Ampihamy	1,680	M/S	10F	0	1.5	100	Partial supply
Beroroha	2,600	M/S	14F	3F	1(2h/2d)	100	Fund shortage for longer operation (FMG 1000)
Antomarify	1,380	M/S	8F	0	0.5(1h/2d)	100	Fund shortage for longer operation (FMG 1000)
Manombo-Atm	3,440	M/S	18F	8F	1.5(3h/2d)	100	Poor maintenance caused by fund shortage (FMG 500)
Ankaraobato	2,120	M/S	12F	0	0.8(2.5h/3d	80	Shortage of O/M fund
Benetsy	2,290	M/S	12F	0	2	100	2 taps have been extended by the villagers themselves
Ankiliberengy	1,700	M/S	10F	0	0.3(1.5h/5d	100	Intentional small supply
Befoly	990	M/S	6F	0	2	100	Fairly good
Anjapirahalahy	500	M/S	2F	0	4	100	Fairly good
Besakoa (2)	1,380	M/S	8F	1F	0.7(2h/3d)	100	Insufficient supply
Andamasiny-Vineta	630	M/S	4F	0	0.4(2.5h/week)	100	Insufficient supply
Analamary	1,150	M/S	6F	6F	2	100	Water use by operating valves without repair of faucets
Ankilimalinika	4,410	M/S	24F	8F	0	0	No operation as battery was stolen

M/S : Motorized System, H/P : Hand Pump Wells

8. PILOT PROJECT

8.1 Objectives and Contents of the Pilot Project

The Pilot Project was carried out with the following objectives:

1) Promotion of the participation of women

As is generally the case with water supply projects including the construction of wells, water associations are organized by the local inhabitants. However, the selected association members consist solely of men in many cases, though most of the water is used by women. Even if women are included, their role is usually limited to sanitation and cleaning around the well. There are many pumps which remain broken without any maintenance work. It is considered that women should be deeply involved with the maintenance work, since collecting water is their work and they benefit most from safe water, thus the participation of women in the water associations is crucial. Therefore, this point was emphatically promoted during the Pilot Project.

2) Education of the inhabitants on sanitation issues

What is important is not only to supply potable water, but to improve the inhabitants knowledge of sanitation. A sound knowledge of the importance of safe potable water will make them move positive about operation and maintenance of the water supply facilities.

3) Technical transfer for the operation and maintenance of the water supply facilities

Ideally, troubles with the facilities should be repaired by the villagers while receiving technical assistance from MEM. In order to repair simple troubles by themselves, the villagers should understand the workings of their water supply facility in order to be able to deal with it.

Six villages were previously selected for the Pilot Project from the 13 villages where test drilling was carried out. The 6 villages were divided into two groups: Group A (Tsianaloka, Beroboka Sud and Andranomena) and Group B (Bezezika, Analaiva and Ambararata). However, pilot facilities were constructed in four villages only. In Andranomena, the test drilling hit a confined aquifer, resulting in a self-flowing well. Though a concrete base was constructed, a pump was not installed. In Ambararata, the construction work was postponed until the next dry season, because the water level rose in Kabatomena River and made crossing impossible.

In the two villages of Group A, Tsianaloka and Beroboka Sud, the villagers prepared materials such as gravel, sand and water for the concrete base, then installed the pump to the well under the instructions of the Study Team. In the two villages of Group B,

Bezezika and Analaiva, the facilities were installed by the Study Team without full participation of the villagers but only with the mechanics from the Water Association.

Enlightenment of inhabitants to organize a water association for the management of water supply was conducted with sanitary education in six villages by means of two posters and a cartoon donated by UNICEF: a poster on cleanliness and operation of the pump, a poster showing the future of the village with a pump, and a cartoon the organization of the villagers and sanitary education.

8.2 Activities for the Pilot Project

The activities taken by the Study Team at the villages for the Pilot Project are as follows:

1) Discussion with the village president
2) Meeting with the village primary school teachers
3) Meeting with women
4) Meeting with men
5) Sanitary seminar for school children.
6) Meeting with the village president after the villagers' conference.
7) Discussion with the Water Association

The meeting with women was held first to show that the role of women in this Project is very important. In the meetings with women and men, the Study Team encouraged the villagers to select women at least as accountant and sanitary coordinator. The Study Team also informed the villagers that, with the regular collection of charges for the Fund, there would be sufficient reserves not only to repair the pump but to contribute towards the welfare of the village. Therefore, it was proposed to use a portion of the Fund for other things for the village; for example, a loan system and a pharmacy system.

The posters donated by UNICEF were very effective in explaining the concept of sanitation and to illustrate an ideal life with a hand pump well. Villagers showed great interest in them and the presidents of the villages requested copies. Demonstration of microbe analysis of water using litmus papers was also effective in exemplifying the contamination of water from rivers, marshes and dug wells. Villagers were interested in the results of analysis, especially in the results of dug wells.

Microbes including coliforms were detected in all water sources of the six villages. Particularly, more microbes were found in most of the dug wells than in rivers and streams. The surroundings of dug wells must be kept clean in order to impede the intrusion of microbes.

8.3 Monitoring of the Pilot Project

Monitoring work of the Pilot Project was conducted in February 1996, in accordance with the following contents, and the monitoring results are presented in Tables 8.1 and 8.2.

1) Interview with the board members of the Water Association
   a. Number of the households taking water from the facility?
   b. How far is the furthest house from the facility?
   c. Did they prepare the list of the members paying the Fund?
   d. Have the villagers agreed to use the pump and continue to pay their contribution for the Fund even during the rainy season?
   e. In case the Project is further implemented in this village, is it possible to maintain several similar facilities?
2) Observation and measurement
   a. Is the surrounding area of the facility preserved clean?
   b. Do the villagers use the drained water, and for what purpose?
   c. Measurement of water consumption
3) Interview with pupils of primary schools and collection of the list of sick pupils checked for one month.
4) Evaluation of the Water Associations
   a. Are they properly organized, and do the presidents of the Associations show good leadership skills?
   b. Do the villagers acknowledge the importance of safe drinking water, as advocated by the Water Association?
   c. Do they keep accounts?
   d. Do they know how to contact MEM or the local authorities in case of troubles with the pump?
5) Comparison of the two groups; two villages where the handpump was installed with the participation of the villagers (Group A) and two villages where the handpump was installed by the Study Team (Group B).

Table 8.1 Monitoring and evaluation in the villages (February 1996)

	Group A		Group B	
	Tsianaloka	Beroboka Sud	Bezezika	Analaiva
1 Conditions of the handpump	Handpump has been broken since Jan. 1, 1996 after one month of use.	Good	Axle bolt of the lever in the hand-pump broke after 1.5 month of use.	Axle bolt of the lever in the hand-pump was broken.
1.1 If not good, did you try to repair it?			Yes, but couldn't. Bolt was replaced by Sues Garage.	Yes. Bolt was replaced but did not fit. The repair has been asked to SIRANALA.
2 Distance of the furthest house from the pump			600 m	300 m
3 Fence around the pump	Fully completed with gate and lock	Fully completed with gate and lock	Under construction	Not completed
4 Draining canal		Waste water is drained to the road	Not good	Not good
5 Use of drained water		Not used	Not used. Plan for vegetable garden in dry season	Not used.
6 Other water source to be used	None	Mandroutra River	Dabara canal, Mandcha River, SAGRIM	Dabara canal, dug wells (for washing and bathing)
7 Need for other facilities		---	another 3 handpumps	another 6 handpumps
8 Bookkeeping				
8.1 List of participants	Made	Made	Made	Made
8.2 Number of participants	142 persons over 18 years old	56 households	125 households	13 households
8.3 Amount of the Fund	500 FMG	500 FMG	500 FMG	500 FMG
8.4 Period of collection of the Fund	Oct.'95 (all members) - Oct.'96 (25 members)	Oct. - Dec. '95	Nov. - Dec. '95	Dec. '95
8.5 Total amount of the Fund (FMG)	224,000	13,500 (-3,500 for woods of the fence)	50,900 (-20,000 for repair)	5,000
9 Remarks:				
9.1 Sanitary conditions around the pump	Clean	Clean	Not clean	Not clean
9.2 Activities of the Water Association	Very good	Not good	Very good	Not good
9.3 Leadership of the President	Very good	Not good	Very good	Not good
9.4 Collection of the Fund	Very good	Not good	Good	Not good

Table 8.2 Summary of the differences among four Pilot Project villages

	Group A		Group B	
	Tsianaloka	Beroboka Sud	Bezezika	Analaiva
Living conditions				
Other water sources (condition in the dry season)	spring 400m away (reduced)	stream 200m away (stable)	6 dug wells, stream & canal 500m away (stable)	many dug wells, canal 500 m away (stable)
Teachers of the primary school	1	1	5	15
Teachers of the secondary school	0	0	0	7
Organizations	0	2 [1)]	5 [2)]	3 [3)]
Averaged annual income per house (FMG)	500,000 - 600,000	350,000 - 450,000	500,000 - 600,000	700,000 - 800,000
Meeting with the Study Team (during the field survey)				
Women attendants	20	8	50	19
Men attendants	10	12	16	27
Water Association				
President	woman	man	woman	man
Leadership of the president	Very good	Not good	Very good	Not good
Women board members	3	2	4	2
Activities of Water Association	Very good	Not good	Very good	Not good
Fence around the pump	Completed	Completed	Under construction	Not completed
Ratio of participation	43.4 %	46.7 %	87.4 %	3.1 %
Members who have contributed at least 500 FMG	142	12	125	13
Total contribution as of February (FMG)	224,000	17,000	70,900	5,000

[1)] Agricultural Association, Christian Association
[2)] Agricultural Association, Christian Association, 6 Women's Water Associations, YMCA, YWCA
[3)] Agricultural Association, Agricultural Water Management Association, Sport Club (Football)