MINISTRY OF IRRIGATION AND WATER DEVELOPMENT
THE REPUBLIC OF MALAWI

BASIC DESIGN STUDY REPORT
ON
THE RURAL WATER SUPPLY PROJECT
IN WEST OF MZIMBA DISTRICT
IN
THE REPUBLIC OF MALAWI

JANUARY, 1997

JAPAN INTERNATIONAL COOPERATION AGENCY
JAPAN ENGINEERING CONSULTANTS, CO., LTD.

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PREFACE

In response to a request from the Government of the Republic of Malawi, the Government of Japan decided to conduct a basic design study on the Rural Water Supply Project in West of Mzimba District and entrusted the study to the Japan International Cooperation Agency (JICA).

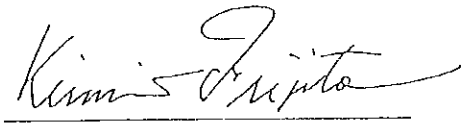
JICA sent to Malawi a study team from August 25 to October 3, 1996.

The team held discussions with the officials concerned of the Government of Malawi, and conducted a field study at the study area. After the team returned to Japan, further studies were made. Then, a mission was sent to Malawi in order to discuss a draft basic design, and as this result, the present report was finalized.

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 Malawi for their close cooperation extended to the teams.

January, 1997



Kimio Fujita
President
Japan International Cooperation Agency

January, 1997

LETTER OF TRANSMITTAL

We are pleased to submit to you the basic design study report on the Rural Water Supply Project in West of Mzimba District in the Republic of Malawi.

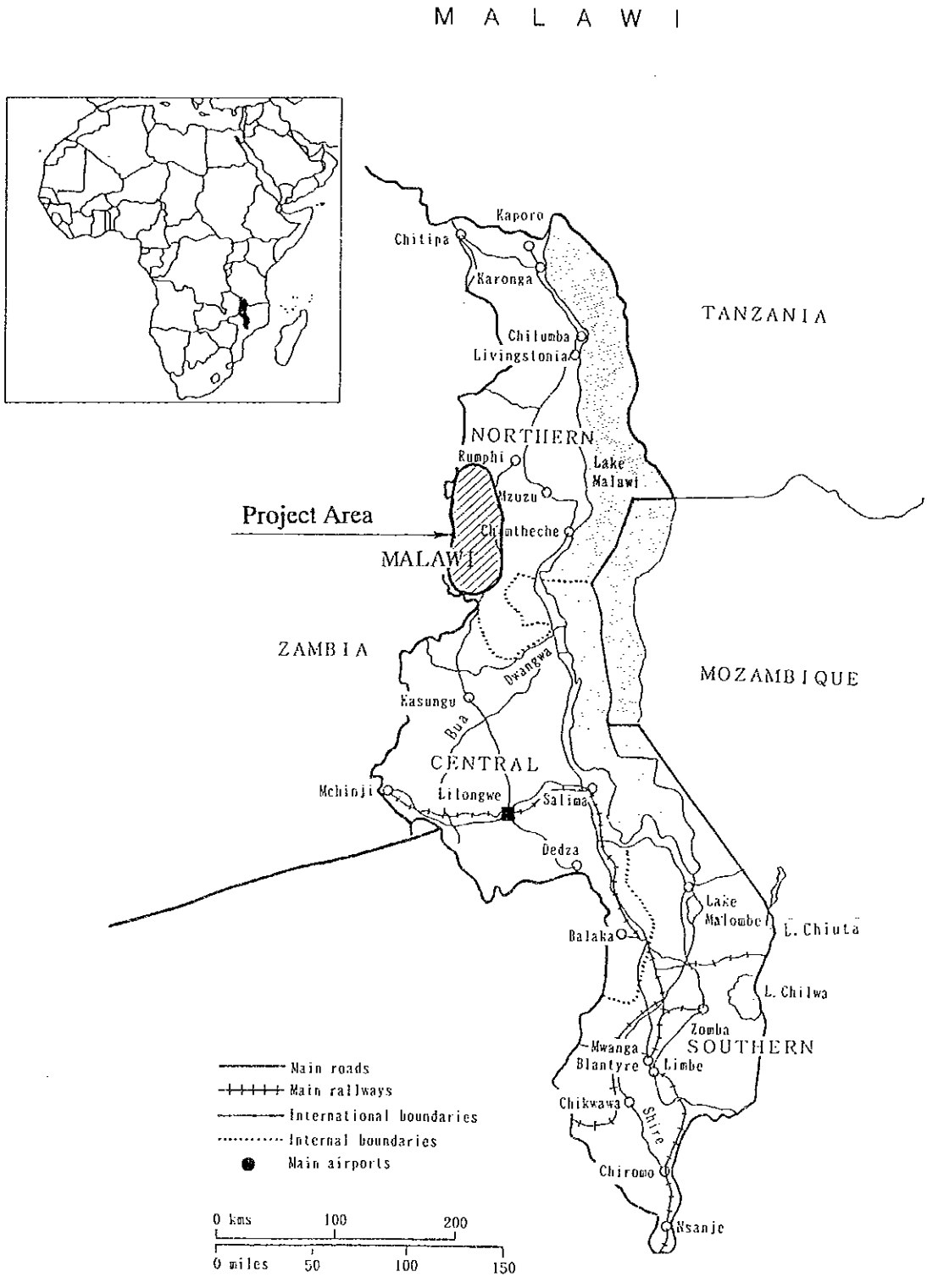
This study was conducted by Japan Engineering Consultants Co., Ltd., under a contract to JICA, during the period from August 19, 1996 to January 31, 1997. In conducting the study, we have examined the feasibility and rationale of the project with due consideration to the present situation of Malawi and formulated the most appropriate basic design for the project under Japan's grant aid scheme.

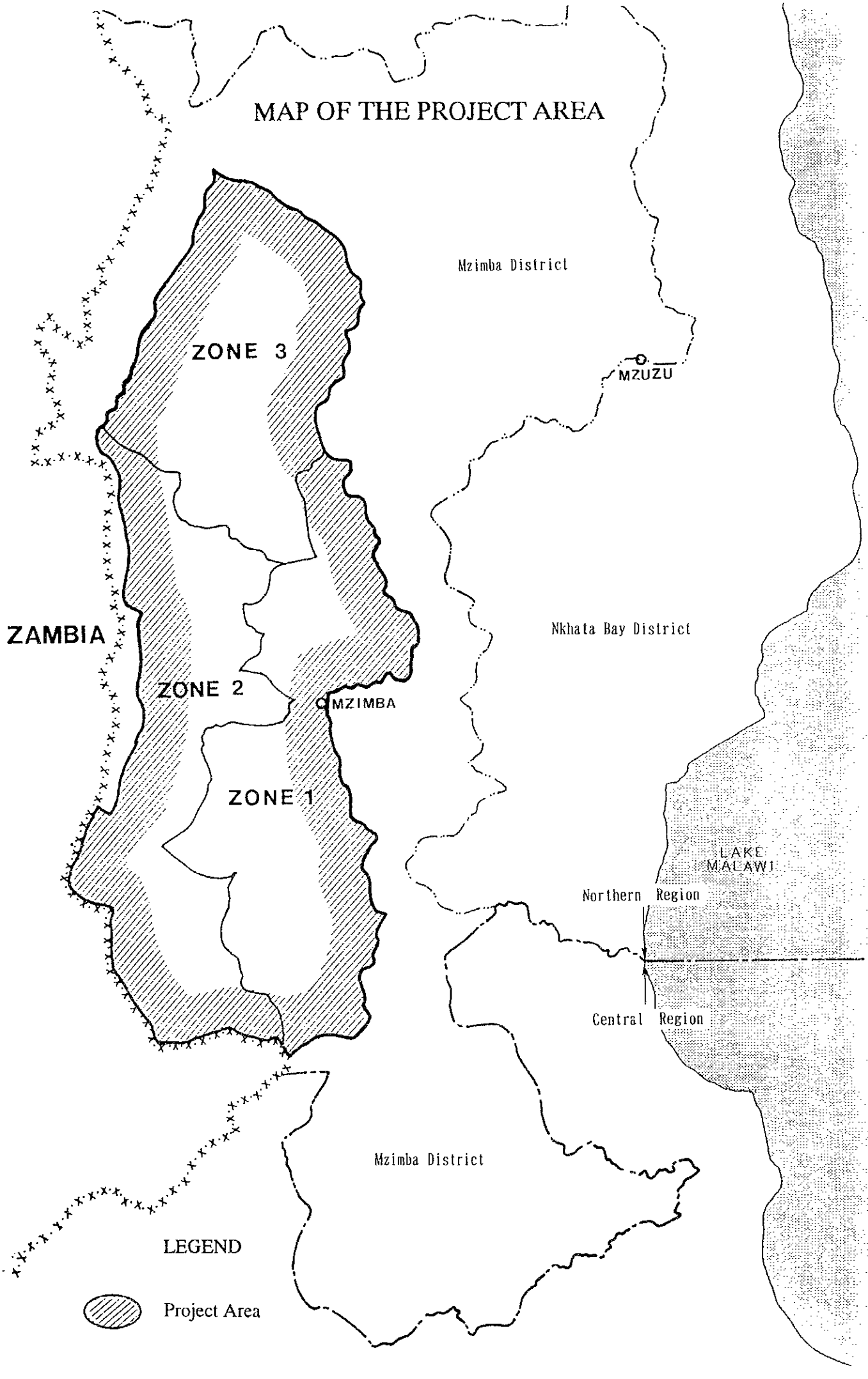
Finally, we hope that this report will contribute to further promotion of the project.

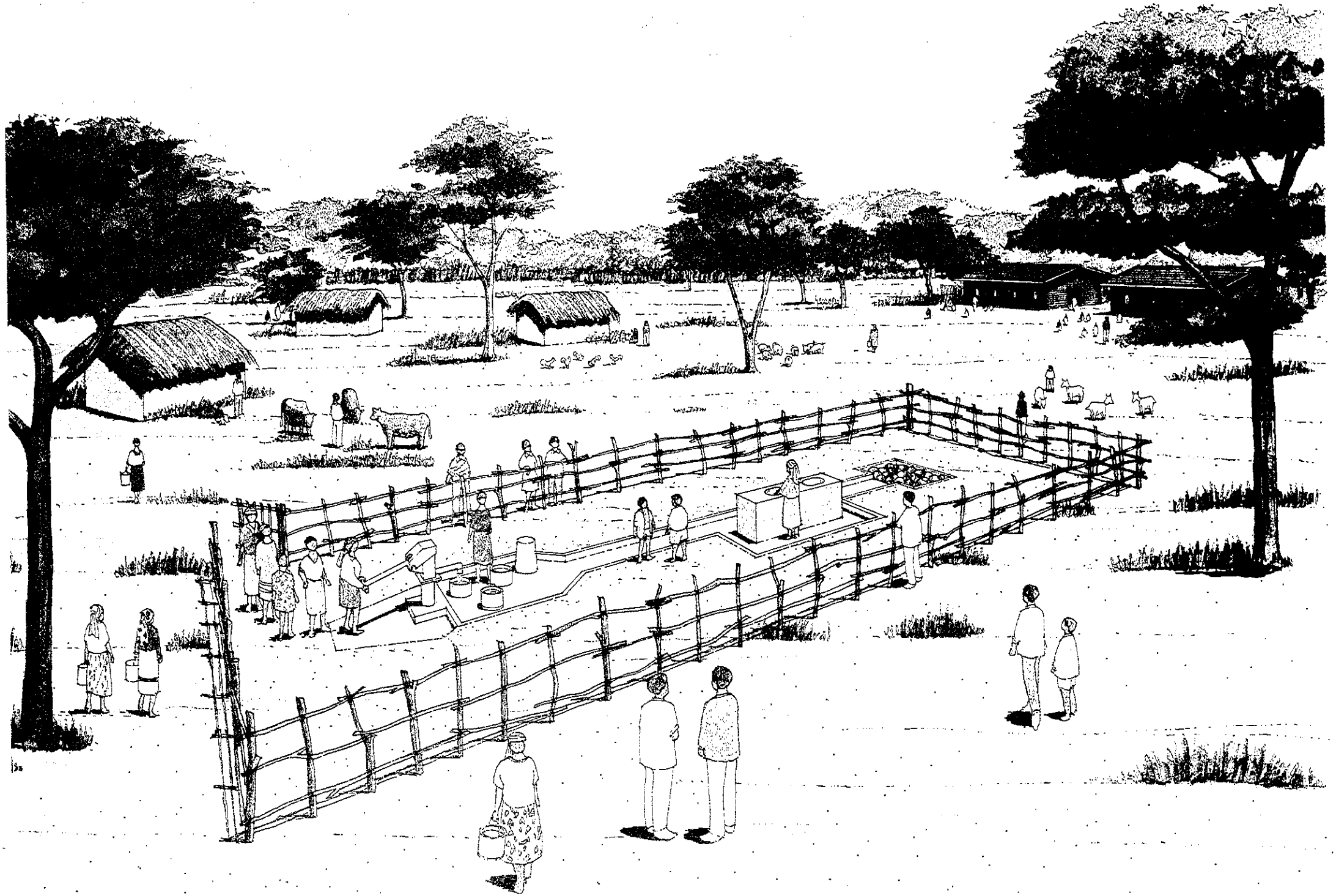
Very truly yours,

Akinori TAKAKU
Project manager,
Basic design study team on the Rural Water Supply Project in West of Mzimba District
Japan Engineering Consultants Co., Ltd.

LOCATION MAP




MAP OF THE PROJECT AREA
Mzimba District
ZONE 3
MZUZU
ZAMBIA
Nkhata Bay District
ZONE 2
MZIMBA
ZONE 1
LAKE MALAWI
Northern Region
Central Region
Mzimba District
LEGEND
Project Area



ABBREVIATIONS

- ADD : Agricultural Development Division
- ADMARC : Agricultural Development and Marketing Corporation
- BHN : Basic Human Needs
- CBM : Community Based Management
- DANIDA : Danish International Development Agency
- DDC : District Development Committee
- ESCOM : Electrical Supply Commission of Malawi
- EP&D : Ministry of Economic Planning and Development
- E/N : Exchange of Noted
- GDP : Gross Domestic Product
- JICA : Japan International Cooperation Agency
- IDA : International Development Association
- MOIWD : Ministry of Irrigation and Water Development
- NGO : Non-Governmental Organization
- OPC : Office of the President and Cabinet
- SCF (UK) : Save the Children Fund
- UNCDF : United Nations Capital Development Fund
- UNCHS : United Nations Centre for Human Settlements
- UNDP : United Nations Development Programme
- UNICEF : United Nations Children's Fund
- VLOM : Village Level Operation and Maintenance
- WID : Women in Development

CONTENTS

CHAPTER 1 BACKGROUND OF THE PROJECT

CHAPTER 1 BACKGROUND OF THE PROJECT

1-1 Background of the Request

The Republic of Malawi is located in the south-eastern part of the African Continent between Lat. 9° 20' and 17° 10' S. and Long. 33° and 36° E. It borders with Mozambique on its eastern and southern sides, Tanzania on its north-eastern side and Zambia on its western side. The country is shaped like a long thin strip, stretching for approximately 800 km from north to south and approximately 145 km from east to west; and the national land area is small at 118,484 km^2 (approximately 30% the area of Japan), 20% of which is accounted for by Lake Malawi. The national population is 9,730,000 (1994, population density 103 people per km^2) and the per capita GNP is 200 US $ (1993).

The Government of Malawi has consistently treated the promotion of agriculture as a priority policy ever since the country gained its independence in 1964. Currently, approximately 87% of the working population is engaged in agricultural activities (as of 1992), and the agriculture sector accounts for 35% of the gross domestic product (GDP is of 1992 is 2,500,000,000 US $). The current National Long-term Development Policy (1987-1996) has made the achievement of an economic growth rate higher than the rate of population increase (3.7%) its target, and the development of agriculture, which plays such an important role in terms of employment and exports, is regarded as the most important factor in realizing this goal.

In this way agriculture is the key industry within the Malawi national economy and, in order to promote this sector, the securing of a sanitary and stable supply of domestic water (the basic necessity for daily life) is an important issue. The Government of Malawi, in line with the United Nations International Potable Water and Environmental Sanitation 10 Year Plan (1981-1990), has made the Ministry of Irrigation and Water Development the agency responsible for the planning and implementation of a program to disseminate water supply facilities throughout the country. The objectives of this program are to 1) secure the necessary volume of domestic water (27 l per person per day), 2) relieve people of the burden of carrying water by providing boreholes for every 250 residents and reducing water carrying distances to no more than 500 m, and 3) reduce the incidence of water-borne diseases by securing clean and stable supplies of domestic water. The two main components of this water supply dissemination program are the drilling of boreholes and the construction of gravity piped water supply facilities. Furthermore, public investment into water supply dissemination has been specifically planned within the latest Five Year Public Investment Plan (1993/94-1997/98), and the ratio of the development budget set aside for water supply and sanitation in 1994/1995 was 6.37%.

Despite all these efforts, the current (1993) water supply rate in rural areas is only around 45% and, moreover, because many of the existing boreholes are not in use due to structural deficiencies, deterioration and breakdowns of hand pumps, etc., the supply rate in reality is even less. For this reason, rehabilitation works are being carried out on the worst affected borehole facilities with the help of funds provided by international aid agencies, and the movement known as VLOM (Village Level Operation and Maintenance), whereby residents (direct beneficiaries) maintain and operate boreholes themselves, is being advanced all over the country. In this way, efforts are being made to make the fullest possible use of the existing water supply facilities.

The Government of Malawi had originally intended within the above-mentioned National Long-term Development Plan to achieve a rural area water supply rate of 74% by 1996, however, in consideration of the increasing population, it compiled the new National Water Service Development Plan in 1994, in which it made 2010 the target year for the achievement of this goal. In specific terms, the new plan aims to carry out the establishment and rehabilitation of new and existing gravity piped water supply systems, the rehabilitation of 5,500 boreholes with pumps, and the drilling of 14,900 new boreholes by 2010. However, due to budget difficulties, etc., all national development plans are not progressing as planned and, with respect to the development of groundwater, too, the country is not in a position to plan and implement activities with its own resources. For this reason, the Government of Malawi has requested help from international aid agencies and advanced donor nations. It was against this background that the Government of Malawi in December 1994 requested the Government of Japan to provide grant aid for the Rural Water Supply Project in the West of Mzimba District (herein referred to as the Project).

1-2 Contents of the Request

(1) Objectives

- To prevent water-borne diseases among people living in rural areas, by drilling boreholes to provide safe and clean water.

- To relieve people of the unproductive need to manually carry water, so that they can spend their time on agricultural and other productive activities (consideration of WID problems).

- To raise technical capacity levels on the local side by encouraging staff from the Ministry of Irrigation and Water supply take part in OJT during the Project implementation.

(2) Implementing Agency

Ministry of Irrigation and Water Development

(3) Target Area

The Western part (area 3,980 km^2, estimated population of 235,940 in 1996, 689 villages and settlements) of the Northern Region of Mzimba District (area 10,430 km^2, estimated population of 601,192 in 1996.

(4) Contents of the Request

1) Borehole Construction

Concerning the 241 villages in the western part of Mzimba District targeted in the request, no more than 300 boreholes shall be constructed for the supply of safe potable water (see Table 1-2-1).

2) Construction of a Workshop in the Target Area

A workshop shall be constructed at Bulala roughly in the middle of the target area with the aim of carrying out maintenance of the completed boreholes.

3) Procurement of Equipment and Materials for the Construction of Boreholes

① Equipment and materials for borehole construction

- Rotary drilling machine (truck-mounted, top drive type)..... 1 unit
- Air compressor (truck-mounted)..... 1 unit
- Casing and screens (PVC, ϕ = 110 mm, class 10)..... Enough for 300 boreholes
- Mud water agent, foam..... Enough for 300 boreholes

② Test equipment

- Electric survey instruments ..... 1 set
- Pump testing equipment (truck-mounted)..... 1 set
- Electric logging equipment..... 1 set

③ Support vehicles

- Pickups (single cabin)..... 2 units
- Pickups (double cabin)..... 2 units
- 8 ton trucks (with 3 ton crane)..... 2 units
- Motorbikes..... 4 units

④ Hand pumps..... 300 units

⑤ Water tank (4 m^3)..... 1 unit

⑥ Fuel tanks (4 m^3) ..... 3 units

⑦ Communications equipment..... 1 set

⑧ Workshop facilities including repair equipment and materials

- Building (stated in 2) ..... 1 unit
- Welder..... 1 unit
- Bench vices and clamping tools ..... 2 units
- Torque wrenches..... 2 units
- Files..... 4 units
- External threading dies ..... 2 units
- Other tools ..... 1 set

⑨ Spare parts for existing drilling machines to be used for the Project ..... 2 sets

4) Enlightenment Activities to Encourage Borehole Operation and Maintenance by Residents

In the implementation phase of the Project, water management committees shall be organized and training carried out with the aim of encouraging residents themselves to carry out the operation and maintenance of the completed boreholes.

(5) Design Targets of the Request

1) Target water supply volume : 27ℓ per person per day

2) Target benefiting population per borehole : 250 persons

3) Target water carrying distance : no more than 500 m

Table 1-2-1 (1) List of Village Site for Borehole Construction

No.	Village	No of Request Boreholes	Remarks	No	Village	No of Request Boreholes	Remarks
1	Ngoli School	2		31	Samuel Makwakwa	0	Outside Project Area
2	Samuel Moyo	2		32	Thunduwike School	(4)	〃
3	Munyehere Chipeta	0	Existing Boreholes Prove Adequate	33	Chivwera Mzumara	(1)	〃
4	Kandodo Chisi	3		34	Thembai Mkandawire	(2)	〃
5	Mtambalika Moyo	2		35	Emchisweni School	1	
6	Mzimba Boma	4		36	Simon Jere	3	
7	Mbongo Mwanza	2		37	Chidyake	2	
8	Jeremia Mahope	1		38	Kahalayi	(1)	Outside Project Area
9	Peter Ndaba X2	2		39	James Jere	(1)	〃
10	Bokosi Dindi	3		40	Manolo	(1)	〃
11	Mirara School	3		41	Thomas Mkandawire	(4)	〃
12	Chaeles Chinula	1		42	Chibula Nguluibe	1	
13	Kafoteka Mkandawire	4		43	Mpocha Mtonga	1	
14	Yesaya Shumba	4		44	Vakaza Banda	0	Existing Boreholes Prove Adequate
15	Chimombo Matimba	1		45	Mtuzu School	2	
16	Yohane Chisi	3		46	Kaphokoto Mwandira	1	
17	Samuel Shumba	1		47	Malanga Mtonga	1	
18	Emazwani School	3		48	Kamalibwe School	1	
19	Chisusu Nyirenda	1		49	Mabanga Mtonga	1	
20	Dolora Ngwira	3		50	Kachinjere Nyirongo	1	
21	kazithole Ziba	1		51	Mhfafuta School	0	Existing Boreholes Prove Adequate
22	Tikatika Lungu	1		52	Malembo School	0	〃
23	George Chelinbda	1		53	Kapopo Market	1	
24	Magogi Nyirenda	1		54	Mdima Mwandira	0	Existing Boreholes Prove Adequate
25	Kanyeru Kadewa	1		55	Chisenga Chipeta	2	
26	Chirombo Jere	1		56	Malayi Phili	0	Existing Boreholes Prove Adequate
27	Nthumba School	1		57	Chafisi	0	〃
28	Hannock Ng'oma	1		58	Kaluwe School	0	〃
29	Eneya Kumwenda	0	Outside Project Area	59	Gwanda Banda	1	
30	Kamangadazi	(1)	〃	60	Hannock Hlanga	2	

Table 1-2-1 (2) List of Village Site for Borehole Construction

No	Village	No of Request Boreholes	Remarks	No	Village	No of Request Boreholes	Remarks
61	Mzilikazai	2		91	Isaac Ngoyi	1	
62	Mavunguti Zimba	1		92	Mapanjira School	2	
63	Samuel Kanga	1		93	Chinjoka Nyirenda	2	
64	Chikondawanga Lusale	2		94	Chigurere Qutoto	2	
65	Mulupani Nyasulu	1		95	Yakobe Soko	1	
66	Robert Mwanda	1		96	Bwanari Nkhalipi	1	
67	Simon Musafire Jere	2		97	Zeleza Moyo	1	
68	Gongo Mkhata	1		98	Chikoweni Nyirenda	1	
69	Kamata	1		99	Matemanga Chikombola	1	
70	Eheleni	1		100	Muswamphira Muzwa	2	
71	Mtusani Jere	(1)	Gravity Piped Water Supply Area	101	Thoza School	1	
72	Chimuri Nyirenda	(1)	〃	102	Mzoma Mithi	1	
73	Kamatabu School	0	〃	103	Chizumba Nguluwe	1	
74	Zheze Chisi	(1)	〃	104	Simon Gondwe	2	
75	Manyalu Banda	(1)	〃	105	Nambambe Gausi	2	
76	Jenda	(2)	〃	106	Yesaya Nkosi	2	
77	Siza Longo	(1)	〃	107	Bauleni Sibande	1	
78	Zebediya Jere	(1)	〃	108	Chibembe School	0	Existing Boreholes Prove Adequate
79	Machilika Nyirenda	(2)	〃	109	Ng'ombeyavuka Kamang	1	
80	Kamatadu Village	(1)	〃	110	Chipata Moto	0	
81	Kanthudu Kanyinji	(1)	〃	111	Zebedia Zighili	0	
82	Magaga Sezi	0	〃	112	Mthapagwa Lungu	1	
83	Chisinga Nkhoswe	0	〃	113	Mbwiriwiza School	1	
84	Luviri School	(1)	〃	114	Edingeni School	1	
85	Machowani Nkhoswe	1		115	Gonani Ngwira	1	
86	Emchakeni School	2		116	Ndembara Ngwira	1	
87	Echingo Dhleni	1		117	Tadeyo Chikwira	1	
88	David Kumwenda	1		118	Bokala School	2	
89	Fimbo Moyo	1		119	Samuel Mapaso	2	
90	Zilahle Mphande	1		120	Patamo Kamanga	1	

Table 1-2-1 (3) List of Village Site for Borehole Construction

No.	Village	No. of Request Boreholes	Remarks	No.	Village	No. of Request Boreholes	Remarks
121	Kadozo Mungutha	1		151	Matambo Ngulube	0	
122	Sauloai Tembo	1		152	Kabuku Phiri	0	
123	Mphongo School	0	Existing Boreholes Prove Adequate	153	Paulosi Nthara	0	
124	Kasoti Phiri	1		154	Njebwa II	0	
125	Mzondi Ndhlovu	1		155	Mtezi Miti	0	
126	David Mumba	0	Existing Boreholes Prove Adequate	156	Bichi Mumba	1	
127	Gaiela Shaba	1		157	Mpanga Visoti	1	
128	Hezeka Mwanza	0		158	Njoka School	0	
129	Chanunkha Shawa	0		159	Chisasa Village	0	
130	Edingeni	3		160	Chisasa Agriculture	1	
131	Daulire Moyo	2		161	Mpeni School	0	Existing Boreholes Prove Adequate
132	Mpeyana Gondwe	1		162	Daniel Tembo	0	〃
133	Malinyete School	0		163	Chimbwangandu	0	〃
134	Kaudi School	2		164	Egalaweni	1	
135	Malangazi School	0	Existing Boreholes Prove Adequate	165	Njinge Agriculture	4	
136	Visenthe School	0	〃	166	Nthondanjala Nyirenda	0	Existing Boreholes Prove Adequate
137	David Sibande	1		167	Njinge School	3	
138	Ching'aya School	1		168	Chuya School	(2)	Outside Project Area
139	Mzalangwe	1		169	Maloza Zimba	0	
140	Eswazini	2		170	Chibuwu Kumwenda	0	
141	Kapoli School	1		171	Kalweya	0	
142	Zebron Kamanga	0		172	Mtolabota	0	
143	Mbelwa Inst.	0		173	Dickson Sakala	0	
144	Kampingo Nyambose	1		174	Thomasi Nyirenda	0	
145	Nthumba Admarc	2		175	Yotamu Ng'oma	1	
146	Mabuka Hlongo	2		176	Zuwayumo Makamo	1	
147	Rufunkunika	1		177	Mateyo Ng'oma	0	
148	Stephano Mwanza	1		178	Manyamula school	1	
149	Sasa School	1		179	Manyamula Agriculture	3	
150	Kavululanga School	2		180	Zebedia Nyirenda	1	

Table 1-2-1 (4) List of Village Site for Borehole Construction

No	Village	No of Request Boreholes	Remarks
181	Chibeku Ngulube	0	
182	Chikonda Jonasi	2	
183	Chimutu	0	
184	Phazima	0	
185	Kamutepa	0	
186	Vibangalala school	1	
187	Inkosi Mbelwa	33	
188	Katambalala	0	
189	Handle Ndhlovu I	1	
190	Handle Ndhlovu II	0	
191	Mharaunda	0	
192	Ndabambe Gausi	1	
193	Malidadi Jere 2	0	
194	Chimsebezo Banda	0	
195	Katondo	1	
196	Njebwa I	1	
197	Mbawa Admarc	0	
198	Mbawa School	1	
199	Kholowani Lungu	(1)	Outside Project Area
200	Etcheyeni school	1	
201	kalungulu school	0	
202	Kambokoto	2	
203	Mzoma School	1	
204	Bongoya Msimuko	0	
205	Mhawi	0	
206	Malepa Manda	0	
207	Dimi School	0	
208	Mphosa Village	1	
209	Foster Jere	0	
210	Embangweni Mission	1	
211	Embangweni Trading	2	
212	Wilson Jere	0	
213	Kapoli Mtonga	0	
214	Kasich Mvula	1	
215	Isaac Lukhanda	0	
216	Chilomba	0	
217	Matekenya Jere	0	
218	Ephangweni Village	2	
219	Ephangweni HQS	2	
220	Vibangalala	0	
221	Baleni Jere	0	
222	Mapupo	0	
223	Mabiri School	0	
224	Swaswa School	0	
225	Mlabamanda	0	
226	Kabinga Banda	0	
227	Eliakimo Mwandira	2	
228	Mpezeni Msimuko	0	
229	Makosikasi School	1	
230	Timothy Mphaka	0	
231	Kapinyuka Village	0	
232	Qolocha Tempo	0	
233	Kamteteka School	1	
234	Daniel Mughogho	0	
235	Chisebe Village	0	
236	Kamteteka Admarc	0	
237	Wajingo Theu	0	
238	Mungoni Wambabvi	0	
239	Chizungu School	0	
240	Chizungu Village	1	
241	Kholwani	(1)	Outside Project Area

1-3 Verification of the Request

Based on the written request presented by the Government of Malawi, the study team verified the contents of the request in the manner described below in discussions with the Ministry of Irrigation and Water Development - the implementing agency for the Project.

(1) Numbers of target villages and boreholes

1) Because parts of the requested area are already served by gravity piped water supply and urban piped water supply (Mzimba City) systems, overlapping areas shall be excluded from the Project.

2) Because some of the requested villages are located outside of the target area, these shall be excluded from the Project.

3) Not withstanding 1) and 2) above, because the number of requested villages is far greater than the number of villages that exist on the national consensus level for the reasons described below, the maximum number of boreholes shall be 300 and construction sites shall be selected in order from those that have the highest degree of water supply hardship (obtained by comparing village population with the number of existing water supply facilities).

① Because many of the village requests have been put forward by Group Village Headmen under wider area names, when the villages are arranged according to the names that appear in the national consensus, many of the requested villages are actually contained within only a few.

② Villages requested under the names of schools, training centers and ADMRC are, etc., as is the case in ① above, contained within only a few officially recognized villages.

4) Villages that are inaccessible for works vehicles shall be excluded from the Project.

5) Areas of unfavorable hydrogeological conditions (where groundwater development is difficult or problems exist in terms of water quality) shall be excluded from the Project.

6) Villages that are not willing to organize water management committees for the operation and maintenance of boreholes after construction (collection of charges, repairing of pumps, etc. by residents) shall be excluded from the Project.

(2) Equipment and Materials for Borehole Construction

1) A total of three drilling machines shall be used for construction of the Project boreholes. One drilling machine shall be newly procured under the Project and the other two shall be the existing drilling machines that were provided through past grant aid projects (one in the North Kawinga project and one in the Mchinji project). The drilling machine from the North Kawinga project shall be used for one year or more, and the drilling machine from the Mchinji project shall be used over the whole period of project implementation.

2) The equipment and materials to be provided free of charge by the Malawi side to the Japanese contractors are as indicated below.

Table 1-3-1 Procured Equipment and Materials to be Provided by the Malawi Side

	North Kawinga Project	Mchinji Project
Drilling machine	1 unit	1 unit
Compressor	1 unit	1 unit
Pump testing truck	1 unit	1 unit
Truck with crane	—	1 unit
Electric logging equipment	1 set	1 set
Water tank	1 unit	1 unit

(3) Construction of Maintenance Workshop

The site at Bulala provided by the Malawi side shall be used as the base camp for the borehole construction works and, following completion of the said works, this base camp shall be made into a workshop responsible for operating and maintaining the completed boreholes. Thus, a permanent building shall be constructed here during the works preparation phase as one part of the borehole construction work.

The Malawi side will need to level the land of the base camp site prior to the start of the construction work.

(4) Implementation Setup (Operation and Maintenance) of the recipient country

The Ministry of Irrigation and Water Development (MOIWD), which is the agency responsible for the construction and operation and maintenance of the Project boreholes, has long been involved in the construction of boreholes using its own equipment.

Regarding enlightenment activities directed at residents, the MOIWD has set up a unit in charge of community based management (CBM Unit) to promote the CBM programme, which is one of the national policies of the government. Moreover, the MOIWD has carried out the rehabilitation of boreholes and enlightenment of villages in aid projects sponsored by the IDA.

However, the budget allotted to the MOIWD is small and the ministry has to rely on aid from donor countries to finance its maintenance and enlightenment activities. Nevertheless, it has been confirmed that the Malawi side will strive to take budget measures to carry out enlightenment activities on a sustained basis in the Project target villages.

CHAPTER 2 CONTENTS OF THE PROJECT

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2-1 Objectives of the Project

One of the most important objectives of the Statement of Development Policies (1987 - 1996) as issued by the Government of Malawi was the development of a domestic water supply in rural areas with a view to providing rural inhabitants with an adequate supply of sanitary domestic water. One of the concrete targets suggested was an increase in the water service ratio to 74% by 1996. However, the target year for achieving the water service ratio of 74% was postponed until 2010 by the National Water Services Development Plan which was newly established in 1994 while taking the increased population into consideration. Concretely, the target has been set to secure the water resources for additional 5,639,000 people by constructing and/or rehabilitating the gravity piped water system, borehole and well with hand pump. Financial hardship in Malawi, has caused a general delay in the implementation of projects envisaged by the Statement of Development Policies and it appears very difficult for the Government of Malawi to conduct the planned groundwater development without assistance from overseas.

To cope with the shortage of domestic water supply in rural areas as mentioned above, the main objective of this project is to improve the water supply condition in west of Mzimba District, where people are particularly suffering from the shortage of domestic water, by means of 300 borehole construction.

2-2 Basic Concept of the Project

2-2-1 Examination of Implementation and Management Capability

The Ministry of Irrigation and Water Development (MOIWD) will have overall responsibility for the implementation of the Project while the construction work will be supervised by the Groundwater Section, Water Resources Branch of the Department of Water. Following completion, the boreholes will be subjected to the CBM (Community Based Management) Program that requires operation and maintenance by the beneficiaries themselves. The borcholes are to be operated and maintained by the Water Management Committee established by the benefiting villagers after the enlightenment education.

The MOIWD experienced Japanese grant aid with the groundwater development projects in the North Kawinga and Mchinji districts and, therefore, has a working knowledge of the mechanism of Japanese grant aid system. Accordingly, it has the appropriate organization and staff to implement the Project. The assignment to the Project of 51 staff members of the

Groundwater Section's total 580 staff members is currently envisaged. These mainly consist of the entire technical staff of the Headquarters and technical staff of the Northern Regional Office under whose jurisdiction Mzimba District is placed. In addition, the Central Regional Office and Southern Regional Office will assign engineers for the purpose of enabling these drillers to undergo on-the-job training on the drilling machines previously procured and to be newly procured by Japan.

In the case of a foreign-assisted project, the budget for project implementation (including the cost of on-the-job training) generally is included in the development budget consisting of grant or loan amount for the project from overseas, and a contribution by the Government of Malawi which is usually equivalent to some 3% of the construction cost (excluding the material and equipment cost). The past development budgets of the Department of Water given below show annual fluctuations due to the predominance of foreign grants and loans. In other words, the budget of the Department of Water depends on how much international organizations and/or foreign governments are intending to provide in a specific fiscal year. Taking all the successfully completed ground water development projects including North Kawinga and Mchinji project, it is reasonable to believe that proper budgetary arrangements will be made on the Malawi side during the Project implementation period.

Development budget by the Department of Water, Unit: K

1991/1992:	27,000,011, actual
1992/1993:	23,845,297, ditto
1993/1994:	44,449,538, ditto
1994/1995:	37,593,422, budget
1995/1996:	35,610,656, ditto

As the Malawi's national policy, the maintenance and management by the villagers themselves (CBM Program) is promoted and the Department of Water is responsible for rehabilitating the boreholes constructed by the IDA assistance and enlightenment activities thereof at the respective villages. However, its budget is limited and majority of the budget required for the enlightenment activities is actually dependent on the respective assisting countries.

The table below shows the source of fund and implementing organization for the major groundwater development projects implemented up to this date for which the CBM Program was adopted

Table 2-2-1-1 Source of fund and implementing organization for the enlightenment activities

	Project name	Source of fund	Implementing organization
①	Karonga	DANIDA/Department of Water	DANIDA / MOIWD
②	Mchinji	NGO (SCF)	NGO (SCF)
③	Rehabilitation work for the Northern and Central Region	IDA	MOIWD
④	Rehabilitation work for Central Region	UNCDF/UNDP	MOIWD
⑤	Mzimba East	UNICEF	NGO (Africare and others)

The on-site survey results and project evaluation data were collected on the projects stated under ① to ③ above, which revealed the maintenance and management activities were relatively well implemented by the villagers at the villages which were subject to the enlightenment activities.

It will be necessary for the MOIWD to secure the funds required for the enlightenment activities of the 300 boreholes, however, it is deemed to be necessary to assist the enlightenment activities as a part of Japanese Grant Aid when promoting the project in view of the real situations at the MOIWD and recent groundwater development method in Malawi.

An engineer, who belongs to the local Maintenance Office of the Groundwater Section and assumes the responsible for 100 boreholes, will provide necessary technical services for the boreholes for which the Water Management Committee has been established.

The Water Management Committee organized for each borehole is to receive technical training through the enlightenment activities, save up the required funds to replace the consumable items by themselves, and to establish a system that enables them to purchase the parts and to repair the borehole. Therefore, it is not necessary for the MOIWD to provide budget for the daily maintenance and management activities. However, the on-site assistance by the MOIWD will be required if it is necessary to make a major repair of the borehole which is beyond the capability of the villagers.

It is desirable to secure the following budget to maintain 300 boreholes in one year which needs to be assumed by the MOIWD.

Personnel Cost (3 operators) :	K 1,000/month × 12 × 3 =	K 36,000/year
Travel Allowance :		K 20,000/year
Vehicle, Fuel & Maintenance Cost :		K 60,000/year
Pump & Spare Parts :		K 70,000/year
	Total :	K 186,000/year

The above budget is understood to be affordable in view of the general budget of the Department of Water in the period of 1991 to 1995 (K 9,560,969 to 14,648,230).

2-2-2 Examination of Similar Projects

(1) Groundwater Development Project

The assistance given by the international organization for the major groundwater development projects in the Mzimba District are as follows.

① Rehabilitation work at Northern and Central Regions (1992 - 1994): IDA

② Drought Program (1996 -): IDA

③ National Water Development (1996 - 2000): IDA

④ Mzimba East (1996 - 1998): UNICEF

For ① stated above, rehabilitation work for 1,450 boreholes was carried out in the Northern and Central Regions which were completed in 1994. The rehabilitation work was implemented at 194 places in the Target Area of the Project. Presently, the enlightenment activities are being implemented in accordance with CBM Program with the funds offered by IDA.

For ② stated above, 206 boreholes are to be constructed for the drought measure, however, no work is currently planned in the Project Area.

The National Water Development project under ③ above is a comprehensive water development project that includes urban water supply, gravity piped water (construction and rehabilitation), dam construction, and others in addition to the development of the boreholes. The businesses related to the borehole include construction of 3,000 boreholes and rehabilitation work for 1,000 boreholes, which are adjusted not to overlap with the Project. The schedule is currently under preparation and the international bidding is planned in 1997 or after.

The Mzinba East project under ④ above is the borehole (drilled by Vonder rig) and protected spring work (a total of 160 places) directly ordered by UNICEF (Malawi) to the NGO acting in Malawi, and the work is expected to commence in October, 1996. The applicable villages are those in the eastern area of Mzimba District, which were confirmed not to be in duplicate with the Project.

As stated above, no problem is anticipated since the adjustments have been made to avoid overlapping of the Project with any one of the currently planned projects ② to ④ shown above.

(2) Urban Water Supply Facility and Gravity Piped Water

It is deemed to be appropriate to exclude the Viphya Plateau and adjacent areas on the southern side since there are existing urban water supply facility for the Mzimba District Headquarter and the gravity piped water facility for Msaka and Champhila North.

2-2-3 Examination of Project Components

(1) Direct Beneficiaries

In accordance with standards in Malawi, if it is assumed that 250 people can benefit from the digging of one borehole, the digging of 300 boreholes as requested can be expected to increase the directly benefiting population by 75,000. That is to say that the water supply rate in the Project target area (estimated population 235,940 in 1996) will increase from the current 22% to 54%, thus enabling it to approach the target value laid down in the national plan (regional water supply rate of 74%).

(2) Subject Villages

It was originally requested by the Government of Malawi to construct the boreholes at 241 villages. However, the number of the subject villages will be a total of 211 villages since they included those with the existing urban water supply and gravity piped water facility (17 villages) and those outside the project area (13 villages) after excluding them.

In addition, survey on those village names and village distribution revealed the following points.

1) The requests are made under the name of Group Village Headman being as an assembly of the village, which often includes multiple villages when it is classified according to the village names registered in the national census.

2) Similarly, the villages requested under the names of school, trading center, ADMARC, etc. also include multiple villages.

As stated above, since it is difficult to pinpoint definite location of the village and distribution of the villages is prejudiced in the central and southern areas, it is necessary to impartially distribute the boreholes including the existing ones in accordance with the original aim of the Malawi Government and to select the villages based on the national census (1987) that enables the geographical distribution of population to be grasped.

(3) Target Supply Rate

The target water supply of 27 liters per person per day has been set by the Government of Malawi for the rural villagers using the borehole. The interview made on site revealed that an average of 27 liters per person per day is secured for the daily needs of the villagers irrespective with the types of the water sources (borehole, open shallow well, etc.), which is deemed to be appropriate.

The water balance calculation for the Project Area indicates that the groundwater recharge is at least $1.6 \times 10^7 m^3$/year. The estimated pump discharge from 511 boreholes is $1.26 \times 10^6 m^3$/year based on the target supply rate of 27ℓ/person/day and a service population of 250 persons/borehole.

As the estimated groundwater recharge far exceeds the estimated pump discharge, an increased water demand in the future due to an improved service ratio, increased service population and improved supply rate will be well catered for.

(4) Service Population/Borehole

Assuming a service population of 250 persons/borehole and a service rate of 27ℓ/person/day, the required pump discharge/borehole will be $6.75 m^3$/day. As the general pumping operation hours in rural areas of Malawi are eight hours (five hours in the morning, one hour in the early afternoon and two hours in the evening), a pump capable of discharging 15ℓ/min will provide $7.2 m^3$/day. Consequently, the standard service population of 250 persons/borehole set by the Government of Malawi is deemed appropriate.

In the case of villages with a population of more than 250 inhabitants, boreholes are constantly used from dawn to sunset, suggesting that boreholes can be used for as many as 14 hours/day. The resulting maximum daily pump discharge is $12.6 m^3$ which is sufficient to meet the domestic water requirement of a village with more than 400 inhabitants.

(5) Target Number of Boreholes to be Constructed

The Project Area has an estimated population of 235,940 (in 1996) and the required number of boreholes to serve a population of this size based on a service population of 250 persons/borehole is 944. Excluding 211 existing boreholes, therefore, the number of boreholes to be constructed is 733. There are 689 villages in the Project Area, of which 262 (38%) are small villages with a population of less than 200. Although it is desirable to provide at least one borehole for each village, a project to meet this requirement would be too large to be practical under the present conditions and given the very low water service ratio. As a result, it appears appropriate that the number of boreholes to be constructed under the Project will be based on the overall population size.

Given the above limitation currently imposed on the Project scope, the subject villages will in principle be those with a population of more than 200. As far as villages with a much larger population are concerned, one borehole will be allocated for each approximately 500 inhabitants based on the examination results in (4) above. The resulting number of boreholes required in the Project Area is approximately 300.

(6) Borehole Construction Priority

The Project Area is divided into three zones and priority is given to Zone 1, followed by Zone 2 and then Zone 3 in view of the current water service ratio and population density.

Table 2-2-3-1 Water Service Ratio and Population Density in Project Area (1996)

Zone	Population	No.of Existing Boreholes	Water Service (%)	Area (km^2)	Population Density (persons/km^2)
Zone 1	73,256	33	11.2	1,413.1	51.8
Zone 2	93,265	117	31.4	1,341.9	69.5
Zone 3	69,419	61	22.0	1,229.9	56.4
Total	235,940	211	–	3,984.9	–
Average	–	–	22.4	–	59.33

(7) Hydrogeological Conditions and Average Drilling Depth of Planned Boreholes

The Project Area can be divided into two major regions according to the hydrogeological conditions, which are the Plain along the South Rukuru river located on the western side of the project area which belongs to Type (I) of the hydrogeological classification and the adjacent areas at the skirts of the mountain and hills at the western rim of the Viphya

Plateau located on the eastern side of the project area which belongs to Type (II) of the hydrogeological classification.

In the Type (I) area, aquifer is formed in the thickly distributed weathering zone, which is favorable for the groundwater development. However, it was revealed that the distribution of the weathering zone substantially rises and falls. The on-site survey results indicate that good aquifer distribution can be expected as high as approximately 90% in this area. The hydrogeological condition in this area closely resembles that of the previous Mchinji project. The success rate in the Mchinji project was approximately 90%.

In the Type (II) area, the aquifer is shallowly distributed because fresh basement rock appears at the shallow depth, and is poorer compared with that in Type (I) area. Accordingly, the groundwater occurring in the fissure such as fault fracture zone etc. also needs to be subjected to the development. Good aquifer distribution can be expected by approximately 65% in this area. The hydrogeological condition in this area is poorer than that of the previous North Kawinga project. The recent success rate for the borehole construction results by the Northern Regional Office of the Department of Water remains in the order of approximately 60% despite the electric prospecting and selection of favorable borehole sites.

Table 2-2-3-2 Hydrogeological condition in the Project area

Type	Topography	Nature of the soil	Aquifer condition
(I)	Plain with relatively small rises and falls on the whole at the altitudes of 1,000 to 1,300 meters. A swamp called Dambo extends along the South Rukuru river that flows in the Project Area.	Alluvium silt and clay near the surface layer in Dambo. Mostly soil of the weathered basement rock in the areas above Dambo. Basement rocks mainly consisting of gneiss.	Weathered portions of the basement rock (ranging from sandy to weathering zone with fractures) are distributed to form a good aquifer.
(II)	Located on the western rim of the Viphya Plateau at the altitudes of 1,200 to 1,600 meters. The monadnocks of the basement rock remain here and there.	Strongly weathered rock of the basement rock nearby the surface layer. Basement rocks mainly consisting of gneiss.	A good aquifer is formed in thickly distributed weathering zone. Development of the aquifer is poor in the shallowly distributed weathered zone and fresh basement rock is distributed at shallow depth. In this case, the fissure in the fracture zone is the viable aquifer.

Electric prospecting was implemented at the selected village sites which were deemed to be most favorable in terms of hydrogeological condition for on-site survey. However, some of the sites were excluded from the borehole construction project since the groundwater development was deemed to be virtually impossible.

Based on the field survey (i.e. electric prospecting) results, topographical and geological features and data on existing boreholes in the Project Area, the maximum and average drilling depths for the new boreholes have been provisionally set at 70m and 50m respectively.

(8) Degree of Difficulty Upon Constructing the Boreholes

Due to the low success rate stated above in the Project Area, on the eastern side of Type (II) hydrogeological classification in particular, many risks are anticipated to properly select the borehole drilling site only by the ordinary electric prospecting and to construct the required numbers of the boreholes within the specified work period.

Accordingly, it is necessary for the Project to provide with measures to increase the success rate of the borehole construction to the fullest extent possible which in turn assures positive completion of the service. For this purpose, it is deemed possible at the Study of Implementation Design to increase the overall success rate up to approximately 80% by effectively implementing the geophysical prospecting such as electromagnetic or electric prospecting, precisely grasping the hydrogeological structure (distribution of the aquifer, permeability of the aquifer, location and distribution of the fracture zone, etc.), increasing the selection accuracy of the borehole site, and selecting favorable locations for developing the ground water.

The philosophy for the degree of borehole construction is summarized in Table 2-2-3-3 based on the site survey results and available data.

Table 2-2-3-3 Philosophy for the degree of borehole construction

Classification according to the hydrogeological conditions	Classification by the electric prospecting and evaluation of aquifer	Degree of difficulty for the bore hole construction			Remarks
		α	β	γ	
Type (I), Plain along the South Rukuru river on the western side of theProject Area	A (90%)	○			• Types A and B are dominant in this area (approximately 74% for the type Aand approximately 26% for the type B), and type C is likely to exist at very limited locations. • Generally, distribution of good aquifer is expected. The success rate of approximately 90% can be expected for the type A or B. • Distribution of the basement rock at a shallow level is expected in some areas, and the success rate of approximately 60% can be expected with increased prospecting accuracy even for the type C. • Accordingly, the overall success rate of approximately 90% can be expected in the Type (I) area.
	B (90%)	○			
	C (–)			○	
Type (II), Western rimof the Viphya Plateau and adjacent hills on the eastern side of the Project Area	A (70%)		○		• Areas of type C is dominant at many of the locations (37%) when compared with type A or B than those of Type (I) (approximately 42% for type A and approximately 21% for type B). • The ratio of the type C locations is expected to further increase since the on-site surveys (electric prospecting) were implemented at the locations that were regarded to have favorable hydrogeological conditions. • The success rate of approximately 70% can be expected in the type A area. • The success rate of approximately 90% can be expected in the type B area. • The success rate of approximately 60% can be expected in the type C area by increasing the prospecting accuracy. • Accordingly, the overall success rate of approximately 70% can be expected in the Type (II) area.
	B (90%)	○			
	C (40%)			○	

Classification according to the form of the ρ - a curve of electrical exploration

A : The aquifer is expected to a relatively deep level with few cracks in fresh basement rock.

B : Although the distribution of aquifer is similar to that in A, fresh basement rock has some cracks with the possibility of containing groundwater.

C : Although the ρ - a curve is similar to that in A, fresh basement rock is distributed at a very shallow level.

Evaluation of the aquifer : Numerical values shown in the parentheses represent the expected ratio of good aquifer

Degree of difficulty of the borehole construction (success rate) : α =90 %, β =80 to 70 %, γ =60 %

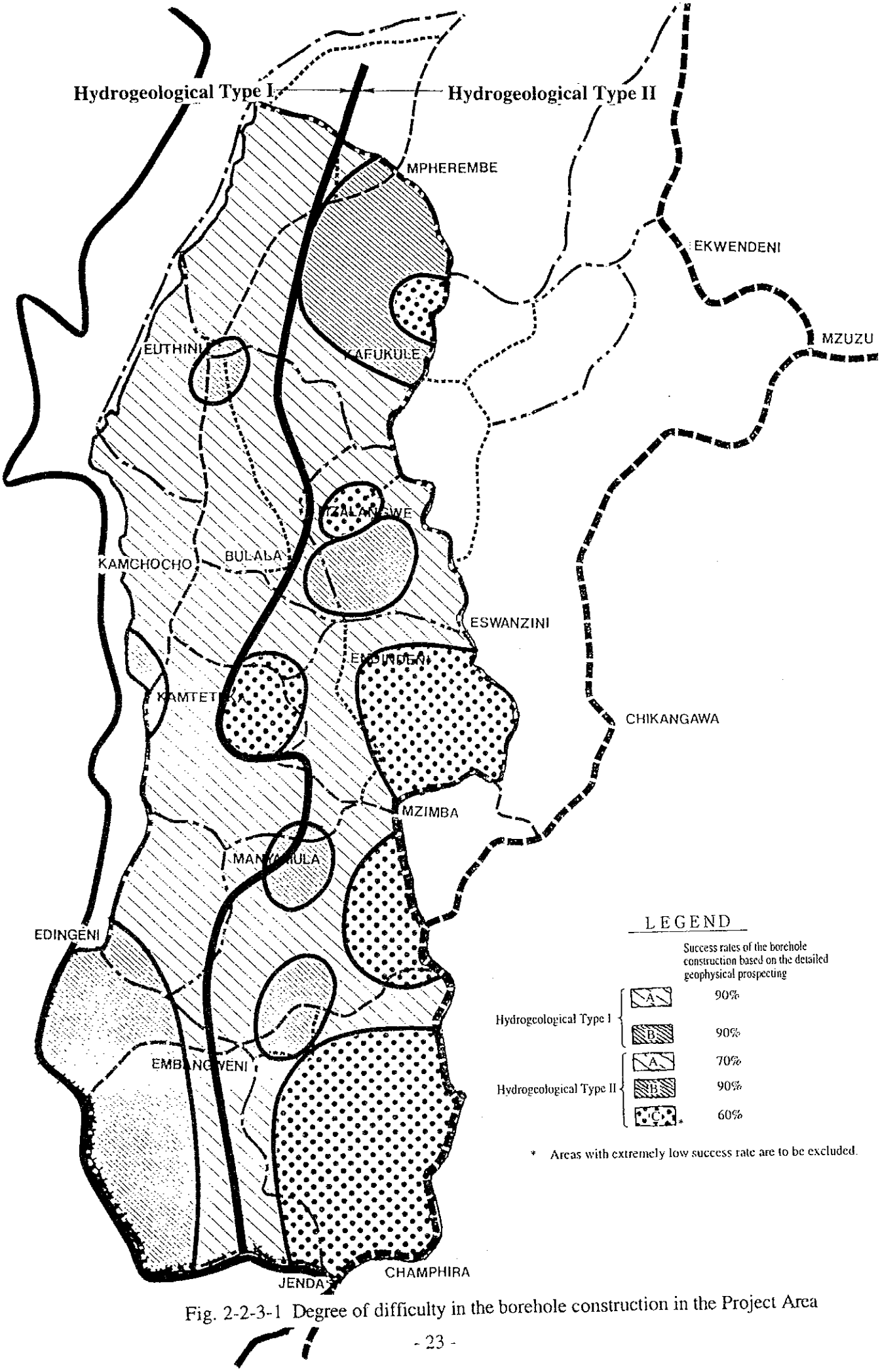


Fig. 2-2-3-1 Degree of difficulty in the borehole construction in the Project Area

(9) Review on the Construction Process

1) The average daily drilling speed, using the requested rotary and air hammer drilling machine, is set to 11 meters in view of the work results and holiday conditions for the previous North Kawinga and Mchinji projects (a series of work including moving the drilling machines, preparation for drilling, drilling, inserting the casing, and hole washing).

2) The success rate is set to 80% for the borehole construction for the Project on the premises that the detailed geophysical prospecting is implemented and favorable borehole site is selected although areas with very low success rate of approximately 60% are included in the Project area.

3) Eight months in the dry season (April to November) are most suitable for the work period, however, the actual work period including the overhauling period is to be extended to 12 months (drilling period of 11 months) while taking into consideration that the drilling can be implemented at the sites along the main routes even under the bad road condition in the rainy season.

4) The work period with one groundwater development team is calculated as follows based on the conditions stated above.

Total drilling length: 50 m × 300 × 1.2 = 18,000 m

Required days of drilling: 18,000 m ÷ 11m per day ≒ 1640 days ≒ 54 months

In addition, it is also necessary to take work preparation and machine maintenance periods into consideration.

5) There will be a total of three machines available to drill the boreholes for the Project; one machine to be newly procured for the Project and one each machine procured in the past for the North Kawinga project and Mchinji project by the Japanese Grant Aid assistance. The drilling machine used for the North Kawinga project is planned to be used for one year and that for the Mchinji project for the entire work period of the Project, respectively.

Based on the above conditions, the Project is expected to successfully complete within the scheduled work period of two years (drilling, pumping test, and ancillary facility work) assuming that three machines are used for the work in the first year and two machines in the second year.

In addition, it is also necessary to consider additional three months or so as the work preparation period in order to repair and maintain the previously procured machines.

(10) Target Year

Implementation of the Project can be divided into two stages; the first stage for the implementation design and the second stage for the procurement and construction.

For the implementation design in the first stage, the main activities will be the consultation work which involves detailed on-site survey to select the borehole sites, which is expected to take approximately four months.

Upon completion of the implementation design in the stage 1, the consultation agreement will be concluded in the second stage, which will take approximately one year before commencing the work for preparing the tenders, concluding the contracts with the contractors, procuring and maintaining the machine and materials.

As stated under (9) above, the borehole construction is expected to complete in approximately two years since three machines can be used in the first year and two machines in the second year.

(11) Pump

The Afridev pump developed by UNDP/World Bank is recommended and standardized in Malawi so that the pump can be repaired on the inhabitant level, which is a part of the activities to maintain the borehole by the inhabitants themselves. The Afridev pump has been adopted for all the large scale groundwater development projects since 1992, and there are four distributors in west of the Mzimba District which assures readily supply of the spare parts.

Accordingly, it is deemed appropriate to adopt the Afridev pump in order to contribute the above activity.

(12) Vehicles for the Enlightenment Activities

In order to successfully conclude the Project, it is indispensable that the completed boreholes will be made good use for a prolonged period of time through the maintenance by the inhabitants themselves according to the CBM program promoted by the Government of Malawi. These enlightenment activities include the guidance to establish the Water Management Committee, and lectures related how to operate the Water Management Committee, maintenance techniques, and health and hygiene which are jointly implemented not only by the MOIWD but also by Ministry of Health, Ministry of Community Service.

Accordingly, it is necessary to secure the specialized staff members and vehicles for transportation purpose upon implementing such activities.

At present, three staff members of the CBM team from the MOIWD are stationed at the maintenance office in Mzimba for the Project Area, and they are involved in the IDA's rehabilitation project. All of these three staff members can participate in the Project since their enlightenment activities are to complete in 1997. Further, it is also expected that another staff member is added to the team to have a total of four persons when the Project is to be implemented.

On the other hand, one motorcycle for each staff member and some light vehicles are required. Since all the motorcycles belonging to the MOIWD are becoming too old, apt to fail, and expected to reach the end of their lifespan when the Project is commenced, the request for four motorcycles made by the Government of Malawi is deemed to be appropriate.

The purpose of the light vehicle is to transport the staff members and teaching materials when holding the lectures, however, shortage of light vehicles has prevented them from smoothly implementing their activities. They have problems with the transportation method even for their daily work since there are only two pickup trucks (both of which are becoming too old and often fail) for 105 staff members at the Northern Regional Office of Department of Water.

In view of the circumstances stated above, it is deemed necessary to additionally procure a pickup truck (double cabin) for the enlightenment activities.

(13) Review on Construction of the Workshop

The MOIWD plans to construct a base camp (permanent workshop) for the construction work of the boreholes at Bulala in the Project Area. Although it will be necessary to construct a temporary workshop at the base camp site, the MOIWD wishes to have a permanent workshop in place of the temporary one that can be used for a prolonged period of time since it plans to use it as the permanent workshop (concurrent office and pump repair workshop) to maintain the completed boreholes.

In view of the objectives for the workshop, the following floor space is required for the borehole construction and their maintenance as shown in Table below, which will require approximately 100 m^2 of floor space in either case.

Table 2-2-3-4 Comparisons on the floor space of the workshops for the respective purposes

	Workshop as the base camp for the boreholes construction	Workshop for the maintenance work of the boreholes (mainly the pumps) *
Purpose	• Concurrent warehouse for the repair materials and equipment, and workshop (20～25 m^2) • Warehouse of the tools and spare parts for the drilling machines (20～25 m^2) • Concurrent office and warehouse for the test related equipment and materials (30～35 m^2) • Concurrent radio communication room and office	• Concurrent office and workshop (to repair the pumps), five staff members, two rooms (Approximately 55 m^2) • Concurrent warehouse for the Afridev pump spare parts and workshop (20 m^2) • Warehouse for the four motorcycles (to be procured for the Project) and the spare parts thereof, and workshop to repair them (20 m^2)
Required floor space	Approximately 100 m^2	95 m^2
Remarks	Another warehouse may be necessary to store various equipment and materials such as the Afridev pumps (60 m^2 or greater), large tools related to the drilling machines (rod and drilling casing), mud-water agent and foam agent, casing and screen, etc., however, it is deemed more appropriate to store them in a container or under the tent or sheet, which does not necessary require a dedicated warehouse since their amounts decrease as the work progresses.	

* Requested by the MOIWD

The purchase price of an assembly house for the on-site office in Japan is less expensive than a house having the equivalent floor space to be built in Malawi by a Malawian construction contractor. However, the difference in the house cost will be offset when the transportation costs from Japan are taken into consideration, and additional costs would be required for the foundation and assembly at the work site. Accordingly, it is economically advantageous to have the house built by a building contractor in Malawi.

In view of the review results stated above, it is deemed appropriate to build a house (workshop as the base camp) as requested by the Government of Malawi that can also be used as the workshop for maintaining the boreholes even after completion of the borehole construction work.

In addition, it is necessary to promptly commence the workshop construction upon concluding the agreement with the construction contractor since it may take as long as approximately six months to construct it if the construction period extends over the rainy season.

2-2-4 Examination of Requested Facilities, Machines, Equipment and Materials

(1) Requested Facilities

[Items related to the construction of the borcholes]

The facilities requested by the Government of Malawi for the Project are water supply facilities consisting of borcholes and ancillary structures. As clean surface water which does not require purification and which is enjoyed through the gravity piped water supply system in neighbouring areas is unavailable in the Project Area, boreholes using deep groundwater are deemed to be the most appropriate water supply facilities in terms of both the construction cost and maintenance.

1) Boreholes

With regard to the actual borehole dimensions, the depth should be determined in line with the geological condition of the site as described in 2-2-3. 100mm is deemed to be an appropriate diameter for the completed boreholes which is the minimum figure given the bottom structure of the pump (the outside diameter of the pumping tube of the Afridev handpump is some 82mm) and borehole maintenance (cleaning of the boreholes).

2) Ancillary Facilities

Ancillary facilities for the boreholes include an apron, drainage channel and washing slab, etc. The construction of these facilities pose few problems if the standard specifications in Malawi are adopted in their planning. Consideration must be given to the structural aspect, i.e. use of reinforced concrete or others, as the existing boreholes often show ① a loose concrete slab holding the pump and ② a number of concrete cracks.

Animal dung is often mixed with standing water in places where the drainage conditions are poor, eventually resulting in contamination of the groundwater. It will, therefore, be necessary to provide an appropriate drainage facilities such as the drainage pit, and the fence to prevent the animals from approaching the borehole.

[Items related to the construction of the workshop]

As reviewed under 2-2-3, it is deemed optimum to construct a workshop as originally requested by the Government of Malawi since it is advantageous in terms of the construction cost and will be of good use as a permanent maintenance base for boreholes

to be completed with the Project in addition to the fact that it is to be used as the workshop for the Project. Approximately four rooms (a total floor space of approximately 100 m^2) would be required in order to properly layout the house for the office, warehouse, workshop, etc. In addition, it is deemed optimum to adopt the brick structure which is generally adopted for the standard local government office in Malawi.

(2) Requested Machines, Equipment and Materials

The machines, equipment and materials originally requested by the Government of Malawi are one set of drilling machine with other machines and equipment, tools and spareparts for two sets of drilling machines procured for the past Japanese Grant Aid, borehole construction materials (such as casings, screens, etc.) for 300 boreholes and pumps.

The MOIWD owns three sets of drilling machines which were procured from Japan in the past. However, it is deemed appropriate to procure another set of drilling machine since the overall working capacity of the MOIWD will be interfered if all those three sets of machines are to be used for the Project, and the construction ability of the Government of Malawi can be substantially enhanced by newly procuring another set of it.

The feasibility of using locally manufactured PVC pipe casings and a low cost mud water agent as a substitute for bentonite is discussed in 2-3-2.

In view of the past construction results and work conditions, the originally requested equipment and materials are insufficient to construct 300 boreholes. Accordingly, it is necessary to review them under (2) 1) of 2-3-2 and to list up equipment and materials which need to be brought in by the construction contractor.

2-2-5 Basic Concept of the Project

As a result of the review stated above, the basic concept of the Project is set to the construction of 300 boreholes and provision of the equipment and materials required for the construction work thereof for the purpose of improving the water service ratio for the daily needs at rural villages in west of Mzimba District, which is the national target.

2-3 Basic Design

2-3-1 Design Concept

The Project intends to dig 300 boreholes over an area of approximately 3,980 km^2 in the western region of Mzimba District, excluding those areas that are already covered by urban piped water supply and gravity piped water supply. The design concept of the Project is described in the following paragraphs.

(1) Concept Regarding Natural Conditions

Because the whole target area is composed of Precambrian gneiss, the groundwater contained in weathered zone and fissures provides a good water resource in terms of both quantity and quality. Due to seasonal fluctuations in the groundwater level, it will be necessary to insert strainers into aquifers that do not dry up even in the dry season.

Regarding hydrogeological conditions, considering the fact that the groundwater storage conditions in 50% of the area are poor and the weathered zone where groundwater can be expected to exist in the remaining 50% are very diverse, in order to raise the success rate of the boring works, boring positions shall be selected after first carrying out detailed geophysical prospecting during the implementation design phase. In view of the success achieved in past boring works in the area, a boring success rate of 80% shall be assumed.

Approximately 95% of the annual rainfall (approximately 800 mm) is concentrated in the rainy season from November through to March and, because Project site access conditions and work efficiency levels deteriorate during this period, the implementation plan shall be compiled with these poor conditions for execution in the rainy season taken into account.

(2) Concept Regarding Social Conditions

In consideration of the population distribution and existing well distribution in the target area, the required volumes of domestic water and the established water supply standards in Malawi, the maximum target water supply conditions shall be a daily per capita water supply of 27 l and a benefiting population per bore hole of 500 people.

Furthermore, in order to first cover the areas which are in most urgent need of water supply, the work shall begin from the eastern region (Zone 1) of the request area, where the water supply rate is lowest, and proceed in order to the northern and western regions (Zones 2 and 3).

(3) Concept Regarding Construction Conditions

It is possible to recruit works laborers by job and position in Malawi, and the five-day week is the norm. There are many cases of work being carried out on holidays in the site works sector, and extra wages are paid to laborers on such occasions. In order to reduce the works period in the Project, Saturday shall also be a work day, meaning that the working month shall be 25 days.

(4) Concept Regarding Utilization of Local Equipment and Materials

In terms of equipment, the two drilling machines owned by the Ministry of Irrigation and Water Development (MOIWD), which were provided through Japan's grant aid in the past, shall be utilized together with one more drilling machine to be newly procured for the purposes of the Project.

Materials that can be obtained locally shall be utilized to the full. Cement, gravel, bricks, fuel, casing screens and other items which can be obtained with no problems in terms of quality and delivery, etc. shall be obtained locally.

(5) Concept Regarding the Operation and Maintenance Capacity of the Implementing Agency

The completed boreholes will be operated and maintained by the direct benefiting residents themselves under the CBM Program, however, looking at the example of the IDA rehabilitation project conducted in the past, the education and enlightenment system conducted by the MOIWD with the support of international aid agencies proved effective, and subsequent enlightenment activities have steadily reached more and more sections of the population. Enlightenment activities are currently being carried out through funds provided by aid agencies, however, regarding the Project, there should be no worries in terms of the budget for operation and maintenance because the Government of Malawi has promised to make use of counterparts funds from the 2KR, etc. Thus, operation and maintenance shall be carried out in line with the CBM Program.

Incidentally, as was mentioned in 2-2-3-(12), support vehicles for use in enlightenment activities shall be provided.

The drilling machines and other equipment that were provided in past grant aid projects will be used in groundwater development work following the Project completion, however, the maintenance conditions of these items of equipment in technical terms are not ideal. Therefore, in the implementation phase of the Project, staff members of the MOIWD

shall be encouraged to participate in the execution works to raise their technical levels through a process of OJT.

Furthermore, it is scheduled that the drilling machine to be introduced under the Project will be used in the boring of 3,000 boreholes under the IDA National Water Development Project following completion of the Project. Here, again, there are no problems in terms of the budget for spare parts procurement and operation and maintenance after the Project.

(6) Concept Regarding the Range and Level of Facilities and Equipment

In order to support the movement for operation and maintenance of boreholes by villagers themselves, water shall be raised by pumps, which are easy to operate and maintain and are economical.

Moreover, in consideration of sanitation and ease of use, structures around boreholes shall consist of the concrete lining of well heads, water receiving aprons, drainage channels, washing areas and catch basins.

Regarding drilling machines, which are the most important items of machinery in borehole works, these shall be models that fit with the local geological conditions, to ensure that work is conducted efficiently. Also, all support vehicles shall be four-wheel-drive in consideration of the poor road conditions in Malawi.

All other equipment and materials not included in the request but necessary for the works shall, as a rule, be carried onto the sites by the contractors.

(7) Concept Regarding Implementation Period

In line with the framework of Japan's grant aid scheme, the Project shall be implemented over three years, with preparation works taking place in the first year of the Project, the digging of 180 boreholes taking place in the second year, and the digging of the remaining 120 boreholes taking place in the third year.

2-3-2 Basic Design

(1) Borehole Site Plan

After reviewing the requested villages, it was agreed to construct the boreholes in those that have higher necessity for the boreholes by taking into consideration the assumed population distribution in 1996 which was calculated based on the national census result in

1987 with expected population increase rate of 3.7% p.a. as shown under 2-2-4, and distribution of the existing boreholes.

The Area was divided into the E.A. (Enumeration Area) which has its borders at the rivers and roads in the T.A. (Traditional Authority)/S.T.A. (Sub-Traditional Authority) being as the lower order administration unit of the district used as the statistical unit for the national census. Further, each E.A. is divided into each village. The population in each E.A. is approximately 500 to 3,000 persons.

The borehole sites will be selected based on the following basic policy.

1) To calculate the number of boreholes required for each T.A. based on the assumed population and number of the existing boreholes.

   Number of the boreholes that require construction in T.A. =

$$\left\{\left(\underset{\text{new boreholes}}{300} + \underset{\text{existing boreholes}}{211}\right) \times \frac{\text{Population in T.A.}}{\underset{\text{(total population)}}{235{,}940}}\right\} - \text{Number of the existing boreholes in T.A.}$$

2) Since the number of the new boreholes allocated to each T.A. needs to be further allocated for each E.A., number of E.A. and new boreholes are calculated so that one borehole will be allocated for each 500 inhabitants in the said E.A.

3) To select the villages that require new boreholes by giving a higher priority to those which were listed up in the request and have a larger population in the selected Enumeration Area. The villages with scattered population are also to be selected in view of geological condition (alternative water source in the dry season).

4) Careful consideration is given to hydrogeological conditions of the candidate sites.

5) Villages where the conditions of access roads are poor are omitted from the candidate locations.

6) Priority is given to villages where such public facilities as schools, clinics and public markets are located.

The number of boreholes to be constructed and their locations which have been determined based on the above conditions are shown in Table 2-3-2-1 and Fig. 2-3-2-1 respectively. Villages where new boreholes will be located are listed in the Appendix.

In addition, as stated under 2-2-4, the Project Area consists of two geological and hydrogeological regions; flat area on the western side and hilly and mountainous area on the eastern side. The weathered zone of the basement rock can be generally expected as the aquifer in the former area (Type I). However, since fresh basement rock appears at relatively shallow depth in the latter (Type II), the groundwater can be expected only at the limited geological location such as those with fracture zone. Table 2-3-2-1 shows the number of new boreholes planned in each zone based on the hydrogeological condition stated above.

Table 2-3-2-1 Number of the new boreholes planned for each T.A./zone

T.A. / S.T.A	Assumed population (1996), persons	Number of existing boreholes	Number of new boreholes planned			
			Zone 1	Zone 2	Zone 3	Total
T.A. M'MBELWA	81,092	85	30	67	0	97
T.A. MTWALO	4,902	3	0	0	9	9
S.T.A KAMPINGO SIBANDE	10,453	5	11	0	0	11
T.A. CHINDI	80,228	65	14	21	74	109
T.A. MZIKUBOLA	18,381	1	31	0	0	31
T.A. MPHEREMBE	13,309	15	0	0	13	13
T.A. MZUKUZUKU	26,180	37	16	11	0	27
MZIMBA URBAN	1,395	0	3	0	0	0
Total	235,940	211	105	99	96	300
hydrogeological classification	Type I		6	73	58	137
	Type II		99	26	38	163

(2) Equipment and material plan

1) Basic policy for selecting the equipment and materials

The 300 boreholes are to be constructed using three drilling machines owned by the MOIWD; one new drilling machine to be procured for the Project, one machine procured for the North Kawinga project (to be used for a period of one or more years), and another machine procured for the Mchinji project (to be used for the entire work period).

The selection of the types of machines, equipment and materials and their respective quantities should be based on the following conditions.

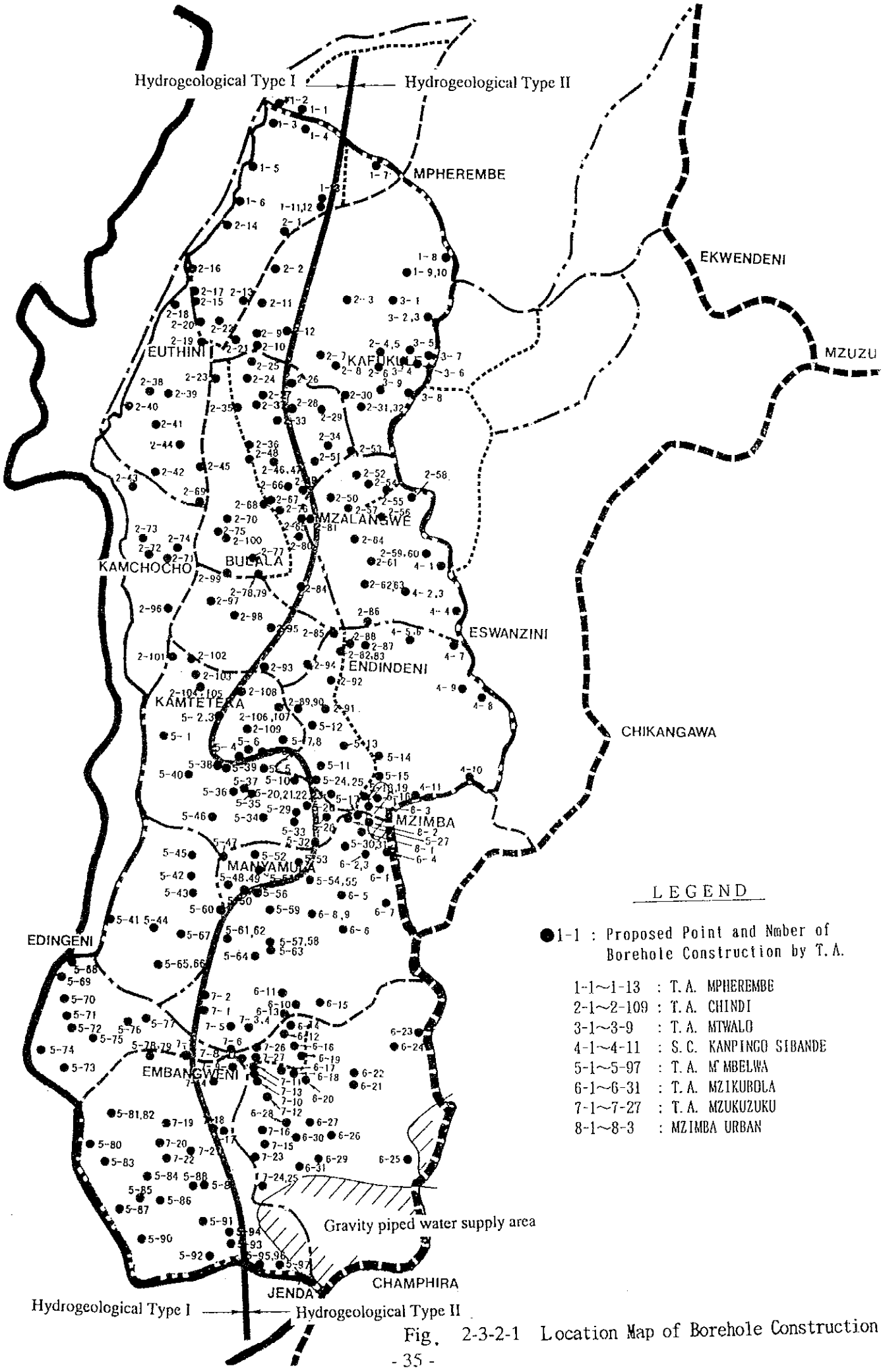


Fig. 2-3-2-1 Location Map of Borehole Construction

① A base camp at Bulala, mobile base in remote area, and liaison office in Mzimba are to be established in order to assure efficient construction of the boreholes within the specified short period of time.

② Selection should take into consideration the organization, staffing strength, technical level, past performance and machines and equipment owned by the MOIWD.

③ Selection should stress machines and equipment with good mobility so that a large number of boreholes can be constructed in an efficient manner in the vast Project Area.

④ The division of labour between the drilling teams and pumping test teams should be established in view of the efficient construction of the boreholes.

⑤ The selected drilling machine should be versatile vis-a-vis working with diverse geological conditions from overburden to hard rocks.

⑥ The equipment and materials to be procured need to be selected in view of the operability, durability, future prospect, readily availability of the spare parts, maintenance, actual results, price, after services, etc.

⑦ Three teams each of the drilling team and pumping test team will be organized, and materials and spare parts will be those required to construct 300 boreholes in two years. At the same time, spare parts required for the maintenance after the delivery will be appropriated.

⑧ In principle, on-the-job training should be conducted in addition to the provision of the drilling machine, other machines, equipment and materials to ensure the transfer of related technologies.

Based on the above equipment and materials basic concept and the design concept indicated in 2-3-1, and in consideration of the borehole construction equipment already possessed by the MOIWD, the equipment and materials required for implementation of the Project are as listed in the following table.

Table 2-3-2-2 Equipment and material plan

Name	Requested	Malawi		Equipment and materials required for the Project		Procure-ment by the Project	Equipment and materials need to be brought for the work	
		North Kawinga (only for the second year)	Mchinji (for the second and third years)	Second year	Third year		Second year	Third year
1) Equipment and materials to construct the boreholes								
1-1 Truck mounted drilling machine	1 unit	1	1	3	2	1		
1-2 Truck mounted compressor	1 unit	1	1	3	2	1		
1-3 Casing and screen (local procurement)	1 set			1	1	1		
1-4 Mud water agent and foam	1 set			1	1	1		
2) Test equipment and materials								
2-1 Electric prospecting machine	1 unit			1	1	1		
2-2 Truck mounted pumping test equipment	1 unit	1	1	3	2	1		
2-3 Electric logging equipment	1 unit	1	1	3	2	1		
3) Supporting vehicles								
3-1 Cargo truck with 5-t crane			1	1	1			
3-2 Cargo truck with 3-t crane	2 units			5	3	2	3	1
3-3 Station wagon				2	2		2	2
3-4 Pickup truck, single cabin	2 units			3	2	2	1	
3-5 Pickup truck, double cabin	2 units			4	3	3	1	
3-6 Motorcycle, 125 cc	4 units			4	4	4		
4) Hand pump (Afridev pump)	300 units			198	132	330		
5) Portable water tank, 4 m^3	1 unit	1	1	3	2	1		
6) Fuel tank, 4 m^3	3 units			* 2	* 2	* 2		
7) Radio communication equipment	1 set			1	1	1		
8) Workshop facilities including the repair equipment and materials								
8-1 House	1 set			1	1	1		
8-2 Welding tools	1 set			1	1	1		
8-3 Bench vise and clamping tools	2 sets			2	2	2		
8-4 Torque wrench	2 sets			2	2	2		
8-5 Filing tools	4 sets			4	4	4		
8-6 Tying tools	2 sets			2	2	2		
8-7 Others	1 set			1	1	1		
9) Spare parts for the existing drilling machines to be used for the Project	2 sets			2	1	2		

* Two tanks in total: One each 6 m^3 for base camp and 4 m^3 for transportation

2) Selection of main machines, equipment and materials

① Drilling Machine and Other Equipment

The drilling machine and other equipment to be procured should be selected in view of the smooth implementation of the Project while noting the following requirements.

- The actual performance of the drilling machines and other equipment provided by Japan in the past should be carefully examined.
- The natural condition, socioeconomic conditions and infrastructure, etc. in the Project Area should be taken into consideration.
- The original contents of the request made by the Government of Malawi and existing groundwater development projects should be taken into consideration.

The main machines for the Project is a drilling machine and Table 2-3-2-3 lists the characteristics of different types of drilling machines while Table 2-3-2-4 gives their evaluation results. The following conditions deriving from the geological condition of the Project Area must be satisfied in the evaluation of these machines.

a) The geology of the Project Area consists of a relatively loose surface layer of unconsolidated sediments and highly weathered rocks with a lower layer of hard rock, mainly gneiss of the Pre-Cambrian. As the groundwater is generally expected to exist in a the fissure zone between the highly weathered rock layer and the upper hard rock layer, the new drilling machine must be capable of dealing with diverse geological conditions.

b) The new drilling machine must have a better work performance than the percussion type drilling machines currently owned by the MOIWD.

c) The new drilling machine must be capable of drilling a relatively large diameter hole throughout the different layers, ranging from collapsible and weak layers to hard bedrock, using the normal mud circulation method.

Table 2-3-2-3 Drilling Methods

Type	Characteristics and Summary	Drilling Method	Rotary Drilling 	Straight Drilling 	Mud Water Normal Circulation 
Percussion Boring	Drilling is conducted by the impact of the free fall bid from a certain height. Has the longest application history of all deep drilling methods. While the machine is cheap, this type of drilling is unsuitable for a consolidated layer.	Percussion		Wire	Mud Collector
Spindle Type Rotary Boring	Drilling is conducted by the rotary and straight movements of the spindle with a fixed drill pipe. Compact and suitable for a core drilling.	Rotary	Spindle	Spindle	Mud Water Normal Circulation
Table Type Rotary Boring	Drilling is conducted by rotary movement using the rotary table and straight movement using the suspension wire. Although a large rotation force is possible, the machine tends to be large.	Rotary	Turn Table	Wire	Mud Water Normal Circulation
Top Drive Type (Power Head Type) Rotary Boring	Drilling is conducted by rotary movement using the hydraulic motor at the top of the drill pipe and straight movement using the hydraulic jack. The machine is relatively small and light and has high efficiency, including good operationability of the drill pipe.	Rotary	Hydraulic Motor	Hydraulic Jack	Mud Water Normal Circulation
Reverse Rotary Boring	The flow direction of the mud water is the reverse of normal rotary boring methods. Need to use much mud water and suitable for a relatively large hole.	Rotary	Spindle Turn Table Hydraulic Motor	Spindle Turn Table Hydraulic Motor	Mud Water Reverse Circulation
Air Rotary Boring	Compressed air is used to discharge the mud to replace the mud water in the rotary boring methods. Efficient but incapable of deep drilling.	Rotary	Spindle Turn Table Hydraulic Motor	Spindle Turn Table Hydraulic Jack	Compressed Air, Foam, Normal Circulation
Air Percussion Boring	Drilling is conducted by the impact of the rotating hammer at the end of the air rotary drill pipe. Highly efficient but incapable of deep drilling.	Rotary & Impact	Spindle Turn Table Hydraulic Motor	Spindle Wire Hydraulic Jack	Compressed Air, Foam, Normal Circulation

Table 2-3-2-4 Drilling Machine Comparisons

◎: Very Good ○: Good △: Slightly Bad ×: Bad

Machine Type and Drilling Method		Drilling Capacity		Applicable Layar			Applicability Below Groundwater Level	Applicability to ⓕ and ⓖ	Availability of Spare Parts	Operationability	Durability	Maintenance	Work Speed	Operation Cost	Price	Comprehensive Appraisal
		Depth (m)	Hole Diameter (mm)	Overburden	Sedimentary Rock	Hardrock										
ⓐ Percussion (Cable Tool)	With bottom sampler	100-200	100-600	○	△	×	△	×	○	○	◎	○	×	○	Inexpensive	×
ⓑ Direct Rotary, Spindle Type	Mud-water normal circulation	500-	46-1,500	○	○	△	○	○	○	○	○	○	△	○	Inexpensive	△
ⓒ Direct Rotary, Table Type		500-	46-1,500	○	○	△	○	○	△	△	○	△	△	○	Expensive	△
ⓓ Direct Rotary, Top Drive, Power Head Type		500	46-1,500	○	◎	△	○	◎	△	△	○	△	△	○	Inexpensive	△
ⓔ Reverse Rotary	Mud-water reverse circulation	100	450-1,500	○	△	△	○	×	×	△	○	△	△	—	Most expensive	×
ⓕ Air Rotary	Conditions only compressed air used	100	100-200	◎	○	×	△	—	△	△	○	△	—	—	—	—
ⓖ Air Percussion		100	100-200	×	△	◎	△	—	△	△	○	△	—	—	—	—
ⓗ Spindle Type, Air Rotary, Air Percussion	Combination of mud-water normal circulation and compressed air	500-	46-1,500	◎	○	◎	○	—	△	△	○	△	○	○	Most expensive	○
ⓘ Table Type, Air Rotary, Air Percussion		500-	46-1,500	◎	○	◎	○	—	△	△	○	△	○	○	Most expensive	○
ⓙ Top Drive Type, Air Rotary, Air Percussion		500	46-1,500	◎	◎	◎	○	—	△	△	○	△	◎	○	Most expensive	◎

Note) ⓗ = ⓑ + ⓕ + ⓖ
ⓘ = ⓒ + ⓕ + ⓖ
ⓙ = ⓓ + ⓕ + ⓖ

d) The new drilling machine must be capable of drilling through hard rock layers with high efficiency using an air-hammer.

e) The new drilling machine must be mounted on a truck to ensure superior mobility to cover the vast Project Area and must be equipped with a mud pump, injection pump (for form drilling) and a hydraulic collapsible boring tower.

Based on the above conditions, the rationals for the best drilling machine for the Project are explained below.

i) Drilling machines are largely classified into the percussion type, rotary type with normal mud circulation and rotary type with reverse mud circulation. Although the percussion type is easy to operate and maintain because of its simple structure, the drilling speed is slow. In addition, its inability to drill through hard rock disqualifies it from use in the Project because of the geological condition of the Project Area and the planned schedule for the Project.

The rotary type machine with reverse mud circulation is normally used for the drilling of a large diameter hole (more than 450mm) and is unsuitable for the Project.

The remaining type, i.e. rotary type with normal mud circulation, is capable of dealing with various geological conditions and work environments. Its additional use for air-percussion drilling or air-rotary drilling is also feasible.

ii) As examined in i) above, the rotary type drilling machine with normal mud circulation appears to be the most suitable for the Project. In fact, this type is further divided into three models, i.e. spindle, table and top drive models. The spindle model requires much work during drilling operation because of the relatively little movement of the spindle and is, therefore, inefficient and most suitable for small jobs, such as test boring. Since the table type is suitable for the drilling of a borehole of more than several 100m in depth, the top drive model appears to be the most suitable for the Project.

iii) When a drilling machine (ⓗ, ⓘ, ⓙ) which has air-rotary (ⓕ) as well as air-percussion (ⓖ) drilling functions is compared to any of the above

3 rotary type drilling machine models (ⓑ, ⓒ, ⓓ), it is found that there is little difference in the price and operation cost, etc. for a similar performance level (expressed in horse power). Consequently, the final selection of the machine should be based on the expected work efficiency.

The drilling machine to be selected is, therefore, the hydraulic top drive power swivel type which is the same as those provided by Japan in the past. Given the planned maximum drilling depth of some 70m, the actual machine must have sufficient capability to drill a final borehole diameter of 6-3/4 inches or greater and a maximum drilling depth of 100 to 200 m with ease. Moreover, as well as high efficiency and safety, the lightweight and good workability requested by the MOIWD must be guaranteed.

Since three drilling machines will be required in the second year and two in the third year, (two machines in the second year and one machine in the third year will be provided by the MOIWD,) it is necessary to procure one drilling machine. The accessory equipment and materials such as the high pressure compressor and borehole drilling tools will be selected to match with the performance of the selected drilling machine.

The functions of the high pressure compressor belonging to the drilling machine are to drive the air hammer and to discharge the drilling sludge by circulating it. The capacity of the air compressor is very critical since it determines the drilling capacity for the hard basement rock.

In view of the above conditions and geological conditions at the respective borehole sites, the truck mounted air compressor having the capacity of 17.5 kg/cm^2 or greater in pressure and 21 $m^3/min.$ or greater in flow rate will be selected.

The number of air compressor to be procured will be one since one to two air compressors are to be borrowed from the Government of Malawi.

② Truck Mounted Pumping Test Equipment

The pumping test teams will be assigned the following work.

- Cleaning of boreholes drilled by the drilling teams.

- Determination of possible pump discharge by pumping tests.
- Installation of handpumps.
- Determination of water quality by conducting quality tests.

Given the above list of assigned work, the provision of the equipment described in a) and b) below is deemed necessary for each pumping test team. However, only one set of pumping test equipment and tools will be newly procured since one set each of the same is included for all the existing drilling machines therefore, only one set of pumping test equipment and tools will be newly provided.
The requirements for the pumping test equipment and tools are as follows.

a) Track-mounted pumping test equipment is selected in view of mobility, including a tower and a winch to lift up and down the compressor and tools for air lifting and air jettisoning. The tower and winch can also be used for pump installation.

   The borehole drilled will be cleaned using the air lift, for which an air compressor having the capacity of 7.0 kg/cm^2 or greater in pressure and 3.5 m^3 or greater in flow rate is mounted on the truck. Further, the submersible pump to be used for the pumping test will have the minimum discharge of 100ℓ/min. at water head of 50 meters, which is also equipped with a generator to drive it.

b) Other equipment includes a submersible pump, generator and groundwater level measuring apparatus, etc. for pumping tests and an electric conductivity meter (with thermometer) and PH meter, etc. for water quality tests.

③ Vehicles

Because of the local road conditions, all vehicles except motorcycles should be right-hand steering vehicles with a four wheel drive mechanism. In the light of the discussion about ① and ② above, the optimal vehicle combination to perform the work using the equipment and materials efficiently are described below.

There will be three groundwater development teams for the second year and two in the third year for the borehole construction work, and each team will consist one each construction group and pumping test group.

One construction group will consist of one truck with the drilling machine, one truck with the air compressor, one truck for transporting the drilling materials, one truck with water tank (with crane), and one supporting vehicle (pickup truck).

The pumping test group will consist of one each truck with pumping test equipment and pickup truck.

Standard composition of the respective groups are shown in Table 2-3-2-5.

a) Transportation truck with crane

Two transportation trucks with crane will be allocated for each drilling group.

One of the two will be used to transport the drilling tools (drill pipes, casing pipes, bits, etc.) and materials to finish the borehole (PVC pipes, gravel, cement, aggregate) from the base camp to the work site and vise versa. It is also used to transport the gravel to be obtained from sand collecting point at Chilumba on the shore of Lake Malawi (approximately 280 km from the base camp at Bulala) to be specified by the MOIWD and PVC pipes delivered to Lilongwe.

The other is to be used to transport water and fuel.

In view of the water situations and contents of the borehole construction, it is understood that securing, storing, and prompt supply of water required for the work will substantially affect smooth implementation of the Project. In terms of the tank capacity, one truck with 4 m^3 tank is required for each drilling group in order not to delay the schedule since there will be an inherent water leakage involved in the mud-water circulation method. The truck is to be equipped with a portable water tank that can be mounted and dismounted using the crane so that it can also be used for transporting the fuel (using the portable fuel tank).

As stated above, two trucks with 3-ton crane are required for each of the drilling groups to load and unload heavy items. Accordingly, a total of six trucks will be required for three drilling groups in the second year and four trucks for two drilling groups in the third year.

Table 2-3-2-5 Standard composition of the main equipment, materials, and vehicles for the borehole construction

Work implementation system / Main equipment, materials, and vehicles	Second year									Third year						
	Total number	Groundwater development team						Comprehensive management (base camp)	Enlightenment activities (MOIWD)	Total number	Groundwater development team				Comprehensive management (base camp)	Enlightenment activities (MOIWD)
		A		B		C					A		B			
		Drilling group	Pumping test group	Drilling group	Pumping test group	Drilling group	Pumping test group				Drilling group	Pumping test group	Drilling group	Pumping test group		
Truck mounted drilling machine	3	1		1		1				2	1		1			
Truck mounted high pressure air compressor	3	1		1		1				2	1		1			
Truck mounted pumping test equipment	3		1		1		1			2		1		1		
Truck with crane	6	2		2		2				4	2		2			
Station wagon	2							2		2					2	
Pickup truck (single cabin)	3	1		1		1				2	1		1			
Pickup truck (double cabin)	4		1		1		1		1	3		1		1		1
Motorcycle	4								4	4						4

The Government of Malawi requested for two trucks with crane. Since one truck with crane as procured for the Mchinji project will be borrowed from the Government of Malawi for the Project, there will be a shortage for three trucks with crane in the second year and one in the third year. However, the number of the trucks with crane will be limited to two for the Project since such shortages are to be covered using the trucks to be brought in by the contractors.

b) Pickup truck

A total of two pickup trucks are required for one groundwater development team, which consists of one each drilling group and pumping test group (pumping test and ancillary facility work pump set), for the purposes of transporting the respective group members, lightweight equipment and materials, communication, and supporting. The single cabin pickup truck is deemed appropriate for the former since it mainly requires transportation of lightweight equipment and materials. The double cabin pickup truck is deemed appropriate for the latter since it mainly requires transportation of the group members.

The Government of Malawi requested a total of four pickup trucks (two each of the single cabin and double cabin pickup trucks), which will only satisfy the requirement for the third year. Accordingly, the expected shortage in the second year (one each of the single cabin and double cabin light trucks) is to be covered with those to be brought in by the contractor.

In addition, another vehicle will be necessary for the enlightenment activities as reviewed under (12) of 2-2-3, for which one double cabin pickup truck will be additionally procured in order to facilitate transportation of the staff members and teaching materials.

c) Station wagon

Two station wagons are required at the base camp to implement comprehensive management and public relation activities, and to transport equipment to be repaired and/or other test equipment (electric prospecting and electric logging). However, since they were not included in the request, they will be brought in by the contractor.

d) Motorcycle

One motorcycle is required for each of the staff members in charge of enlightenment activities who provide assistance for organizing the Village Water Committee. Since there will be four staff members assigned for the Project, a total of four motorcycles are to be procured as originally requested. Regarding these four motorcycles, the off-road type motorcycle with engine displacement of 125-cc is deemed appropriate in view of the local road condition.

④ Casings and Screens

In the case of the present Project, the use of PVC casings is planned because of the newly established PVC pipe local production system, allowing orders in small quantities and fast delivery. Although the PVC pipe is more vulnerable to heat than the FRP pipe, a minimum inventory level of PVC pipes on site should ensure the use of new pipes which have not been subject to deformation or deterioration due to heat.

Therefore, PVC pipes made in Malawi are to be adopted.

⑤ Mud-water agent and foam

These consumable items are calculated for 300 boreholes with the failure rate of 20%.

a) A liquid chemical product will be appropriated as the mud-water agent which is lighter in its weight than the bentonite and more economical due to its lower transportation cost.

In general, 25 kg of bentonite will be required to drill a borehole of 10 5/8" to 8 1/2" diameter by 1 meter, which will require the following amount to complete the entire work.

$$25 \text{ kg/m} \times 20 \text{ m} \times 360 \text{ boreholes} = 180{,}000 \text{ kg}$$

If the liquid chemical product is to be used in place of the bentonite, the following amount will be required.

$$180{,}000 \text{ kg} \div 100 = 1{,}800 \text{ kg}$$

b) In general, the following amount of the foam will be required.

1.08 kg× 30 m × 360 boreholes = 11,664 kg

However, its use is expected to be minimal due to the superior discharge characteristics of the sludge with the construction work in Malawi. However, since it will be necessary to use it if the geology is found to be complicated, one tenths of the original amount, which is equal to 1.1 ton, will be appropriated.

⑥ Electric prospecting equipment

The electric prospecting equipment is used to seize the underground hydrogeological condition, which is required to select an alternative borehole site in case the dry hole is obtained after the work. One equipment will be appropriated as originally requested since it will be stored at the base camp so that it can be readily used.

⑦ Electric logging equipment

The electric logging equipment is used to seize the distribution of the aquifer in the drilled borehole and to program the casing position before inserting the casing and screen into the drilled borehole. One equipment is required for each drilling machine. One equipment will be procured as originally requested since two equipment and one equipment will be borrowed from the Government of Malawi for the second year and third year, respectively.

⑧ Hand pump

The planned pump is the Afridev handpump which is requested by the Government of Malawi. This decision is also based on the Afridev handpump's maintainability, durability and ease of securing spare parts in the future. 330 pumps will be provided against the originally requested quantity of 300 units by including the spare pumps.

⑨ Water Tank

One water tank (4 m^3) is required for each drilling machine to supply drilling water. Instead of a fixed tank, a removable tank using a crane will be employed to ensure efficient vehicle use.

One water tank will be procured as originally requested since it is equipped with each of the drilling machine to be borrowed from the Government of Malawi.

⑩ Fuel tank

The Government of Malawi originally requested three 4 m^3 tanks since it will be possible to transport the required fuel to the work site using the portable 4 m^3 tank and one fixed large tank (6 m^3) installed at the base camp.

Accordingly, two fuel tanks (one each fixed tank (6 m^3) and portable tank (4 m^3) will be adopted.

⑪ Radio communication equipment

The communication equipment is required to maintain the implementation management systems that assures periodical reporting, business communications, emergency communications and to effectively manage the procured equipment and materials, which is used to communicate among the base camp at Bulala, liaison office at Mzimba, and supporting vehicles.

- Base camp at Bulala and liaison office at Mzimba:
  One set each or a total of two sets (including the antenna, mast, and other accessories)
- Pickup truck : 4 sets

⑫ Workshop facilities including the repair equipment and materials

The following items were originally requested.

- Welding tools : One set
- Bench vise and clamping tools : Two sets
- Torque wrenches : Two sets
- Filing tools : Four sets
- Tying tools : Two sets

In addition to the above, the following items will be appropriated.

- Electric drill with bits
- Bench grinder with grindstone
- Disc grinder with grindstone
- Measuring tool, punch, calipers, ruler, and compasses

- Gas cutting tool
- Grease pump
- Hydraulic jack

⑬ Spare parts for the existing drilling machine to be used for the Project

The spare parts including the repair equipment and materials will be appropriated for the existing drilling machines procured by the past Japanese Grant Aid which are to be borrowed from the Government of Malawi during the work period.

a) Machine for North Kawinga project

- Drilling machine : One set
- High pressure compressor : One set
- Pumping test equipment : One set

b) Machine for Mchinji project

- Drilling machine : One set
- High pressure compressor : One set
- Pumping test equipment : One set
- Truck with 5-ton crane : One set

3) Equipment and material plan

The equipment and materials required to implement the Project will be provided with the Government of Malawi by the Japanese Grant Aid, and Table 2-3-2-6 shows the specifications and quantities of such equipment and materials determined based on the review results and basic policy.

Table 2-3-2-6-(1) List of Machines, Equipment and Materials Specifications and Quantities

Items and Specifications	Number of Items Procured
I. Equipment and materials for borehole construction	
1. Drilling machine	
1-1 Drilling machine	1
A truck-mounted rotary and air hammer types	
Specifications for the truck : Water-cooled diesel engine, right-hand steering, 4 × 4	
Capacity of the drilling machine : Final drilling diameter - 6-3/4" (170 mm)	
Drilling depth - approx. 100 m (air hammer)	
Capacity of the sludge pump : Discharge volume - 600 /min, pressure - 20 kg/cm^2 or more	
1-2 Standard accessories of the above	1 set
1-3 Tools for the above	1 set
a) Drilling tools	
(Mud-water drilling tools, down-the-hole hammer drilling tools, etc.)	
b) Casing tools	
(Surface casing, casing holder, pipe, etc.)	
c) Fishing tools	
(Jacks, inside/outside taps, etc.)	
2. Truck-mounted air compressor	1 set
Capacity: 17.5 kg/cm^2 × 20 m^3/min or more, with standard accessories	
3. Casing screen (to be procured at the site)	
3-1 PVC casing 4", 3 m	3,850
3-2 PVC screen 4", 3 m	1,650
3-3 PVC bottom plug 4", 1 m	330
3-4 Solvent cement	266
3-5 Drills and rivets	1 set
4. Mud-water agent, foam	
4-1 Mud-water admixture : For mud-water rotary	1 set
4-2 Foam : For air percussion	1 set
II. Testing equipment and materials	
1. Electrical prospecting equipment (Maximum prospecting depth: 200m or more)	1 set
2. Pumping test equipment and materials	1 set
2-1 Truck-mounted well development unit (with a derrick and winch)	
Specifications for the truck : Water-cooled diesel engine, right-hand steering, 4 x 4	
2-2 Air-lift tools	
Compressor : 7 kg/cm^2 × 3.5 m^3/min or more	
Discharge pipe - 2" ┐	
Air pipe - 3/4" ┘ total 75 m	
2-3 Generator : 50 Hz, 220 V, 20 kVA	
2-4 Submersible pump : Head - 50 m, discharge volume - 100 l/min or more	
Lifting pipe - 1-1/2"	
2-5 Groundwater level measuring apparatus : 100 m	
2-6 PH meter	
2-7 Electric conductivity meter (with a thermometer)	

Table 2-3-2-6-(2) List of Machines, Equipment and Materials Specifications and Quantities

Items and Specifications	Number of Items Procured
3. Electric logging equipment Type : Automatic recording, with 100-m cord Logging items : Natural potentiality, resistivity (with micro, log) Accessories : Batteries, recording paper, etc.	1 set
III. Supporting vehicles	
1. Cargo truck with a crane Specifications : Water-cooled diesel engine, right-hand steering, 4 × 4 Capacity : With a 3-ton crane, GVW - 16 tons	2 units
2. Pickup (single-cabin) Specifications : Water-cooled diesel engine, right-hand steering, 4 × 4 500 kg	2 units
3. Pickup (double-cabin) Specifications for the pickup : Water-cooled diesel engine, right-hand steering, 4 × 4 500 kg	3 units
4. Motor bike For off-road running : 100- to 125-cc class	4 units
IV. Hand pump Specification : Afridef pump	330 units
V. Water tank Specification : 4 m^3 (truck mountable) With a water pump	1 unit
VI. Fuel tank	
1. For the base camp - 6 m^3 (to be installed on the ground)	1 unit
2. For carrying - 4 m^3 (portable type)	1 unit
VII. Communicating equipment For the base camp (with accessories including the antenna and mast): 2 units For moving vehicles : 4 Output : 100 W (for both of the above)	1 set
VIII. Workshop facilities including repair equipment and materials	
1. Welding tools	1 set
2. Bench vice and clamping tools	2 sets
3. Torque wrenches	2 sets
4. Filing tools	4 sets
5. Tying tools	2 sets
6. Electric drills with bits	1 set
7. Bench grinder with grindstone	1 set
8. Disk grinder with grindstone	1 set

Table 2-3-2-6-(3) List of Machines, Equipment and Materials Specifications and Quantities

Items and Specifications	Number of Items Procured
9. Measuring tools, punches, calipers, rules, and compasses	1 set
10. Gas cutter	1 set
11. Grease pump	1 set
12. Hydraulic jacks	1 set
IX. Spare parts for existing drilling machines to be used for the project	
1. Spare parts for machine used in North Kawinga 1-1 Drilling machine (FSW-7T), (NZ227) 1-2 Compressor (PDSH750), (NZ227) 1-3 Pumping test equipment and materials (DWT-60C), (PDS125), (DCA-27PI) (40BHS 12-52. 2), (ST-Type), (SC-51), (PH 81) 1-4 Electric logging equipment (Geologer 3030)	1 set
2. Spare parts for machine used in Mchinji 2-1 Drilling machine (FSW-7T), (NZ227) 2-2 Compressor (PDSH750), (NZ227) 2-3 Pumping test equipment and materials (DWT-60C), (PDS 125), (DCA-27PI) (40BHS12-52, 2), (ST-Type), (SC-51), (PH81) 2-4 Truck with a 5-ton crane (NZ 227) 2-5 Electric logging equipment (Geologer 3030)	1 set
X. Tools for existing equipment and materials (for 180 boreholes)	
1. Drilling tools Drill pipe, drill collar, stabilizer, down-the-hole hammer, shock absorber, casing tool 7-1/2", tools, etc.	1 set
2. Air lifting tools Discharge pie 2", air pipe 3/4"	1 set
3. Others, tools	1 set

(3) Borehole Construction Method and Ancillary Facilities

The borehole construction process using the procured machines, equipment and materials is outlined below.

1) The drilling diameter at the borehole mouth will be 10 5/8". Mud water drilling will be conducted to a depth of 6m and a conductor pipe with an internal diameter of 10" will be inserted.

2) In the case of the overburden and/or highly weathered rock layer (10-20m below the ground surface) below the depth given in (1) above, further mud water drilling will be conducted with a drilling diameter of 8 1/2" and a guide pipe with an internal diameter of 7 1/2" will be inserted. Electric logging will be conducted where deemed necessary to confirm the existence of an aquifer before the insertion of the guide pipe.

3) In the case of the hard rock layer below 2) above, air-hammer drilling will be conducted with a drilling diameter of 6 3/4".

4) When the predetermined drilling depth has been reached, the existence of an aquifer will be confirmed by electric logging and a screen and casing, both with an internal diameter of 4", will be installed.

5) Gravel of a predetermined size and clay will be firmly packed around the screen and casing respectively.

6) The borehole will be cleaned using the air lift equipment until clean water is obtained.

7) Pumping and water quality tests will be conducted to determine the usability of the borehole. In the case of the pumping test, the phased pumping test and/or recovery test will be conducted where deemed necessary.

8) When the borehole is judged to be usable based on both the pumping and water test results, a pump will be installed and the work relating to such ancillary facilities as the apron, drainage channel and washing slab etc. will be implemented to complete the borehole construction process.

The above ancillary facilities will be designed based on the following conditions.

- Measures will be introduced to keep the environment around the borehole clean and the facility layout will ensure the convenience of users.
- All the facilities will be of a durable structure.
- The apron will have an area of some $4m^2$ which should not disturb water drawing and will be provided with a bucket stand so that users can easily place the buckets on their heads.
- The drainage channel will have a total length of 7.6m to prevent the area around the mouth of the borehole from becoming muddy.
- Two washing basins will be provided in the washing slab.
- In view of the prospective use of the Afridev handpump, standing area with the same structure as the apron will be constructed at the back of the handpump.
- In view of the fact that animals are attracted to standing water which occurs in places where the drainage conditions around a borehole are poor, causing groundwater

pollution by dung and encouraging the propagation of mosquitoes, a drainage pit will be constructed near the borehole and a wooden fence to prevent animals approaching the drainage pit will be constructed by local inhabitants.

Figs. 2-3-2-2, 2-3-2-3 and 2-3-2-4 show the structures of the borehole, ancillary facilities and drainage pit respectively.

The operations shown under 1) to 5) above will be implemented by the drilling machine group, and the operations under 6) and 7) by the pumping test group.

To complete 300 wells within 2 years with the above mentioned two or three teams, it is important for the Government of Malawi to repair or construct the access roads by obtaining cooperations of local inhabitants so that the running of vehicles is not hindered.

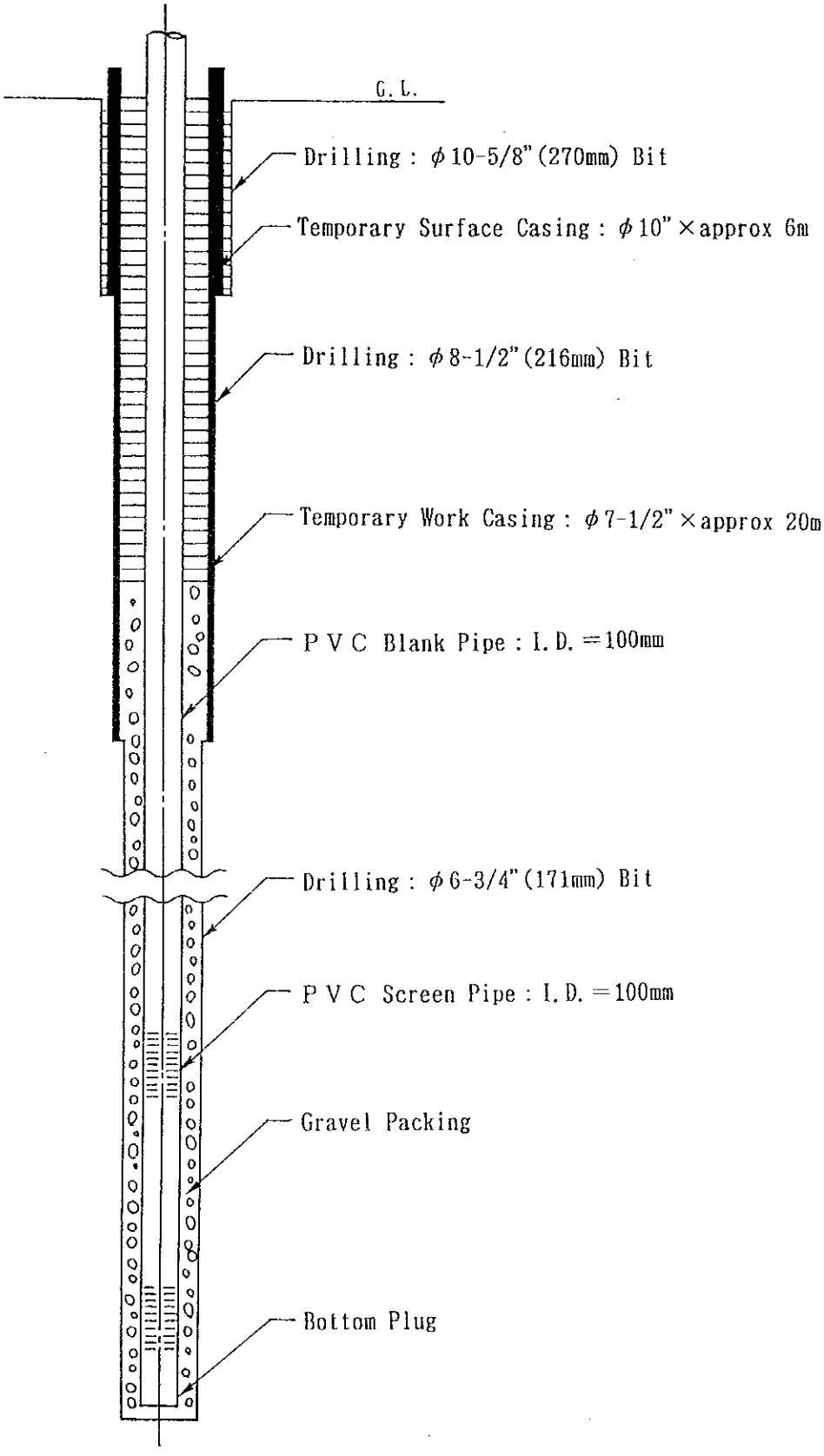


Fig.2-3-2-2 Structure of Borehole

Fig.2-3-2-3 Plan and Section of Ancillary Facilities

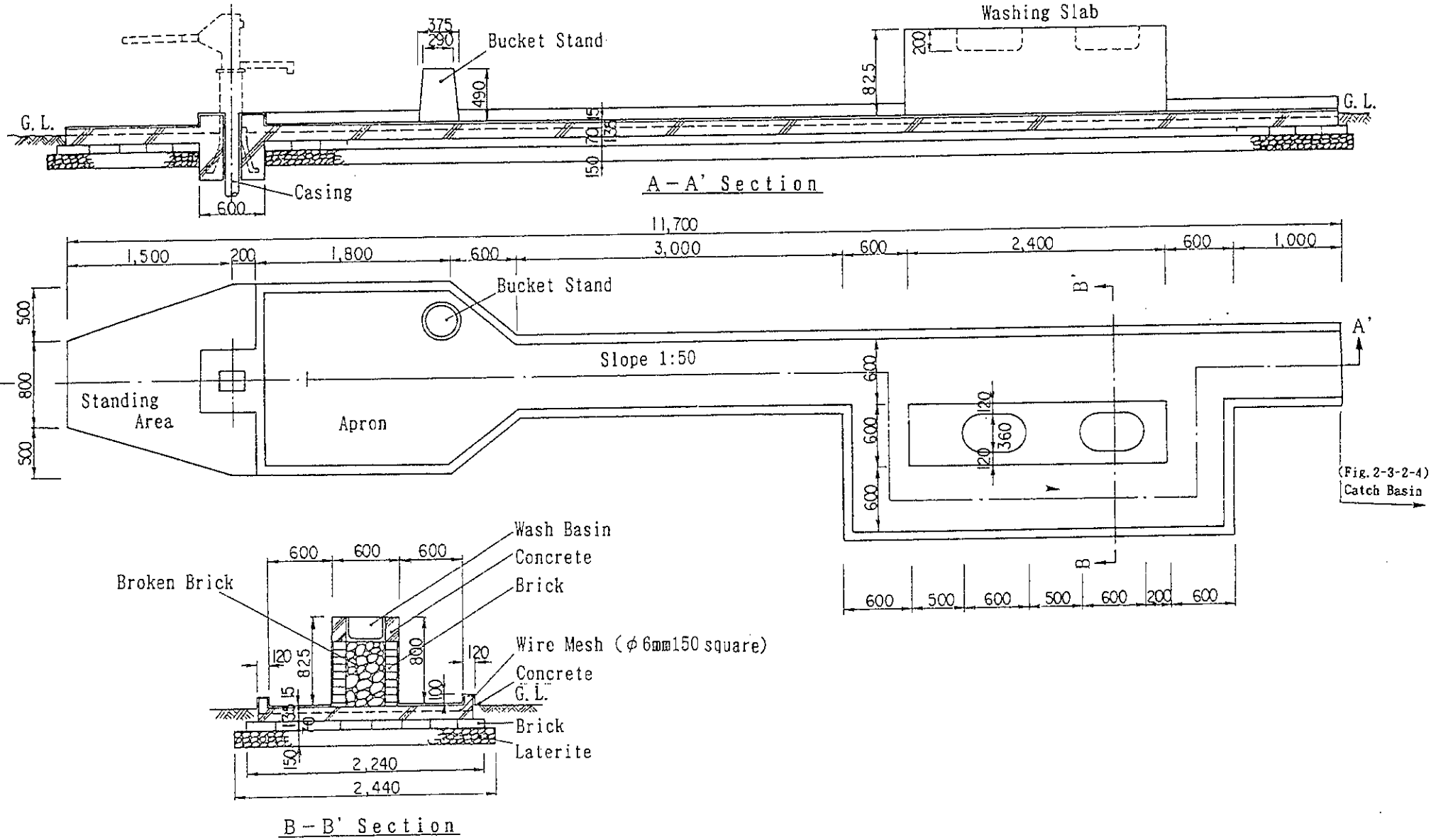
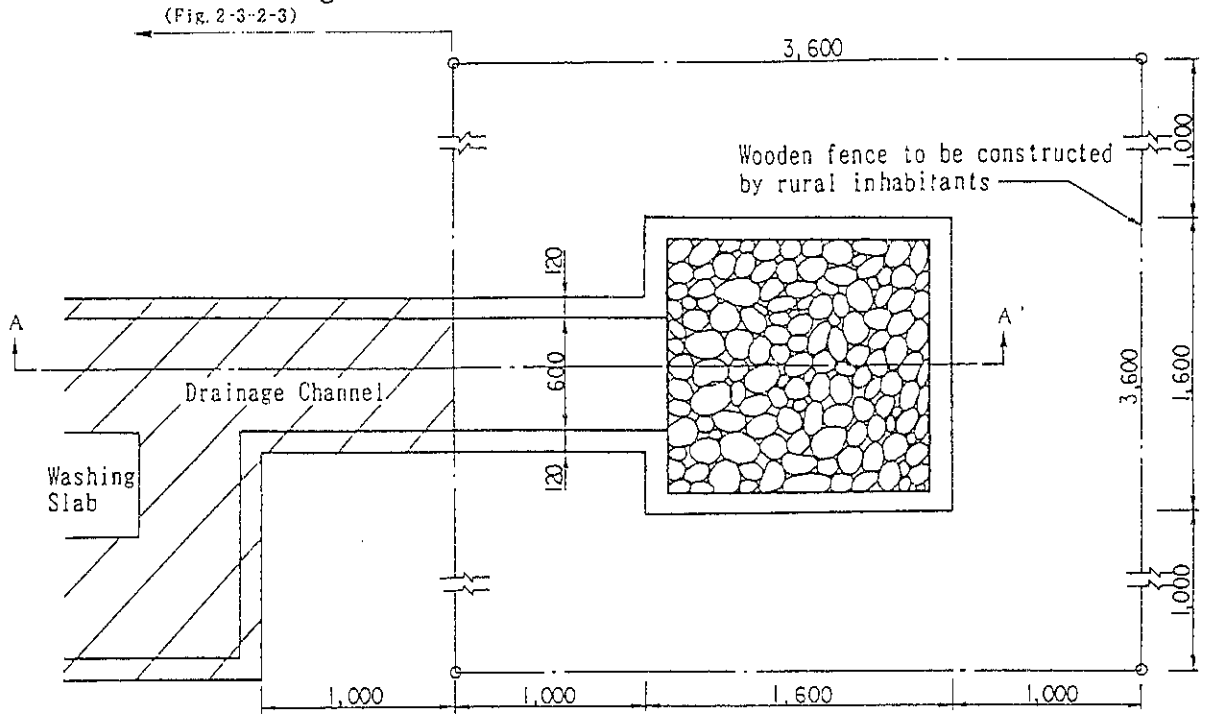


Fig. 2-3-2-4 Plan and Section of Catch Basin



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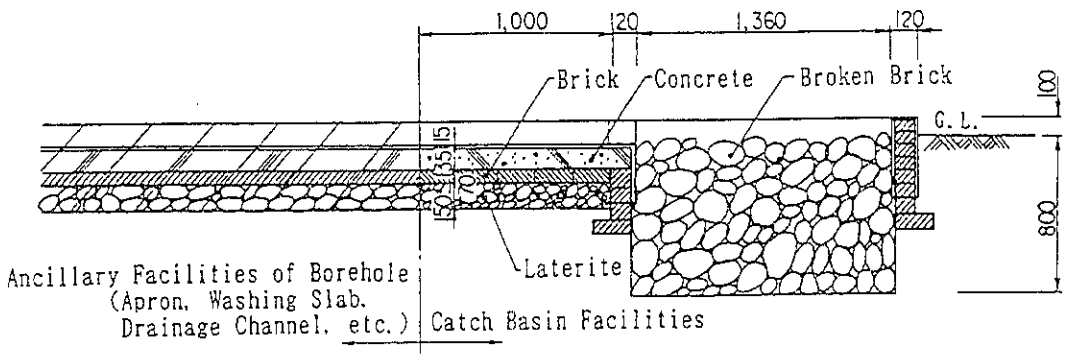


A－A' Section

(4) Workshop Building Plan

1) Layout plan

The land to accommodate the following is required for the entire workshop facility since it needs to function as the base camp for construction of the boreholes.

① Workshop building (Office, repair shop, and equipment and material warehouse): One building

② Three container to store the hand pumps

③ Three containers to store large spare parts for the drilling machines

④ Gravel yard to finish the well

⑤ Area to install the fixed fuel tank (6 m^3)

⑥ Well

⑦ Pit latrine

⑧ Parking space for the trucks mounted with drilling machines and supporting vehicles (12 large trucks, 3 small trucks, and 8 supporting vehicles)

The respective facilities are laid out using the fence at the required site having the area of 50 m × 60 m (3,000 m^2) as shown in Fig. 2-3-2-5 by taking the facility functions, work environment, hygienic environment, and access roads into consideration.

2) Determination of the size and make of the workshop building

The size is determined as follows based on the review result under 2-2-3 (13).

①	Concurrent office and radio communication room :	Approximately 20 m^2
②	Concurrent office and testing equipment storage area :	Approximately 35 m^2
③	Storage area for the drilling tools and spare parts :	Approximately 20 m^2
④	Repair workshop and storage area for the equipment and material :	Approximately 20 m^2
	Total :	Approximately 95 m^2

As shown in the Table 2-3-2-7 below, it is judged to most economical and efficient to have the brick structure with steel roof for the building.

Fig. 2-3-2-6 shows the plan drawing for the basic structure of the building.

In addition, other details are to conform to the finish Table 2-3-2-8 in view of the local building method and security of the facility.

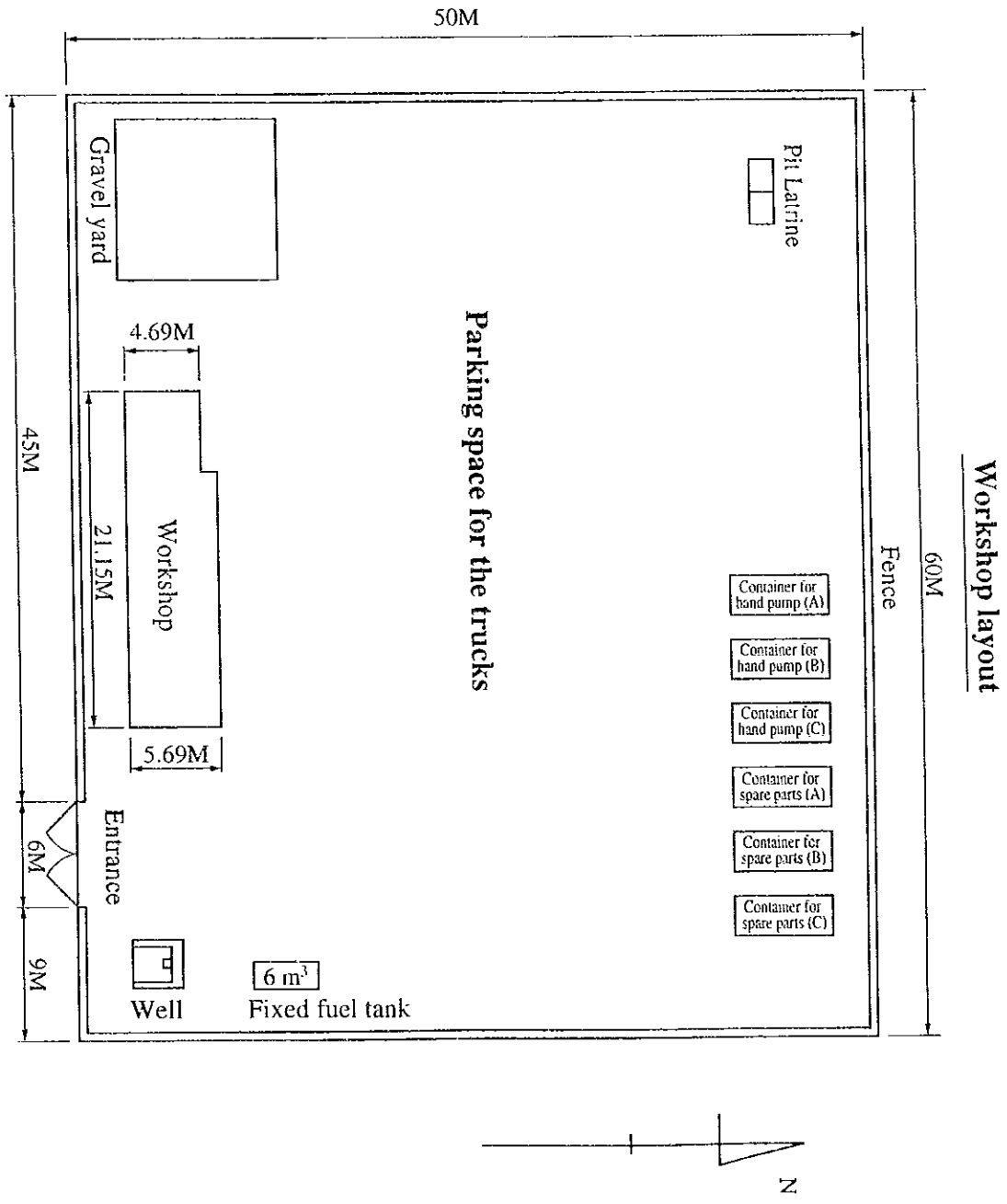


Fig. 2-3-2-5 Site Plan for Workshop

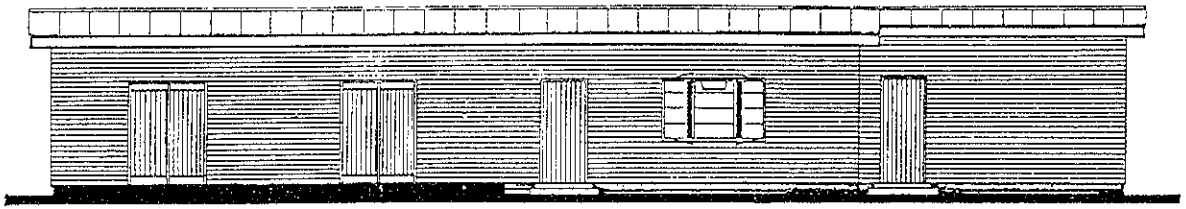
Table 2-3-2-7 Structure comparison table

Structure	(1) Brick structure with steel roof	(2) Assembly type temporary house	(3) Unit house
Construction method	Local method	Factory fabrication and on site assembly	Factory assembly
Function ability	Can be designed for the particular purpose	The available sizes are limited. Temperature inside the room substantially changes.	The maximum size available is approximately 20 m^2.
Cost	○ Relatively inexpensive. (The cost is the same as the FOB factory price of (3)).	△ (The delivered cost is the same as that of (1). However, foundation work and assembly costs are required in addition to it.)	× (The transportation size is excessive and transportation cost is expensive.)
Usage upon completion of the Project	Can be used as the maintenance office.	Can not be used as the permanent facility.	Can not be used as the permanent facility.
Evaluation result	○	×	×

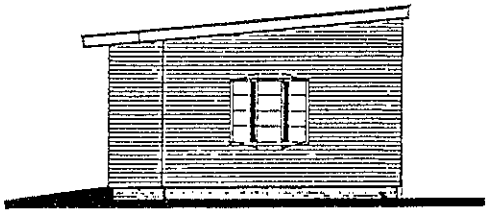
Table 2-3-2-8 Finish table

Exterior Finish Schedule	
Roof	Corrugated galvanized Iron Sheet
Wall	Brick Finishing
Door	Wood hinged door, calking out side
Window	Steel window, calking out side

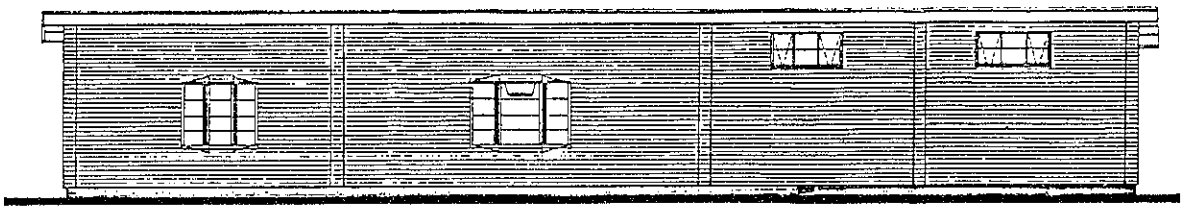
Interior Finish Schedule				
	office, radio communication room	Office, store for testing equipment	Store for tools & spareparts	Store, workshop
Floor	Trowelled mortar finish (T=30mm)	Trowelled mortar finish (T=30mm)	Trowelled mortar finish (T=30mm)	Trowelled mortar finish (T=30mm)
Wall	Venyl paint on trowelled mortar finish (T=20 mm)	Venyl paint on trowelled mortar finish (T=20 mm)	Trowelled mortar finish (T=20mm)	Trowelled mortar finish (T=20mm)
Ceiling	Oil paint on veneer plywood	Oil paint on veneer plywood	Corrugated iron sheet finishing	Corrugated iron sheet finishing
Others			Shelf	Shelf



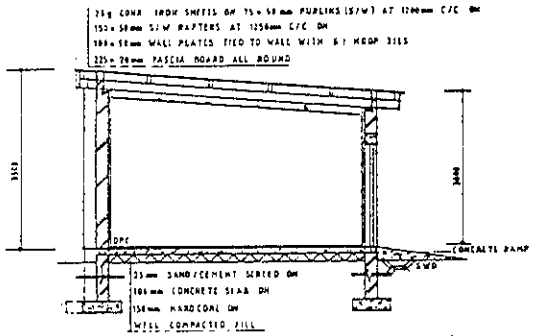
FRONT ELEVATION



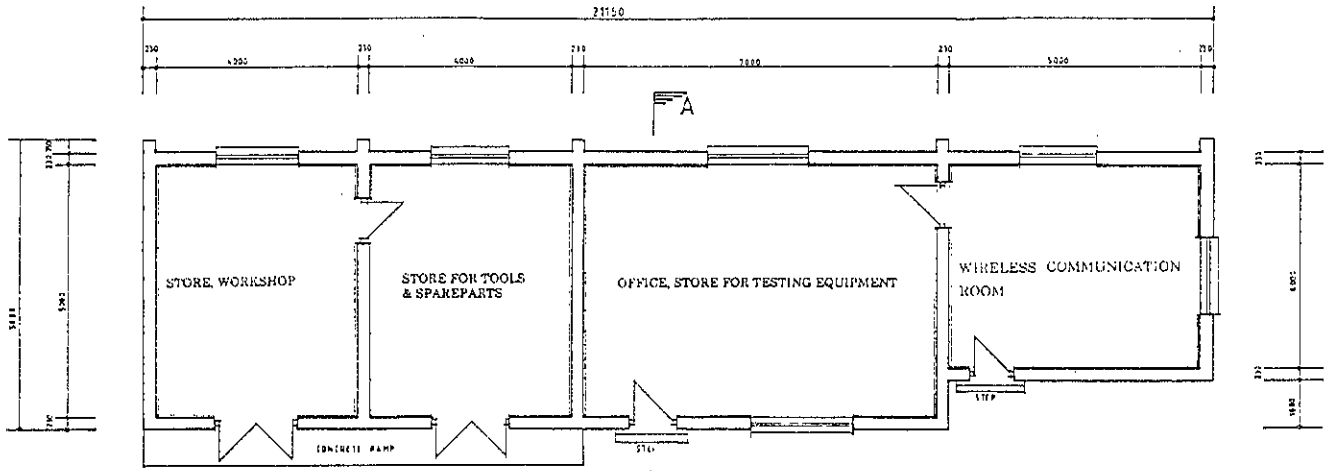
SIDE ELEVATION (RIGHT)



REAR ELEVATION



SECTION A - A



FLOOR PLAN

SCALE 1:100

FINISH SCHEDULE

EXTERIOR FINISH SCHEDULE	
ROOF	CORRUGATED GALVANISED IRON SHEET
WALL	BRICK FINISHING
DOOR	WOOD HINGED DOOR, CALKING OUT SIDE
WINDOW	STEEL WINDOW, CALKING OUT SIDE

INTERIOR FINISH SCHEDULE				
	OFFICE, WIRELESS COMMUNICATION ROOM	OFFICE, STORE FOR TESTING EQUIPMENT	STORE FOR TOOLS & SPAREPARTS	STORE, WORKSHOP
FLOOR	TROWELLED MORTAR FINISH (T=30mm)	TROWELLED MORTAR FINISH (T=30mm)	TROWELLED MORTAR FINISH (T=30mm)	TROWELLED MORTAR FINISH (T=30mm)
WALL	VENYL PAINT ON TROWELLED MORTAR FINISH (T=20mm)	VENYL PAINT ON TROWELLED MORTAR FINISH (T=20mm)	TROWELLED MORTAR FINISH (T=20mm)	TROWELLED MORTAR FINISH (T=20mm)
CEILING	OIL PAINT ON VENEER PLYWOOD	OIL PAINT ON VENEER PLYWOOD	CORRUGATED IRON SHEET FINISHING	CORRUGATED IRON SHEET FINISHING
OTHERS			SHELF	SHELF

Fig.2-3-2-6 PROPOSED WROKSHOP