CHAPTER 3 OUTLINE OF THE PROJECT AREA

3-1 General Conditions

Malawi's Southern Region is divided into 11 Extension Planning Areas, namely MGA 1 through MGA 11. Noth Kawinga is an area mainly comprised of MGA 9 and MGA 10 in the northeastern part of Machinga District.

3-1-1 Location and Population

The Project Area is located in the nothern part of Kawinga Area excluding the gravity priped water supply area, and in terms of Extension Planning Areas, it consists of the entire area of MGA 9, the northern part of MGA 10 and a part of MGA 8 and of MGA 11, covering an area of 655.5 km^2. (Refer to Fig. 3-1) It ranges between Lat. 14°35'S. and 14°50'S and between Long.35°30'E and 35°50'E. The Project Area boreders Mozamibque on the east.

The number of villages in the Project Area is 223, and its estimated population in 1990 using the population growth rate of 2.7% per year projected for Machinga District by the National Statistical Office based on the national census data of 1977 will be distributed as shown in Table 3-1.

Fig. 3-1   Map of the Project Area

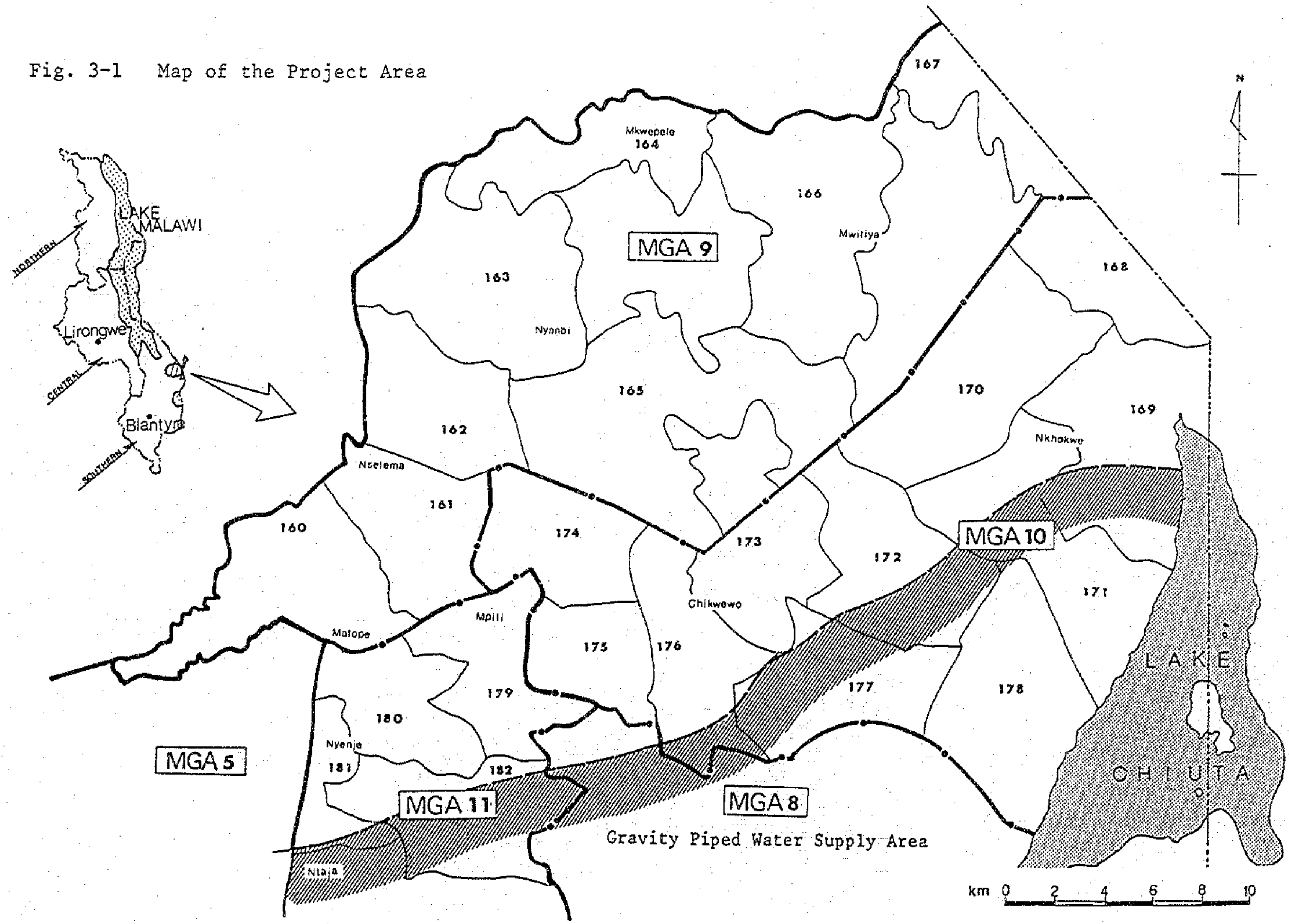


Table 3-1 Area and Population of the Project Area

MGA	Ext. Section	Number of Village	Area (km²)	1977 Population (person)	1977 Population Density (person/km²)	1990 Estimated Population (person)	1990 Estimated Population Density (person/km²)
8		2	7.6	331	43.6	480	61.8
9	160	12	43.0	3,430	79.8	4,840	112.6
	161	15	29.3	2,629	89.7	3,710	126.6
	162	13	31.0	3,314	106.9	4,670	150.7
	163	18	53.3	4,994	93.7	7,040	132.1
	164	10	29.4	2,262	76.9	3,190	108.5
	165	18	68.5	3,438	50.1	4,850	70.8
	166	12	57.5	1,410	24.5	2,000	34.8
	167	6	17.0	597	35.1	840	49.4
10	168	6	24.5	866	35.3	1,220	49.8
	169	6	29.2	863	29.5	1,220	41.8
	170	16	44.2	3,039	68.8	4,290	97.1
	171	6	9.5	834	87.8	1,180	124.2
	172	9	28.1	1,372	48.8	1,940	69.0
	173	14	30.9	1,527	49.4	2,150	69.6
	174	9	31.5	2,684	85.2	3,780	120.0
	175	2	19.1	1,197	62.6	1,690	88.5
	176	15	28.6	2,612	91.3	3,680	128.7
11	179	13	25.8	3,726	144.4	5,250	203.5
	180	12	24.2	3,650	150.8	5,150	212.8
	181	4	10.8	1,115	103.2	1,570	145.3
	182	5	12.5	872	69.8	1,230	98.4
Total	22	223	655.5	46,762	71.3	65,940	100.6

Source: Department of Water

3-1-2 Climate and Hydrology

The Project Area has a mean annual temperature of 22.5°C with the lowest and highest mean annual temperatures of 18°C and 26°C respectively. The rainy season is from December to March and the dry season is from April to November. June and July are the coldest months and the temperature reaches its highest in October and November when the dry season ends and the rainy season commences.

The annual rainfall ranges between 900 - 1,100mm with a mean annual rainfall of 994mm, of which 21.8% is assumed to run off into the rivers (1986 National Water Resources Master Plan). Although the rainfall is concentrated in the December - March rainy season, some years also see rain falls in April and/or November. There is virtually no rain falls in the May - September dry season. As the rivers in the Project Area generally dry up in the dry season, only such rivers as the Lifune, Mpila, Mpili and Nyenesi where the rage of discharge is relatively large can be utilized. The annual water balance can be estimated using the following equation.

Precipitation x Catchment Area = Actual Evapotranspiration + Surface Runoff + Groundwater Recharge

The amount of evapotranspiration has not been accurately measured and, therefore, the groundwater recharge was estimated as a guide on the Basis of the data on Dowa West where the hydrological conditions are similar to those of the Project Area.

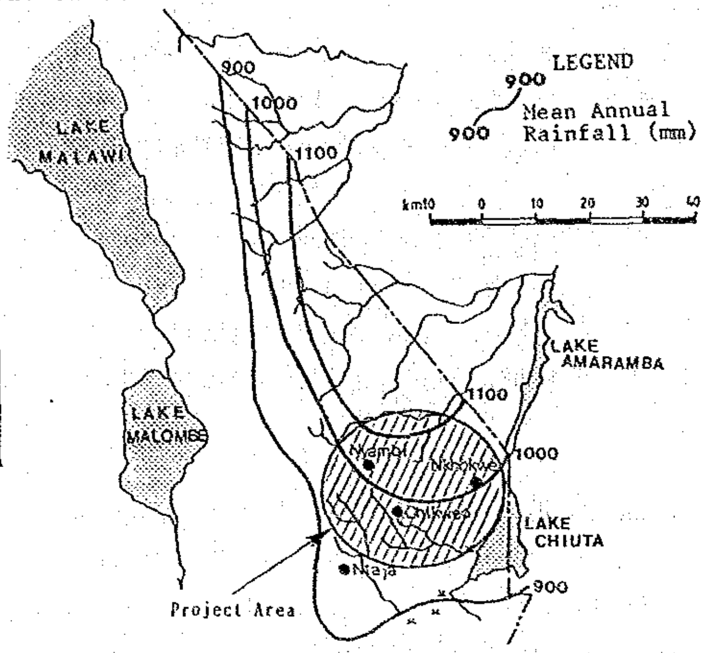
Groundwater Recharge in the Project Area = Area x Mean Groundwater Recharge
= $655 km^2$ x 16mm*/year
= $1.05 \times 10^7 m^3$/year

*Mean Groundwater Recharge in Dowa West (4 - 36mm/year)

Groundwater recharge of some $2.6 \times 10^6 m^3$/year can be expected in the Project Area even if the minimum groundwater recharge figure of 4mm/year for Dowa West is used.

Fig. 3-2 shows the meteorological stations in the Project Area. The rainfall, number of rainy days and the temperature data of these meteorological stations are compiled in Tables 3-2 - 3-4 and Figs. 3-3 - 3-5.

Fig. 3-2 Location of Meteorological Station and Distribution of Mean Annual Fainfall



Meteorological Station	Above Sea Level (m)	Observation Period
Ntaja	731	Jan. 1975 - Jun. 1986
Chikweo	717	Jan. 1982 - Jun. 1986
Nyambi	853	Jan. 1975 - Jun. 1986
Nkhokwe	655	Jan. 1975 - Jun. 1986*

*: No record between July 1980 and October 1981 and in April 1982

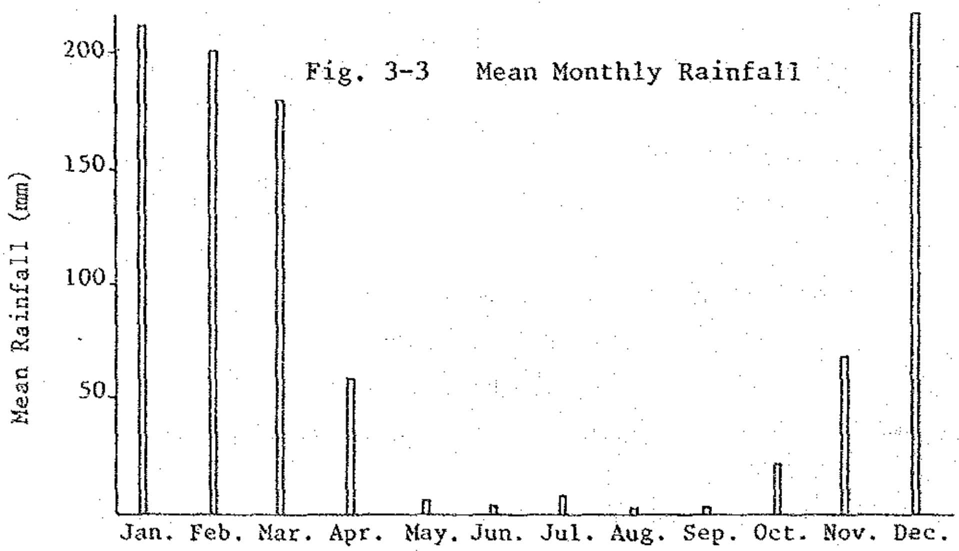
Source: Meteorological Department

Table 3-2 Mean Monthly and Annual Rainfall

Meteorological Station	Mean Monthly Rainfall (mm)												Mean Annual Rainfall (mm)
	Jan.	Feb.	Mar.	Apr.	May.	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	
Ntaja	205.9	200.5	161.7	47.8	4.3	2.8	5.7	2.4	0.6	22.8	65.4	192.0	927.2
Chikweo	186.8	228.6	153.3	41.3	5.0	1.9	8.0	4.6	5.7	10.4	80.7	228.4	960.7
Nyambi	230.3	210.8	213.0	72.8	10.9	4.8	13.3	2.0	0.9	23.1	52.4	249.5	1086.3
Nkhokwe	218.3	168.2	186.2	72.3	2.4	2.9	5.3	0.6	3.0	27.7	75.2	205.0	1000.2
On Average	210.3	202.0	178.6	58.6	5.7	3.1	8.1	2.4	2.6	21.0	68.4	218.7	993.6

Soirce: Meteorological Department

Fig. 3-3 Mean Monthly Rainfall



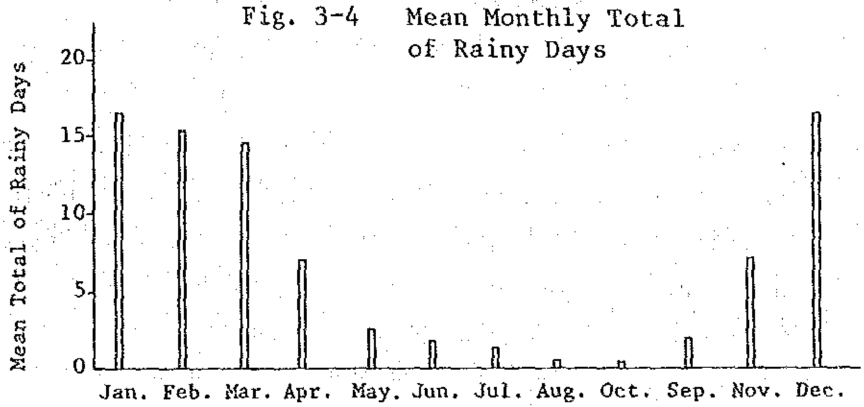
Source: Meteorological Department

Table 3-3 Mean Monthly and Annual Total of Rainy Days

Meteorological Station	Mean Monthly Total of Rainy Days												Mean Annual Total of Rainy Days
	Jan.	Feb.	Mar.	Apr.	May.	Jun.	Jul.	Aug.	Oct.	Sep.	Nov.	Dec.	
Ntaja	15.5	14.5	13.8	6.2	2.6	1.4	1.4	0.6	0.2	2.1	5.9	14.3	79.4
Chikweo	18.0	15.8	13.5	6.8	2.3	1.0	1.0	0.8	0.5	1.3	9.0	17.7	94.0
Nyambi	16.0	15.9	16.4	7.9	2.9	3.0	1.9	0.1	0.5	2.5	6.6	17.8	91.4
On Average	16.5	15.4	14.6	7.0	2.6	1.8	1.4	0.5	0.4	2.0	7.2	16.6	88.3

Source: Meteorological Department

Fig. 3-4 Mean Monthly Total of Rainy Days



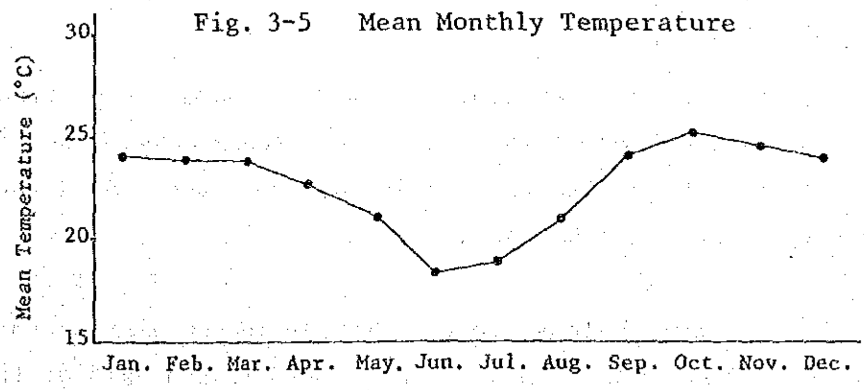
Source: Meteorological Department

Table 3-4 Mean Monthly and Annual Temperature

Meteorological Station	Mean Monthly Temperature (°C)												Mean Annual Temperature (°C)
	Jan.	Feb.	Mar.	Apr.	May.	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	
Chikweo	24.1	23.9	23.9	22.7	21.1	18.4	18.9	21.0	24.1	25.2	24.6	24.0	22.5

Source: Meteorological Department

Fig. 3-5 Mean Monthly Temperature



Source: Meteorological Department

3-1-3 Topography

Malawi is situated at the southern tip of the East African Rift Valleys which run through the African continent in the north-south direction and form Lake Malawi, Lake Malombe and the Shire River. The topography of Malawi is classified into the following four types (see the Map of Physiographic Zones in Fig. 2-1).

(1) Rift Valley Plains

The plains along Lake Malawi and the Shire Valleys form areas with little undulation. The elevation is below 600m above sea level and there is an extensive distribution of relatively new Quarternary deposits.

(2) Rift Valley Escarpments

These areas form steep slopes at the boundaries between the plateaus and rift valley plains. Due to erosion, the bedrocks, outcrop and their dissection is well advanced.

(3) Plateau Areas

These areas are on both sides of the Rift Valleys and are generally 900 - 1,300m above sea level and have many undulations. Old alluvial deposits are distributed in the valley and river sections. Most of the surface water runs off to the grassy swamps called Dambo.

(4) Highland Areas

These have an elevation of 2,000 - 3,000m and protrude from the plateau areas to form a steep topography. Such plutonic rocks and granite and syenite are dominant and advanced dissection can be seen.

The Project Area belongs to the plateau to the east of the Rift Valleys and has many undulations. The northern half of the Area is mountainous and has an elevation of 1,000 - 1,400m. Plains spread in the south and in the east towards Lake Chiuta, making the difference in the Area's elevation almost 800m. The Area is 30km wide in the east-west direction and 20km in the north-south direction, forming a total area of some 650km^2. The topography of the Project Area can be classified into the following three.

(1) 5 isolated mountain masses (elevation of 1,100 - 1,200m) are located from the central to the northern part of the Project Area with Unango Hill (1,444m) being the Area's highest point. The slopes of the inselbergs are steep and outcrops of weathered rocks are observed. The flat area consists of degrated soil and alluvial soil layers with well developed small streams. The Nyenyesi River, which runs in the east-west direction at the northern edge of the Area, forms a border with the Mangochi District located in the north of the Area.

(2) A series of mountain masses of some 1,000m above sea level are located at the eastern edge of the Project Area along the Mozambique border, forming a small scale mountain range. Several small streams flow into Mozambique through the valleys in this mountain range which dry up during the dry season.

(3) A flat alluvial plain spreads from the south to the south-east towards Lake Chiuta. Its elevation at the southern part is 700m, gradually declining to 640m towards Lake Chiuta. Small inselbergs are scattered on this plain.

3-1-4 Geology

The Project Area is located to the east of the Rift Valleys formed from the Late Mesozoic to the Cenozoic. The geological composition of the Area is as follows (see Fig. 3-6).

(1) Basement Complex

The main component is biotite gneiss of the Pre-Cambrian and gneiss containing hornblende and feldspan is also distributed. These rocks are hard with few pores and are mainly distributed in the southern and south-eastern parts of the Area. The strike runs in the north-the north-northeast direction and dips towards the west.

(2) Plutonic Rocks

These are granite and syenite of the Pre-Cambrian and Lower Palaeozoic, forming inselbergs in the northern part of the Area. Those areas where plutonic rocks are distributed show a unique topography where protruding inselbergs (monadnocks) formed by segregated erosion under strong weathering conditions are seen.

(3) Sediments

The sediments observed in the plains are mainly unconsolidated sand and clay of the Alluvium and Diluvium of the Quaternary. The alluvial layer is mostly distributed near Lake Chiuta.

(4) Geological Structure

The gneiss shows a fold axis running in the north - south-east by south direction. To the west of Ntaja located in the south-western part of the Area, an anticline and syncline are seen. A light syncline is also observed in the west of the Nyenyezi Estate. The direction of the faults is conspicuous in the north-west by north due to the influence of the Rift Valleys. The Ulungwe Fault between Ulungwe Hill and Unango

Hill in the north-western part is a good example. The faults mostly run in the north-south direction on Majuni Hill at the eastern edge. In the south-eastern part, the continuity of these faults cannot be traced due to sediment cover. The above-described geological distribution is shown in Fig. 3-7 which is a geological section of the Project Area in the north-south direction.

Fig. 3-6 Geological Map of the Project Area

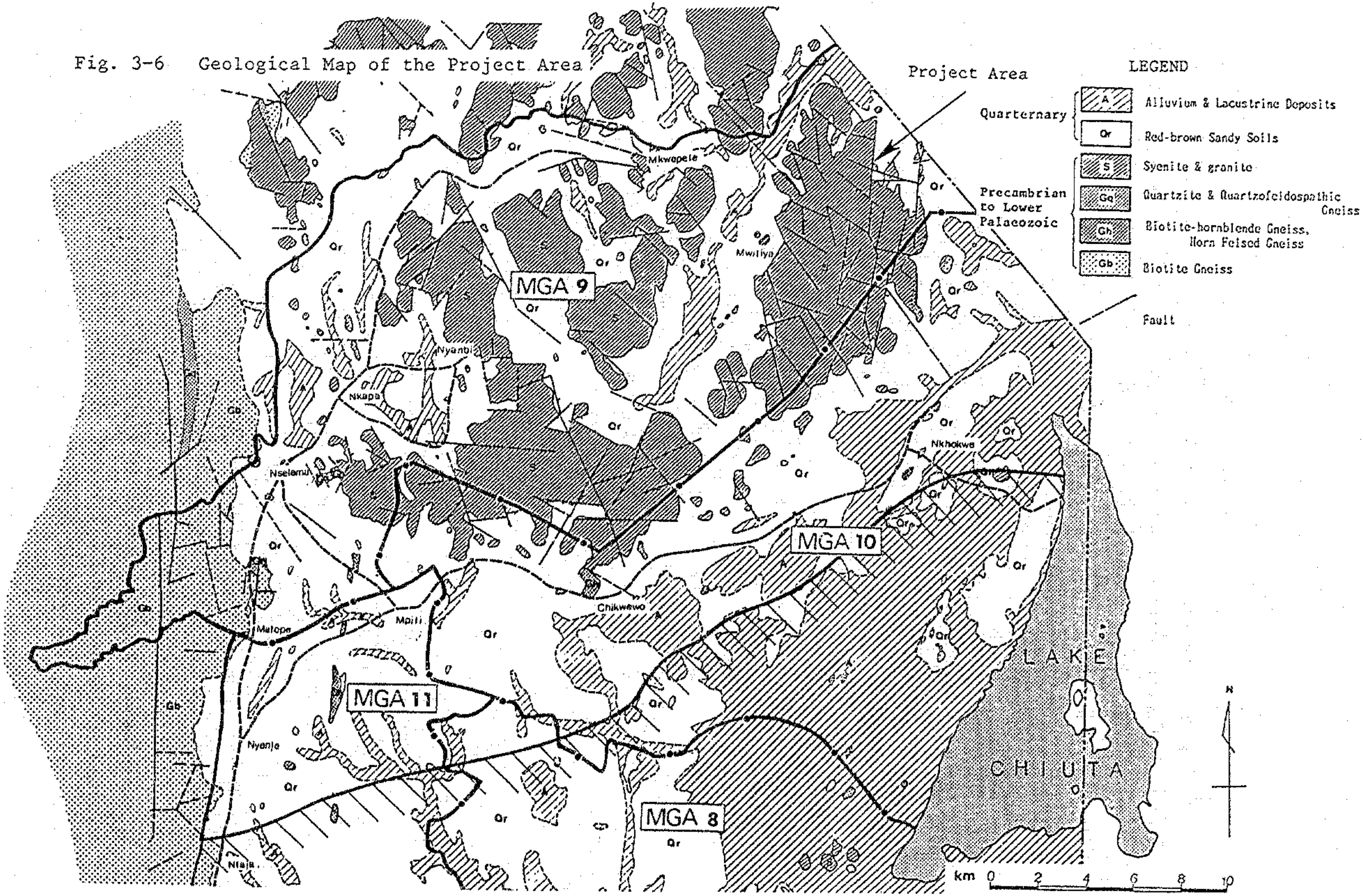
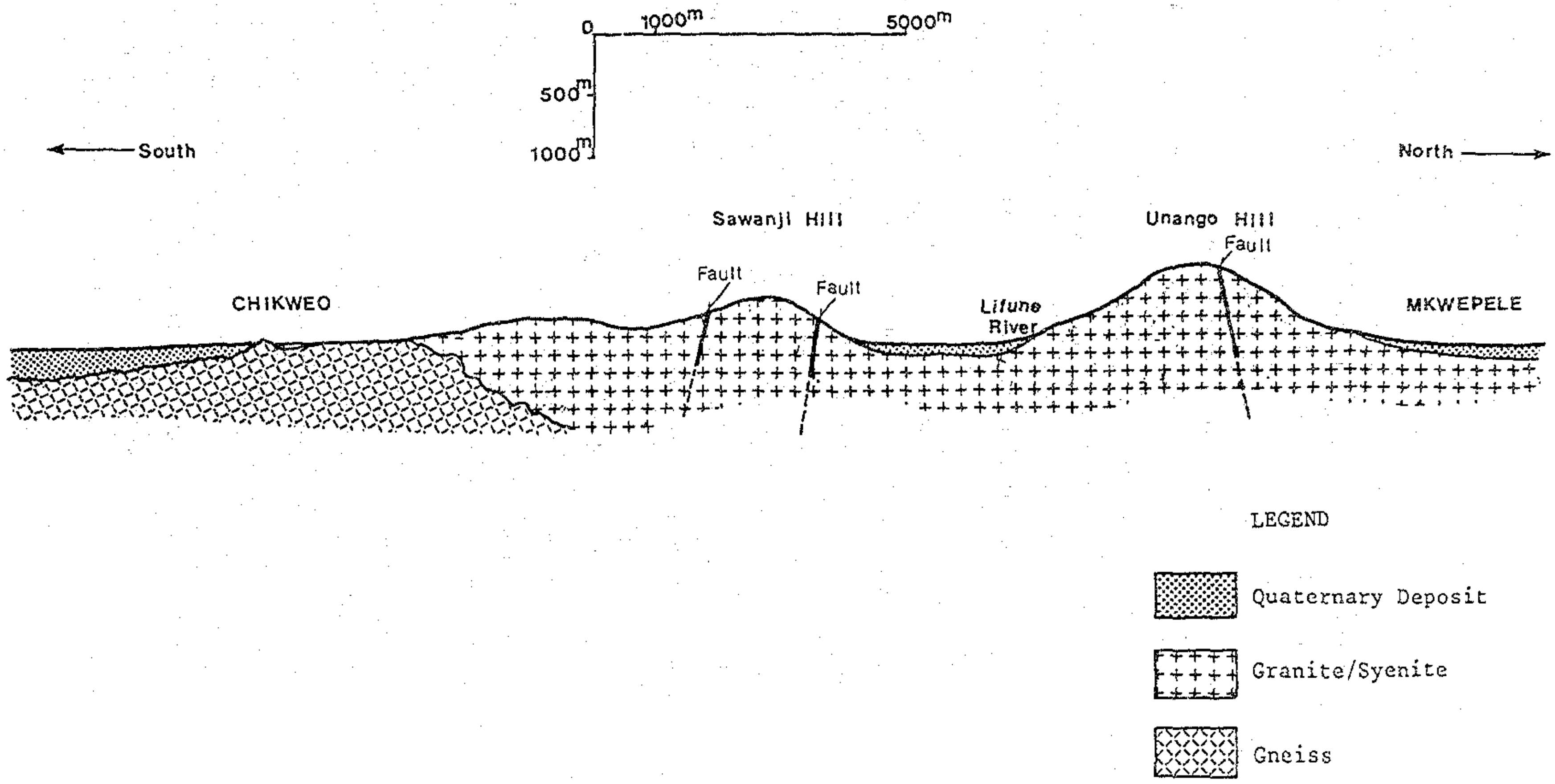


Fig. 3-7 Geological Section



3-2 Hydrogeology Conditions

The hydrogeological conditions of the Project Area can be described in terms of the following two areas based on the topographical and geological conditions.

(1) The northern area with MGA 9 at its core where mountain masses composed of plutonic rocks, particularly syenite and granite, are located.

(2) The southern area with MGA 10 (including MGA 8 and 11) at its core where the plains spread out.

At the mountain masses in MGA 9 have steep slopes, rainwater tends to flow down. In addition, the area is mainly composed of hard rocks where the permeation of surface water or rainwater is hardly expected. However, unconsolidated sediments (alluvial and degraded soil), strongly weathered rocks and weathered rocks with well developed fissures are distributed in the valleys and basins between the mountain masses, forming aquifers.

In comparison, muddy soil (mostly silt and clay) with low permeability is mostly distributed in the plains. Weathered gneiss (sediments or rocks with well developed fissures) are located below this muddy soil, forming aquifers.

In both areas, the main aquifers are formed by weathered rocks with well developed fissures. In some cases, the groundwater is stored in sand or gravel layers intercalated with unconsolidated sediments on the ground surface. As the level of this type of groundwater is likely to be affected by the dry and rainy seasons, the distribution conditions of an aquifer are largely determined by the state of the bedrocks and the thickness of the weathered zone. Fig. 3-8 is a typical profile of weathered basement aquifer.

Although abundant groundwater can be expected from the fractured zones besides from such weathered zones as above, the fractured zones are generally distributed along such tectonic lines as faults and, therefore, are exceptional cases.

The recharges groundwater from the surface in the northern mountain area is believed to flow along the present water veins towards Mozambique in the east. In the case of the southern plains, however, the groundwater flow shows a similar gentle hydraulic gradient to that of the topography of the area towards the south-east, i.e. Lake Chiuta (see Fig. 3-9).

Fig. 3-8 Typical Profile of Weather Basement Aquifer

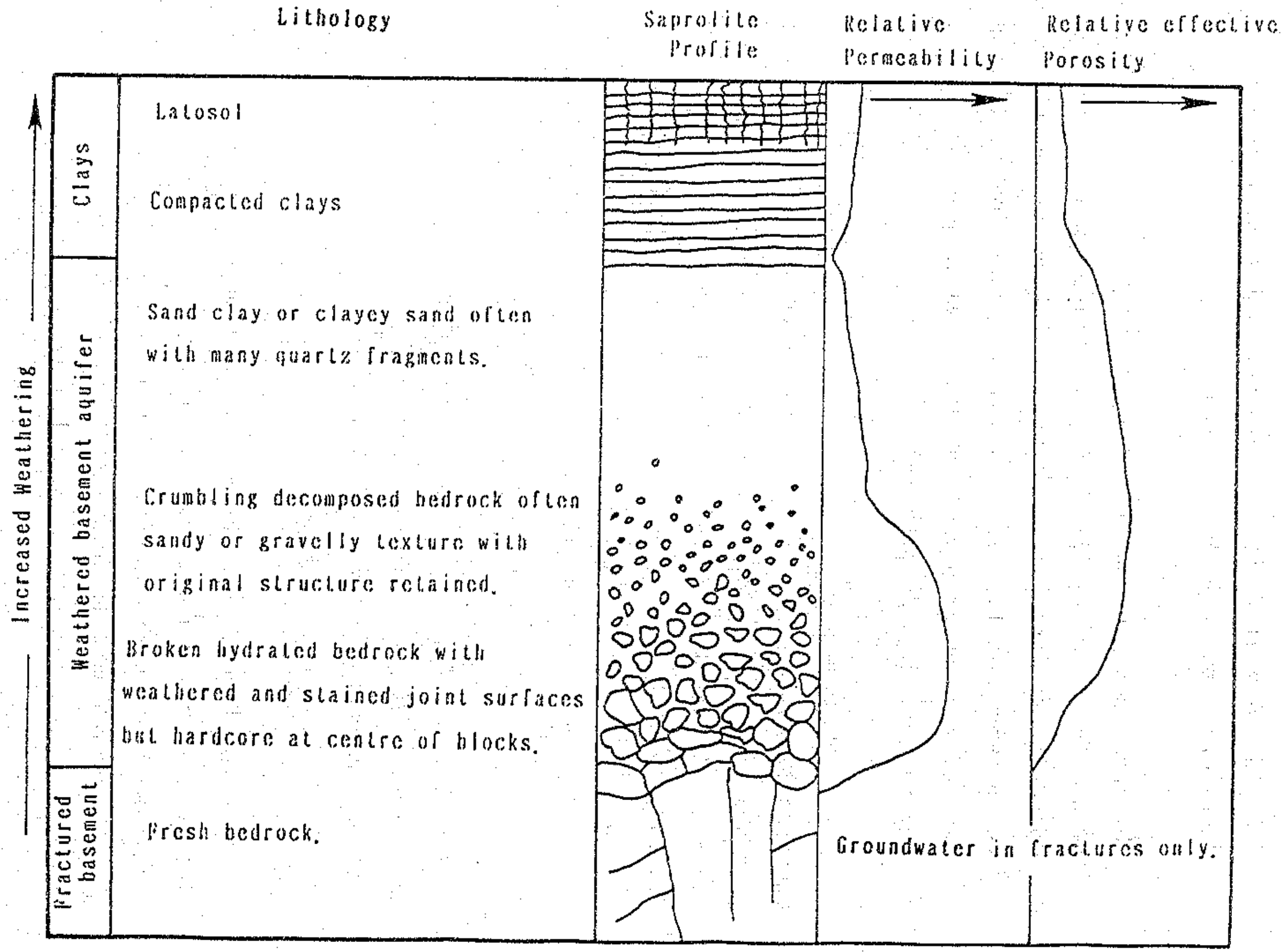
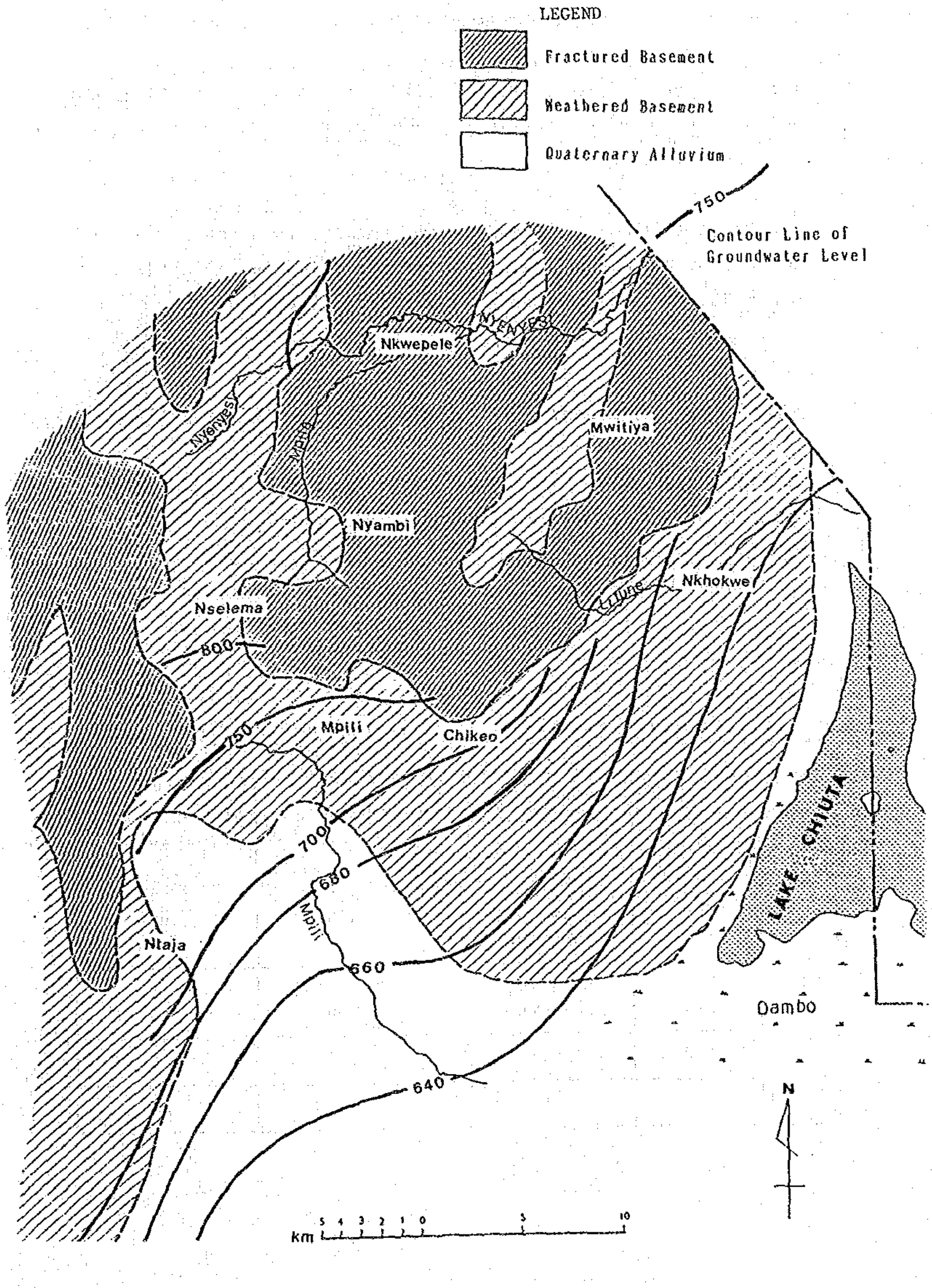


Fig. 3-9 Hydrogeological Map



3-2-1 Groundwater Existence (Electric Prospecting Results)

The distribution and characteristics of the aquifers are given below based on the electric prospecting conducted on-the-spot and data on existing wells.

The Project Area was classified as follows in terms of its topographical and geological characteristics and electric prospecting was conducted at 6 selected sites.

<u>Geological Classification</u>

G ..... Gneiss

S ..... Plutonic Rocks (Syenite and Granite)

Q ..... Sediment of the Quaternary

<u>Topographical Classification</u>

1. Plain
2. Basin
3. Valley
4. Piedmont

Table 3-5 Details of Electric Prospecting Sites

Subject Sites			Type of Classification	No. of Points Prospected
MAG	Ext. Sec.	Place Name		
9	163 164 166	Nyambi Mkwepele Mwitiya	S-4 S-3 S-2	4 4 3
10	171 176	Nkhokwe Chikweo	G-1, Q-1 G-4	5 6
11	179	Mpili	Q-1	4
Total	-	6	-	26

(1) Prospecting Method and Equipment Used

Prospecting down to a depth of 100m was conducted using the Wenner method. As the earth resistance was high due to it being the dry season, 2 electrodes were used after water being sprinkled over the earth points. Stacking type equipment was used to improve the S/N ratio.

Model	Specifications
McOHM	Current: 200mA (max) No. of Stacking: 1, 4, 16, 64 Measuring Electric Potential: 0-0.6V, 0-6V Power Source: DC12V

An analysis was subsequently conducted using Sandberg's standard curve and Hummer's auxiliary curve.

(2) Prospecting Results

The cross-sectional resistivity of each prospecting site is given in Figs. 3-11 (1)-(6). Based on the resistivity value, the geological formation can be divided into 3-4 layers. When the surface is considered to be the first layer, the prospecting results at each site can be compiled as shown in Table 3-6.

Fig. 3-10 Distribution of Electric Prospecting Points

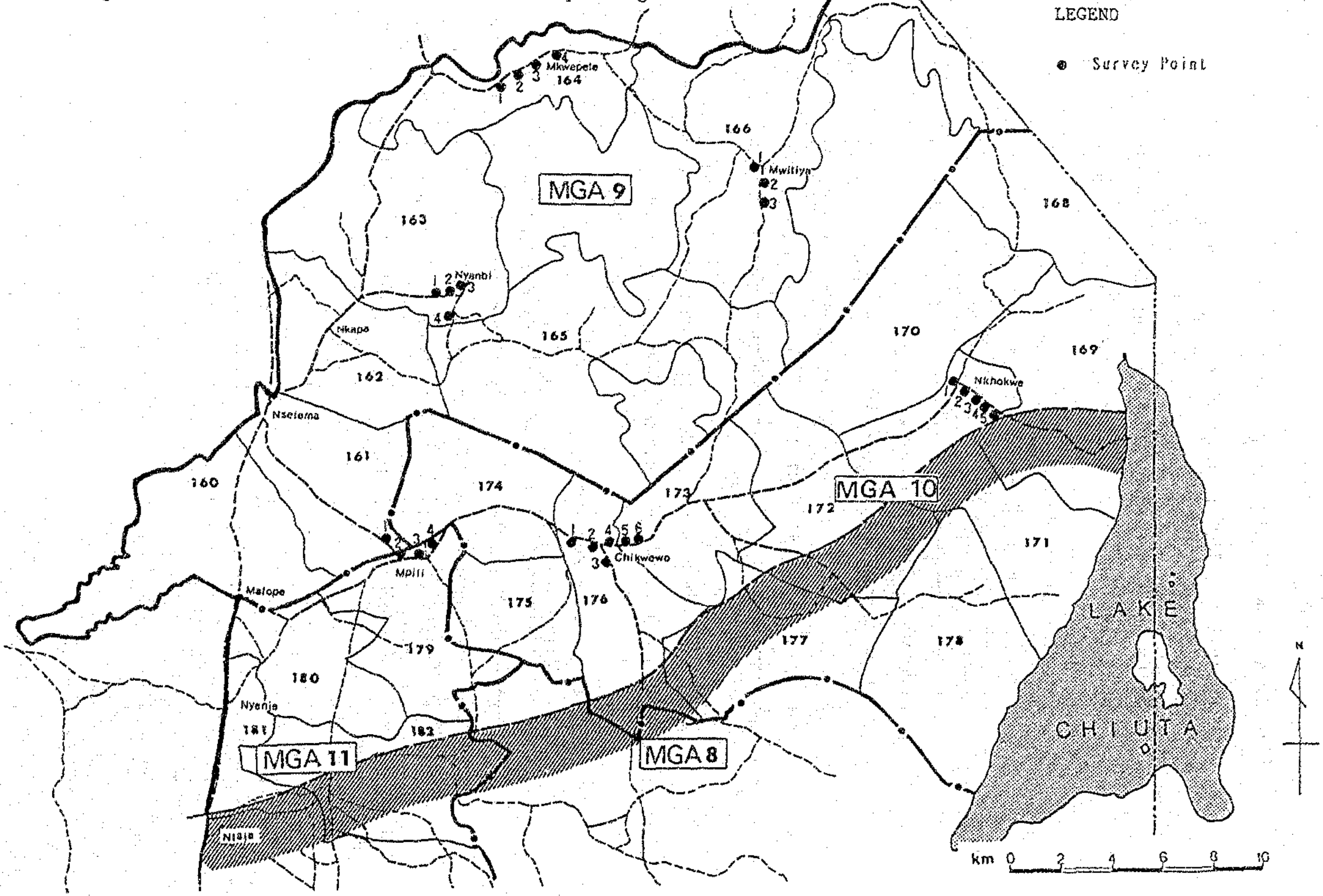


Fig. 3-11 (1) Geological Section by Electric Prospecting
Nyambi (MGA9-163)

Unit: Ohm-m

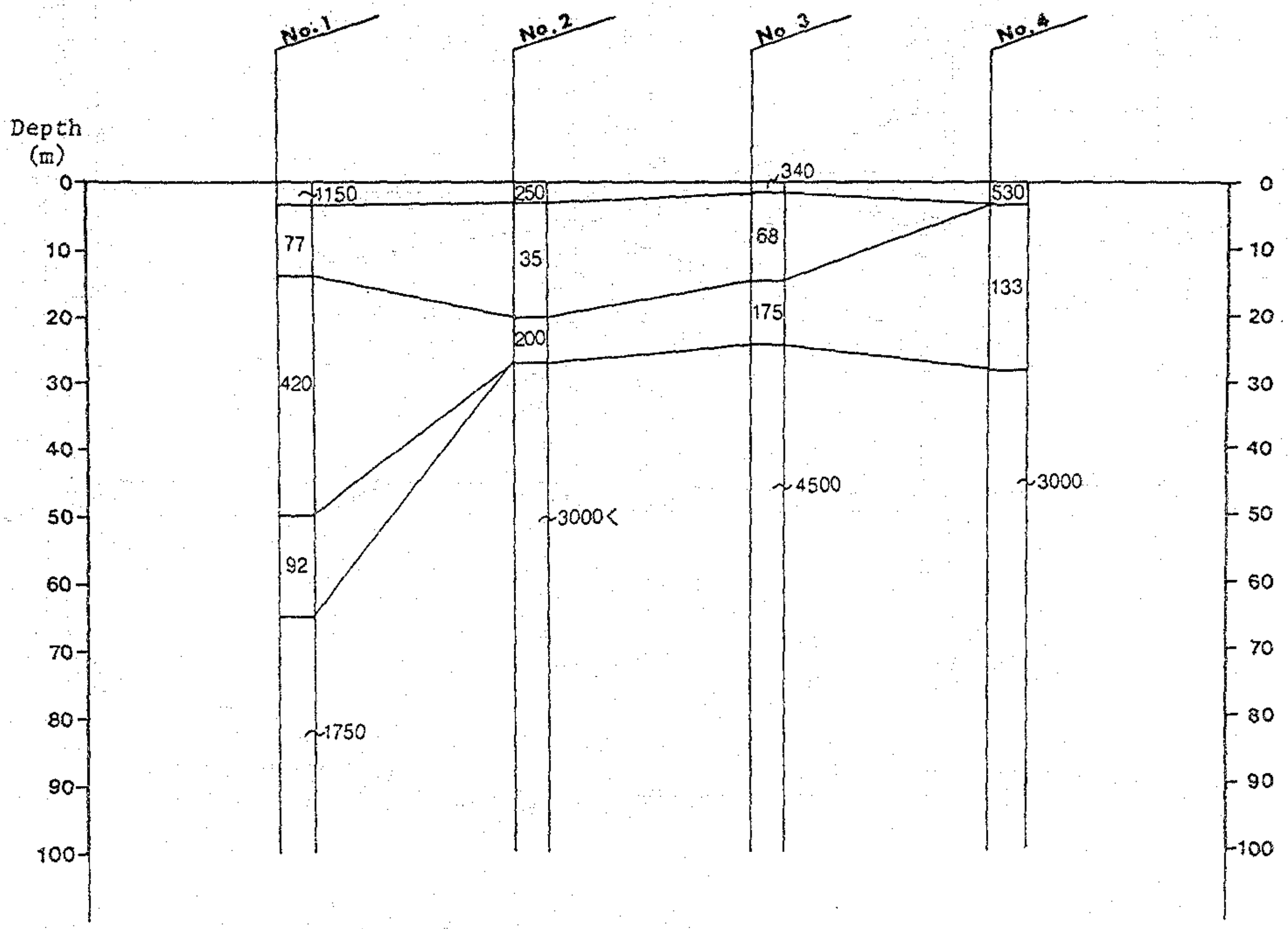


Fig. 3-11 (2) Geological Section by Electric Prospecting Mkwepele (MGA9-164)

Unit: Ohm-m

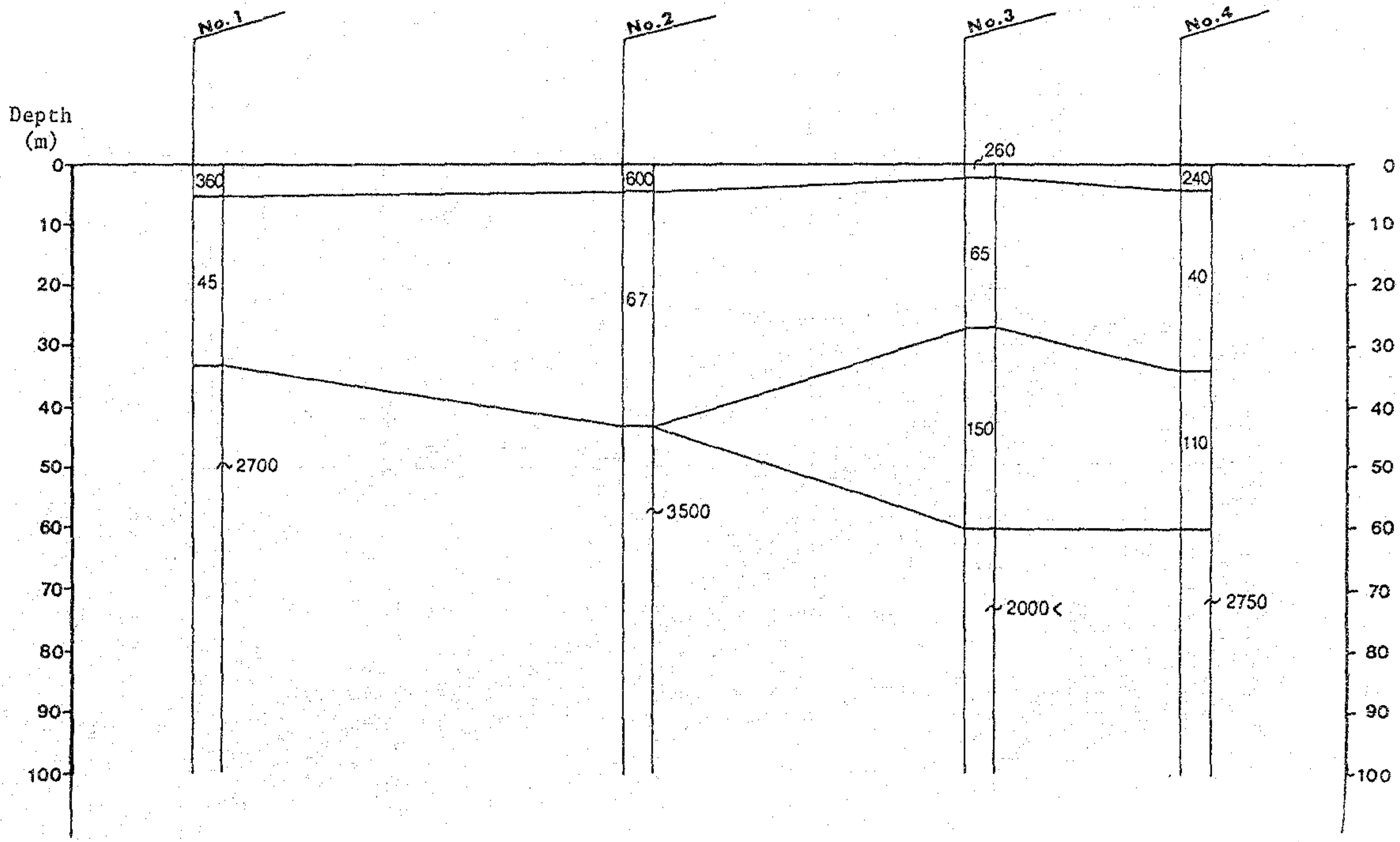


Fig. 3-11 (3) Geological Section by Electric Prospecting Mwitiya (MGA9-166)

Unit: Ohm-m

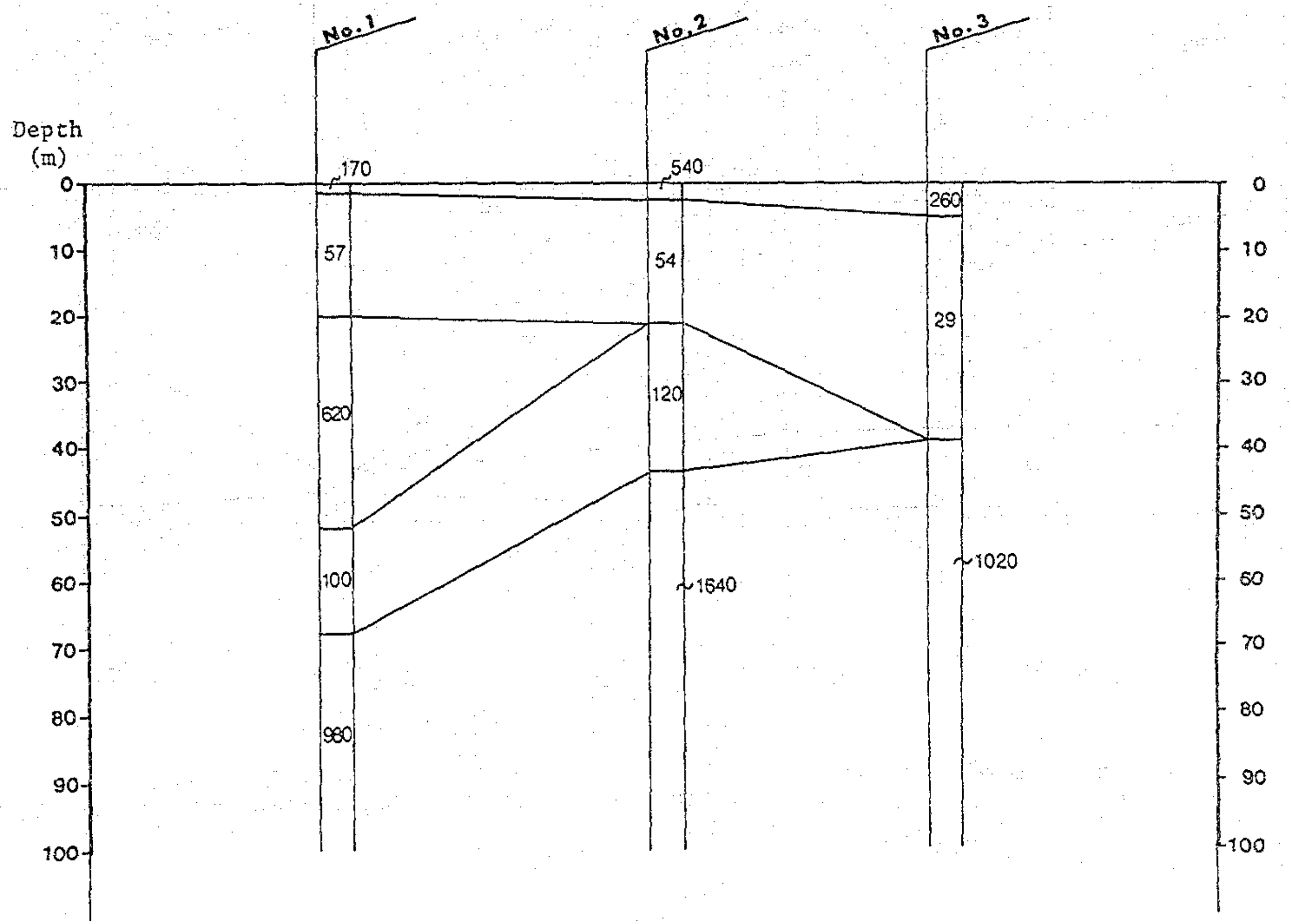


Fig. 3-11 (4) Geological Section by Electric Prospecting
Nkhokwe (MGA10-171)

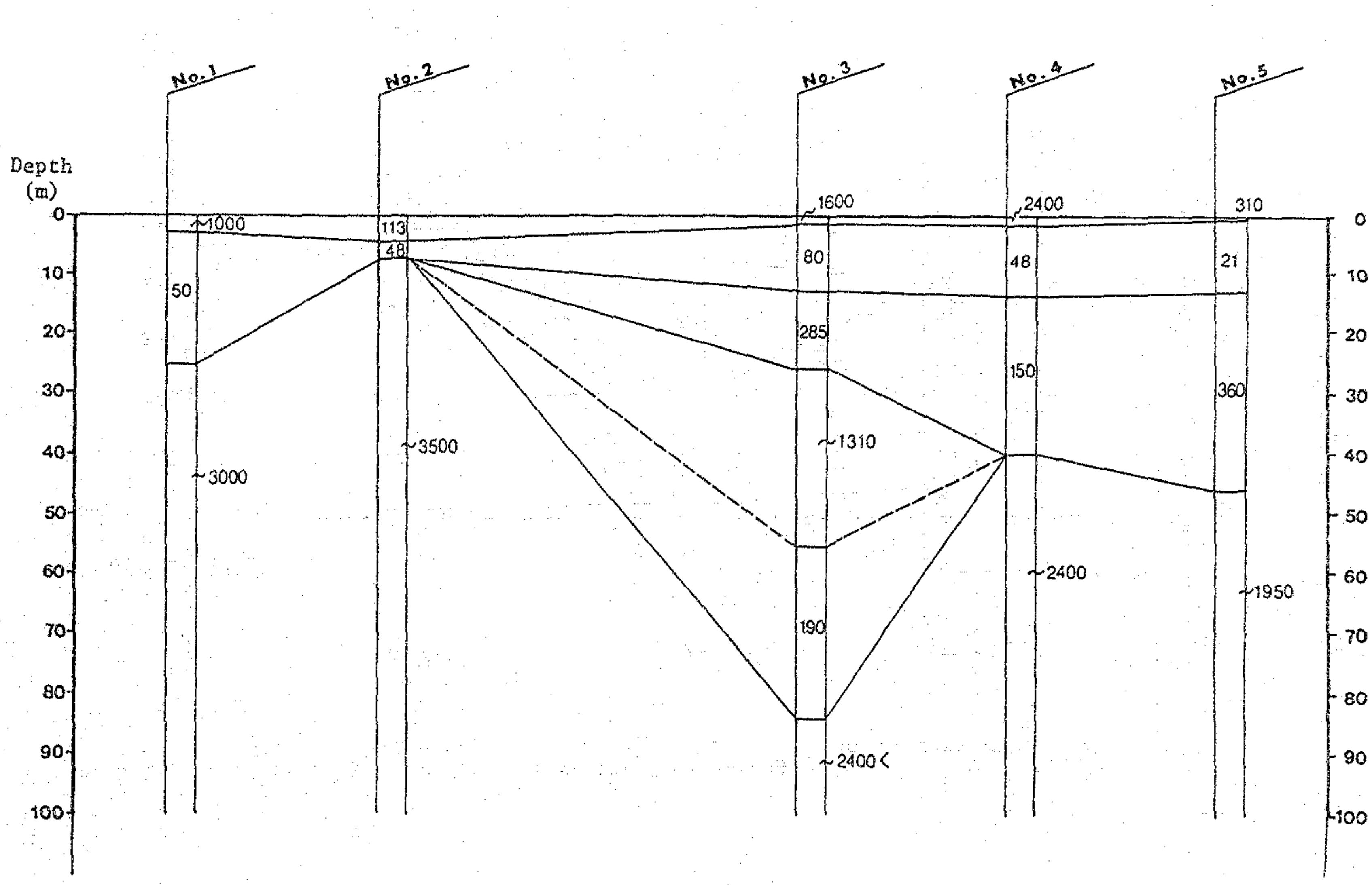


Fig. 3-11 (5) Geological Section by Electric Prospecting
Chikweo (MGA10-176)

Unit: Ohm-m

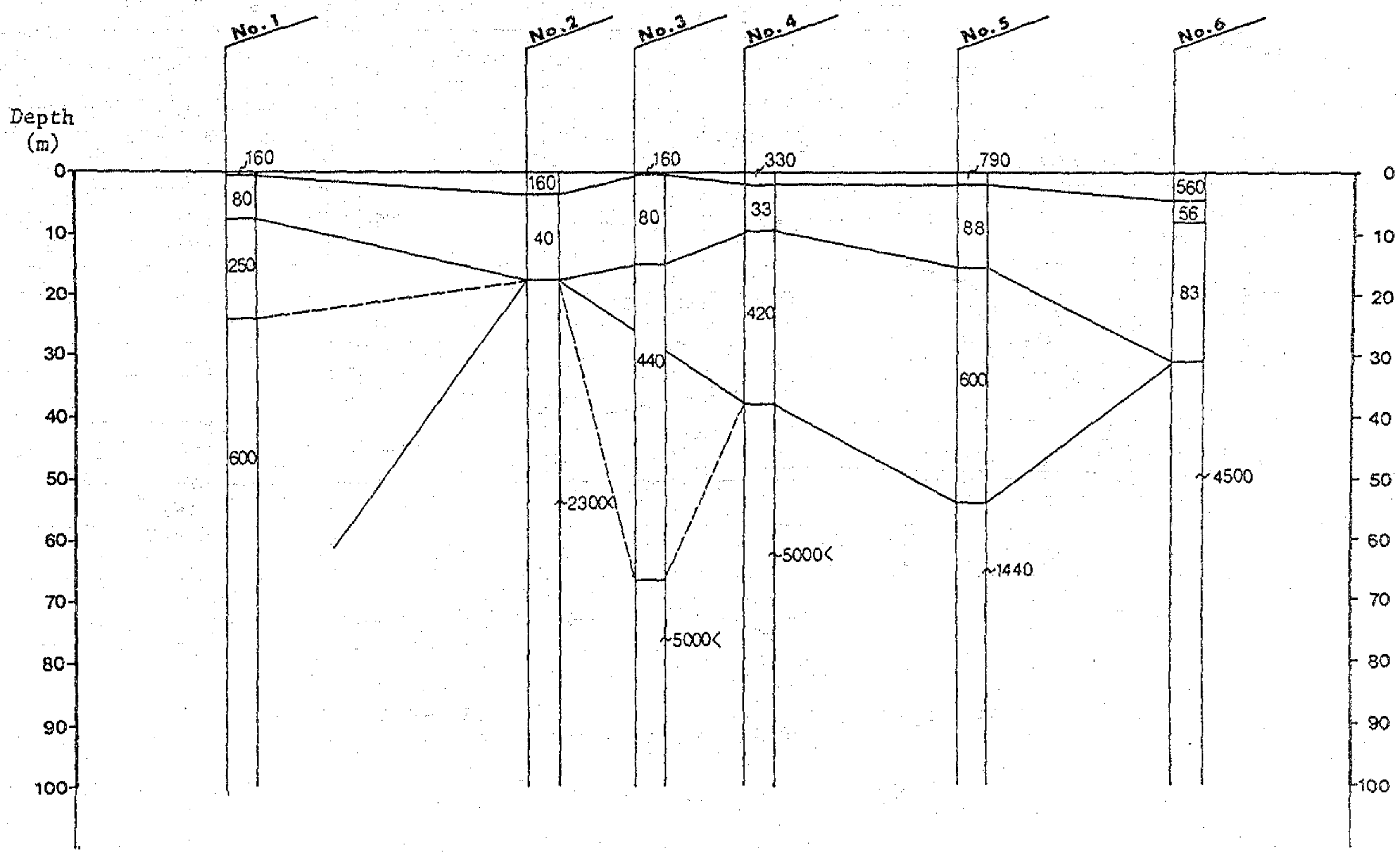


Fig. 3-11 (6) Geological Section by Electric Prospecting
Mpili (MGA11-179)

Unit: Ohm-m

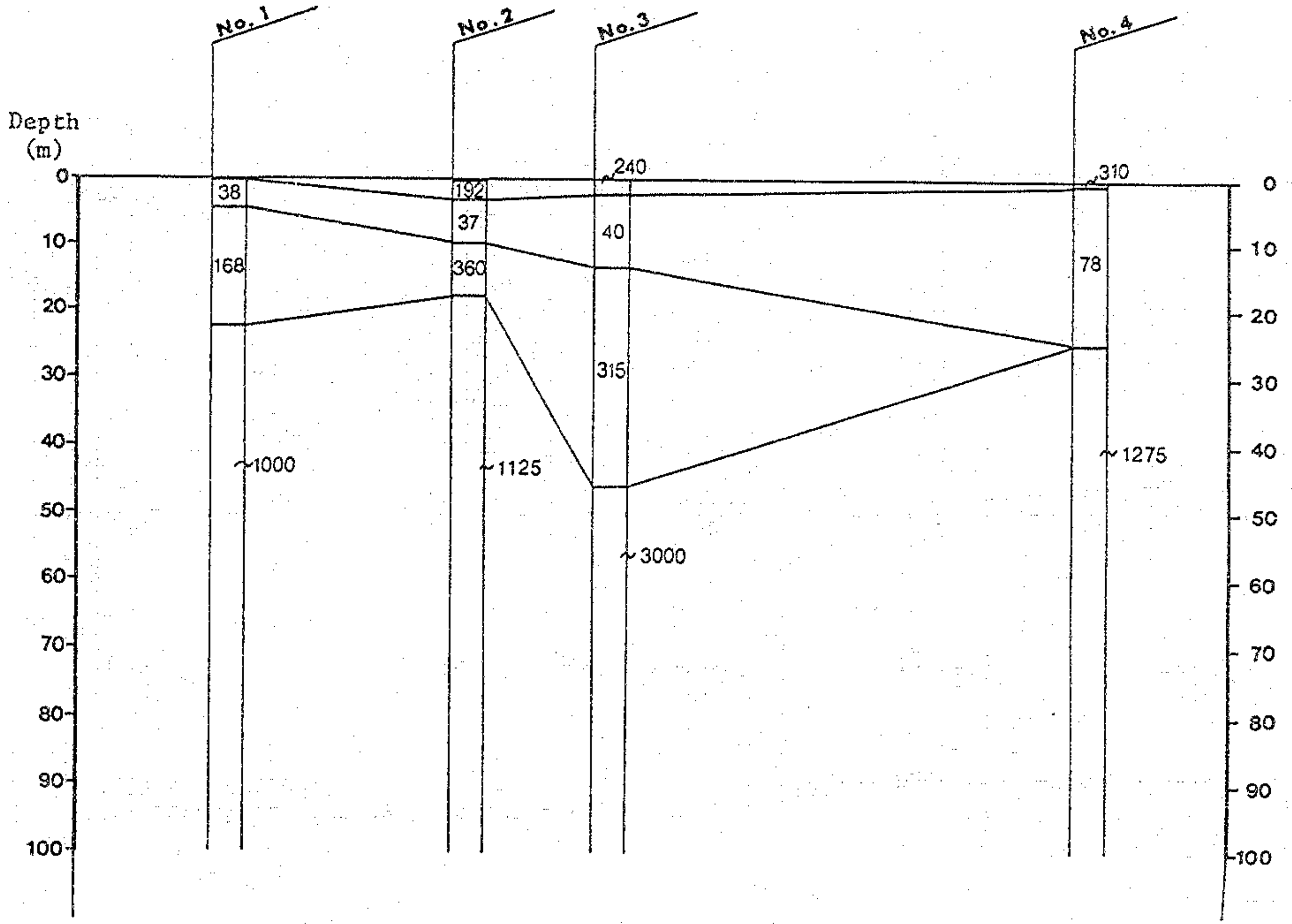


Table 3-6 Electric Prospecting Results

Prospecting Site	1st Layer		2nd Layer		3rd Layer		4th Layer		Remarks
	ρa	Thick-ness	ρa	Thick-ness	ρa	Thick-ness	ρa	Depth	
Nyambi	250 - 1,150	2 - 3	35 - 77	0 - 17	133 - 420	7 - 31	1,750 - 4,500	24 - 65	Low resistivity layer at boundary of 3rd & 4th layers (No. 1)
Mkwepele	240 - 600	4 - 6	40 - 67	22 - 38	110 - 150	0 - 26	2,000 - 3,500	28 - 60	Geological formation changes from 3 to 4 layers from west toward east.
Mwitiya	170 - 540	2 - 5	29 - 57	19 - 34	120 - 620	0 - 48	980 - 1,640	44 - 68	Low resistivity layer at boundary of 3rd & 4th layers (No. 1)
Nkhokwe	113 - 2,400	2 - 5	21 - 80	3 - 22	150 - 360	0 - 32	1,310 - 3,500	8 - 42	Low resistivity layer in 4th layer (No. 3)
Chikweo	160 - 790	1 - 5	33 - 88	7 - 36	250 - 600	0 - 40	1,440 - 5,000	17 - 67	4th layer is fragmented, showing low resistivity down to a very deep area (No. 1)
Mpili	129 - 310	1 - 3	37 - 78	4 - 24	168 - 360	0 - 33	1,000 - 3,000	18 - 46	3 layers in eastern part

Notes

ρa : Apparent resistivity value of the layer (Ω - m)

Thickness: Thickness of each resistance layer (m)

The figure for the 4th layer shows the depth from the ground surface

Table 3-7 Resistivity and Geological Classification

Layer	Resistivity (Ω-m)	Thickness or Depth (m)	Corresponding Geological Features
1st	113 - 2,400	1 - 5	Dry surface soil, clay, silt and sandy soil
2nd	21 - 88	0 - 38	Wet clay, silt, sandy soil and strongly weathered rocks
3rd	110 - 600	0 - 48	Sand, gravel, strongly weathered rocks and weathered rocks
4th	980 - over 5,000	8 - 68	Slightly weathered rocks - unweathered rocks

(3) Aquifer Appraisal

The resistivity (ρa) of a favourable aquifer can be estimated using the following equation.

$\rho a = F \times \rho w$ ρw : Resistivity of Grounwater

F : Formation Factor (1 - 6)

The resistivity of the groundwater in the Project Area has been measured to be 45 - 92Ω - m. Therefore, the resistivity of the aquifer is 45 - 5005Ω - m, corresponding to the 2nd and 3rd layers. As a geological layer with good permeability generally has a value of F of between 2 and 5, the most promising aquifer is considered to be one showing a resistivity of 90 - 460Ω - m.

A comparison of the data on existing boreholes and the electric prospecting results is made in Table 3-8.

Table 3-8 Comparison of Electric Prospecting Results and Existing Borehole Data

Subject Site	Well No.	Geological Features	Resistivity (Ω-m)	Well Depth (m)	Yield (ℓ/min)	Remarks
Nyambi	E-164	Weathered Rock	200	24.4	36	
Mkwepele	SM-447	Clay/Silt Fine Sand	45	25.5	30	Pumped up amount is lowered
	CC-96	Weathered Rock	110	36.0	100	
Mwitiya	A-250	Weathered Rock	620	32.7	8	Pumped up amount is low
Chikweo	E-244	Weathered Rock/Un-weathered Rock	40/2,300<	24.0	14	100m away from the prospecting point
	FM-85	No Data	420 - 440	28.4	83	"
Mpili	GM-24	Weathered Rock/Un-weathered Rock	360/1,125	21.0	83	Unweathered rock is more than 18m in depth
	R-85	Clayey Soil/ Weathered Rock	40-78/315	41.2	46	200m away from the prospecting point

* No borehole data are available for Nkhokwe.

Based on the comparison with the borehole data, the resistivity of a favourable aquifer is 110 - 460Ω - m, showing a correspondence to the prospecting results. The aquifers mostly consist of weathered rocks.

The 4th layer with a resistivity of over 1,000 Ω - m is bedrock with few fissures and the existence of groundwater cannot really be expected excepting those areas bordering the 3rd layer. The average depth down to the 4th layer at each prospecting site is summarized in the table below. The cases where the distribution of the 4th layer is shallower than 20m are, however, excluded.

Place Name	Depth down to 4th Layer	Average Depth	Classification Type
Nyambi	24 - 65m	36m	S-4
Mkwepele	28 - 60m	48m	S-3
Mwitiya	44 - 68m	51m	S-2
Nkhokwe	26 - 42m	33m	G-1, Q-1
Chikweo	24 - 67m	43m	G-4
Mpili	22 - 46m	31m	Q-1
6 Sites		40.3m	

In the survey conducted this time, fractured zones were detected at a depth of around 60m in the 3rd and 4th layers at 4 sites, i.e. Nyambi, Nkhokwe, Mwitiya and Chikweo. Since abundant, good quality groundwater can often be obtained from a fractured zone, it is believed to be important that detailed survey be carried out prior to drilling in order to determine the sizes, distribution scopes and characters of these zones.

3-2-2 Existing Boreholes and Groundwater Situation

(1) Conditions of Existing Boreholes

The Project Area currently has a total of 30 boreholes which are located as shown in Fig. 3-12. The existence of 15 of these was confirmed during the field survey, of which 7 were in operation. These boreholes were constructed in the period between 1954 and 1984, most of them being completed either before 1960 or after 1980.

Before 1960	12
1960 - 1970	4
1970 - 1980	3
After 1980	11

Hand pump models installed are as follows.

Model	Country of Origin	No.	Remarks
Bush	Malawi	12	Installed at old boreholes constructed before 1961
Climax	U.K.	10	Wheel type and heavy
Limani	South Africa	5	
Uganda	Uncertain	1	
Maldev	Malawi	1	Prototype of Afridev

The drilling depth varies from 19.3 to 41.2m with an average depth of 30m. The static water level varies from 1.8 to 11.5m with an average of 6.7m. The maximum yield at the time of borehole completion was 3 - 100ℓ/min and 2 boreholes had a maximum yield of less than 10ℓ/min. It was found impossible to conduct the field pumping test due to the fact that the closed type boreholes did not allow the observation of the water level. Details of these boreholes are given in Table 3-9.

The boreholes are widely distributed over the Project Area although some concentration is seen in the south-eastern part where there is a high population density. They are mostly located near major roads and there is tendency for them to be found at village centres or village boundaries due to their use by more than one village.

14 of the total 30 boreholes confirmed either by the field survey or existing data have the following problems.

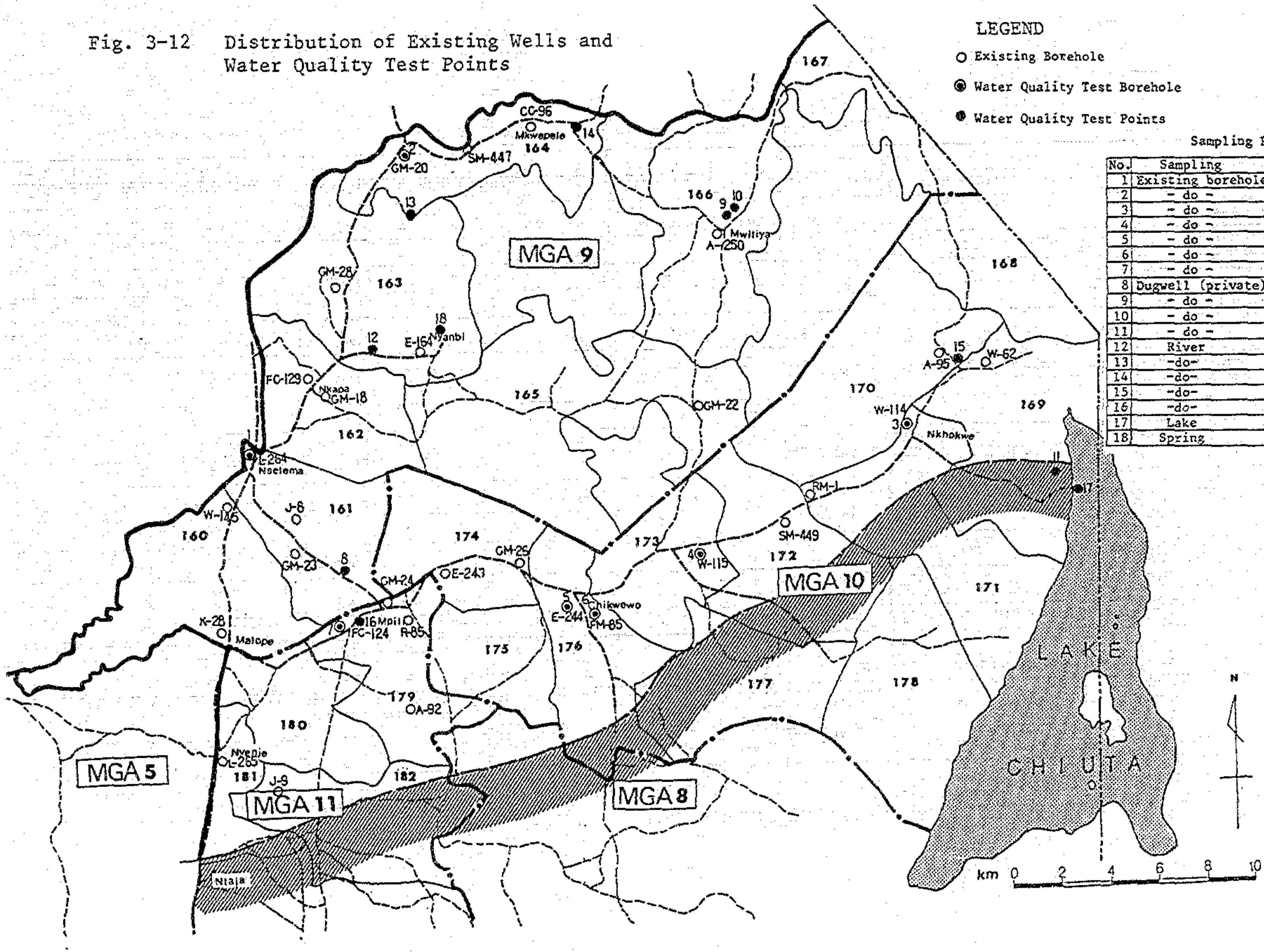
1) Lack of detailed data due to breakdowns, in turn caused by deterioration.

2) Groundwater pollution due to the proximity of toilet and other facilities.

3) Poor yield according to interviews with local inhabitants or data at the time of borehole completion.

It is believed that the rehabilitation of these boreholes will not improve their expected functions in terms of either water quality or water supply volume.

Fig. 3-12 Distribution of Existing Wells and Water Quality Test Points



Sampling Point

No.	Sampling	Location
1	Existing borehole	9-161, L-264
2	- do -	9-164, GM-20
3	- do -	10-171, W-114
4	- do -	10-173, W-115
5	- do -	10-176, E-244
6	- do -	10-177, FM-85
7	- do -	11-179, FC-124
8	Dugwell (private)	9-161
9	- do -	9-166
10	- do -	9-166
11	- do -	10-169
12	River	9-163, Nsilima
13	-do-	9-164, Mpila
14	-do-	9-164, Nyenyesi
15	-do-	10-170, Lifune
16	-do-	11-179, Mpili
17	Lake	10-169, Chiuta
18	Spring	9-163

Table 3-9 (1) Data on Existing Boreholes

Borehole No.	Location MGA	Location Ext. Section	Location Name of Village	Drilling Year	Diameter (mm)	Depth (m)	Static Water Level (GL-m)	Max. Safe Yield at Completion Time (ℓ/mim)	Depth at which Main Supply Struck (GL-m)	Depth of Cylinder (GL-m)	Length of Screen (m)	Type of Pump	Geology	Present Conditions	Remarks
K-28	9	160	Nyanje	Fev/1954	100	30.5	4.6	40	15.3	29.3	-	Bush	4.3-30.5m weathered rock	--	unsuitable for rehabilitation due to deterioration
W-145	9	160	Chiwalo Court	Nov/1959	152	36.0	14.6	51	29.0	32.9	-	Bush	15.0-36.0m weathere rock	--	- do -
L-264	9	161	Vselema	Jun/1965	150	30.2	7.32	34	26.5	29.3	-	Bush	weathered rock/fresh bed rock (syenite)	in operation	possible to be rehabilitated
J-8	9	161	Kapoloma	Nov/1959	-	36.9	16.8	82	-	-	-	Bush	--	in operation (as of Nov. 1986)	- do -
GM-23	9	161	Nkhweya	Apr/1983	-	22.0	3.5	45	14.0-20.0	18.0	14.6	Climax	22m hard rock	--	- do -
FC-129	9	162	Nyambi Dispensary	Oct/1972	-	40.3	7.6	26	30.5-33.6	30.5	12.2	Climax	26.5-39.7m sand 39.7-40.3m hard rock	out of order	- do -
GM-18	9	162	Nyambi/Nkapa	Mar/1983	110	31.1	8.3	90	22.0-23.0	28.0	14.5	Climax	Coarse sand/sandy clay	-do- (1984)	- do -
E-164	9	163	Malundani Court	Nov/1958	100	24.7	2.4	36	18.3	22.0	-	Bush	10.7-24.7m weathered rock	-do- (1972)	unsuitable for rehabilitation due to decline of yield
GM-28	9	163	Kaukutu	Apr/1983	-	35.6	12.0	30	31.0-32.0	30.0	17.7	Limani	0-28m clay, sandy clay 28-34m weathered rock	-do- (1983)	unsuitable for rehabilitation due to the pump and well being condemned
CC-96	9	164	Mkwepele	Nov/1981	-	36.0	11.5	100	25.0-26.0	33.0	19.2	Limani	21.5-36.0m hard rock	-do-	possible to be rehabilitated
GM-20	9	164	Mwinjirani	Apr/1983	110	19.3	5.3	15	-	-	14.7	Limani	--	in operation	- do -
SM-447	9	164	M'bwabwa	Jun/1983	110	25.5	10.35	60	19.0-21.0	24.0	13.7	Limani	0-19m clay, 19-24m fine sand 24-25.5m weathered rock	out of order	unsuitable for rehabilitation due to decline of yield
GM-22	9	165	Mongola	Jul/1983	-	22.0	6	15	10.0-20.0	18.0	13.0	Maldev	12-18m gravel 20-22m hard rock	--	possible to be rehabilitated
A-250	9	166	Mwitiya	Nov/1964	150	32.7	26.2	7	26.2	29.3	-	Climax	8.2-32.7m weathered gneiss	out of order	yield is samll
W-62	10	169	Natuli	Sep/1959	-	35.7	10.7	3	12.2	-	-	Bush	12.2-35.7m fresh bed rock	--	- do -

Source: Department of Water

Table 3-9 (2) Data on Existing Boreholes

Borehole No.	Location			Drilling Year	Diameter (mm)	Depth (m)	Static Water Level (GL-m)	Max. Safe Yield at Completion Time (ℓ/mim)	Depth at which Main Supply Struck (GL-m)	Depth of Cylinder (GL-m)	Length of Screen (m)	Type of Pump	Geology	Present Conditions	Remarks
	MGA	Ext. Section	Name of Village												
A-95	10	170	Muwawa	Sep/1961	150	29.3	7.32	68	23.8	-	-	Bush	23.8-29.3m granite	out of order	unsuitable for rehabilitation due to deterioration
W-114	10	171	Nkhokwe	Sep/1959	-	30.5	12.2	82	-	-	-	Climax	--	in operation	unsuitable for rehabilitation due to bad water quality
RM-1	10	171	Mwala	Jan/1975	-	20.7	11	67	12.2-12.8		10.0-16.8	Uganda	14.0-20.7m hard gneiss	--	possible to be rehabilitated
SM-449	10	172	Mwegama	Jun/1983	-	38.0	3	90	24.0-36.0	30.0	19.2	Climax	36.0-38.0m rock	--	- do -
W-115	10	173	Mapanje	(1959)	-	31.1	12.2	21	-	-	-	Bush	--	in operation	- do -
E-243	10	174	Chisowa	Nov/1952	-	23.5	1.8	22	18.3	22.0	-	Bush	weather gneiss	--	unsuitable for rehabilitation due to deterioration
GM-26	10	174	Mowele	Apr/1983	-	27.0	7.0	83	17.0-26.0	21.0	20.5	Climax	19-27m rock	--	possible to be rehabilitated
E-244	10	176	Chikweo's Court	Nov/1958	-	24.4	6.1	14	18.3	22.0	-	Climax	--	in operation	- do -
FM-85	10	176	Chikweo EPA	Dec/1984	-	28.4	12.0	83	-	-	-	Limani	--	-do-	- do -
A-92	11	179	Mpunga	Aug/1961	100	32.6	5.5	65	-	-	-	Bush	Alluvium	--	unsuitable for rehabilitation due to deterioration
R-85	11	179	Mpiri Mission	Nov/1969	-	41.2	7.6	46	30.5-32.0	36.6	-	-	30.5-41.2m granulite	extinct	
FC-124	11	179	Mahuta	Apr/1972	-	26.2	7.6	26	18.3-21.4	24.4	12.2	Climax	0-12.2m sand 12.2-26.2m gneiss	in operation	possible to be rehabilitated
GM-24	11	179	Likhomo	Apr/1983	-	21.0	2.8	83	6.0	15.0	11.6	Climax	10-18m weathered rock 18-21m fresh rock	out of order	- do -
C-265	11	181	Chenyenje	Apr/1956	152	31.1	5.5	26	23.8	29.3	-	Bush	15.3-31.1m rock	--	unsuitable for rehabilitation due to deterioration
J-9	11	182	Nkomera	Nov/1959	152	38.1	5.8	82	18.3	36.0	-	Bush	18.3-38.1m rock	--	- do -

Source: Department of Water

(2) Groundwater Utilization

Most of the boreholes use groundwater contained in the fissures of the weathered rock layers. Although some of the boreholes were judged to be using groundwater contained in the sediment layers, no confirmation was made on the use of groundwater contained in the fissures of a fractured zone. Some of the boreholes showed a declining yield at the time of or immediately following their completion. Based on the survey results, the following points can be made with regard to these.

1) Drilling ends at the depth where the weathered rocks are slightly harder than those above. According to the electric prospecting results, the distribution of the fissures containing groundwater is indicated to be below this layer. It is assumed that drilling work was terminated at this point since the percussion type drilling rig rapidly loses its efficiency against hard rocks.

2) The boreholes are located in places where the aquifers are thin due to the lack of adequate prior surveys.

3) As the cylinder is located near the bottom, it tends to become blocked by deposits. Further drilling is, therefore, required at the top side of the bedrock where some fissures were observed in order to provide an extra margin below the cylinder.

4) The relationship between the location of the strainer and the aquifer is uncertain. Electrical logging must be carried out at the time of drilling to clearly determine the thickness of the aquifer and the length of the strainer to be installed, as well as the installation location.

5) In the case of those boreholes using groundwater in the sediment layers, the permeability decreases in accordance with the increased ratio of clayey soil, thus reducing the yield. It is, therefore, advisable that sediment layers with a resistivity of less than 45Ω - m be excluded.

3-2-3 Water Quality

The water quality was analyzed using 18 water samples taken from the boreholes, dugwells (private), rivers, spring and the lake used as domestic water sources in the Project Area (see Fig. 3-12).

Water Source	No. of Samples	Remarks
Boreholes	7	4 samples analyzed by the Water Laboratory
Dugwells (private)	4	Depth largely varies from 1 to 5m depending on the location
Rivers	5	Used for washing, bathing and drinking in certain locations
Lake	1	Lake Chiuta
Spring	1	At piedmont. Used for drinking water

The water quality test results are given in Table 3-10.

The characteristics of the water quality are summarized as follows.

(1) The PH is 6.2 - 7.7 and many samples show a weak acidity of less than 7.0.

(2) The electric conductivity is 37 - 317μs/cm. In the existing boreholes, the value is 109 - 225μs/cm while the water from

Lake Chiuta gives the largest value of 317μs/cm. This electric conductivity is used as an index of the electrolyte content in the layer. In those areas where the dry and rainy seasons are clearly distinguishable, the electric conductivity value is fairly useful for determining the salt content in the soil. The obtained values are within the range of good water quality. (The relevant surface and groundwater values in Japan are 50 - 200μs/cm on average.)

(3) The water existing near the surface, such as that from the rivers, dugwells (private) and the spring, tends to be white or light brown in colour due to organic floating matter and fine grains of clay, etc.

(4) In one sample, the manganese and iron ion are above the permissible levels given by WHO.

(5) The ammonia content is above the permissible level given by WHO in 2 borehole water samples.

(6) Other than the boreholes, all the water sources are contaminated by coliform group. This is also detected at those boreholes located near contamination sources or where good drainage facilities are not provided.

(7) None or only a minute quantity of ordinary bacteria is detected for boreholes but its existence is confirmed in the case of water from other sources.

The above results indicate that surface water and water near the ground surface is relatively prone to pollution and is unsuitable for drinking purposes. Since the groundwater does not originally contain much manganese and iron ion, these must have come from iron pipe of the pump. The pollution by ammonia and coliform group is of artificial origin and can be prevented by giving careful consideration to borehole/drugwell location and by providing drainage facilities for waste water. Therefore, the groundwater quality in the Project Area is judged to be suitable for use as drinking water.

Table 3-10 (1) Results of Water Quality Analysis

Water Sampling Point: Place Name or Borehole No.	MAG	Ext. Section	Water Source	Water Temperature (°C)	Conductivity μs/cm (at 25°C)	PH	Turbidity	Bad Odor	NH^4 (ppm)	NM^{2+} (ppm)	Fe^{2+} (ppm)	$C\ell^2$ (ppm)	Coliform Group	Bacteria	Remarks
L-264	9	161	E-Borehole	25.3	169	7.0	None	None	0.6	0.2	0.5	0.1	Existed	S-Existed	
GM-20	9	164	- do -	22.3	129	6.5	- do -	-do-	below 0.1	below 0.1	0.2	below 0.1	None	None	
W-114	10	171	- do -	27.2	198	6.8	- do -	-do-	2.5	0.0	0.2	0.0	-do-	-do-	located by a toilet
W-115	10	173	- do -	24.4	178	6.4	- do -	-do-	1.5	0.0	0.1	0.0	-do-	-do-	
E-244	10	176	- do -	24.2	225	6.5	- do -	-do-	0.4	0.1	0.2	0.0	S-Existed	S-Existed	
FM-85	10	177	- do -	26.0	149	6.3	L-Brown	-do-	below 0.1	0.1	0.4	below 0.1	None	None	
FC-124	11	179	- do -	25.1	109	7.7	None	-do-	-	-	-	-	-	-	
Chikumba	9	161	Dugwell (private)	24.0	85	7.0	Brown	-do-	0.0	0.0	0.1	0.1	Existed	Existed	Depth; 5.0m Water Level; 4.7m
Mwitiya(1)	9	166	- do -	30.2	84	6.3	S-Opaque	-do-	0.4	0.4	0.2	0.1	-	-	for washing
Mwitiya(2)	9	166	- do -	24.5	67	6.3	W-Brown	-do-	0.1	0.1	0.2	0.0	Existed	Existed	Depth; 3m
Mpakaka	10	169	- do -	23.1	37	6.9	S-Opaque	-do-	-	-	-	-	-	-	Depth; 1.2m
Nsilimina	9	163	River	18.5	67	6.2	S-Opaque	-do-	0.1	0.2	0.2	0.0	-	-	for washing
Mpila	9	164	- do -	25.6	72	6.5	L-Brown	-do-	0.0	0.0	0.2	0.0	Existed	Existed	drinking water
Nyenyesi	9	164	- do -	19.7	112	6.6	Brown	-do-	below 0.1	0.1	0.2	below 0.1	-do-	-do-	drinking water
Lifune	10	170	- do -	21.1	113	6.8	L-Green	-do-	below 0.1	0.1	0.1	below 0.1	M-Existed	-do-	for washing and bathing
Mpili	11	179	- do -	22.8	194	6.7	C-Brown	-do-	0.1	below 0.1	0.1	0.1	-do-	-do-	destributed from a elevated tank
Chiuta	10	169	Lake	25.6	317	7.6	None	-do-	below 0.1	0.1	0.2	0.1	Existed	Existed	
Nyambi	9	163	Spring	23.8	62	6.2	- do -	-do-	0.3	0.0	0.1	0.0	-do-	-do-	drinking water
WHO Standards						6.5-8.5			0.5	0.1	0.3	250			
Proposed Standards in Malawi						6-9.5			-	0.5	3.0	750			

E- : Existing W- ; Whity
L- ; Light C- ; Cloudy
S- ; Slightly M- ; Moderately

Table 3-10 (2) Results of Water Quality Test

(unit: ppm)

Borehole Sampled \ Analyzed Item	SO_4^{2-}	NO_3^-	Cu	Zn	Ca^{2+}	Mg^{2+}	Fe^{2+}	Mn^{2+}	Cd	Total Hardness $CaCO_3$	As
L-264	0.8	0.6	0	0	10.0	3.7	1.45	0.18	less than 0.005	43	0
GM-20	1.6	0.8	0.23	0	8.2	2.9	0.38	0.06	less than 0.005	33	0
W-114	1.2	0.6	0	0	5.2	8.2	0.33	0.12	less than 0.005	49	0
E-244	3.7	0.2	0.46	0.17	9.4	2.8	0.59	0.06	less than 0.005	36	0
WHO Standards	400	45	1.0	5	-	-	0.3	0.1	0.005	500	0.05
Proposed Standards in Malawi	800	100	1.0	10	-	-	3.0	0.5	0.01	800	0.05

3-3 Social Conditions and Water Supply Situation

3-3-1 Infrastructure

Ntaja is the largest town in the vicinity of the Project Area where local offices of various government agencies are located. A truck road of about 10m in width which passes through Ntaja runs in the north-south direction at the western edge of the Project Area, from which a road passable for vehicles is branched toward the Project Area on its east, and settlements have been developed and various social facilities have been arranged along this road (see Fig. 3-13).

Primary schools, hospitals, dispensaries and market-related facilities are distributed evenly throughout the Project Area, but the only post office in the Area is located in Mpili. Telehpone circuits are extended as far as Ntaja. Although there is a plan to lead in electricity into the Project Area, its benefit extends only up to the area about 20km south of Ntaja at present. The road network in the Project Area can be classified into major roads and branch roads as outlined below.

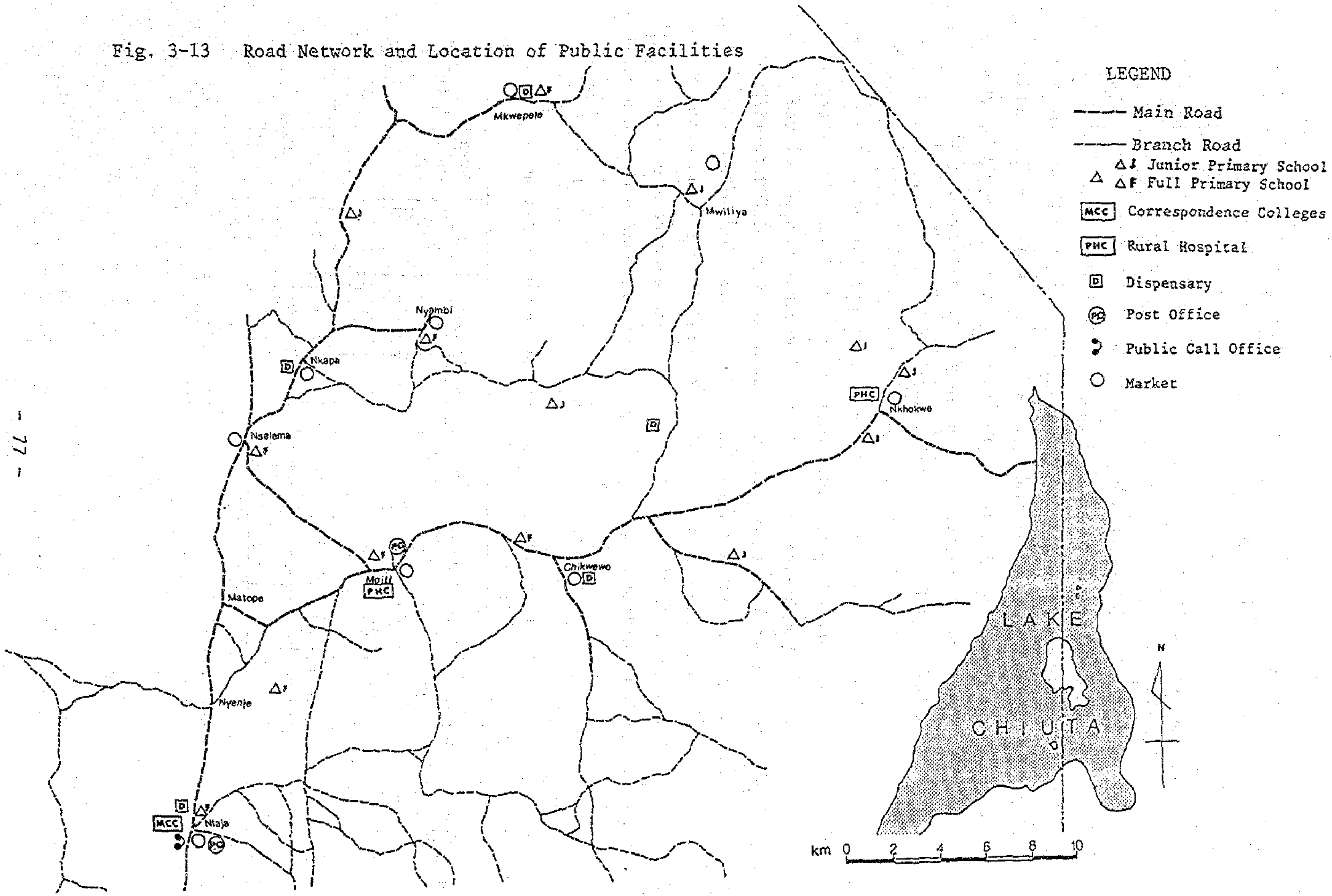
Major Roads:

Major roads have a width of 7 - 8m with drain ditches of 1m in width and 0.8m in depth on both sides. The surfaces is covered by laterite. The bridges over rivers are constructed of wood and have concrete foundations. Approximately 4m in width, the bridges have a structural strength capable of supporting large vehicles.

Branch Roads:

Branch roads have a width of 2 - 6m and it is difficult for large vehicles to pass in some places. The surface is covered by soil or clay or is partially bedrock in the piedmont areas. There is no surface covering of laterite or gravel. All the bridges over rivers are constructed of wood and the structural strength appears inadequate in view of supporting large vehicles. The road conditions between Mwitya and Mkwepele in the northeastern part are particularly bad and there is a layer of powdered clay of 10 - 20cm thick on the surfaces. The roads have many undulations in the piedmont areas. Most branch roads are closed to traffic during the rainy season.

Fig. 3-13 Road Network and Location of Public Facilities



3-3-2 Socioeconomic Conditions

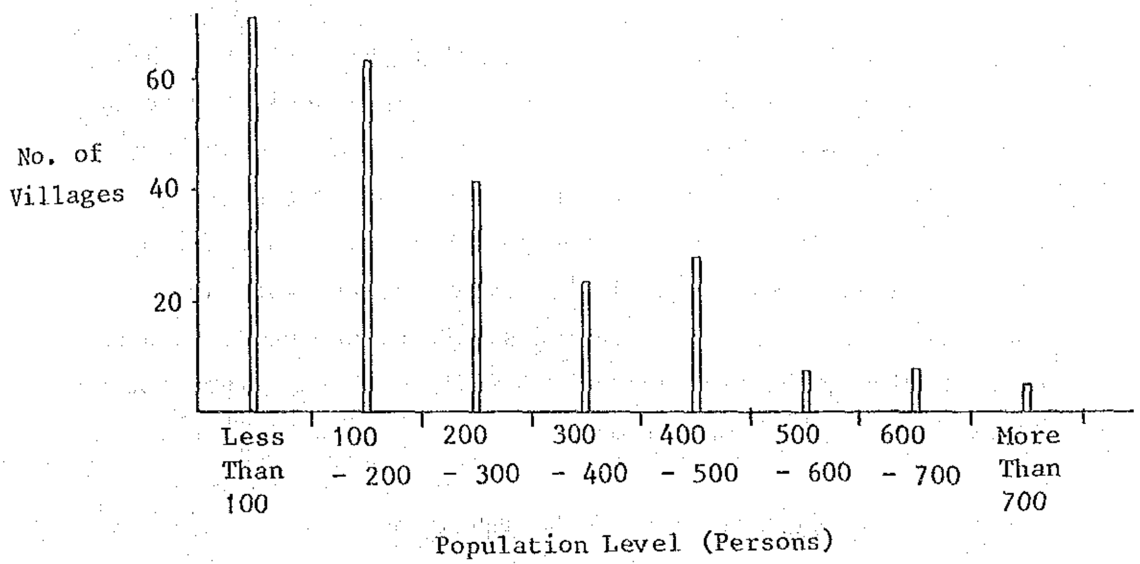
(1) Social Conditions

Most of the Project Area's population is concentrated along the trunk road, forming villages of relatively large population. Relatively speaking, many of the villages in the western part of the Area have a concentration of houses while the population density in the eastern part is low and houses are sparesely dispersed, and boundaries and centers of villages also tend to indistinctive.

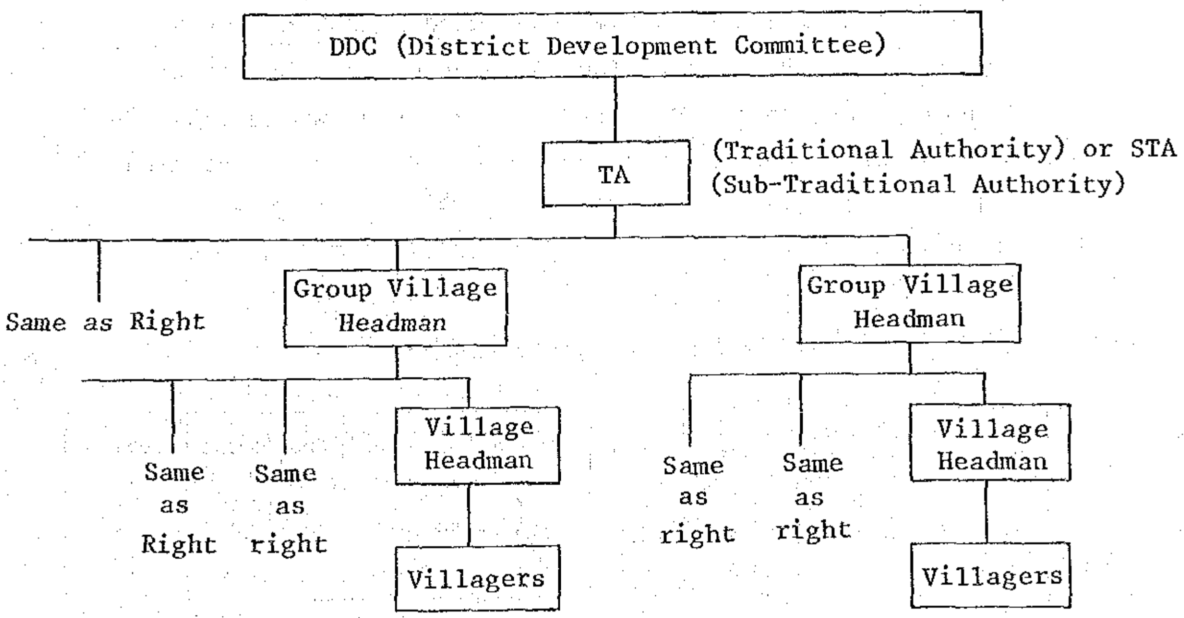
When the number of villages and their population size are classified using the 1977 national census data, the villages with a population of less than 200 account for 58% of the total, those with a population between 200 and 500 for 37% and those with a population of 500 or more for only 5%, as shown in the following table. Most of the villages are clustered in the vicinity of rivers and between mountains where surface water and subsoil water are easily obtainable.

Table 3-11 Population Level and Number of Villages

Population (Persons)	Less Than 100	100-200	200-300	300-400	400-500	500-600	600-700	More Than 700	Total
No. of Villages	67	63	38	21	22	5	4	3	223
Ratio (%)	30	28	17	10	10	2	2	1	
	58		37			5			



The social structure concerning villages is as shown above and the DDC not only discusses matters relating to village life but also makes decisions in regard to village management.



(2) Economic Conditions

Kawinga Area (MGA 7 through 10) including the Project Area is considered to be an area with a high potential capacity for agricultural development. While its estimated population in year 2000 is 266,000, its arable land is considered to be capable of feeding up to 360,000 persosns. In other words, it is an area where large repercussive effects, such as increased production of agricultural crops, can be counted on by improving its infrastructure starting with the improvement in the water supply situation.

The overwheliming majority of the inhabitants in the Project Area are engaged in agriculture, the present status of which is as described below. The major crop is maize although tobacco is also cultivated actively in the mountain areas. Both maize and tobacco play important roles, the former as the subsistence crop and the latter as a cash crop, respectively.

According to the 1981 survey conducted by the Ministry of Agriculture, the cultivation patterns of each Extension Planning Area in the Project Area are shown in Table 3-12 with maize accounting for more than 70% of the total area under cultivation.

Table 3-12 Ratio of Cultivated Area (%)

MGA	Maize	Maize/ Beans	Maize/ groundnuts	Maize/ Cassava	Rice	Sorghum	Cassava	Chalimbana	Tobacco
9	70.4	-	7.9	4.5	1.4	3.7	1.5	10.6	-
10	43.1	3.4	32.1	1.5	10.6	1.2	8.1	-	-
11	65.3	1.3	7.1	10.0	6.9	0.1	4.0	4.0	1.3

Source: Liwonde ADD

Tobacco, the main export crop, is mainly produced by estate farming and its production in 1984 - 1987 in Kawinga changed as shown in Table 3-13.

Although fire-cured tobacco is produced by independent farmers, the production volume is on a declining trend while the production by estates is on the rise.

Table 3-13 Tobacco Production

	Flue-Cured			Burley			Fire-Cured		
	No.of Workers (Persons)	Area (km^2)	Production Volume (kg)	No.of Workers (Persons)	Area (km^2)	Production Volume (kg)	No.of Workers (Persons)	Area (km^2)	Production Volume (kg)
1984 - 1985	38	792	1,368,988	184	1,540	2,070,866	217	98	39,060
1985 - 1986	50	888	1,451,457	183	1,765	1,266,648	240	105	24,350
1986 - 1987	50	1,049	1,663,078	185	1,843	2,345,713	91	41	-

Source: Liwonde ADD

3-3-3 Water Supply Situation

(1) Water supply situation

The Project Area is reported to have 30 boreholes as the water supplying facilities, but their actual operating rate is estimated to be around 50% on account of the breakdown of pumps. The inhabitants of the Project Area are also using dugwells, spring water and river water as other sources of water supply. As shown in 3-2-3 the quality of water from those supply sources other than the boreholes is remarkably polluted and unsuitable for drinking.

The boreholes in operation serve 300 - 500 people each, however, many of them are showing signs of a declining yield, causing an inadequate water supply excepting for those living nearby.

The need for borehole repair is examined by the DDC on receipt of a request from villagers. The DDC then decides the priority of the borehole repair in question and the method of raising the necessary funds. The Maintenance Section of the Department of Water conducts the required repairs with 350 Kwacha per borehole. Since the DDC cannot always raise the necessary funds, the number of boreholes left in a state of unrepair is increasing. Other boreholes also remain unrepaired due to the bad road conditions, heavy weight of the hand pumps or the lack of repair equipment and materials. In the case of requests for borehole repair only do not come to the Department of Water via the DDC, the Department lacks sufficient data on the working conditions of all boreholes.

Dugwells are owned by either individuals or village communities and some 150 people use one dugwell at a water supply volume of 12ℓ/capita/day. While spring water is used in mountainous areas, the fact that the springs are often located far from the villages imposes a heavy burden on the villagers in terms of transporting the water. As a result, the water supply volume is less than 10ℓ/capita/day at those villages far from springs. The rivers in the mountainous areas dry up in the dry season and, therefore, water sources some 8 - 10km distant from the villages are used as a supply of domestic water.

The field survey results given above reveal that the domestic water in the Project Area is both qualitatively and quantitatively belowed the required standard and also that many people are forced to carry out heavy labour to secure domestic water. The supply of a sufficient volume of good quality water is, therefore, a pressing task in the Area.

The area which is supplied water by the gravity piped system includes parts of MGA 8, 10 and 11 which are located in the southern part of the Project Area. Water taps are located at a rate of one per 120 - 130 persons with a water supply volume of 36ℓ/capita/day. The gravity piped water supply system in Kawinga is summarized as follows.

Project Area	Population	Total Pipe Length	No. of Taps	Year of Completion
Kawinga	70,000	571 km	450	1983

Source: Department of Water

(2) Waterborne Diseases

The following waterborne diseases in Malawi were listed in 1984 by the Ministry of Health.

Disease	No. of Cases	No. of Deaths
Typhoid, Paratyphoid, Salmonella Infections	600	51
Bacillary or Amoebic Dysentery	961	31
Enteritis, Diarrhea	10,539	532
Schistosomiasis	1,822	5
Ancylostomoiasis	1,702	1
Other Helminthiasis	271	4
Malaria	32,060	471

According to data from 1982 to 1986 compiled by the 6 Health Centres in the Project Area, no dysentry or typhoid cases have been found and the only reported cases were of cholera and gastroenteritis.

Cholera .... 21 cases
Gastroenteritis .... 106 cases

During interviews, however, many villagers from those villages using river or dugwell water for drinking complained of feeling unwell due to stomach pains or diarrhea.

Poor physical condition causes loss of appetite and a reduction of physical strength, opening the door to other disease. Those who are poorly fed and/or physically weak have less resistance to malaria which is by far the most common waterborne disease in Malawi. When a sufficient supply of good quality drinking water is secured through the completion of this Project, the current dependence on easily polluted river water and dugwell water will be withdrawn, contributing to the improvement of the health and life of rural inhabitants in Malawi.

CHAPTER 4 CONTENTS OF THE PROJECT

4-1 Purpose of the Project

This Project is planned as part of the Groundwater Development Programme currently being implemented nationwide by the Malawi Government. The purpose of the Project is the supply of domestic water to 65,000 people in North Kawinga, an area of high priority in Malawi's economic development. However, as the implementation of the Programme is making slow progress due to the inadequate financial state of Malawi and the deterioration, as well as low efficiency, of the government-owned machines and equipment, the Government of Japan intends to provide the necessary machines, equipment and materials for this Project in North Kawinga Area (including technology transfer) and to carry out borehole construction.

The implementation of the Project is expected to result in a high modern borehole provision rate in the Project Area, thereby contributing to the improvement of rural life. Together with the Project, the establishment of policies from the long-term perspective for the rational development of groundwater resources is intended to solve the chronic water shortage and, in addition, the establishment of policies to facilitate the permanent settlement of rural inhabitants and to increase agricultural production is also aimed at.

4-2 Examination of Requested Contents

4-2-1 Requested Contents and Confirmed Items

The contents of the request were confirmed and the following items were clarified through consultations between the study team and the Malawi counterpart.

(1) Project Area

The subject area of the Project (hereinafter referred to as the Project Area) is North Kawinga of the Machinga District in the Southern Region of Malawi. The Project Area excludes those areas already provided with the gravity piped water supply system and mainly consists of MGA 9 and 10, including parts of MGA 8 and 11. The characteristics of the Project Area are shown in Table 3-1.

(2) Beneficiaries

Based on the results of the 1977 national census (National Statistical Office data) and an estimated population growth rate of 2.7% for the Machinga District, the planned number of beneficiaries is 65,000 in view of the Project Area's estimated population in 1990.

(3) Planned Target Year

Although the planned target year is 1990, some delays may be experienced in view of the commencement year of the Project and the number of boreholes to be constructed. However, even in the case of inevitable delays, the original target year will be adhered to as far as possible.

(4) Selection of Borehole Locations

1) Selection Criteria

a) Villages with large populations will be given priority.

b) Villages which have difficulty in securing domestic water due to long transportation distances will be given priority.

2) Selection Method

Either the Japanese "consultant" or "sub-contractor" who has obtained the Project contract will conduct prior studies, including electric prospecting, and will prepare the basic materials for the selection of borehole locations.

The Department of Water, which is responsible for the implementation of the Project, will hold discussions with the beneficiaries, i.e. villagers, based on these materials and will make the final decision on borehole locations.

(5) Project Details

1) The target water supply volume is 27ℓ/capita/day.

2) The target supply population per borehole is 250.

3) The target number of boreholes to be constructed is 260 (65,000 persons ÷ 250 persons/borehole), of which 236 will be newly constructed and 24 will be rehabilitated.

4) The average borehole depth is 60 m.

5) The finishing borehole diameter is 10 cm and either PVC or FRP pipes will be installed.

6) All boreholes will be fitted with hand pumps.

(6) Borehole Drilling Rigs

The drilling rigs currently owned by the Department of Water are of the percussion type and, therefore, have a relatively low work efficiency. The request made by the Department of Water includes the provision of new rigs which combine the use of a rotary and air hammer in view of their superior efficiency vis-a-vis not only loose layers consisting of unconsolidated sediment and strongly weathered rocks but also hard rocks and the transfer of the relevant technologies. In addtion, these rigs will be mounted on trucks in order to increase their mobility.

Furthermore, as the drilling is expected to be conducted in areas with poor road conditions, it is requested that the rigs to be provided be light in weight and that the compressors (auxiliary machines) also be mounted on trucks.

(7) Borehole Construction Teams

The construction work aims at the completion of 260 boreholes (236 boreholes to be newly constructed) in 3 years in the Project Area and the necessary machines, equipment and materials for 2 borehole construction teams is requested.

(8) Pump Selection

Out of Malawi's total 5,100 boreholes, between 30 - 50% are currently out of operation due to pump breakdowns and other reasons and this situation is aggravated by the Department of Water's shortage of repair staff. In view of this, the Government of the Republic of Malawi has introduced a basic pump selection policy which specifies that the pumps be strong, light in weight, have a simple structure and be easy to repair (by the villagers themselves).

4-2-2 Examination of Requested Contents

(1) Appropriateness of the Project

The majority of the Project Area's inhabitants rely on either unsanitary river or dugwell water for domestic purposes. These water sources, however, generally dry up in the dry season, necessitating the heavy work of transporting water from distant water sources. Therefore, it is believed that the provision of a steady supply of sanitary water for domestic purposes by groundwater development will prove extremely effective in regard to improving the living environment, shortening the non-productive labour time, promoting highly productive agriculture, facilitating the permanent settlement of rural inhabitants and reducing the number of cases of waterborne diseases.

The Malawi Government's National Groundwater Development Programme has so far been entirely implemented by the assistance of either foreign governments or international organizations due to Malawi's inadequate financial state and the Malawi Government's difficulties in conducting borehole construction by its own efforts.

In view of the above, the study team concludes that the granting of assistance by the Government of Japan for the borehole construction requested by the Government of the Republic Malawi is appropriate.

(2) Project Area

It is estimated that the Project Area (North Kawinga in the Machinga District) will have a total population of some 65,000 in 1990 with the majority of the inhabitants being engaged in agriculture, mainly maize and cassava production in addition to tobacco being grown as a cash crop. According to the Department of Water, the number of boreholes in the Project Area is as low as 30. As well as this low absolute number of

boreholes, frequent pump breakdowns are believed to have reduced the borehole operation ratio to around 50%.
A noticeable difference in the provision of domestic water can be seen between North Kawinga and its southern neighbour which is provided with the gravity piped water supply system.

As the Project Area's annual rainfall is some 1,000mm and as the weathered bedrock is suited to the formation and wide distribution of aquifers, the Area has favourable conditions for groundwater development. No foreign assistance is currently provided in the Area, presenting no specific problems for the implementation of the envisaged type of project.

(3) Beneficiaries

Excluding the areas with the gravity piped water supply system in MGA 9 and 10 and including the areas without the gravity piped water supply system in MGA 8 and 11 in the Machinga District, it is estimated that the Project Area will have a population of 65,940 in 1990. Since this figure is almost the same as the number of beneficiaries cited in the Malawi Government's request, 65,940 is employed as the number of beneficiaries.

(4) Selection of Borehole Locations

The selection criteria giving priority to villages with large populations and the degree of difficulty of obtaining domestic water appear appropriate. In regard to the Department of Water's policy of consulting villagers to determine the final borehole sites, however, field surveys, including electric prospecting, should be conducted prior to such consultations to provide basic data for site selection.

(5) Target Water Supply Volume

Interviews with local people revealed that the water supply volume for those living in villages located far from boreholes is 12 - 20ℓ/capita/day while the figure for those living near boreholes is 20 - 27ℓ/capita/day. The target water supply volume of 27ℓ/capita/day is, therefore, judged to be appropriate.

In terms of the water balance of the Project Area as a whole, a minimum groundwater recharge of $2.6 \times 10^6 m^3$/year can be expected (see 3-1-2).

Based on the target water supply volume of 27ℓ/caita/day, the annual water consumption volume of a population of 65,940 will be $6.5 \times 10^5 m^3$, the groundwater recharge far exceeding the consumption volume. Even if the increased groundwater demand in the future due to a population increase and the increased baisc unit of water supply are taken into consideration, the present recharge still has an adquate margin to deal with the water demand increase.

(6) Borehole Service Population

Assuming a borehole service population of 250 and supply volume of 27ℓ/capita/day, a pumping volume of 6.75m^3/borehole/day will be required. In rural Malawi, pump operation hours are 5 hours in the morning, 1 hour in the afternoon and 2 hours in the evening, a total of 8 hours on average.

Assuming a pumping volume of 15ℓ/min., the maximum pumping volume will be 7.2m^3/day. Therefore, the contents of the request in this regard appear to appropriate.

(7) Target Number of Boreholes

Based on the Project Area's estimated population of 65,940 in 1990, the target number of boreholes to be constructed (including rehabilitated boreholes) is 263 with a target service population of 250 persons/borehole. This figure is similar to the requested number of boreholes of 260 (236 new boreholes and 24 rehabilitated boreholes). However, in view of the Malawi Government's basic policy of boreholes being located in villages with a population of over 125 and taking into consideration the actual population of each village, the required number of boreholes is 255 (see APPENDIX III A-6).

Although it is indeed preferable for those villages with a population of 125 or less to be provided with a water supply, the prospect of this is dim in view of the current scarcity of water supply facilities in the Project Area. Therefore, the use of the population distribution as the main selection criterion is preferred for the time being.

As stated above, the target number of boreholes to be constructed of 255 includes rehabilitated boreholes. Since borehole breakdowns to date have been mainly caused by frequent pump breakdowns and delayed repairs rather than any structural fault of the boreholes themselves, tha main contents of the rehabilitation work will be the installation of new pumps and the improvement of the borehole-related facilities.

Some of the existing boreholes which have the characteristics given below and where rehabilitation cannot be expected to improve their functions are excluded from the rehabilitation work.

- o Poor water quality
- o Poor pumping volume according to inveterviews with villagers and data obtained at the time of the completion of the original construction

- Breakdowns due to deterioration (including those cases where the relevant data is unabailable)

The resulting number of new boreholes to be constructed is, therefore, 239 with the rehabilitation of an additional 16 existing boreholes.

(8) Average Borehole Drilling Depth

The field survey showed that the weathered zone where the existence of groundwater can be anticipated has many undulations. The prior implementation of electric prospecting to obtain an accurate understanding of the geological structure is, therefore, of the utmost importance for deciding the final borehole locations which have favourable conditions for groundwater development. The topographical and geological characteristics, determined based on the field survey results (i.e. the electric prospecting in each model or Extension Section) and data on existing boreholes, are given in this Report and the borehole depth for each Extension Section are determined. The maximum drilling depth will be some 60m with an average depth of 43.1m (see Table 4-1).

In view of the above, the requested average depth of 60m is believed to be excessive and it is judged that an average drilling depth of 45m is sufficient for the purpose of this Project, giving an extra margin for successful drilling.

Table 4-1 Target Average Drilling Depth by Extension Sections

Location of New Boreholes MGA	Ext.Sect.	Topographical & Geological Classification*	Average Drilling Depth(m)	Target No. of New Boreholes	Remarks
8		Q-1	45	2	
9	160	G-4	45	16	
	161	G-1, S-4	40	11	
	162	S-4, S-2	50	15	
	163	S-4, S-1	40	26	Elect.Prospecting Site
	164	S-3	50	11	- do -
	165	S-3	50	18	
	166	S-2	55	8	Elect.Prospecting Site
	167	S-4	40	4	
10	168	G-1, S-4	40	5	
	169	Q-1	35	5	
	170	G-1, G-4	45	16	
	171	G-1, Q-1	40	4	Elect.Prospecting Site
	172	Q-1	35	7	
	173	Q-1, S-4	40	8	
	174	Q-3, S-1	50	14	
	175	Q-1	35	7	
	176	Q-4	45	13	
11	179	Q-1	35	19	Elect.Prospecting Site
	180	Q-1	40	20	
	181	Q-1	35	6	
	182	Q-1	45	5	
Total	22		10,300	239	Average Borehole Depth: 43.1m

* See 3-2-1

(9) Number of Drilling Rigs

In regard to the use of the requested type of drilling rigs, i.e. combined rotary - air hammer type, for borehole drilling in the Project Area, one work cycle (transportation to construction site, drilling and insertion of casing, etc.) is expected to take 5 days in view of the geological conditions of the Area. Assuming a real working period of 8 months/year using 2 rigs, the completion of the entire work by the target year (1989/1990) given by the Government of the Republic of Malawi appears difficult. The used of 3 drilling rigs is, therefore, preferred in order that the construction work can be completed by the target year. Nevertheless, the provision of 2 drilling rigs for 2 construction teams is deemed adequate for the present purposes in view of the work system currently planned by the Department of Water.

(10) Target Year

Although 1989/1990 is given as the Project's target year by the Government of the Republic of Malawi, the completion of 239 boreholes using 2 drilling rigs will be in 1991 because of the delay of the Project's commencement year and the fact that the actual working period will be only 8 months/year due to Malawi's rainy season lasting from December to March.

(11) Borehole Construction

The Department of Water, the recipient of the granted drilling rigs and related equipment, has both the organization for borehole construction and the necessary staff, as well as previous experience in borehole construction. From the technical point of view, however, the staff's experience is with percussion type drilling rigs and not with the type of rigs to be granted. Therefore, the transfer of technologies relating to the latter is of crucial importance.

Since not only the necessary machines, equipment and materials for borehole construction but also the actual construction work itself has been requested due to the financial state of Malawi, economic assistance whereby the machines, equipment and materials are granted and the actual drilling work is simultaneously carried out is preferred so that the engineers of the Department of Water can learn the necessary techniques to operate the new rigs during the construction period of 2 years.

(12) Machines, Equipment and Material Amounts

It is expected that 3 years will be required to complete the construction of 239 boreholes. The provision of the machines, equipment and materials required for the total 3 year period at one time may cause such problems as deterioration due to the storage conditions, loss or their use for other than Project purposes. Bulk provision is, therefore, deemed to be unsuitable in terms of security and maintenance. Accordingly, the machines, equipment and material specifications, the amounts and combinations should be reviewed on the basis of initially supplying the necessary amounts for the construction of 160 boreholes which is the equivalent of 2 years' work.

4-2-3 Examination of Machines, Equipment and Materials Supply Plan

A comparative examination between the contents of the request and the field survey results was made for each Project item in view of the Project's smooth and efficient implementation. The Project size was then decided by selecting the most suitable machines, equipment and materials and the amounts required.

(1) Drilling Rig Type

With regard to the selection of the drilling rig type and the required number of rigs, the following points were noted for the smooth implementation of the Project.

1) Machines, equipment and materials required for the drilling and construction of boreholes.

2) Equipment and material amounts to be supplied should be based on an assumed initial construction period of 2 years.

3) 2 construction teams using 1 drilling rigs each.

4) Natural conditions, socioeconomic conditions and the infrastructure, etc. of the Project Area.

5) Manoeuverability, durability, applicability and future use of the drilling rigs.

6) Contents of the request made by the Government of the Republic of Malawi and contents of the Groundwater Development Programme.

7) Department of Water's organization, staff, technical level and experience, etc.

8) Others

The selected drilling rig should be capable of the combined application of rotary and air hammer drilling due to the following.

a) The geology of the Project Area is characterised by the distribution of relatively loose, unconsolidated sediment and strongly weathered rocks at the surface and such hard rocks as gneiss, syenite and granite below the surface. As the existence of groundwater is expected from the strongly weathered zone to the fissure zone at the top of the hard rock layer, the drilling rig should be flexible to deal with the various types of geological layers.

b) The new rig should have better efficiency than the percussion type drilling rigs currently owned by the Department of Water.

c) The new rig should be capable of continuously drilling a relatively large hole throughout the drilling process, from the loose collapsible layer to the hard bedrock, using the muddy water, normal circulation method.

d) The new rig should be capable of highly efficiently drilling the hard rock using the air hammer method.

e) Since the subject sites for borehole construction are scattered in the extensive Project Area, the drilling rig should be truck-mounted for good mobility. A muddy water pump, an injection pump (for form drilling) and a hydraulic, collapsible test drilling mast should also be provided.

The type of drilling rig which satisfies the above conditions is basically a hydraulic, top-drive power swivel type (see Tables 4-2 and 4-3). In view of the Project's expected maximum drilling depth of 60m, the rig's air hammer drilling should have an adequate margin to allow for a hole bottom diameter of some 165mm and a maximum drilling depth of some 100m. Additional requirements include highly efficient and safe operationability. A light weight and good drilling performance are also required by the Department of Water.

The types of compressor and drilling tools, etc. are selected in accordance with the performance of the selected drilling rig. With regard to transport vehicles and support vehicles, their types and numbers are determined in view of organizing drilling teams capable of performing highly efficiently.

Table 4-2 Drilling Methods

Type	Characteristics and Summary	Drilling Method	Rotary Drilling	Straight Drilling	Muddy Water Normal Circu-lation
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 rig is cheap, this type of drilling is unsuitable for a consolidated layer.	Percuss-ion	-	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 care drilling.	Rotary	Spindle	Spindle	Muddy 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 rig tends to be large.	Rotary	Turn Table	Wire	Muddy Water Normal Circulation
Top Drive Type (Power Head Type) Rotary Boring	Drilling is conduted by rotary movement using the hydraulic motor at the top of the drill pipe and straight movement using the hydraulic jack. The rig is relatively small and light and has high efficiency, including good operationability of the drill pipe.	Rotary	Hydraulic Motor	Hydraulic Jack	Muddy Water Normal Circulation
Reverse Rotary Boring	The flow direction of the muddy water is the reverse of normal rotary boring methods. Need to use much muddy water and suitable for a relatively large hole.	Rotary	Spindle Turn Table Hydraulic Motor	Spindle Turn Table Hydraulic Motor	Muddy Water Reverse Circulation
Air Rotary Boring	Compressed air is used to discharge the mud to replace the muddy 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, Blowing Agent, 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, Blowing Agent, Normal Circulation

Table 4-3 Drilling Rig Rating

Machine Type & Drilling Method	Drilling Capacity		Applicable Geological Layer			Applicability Below Groundwater Level	Applicability to (f) and (g)	Availability of Spare Parts	Operation ability	Durability	Maintenance	Future Prospects	Price	Suitability to Request	Comprehensive Appraisal
	Depth (m)	Hole Dia- meter (m)	Upper Layer	Sedimentary Rock	Bedrock										
a) Percussion (Cable Tocl)			○	△	×	○	×	○	○	△	○	×	low	×	×
b) Direct Rotary, Spindle Type			○	○	△	○	○	○	○	○	○	○	High	×	×
c) Direct Rotary, Table Type			○	○	△	○	○	△	△	○	△	○	High	×	×
d) Direct Rotary, Top Drive, Power Head Type			○	◎	△	○	◎	△	△	○	△	◎	High	△	×
e) Reverse Rotary			○	△	×	○	×	×	△	○	△	○	High	×	×
f) Air Rotary			◎	○	×	△	–	△	△	○	△	○	High	△	×
g) Air Percussion			×	△	◎	△	–	△	△	△	△	◎	High	△	×
b)+f)+g) Spindle Type, Air Rotary, Air Percussion			◎	○	◎	○	–	△	△	○	△	○	Very High	△	○
c)+f)+g) Table Type, Air Rotary, Air Percussion			◎	○	◎	○	–	△	△	○	△	○	Very High	△	○
d)+f)+g) Top Drive Type, Air Rotary, Air Percussion			◎	◎	◎	○	–	△	△	○	△	◎	Very High	◎	◎

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

In view of the comparison results shown below between the expected drilling efficiency of the combined rotary and air hammer drilling rig and the percussion type drilling rig owned by the Department of Water, the efficiency of the Department's drilling work will be improved by the introduction of the former.

	Drilling Depth(m)	Subject Geological Formations	Required Drilling Period
Combined Rotary and Air Hammer Type	45	Sediment - Hard Rock	2.5 Days
Percussion Type	45	Only Unconsolidated Sediment	7-11 Days

(2) Test Pumping Equipment

The test pumping equipment teams are mainly expected to be responsible for the following.

1) Cleaning of boreholes drilled by the drilling teams.

2) Judgement of possible pumping volume by conducting pumping tests.

3) Setting up of pumps.

4) Judgement of water quality by conducting water quality tests.

5) Rehabilitation of existing boreholes

In view of the above, it is decided that 1 unit each of the following equipment shall be provided for each drilling rig.

a) Test pumping equipment which is truck-mounted in view of good mobility. A mast and a winch for lifting the compressor up and down and the tools for air-lifting and air-jettisoning should also be provided and should also be used for pump installation.

b) Such test pumping equipment as a water pump, a generator and groundwater level measuring apparatus and such water testing equipment as electric conductivity, temperature and PH testing equipment should be included.

(3) Truck-Mounted Borehole Servicing Machine

The truck-mounted repair machine aims at pump installation and the repair of future pump breakdowns. As this type of work can be adequately carried out using the above-described test pumping equipment, it is decided that repair machine of this type shall not be provided.

(4) Mobile Workshop Truck

It is decided that a mobile workshop truck shall not be provided as the repair equipment will be kept at the base camp and at other suitable locations.

(5) Geological Survey Equipment

2 electric prospecting devices appropriate for studying the groundwater in view of selecting borehole locations shall be provided to meet the request for geological survey equipment.

(6) Borehole Logging Equipment

Since borehole logging equipment is required to decide the casing and strainer combination following the completion of drilling, it is decided that 1 electric logging device shall be provided for each drilling rig.

(7) Transportation Vehicles

Excepting motorcycles, all the vehicles to be provided shall be 4-wheel drive with right-hand steering in view of the road conditions. The combination of vehicles requested by the Malawi Government has been modified in view of efficiently conducting the work described in (1) and (2) above.

1) 8 Ton Cargo Trucks with Cranes

These trucks will be used to transport the equipment and materials from the base camp. After the drilling work commences, the trucks will also be used for the transportation of drilling tools, bentonite, drilling water, gravel, borehole casings and screens, in addition to such materials as cement, sand, gravel and bricks for the facilities surrounding the boreholes. Petrol and light oil will also be transpoted by the trucks in drums. 2 trucks with cranes have been added to the requested 2 trucks as the latter would not be able to conduct the work with sufficient mobility.

Although water tanks ($4m^3$ each) will be used to transport the drilling water, these tanks will not be fixed to the trucks but will be loaded and unloaded using the cranes.

2) Water Tank Lorry

A water tank lorry shall not be provided due to the reason given in 1) above. Instead, water tanks shall be provided.

3) Motorcycles

The motorcycles will be used to patrol the boreholes for maintenance purposes. As 1 assistant maintenance engineer is responsible for 100 boreholes in Malawi and as 160 boreholes will be constructed in the first 2 years of the construction period, it is decided that 2 motorcycles shall be provided. These will be 100 - 125cc off-road type in view of the road conditions.

(8) Communication Equipment

Ntaja, where the equipment and materials required for borehole construction will be stored, could also be used as the location for the base camp (control centre for the Project and related work, construction machines, equipment and material depository and engineer accommodation location). Communication between the base camp and the Department of Water in Lilongwe can be made by extending the existing telephone lines. However, a method of communication between the base camp and the mobile work sites will be required and radio communication equipment shall be provided in this regard.

For Base Camp	:	FM Radio Communication Equipment	1 set
For Mobile Work Sites	:	FM Radio Communication Equipment	5 sets

(9) Borehole-Related and Other Equipment and Materials

It is believed that the provision of other construction equipment and materials, including spare parts, in bulk is undesirable from the security and maintenance points of view because of the long construction period which extends over 3 years. Therefore, borehole-related equipment and materials, including spare parts, shall be provided to satisfy the requirements of the first 2 years.

The borehole-related equipment will include pumps and casings (including screens) with their amounts decided on the basis of the requirements of 160 boreholes.

With regard to pumps, the foot pump which has a satisfactory history in Japan's overseas aid is selected. This pump will satisfy the required conditions that it be easy to maintain by the villagers and seldom breaks down.

As the casing pipes to satisfy the 2 year requirement will be initially supplied in bulk, many of them will be stored for a long period of time. FRP pipes, therefore, are selected because of their quality stability against heat and strong resistance to deformation and deterioration.

Since no adequate accommodation is available in Ntaja, the possible location of the base camp, the provision of 1 set of camping equipment is decided as part of the extra equipment.

4-3 Project Summary

4-3-1 Implementation Organization and Management System

The organization responsible for the general implementation of the Project is the Department of Water of the Ministry of Works and Supplies.

The Department of Water is the competent organization for the planning, execution, maintenance and management systems of the national groundwater supply projects currently being implemented in various parts of Malawi. As it has also carried out several groundwater supply projects in the past with the assistance of foreign governments and international organizations, it is believed to have sufficient experience in the implementation of this type of project.

Project implementation has, however, often been delayed by the deterioration and low efficiency of the drilling rigs owned by the Department of Water, coupled with a shortage of the necessary machines, equipment and materials. The Department of Water, therefore, intends to further consolidate its organization for borehole construction in the future by enlisting the assistance of international organizations and industrialized countries to improve and strengthen its functions and facilities.

The management system consists of the Economic Planning and Development Division (EP & DD) of the Office of the President and Cabinet (OPC), the Department of Water and Borehole Maintenance Committees. Their respective roles are descrived below.

(1) EP & DD

The EP & DD is a division of the OPC and is responsible for the examination and approval of the national groundwater supply projects which are planned by the Department of Water. The EP & DD also makes the decision on project commencement and supervises project progress.

(2) Department of Water

The Department of Water prepares the national groundwater supply projects and, on receipt of approval from the EP & DD, carries out the projects in a concrete manner. The Department has a nationwide organization, engineers, past experience, workshops, and warehouses, etc.

(3) Borehole Maintenance Committees

A Borehole Maintenance Committee is established for each borehole constructed as part of a national groundwater supply project. These Committees are responsible for borehole maintenance and are expected to conduct daily maintenance work and minor borehole repairs, as well as provide public health education for the inhabitants of the area. Following borehole completion, 1 assistant maintenance engineer is permanently assigned the responsibility for 100 boreholes by the Department of Water. With regard to those boreholes where repair work is both technically and financially difficult, this engineer discusses the possible measures which can be locally employed with the Borehole Maintenance Committees.

4-3-2 Water Supply Facilities Plan

The details of the Water Supply Facilities Plan are as follows.

(1) The Project Area is some 650km^2 in North Kawinga, Machinga District of the Southern Region where the gravity piped water supply system is not provided and mainly consists of MGA 9 and 10.

(2) The water supply facilities should be capable of providing an adequate volume of clean, potable water and boreholes offering stable water quality and quantity are adopted.

(3) The target water supply volume and service population are 27ℓ/capita/day and 250 persons/borehole respectively.

(4) The water source is the abundant and clean groundwater contained in either the weathered or fissure zones of the bedrock.

(5) Strainers will be installed in those aquifers which do not dry up in the dry season.

(6) A foot pump will be used for pumping to satisfy the easy maintenance and economy conditions in view of the small number of beneficiaries per borehole.

(7) The borehole mouth will be covered by a concrete slab and a water recieving apron, drainage channel and washing area will be provided at each borehole in view of the sanitary and functional aspects.

(8) Inhabitants will be provided with public health education to prevent artificial secondary water pollution.

(9) In view of the population per village in the Project Area, the number of required boreholes is 255.

(10) Since 16 of the 30 existing boreholes can be rehabilitated (the remaining having problems in regard to the water quality, pumping volume or deterioration), the number of boreholes to be newly constructed is 239.

(11) 80 new boreholes will be constructed in the first year of the Borehole Construction Plan, 80 in the second year and 79 in the third year. The rehabilitation of the 16 existing boreholes will be carried out in the third year.

4-3-3 Borehole Construction

(1) Implementation System of Borehole Construction Plan

The work in the first year of the Borehole Construction Plan, including the transfer of technologies to Malawi, will be carried out by a Japanese contractor. The actual borehole construction will be conducted under the implementation system whereby 2 drilling teams and 2 test pumping teams are organized.

(2) Borehole Construction Plan

The number of boreholes to be constructed in each MGA in the Machinga District is as follows.

MGA 8	2	(New)			= 2
MGA 9	108	(New)	8	(Rehabilitated)	= 116
MGA 10	79	(New)	6	(Regabilitated)	= 85
MGA 11	50	(New)	2	(Rehabilitated)	= 52
				Total	= 255

With regard to the 80 boreholes to be constructed in the first year of the construction work those villages with large populations will be given priority in the distribution of the boreholes and those villages with a population of 700 or more will have 2 boreholes. Those villages where the boreholes to be rehabilitated in the third year of the construction work are located are, however, excluded from the first year's construction schedule.

Table 4-4 shows the number of boreholes to be constructed in each Extension Section in the first year.

Table 4-4 Borehole Construction Plan: First Year of the Construction

MGA	Extension Section		No. of Boreholes to be Constructed in First Year
	No.	Representative Place Name	
9	160	Umbwa	9
	161	Kapoloma	1
	162	Nkapa	7
	163	Nyambi	11
	164	Nkwepele	4
	165	Ntali	6
	166	Nwitiya	1
	167	Chimbila	1
10	168	Mwepeta	1
	169	Bakali	1
	170	Muwawa	5
	171	Chikumba	1
	172	Makanalia	2
	173	Kondani	1
	174	Chisama	5
	175	Ntaja	3
	176	Chikweo	3
11	179	Likhomo	7
	180	Chiuja	7
	181	Nyenje	2
	182	Chidamba	2
Total			80

(3) Aquifers and Drilling Depth

The hydrogeological structure of a wide section of the Project Area has been clarified by the field survey (including electric prospecting) and existing data and it is now known that aquifers with high groundwater potential are intercalated in the weathered or fissure zones of the bedrock. Since the weathered bedrock has many undulations, a thorough understanding of the underground structure through the prior implementation of electric prospecting is of crucial importance in view of the success of the drilling. The average drilling depth for the this Project, determined on the basis of the survey results and the topographical and geological conditions, is 45m. The average drilling depth for each Extension Section is given in Table 4-5.

(4) Degree of Difficulty of Groundwater Development

The Project Area currently has a total of 30 boreholes. In general, the Area has abundant groundwater and the potential pumping volumes of these boreholes at the time of their completion are believed to have been largely satisfactory (see Tabel 3-9). Although 2 of these boreholes have a potential pumping volume of less than 10r/min., the ratio of dry boreholes can be reduced by paying strict attention to the following points at the time of borehole construction, thus making groundwater development easier.

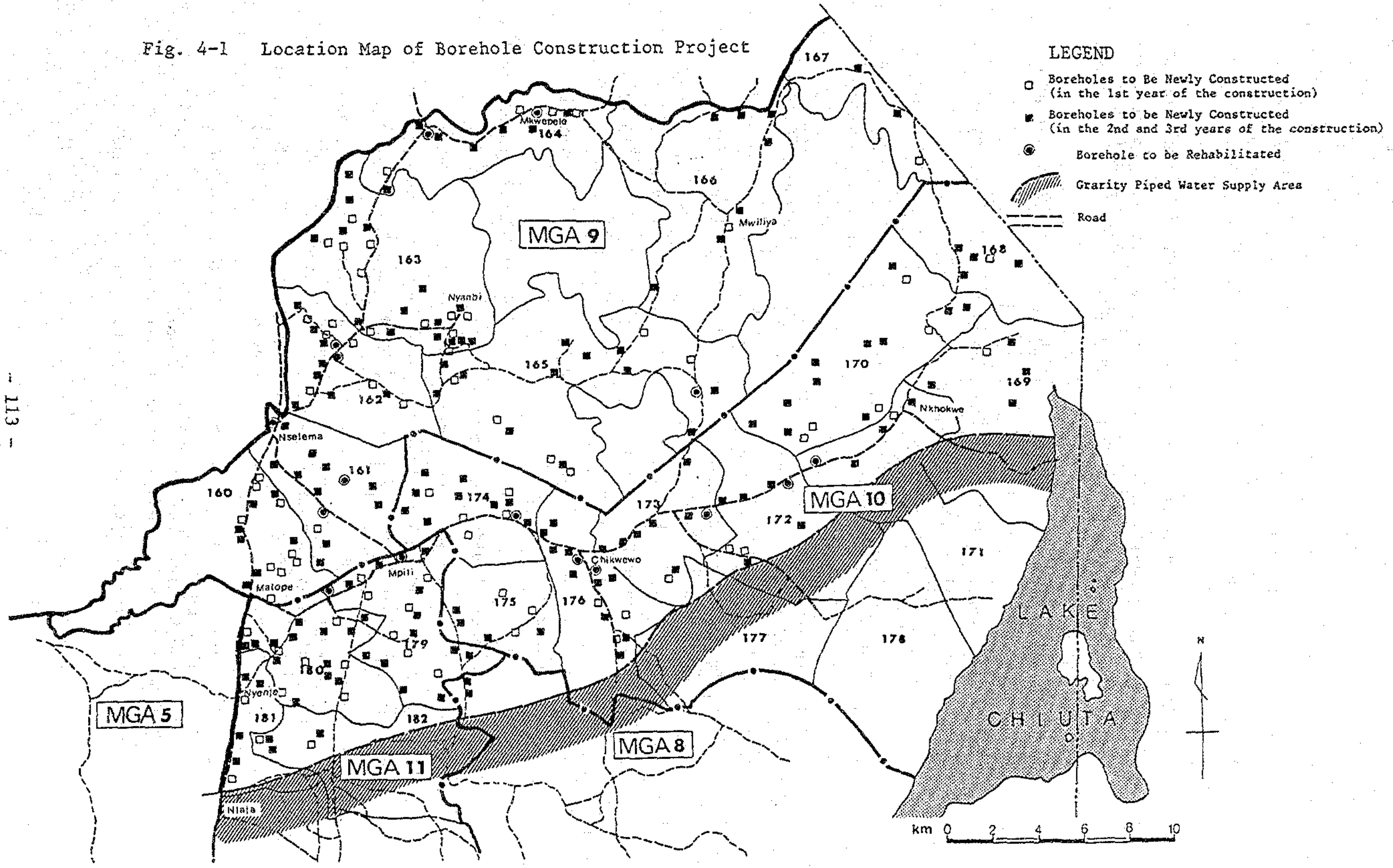
1) Appropriate locations for groundwater development should be selected based on a proper understanding of the geological structure, in turn based on prior electric prospecting, etc.

2) In the case of the prospective layer consisting of hard rocks, if groundwater development can be expected from a fissure zone, the drilling should be carried out to a predetermined depth using the rotary - air hammer type drilling rig which has superior drilling capability.

Table 4-5 Area and Number of Boreholes to Be Newly Constructed and Existing Boreholes to Be Rehabilitated

MAG	Ext. Section No.	Ext. Section Name of Representing Place	No. of Village	Population (1977) Male	Population (1977) Female	Population (1977) Total Population	Estimated Population (1990)	No. of Target Borehole Construction Total	Boreholes to Be Newly Constructed QTY	Boreholes to Be Newly Constructed Average Depth(m)	Rehabilitation of Existing Borehole QTY	Rehabilitation of Existing Borehole No.	Remarks
8		Kwilasya	2	129	202	331	470	2	2	45			Gravity piped water has been laid on to the most part of MGA8
9	160	Umbwa	12	1,531	1,899	3,430	4,840	16	16	45			
	161	Kapoloma	15	1,127	1,502	2,629	3,710	14	11	40	3	L-264 J-8 GM-23	
	162	Nkapa	13	1,497	1,817	3,314	4,760	17	15	50	2	EC-129 GM-18	
	163	Nyambi	18	2,243	2,751	4,994	7,040	26	26	40			
	164	Mkwepele	10	1,079	1,183	2,262	3,190	13	11	50	2	CC-96 GM-20	
	165	Ntali	18	1,629	1,809	3,438	4,850	19	18	50	1	GM-22	
	166	Mwitiya	12	734	676	1,410	2,000	8	8	55			
	167	Chimbila	6	266	331	597	840	3	3	40			
10	168	Mwepeta	6	420	446	866	1,220	5	5	40			
	169	Bakali	6	391	472	863	1,220	5	5	35			
	170	Muwawa	16	1,358	1,681	3,039	4,290	16	16	45			
	171	Chikumba	6	348	486	834	1,180	5	4	40	1	RM-1	
	172	Makanalia	9	607	765	1,372	1,940	8	7	35	1	SM-449	
	173	Kondoni	14	696	831	1,527	2,150	9	8	40	1	W-115	
	174	Chisawa	9	1,200	1,484	2,684	3,780	15	14	50	1	GM-26	
	175	Ntaja	2	524	673	1,197	1,690	7	7	35			
	176	Chikweo	15	1,139	1,473	2,612	3,680	15	13	45	2	E-244 FM-85	
11	179	Likhomo	13	1,623	2,103	3,726	5,250	21	19	35	2	FC-124 GM-24	
	180	Chiuja	12	1,509	2,141	3,650	5,150	20	20	40			
	181	Nyenje	4	509	606	1,115	1,570	6	6	35			
	182	Chindanba	5	365	507	872	1,230	5	5	45			
Total			223	20,924	25,838	46,762	65,940	255	239	--	16	--	

Fig. 4-1 Location Map of Borehole Construction Project



4-3-4 Machines, Equipment and Materials Supply Plan

Following examination of the original request, it is decided that the following machines, equipment and materials shall be provided for the first 2 years of the construction.

		Planned	(Requested)
(1)	Truck-Mounted Drilling Rigs (rotary - Air hammer type)	2 units	(2)
(2)	Compressors	2 nos.	(-)
(3)	Truck-Mounted Test Pumping Equipment	2 units	(2)
(4)	Truck-Mounted Borehole Servicing Machines	-	(1)
(5)	Mobile Workshop Trucks	-	(1)
(6)	Electric Prospecting Equipment	2 sets	(2)
(7)	Borehole Logging Equipment	2 sets	(2)
(8)	Other Testing Equipment		
	Groundwater Level Measuring Apparatus	2 sets	(-)
	Electric Conductivity Meters (with Thermometers)	2 sets	(-)
	PH Meters	2 sets	(-)
(9)	Vehicles		
	4WD Station Wagons	2 nos.	(2)
	4WD Pick-Up Trucks	2 nos.	(2)
	Cargo Trucks with Cranes	4 nos.	(2)

	Motorcycles	2 nos.	(4)
	Water Tank Lorries	-	(1)
(10)	Water Tanks ($4m^3$)	1 no.	(-)
(11)	Communication Equipment	1 unit	(1)
(12)	Casings and Screens	for 160 B/H	(280 B/H)
(13)	Pumps	160 sets	(300)
(14)	Repair Equipment	1 unit	(-)
(15)	Spare Parts, etc.	1 lot	(1)
(16)	Base Camp Equipment	1 set	(-)
(17)	Muddy Water Agent, Blowing Agent	for 160 B/H	(-)
(18)	Materials for Civil Work	1 set	(-)

4-3-5 Technical Cooperation

Although 13 borehole construction teams are currently organized by the Department of Water, their drilling experience is limited to work using the percussion type of drilling rig. It is, therefore, extremely important in view of the Project's successful conclusion that the engineers of the Department of Water master the drilling technique for the rotary - air hammer type of drilling rig.

The Government of the Republic of Malawi is well aware of the necessity of technical cooperation for the Project and has, therefore, requested the transfer of the relevant technologies in addition to the provision of machines, equipment and the actual construction work.

For the smooth construction of 239 new boreholes in a 3 year period, as stipulated by the Project, the successful completion in the first and second years of the construction work is of particular importance. In view of the technical level of the Malawi counterpart, it is preferable that the engineers of the Department of Water participate in on-the-job training during the initial 2 years' construction work in order to acquire the machine operation and drilling techniques. It is, therefore, planned to provide these engineers with technical advice within the scope of the grant cooperation.

CHAPTER 5 BASIC DESIGN

5-1 Basic Policy for Machines, Equipment and Materials Supply Plan

The types and quantities of the machines, equipment and materials to be supplied were decided based on the following conditions in view of the smooth execution of this Project.

(1) The natural conditions, socioeconomic conditions and the infrastructure, etc. of the Project Area should be taken into consideration.

(2) Reference should be made to the organization, staff, technical level, experience, machines and equipment currently in possession, etc. of the Department of Water.

(3) Machines and equipment with extremely good mobility should be selected in view of the construction of a large number of boreholes in the extensive Project Area.

(4) A special task force, with the borehole construction teams and test pumping teams conducting specific work, should be introduced for efficient borehole construction.

(5) The selected drilling rigs should be capable of a wide application range, i.e. can be used for both sediment and hard rock layers.

(6) Such factors as applicability, operationability, durability, future prospects, maintenance and price, etc. should be stressed in the selection of the machines, equipment and materials.

(7) 2 borehole construction teams and 2 testing pumping teams should be established and the necessary materials and spare parts for the first 2 years' requirements should be provided.

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

5-2 Examination of Main Machines, Equipment and Materials

(1) Truck-Mounted Drilling Rig

The ground surface in North Kawinga is generally covered by a layer of sediment and strongly weathered rocks with a thickness of 10 - 20m with hard rocks being distributed below this surface layer. The drilling rig to be provided should be capable of being used against such various types of geological layers with steady drilling efficiency and a rig which is capable of using both the rotary - air hammer methods should be selected.

Since the maximum depth of the fissure zone is estimated to be 60m, it is decided that the drilling rig should be capable of drilling a hole bottom diameter of 165mm and have a maximum drilling depth of some 100m.

(2) Air Compressor

Together with the drilling rig, it is decided that a compressor shall be provided, the role of which is the discharge of earth and rocks by air hammer operation and air circulation. The capacity of the air compressor is extremely important as it largely determines the drilling performance against hard rock.

In view of the above and also in view of the geological characteristics of the Project Area, the selected compressor should have an air pressure of 17.5 kg/cm^2 or more and an air blowing volume of 20 m^3/min or more.

(3) Truck-Mounted Test Pumping Equipment

The testing pumping equipment is used for cleaning the boreholes after the completion of drilling, for confirmation of the water quality and the pumping volume by water quality and pumping tests, for water pump installation and for the rehabilitation of the existing boreholes. A mast and a winch shall also be provided for lifting the tools up and down the boreholes.

The air lift method will be used for borehole cleaning and a compressor with an air pressure capacity of 7.0 kg/cm^2 and an air blow volume of 3.5 m^3/min or more will be mounted on a truck in view of the required work.

The water pump used for the test pumping should have a pumping capacity of upto 50m in depth and a discharge volume of 100ℓ/min or more. A generator to operate the pump shall also be provided.

In addition, groundwater level measuring apparatus for the test pumping and electric conductivity, temperature and PH meters for the water quality testing shall also be provided.

(4) Other Survey Equipment

The geophysical survey equipment to be provided shall be electric prospecting equipment to determine the underground hydrogeological structure and, therefore, select appropriate borehole location. Given the geological characteristics of the Project Area, the equipment is expected to have a prospecting capability of upto 200m below the surface.

Electric logging apparatus shall be provided as geophysical logging equipment for the casing programme, including aquifer confirmation. This apparatus should have a resistivity and natural electric potential measuring capability of upto 100m below the surface.

(5) Vehicles

With regard to the present road conditions, although trunk roads are paved with laterite, many local roads are unpaved. Furthermore, in view of the necessity of passing through places which are not shown to have roads on the map, all the vehicles to be provided should be of the 4-wheel drive type.

Each of the construction teams shall be provided with 1 turck-mounted drilling rig, 1 station wagon and 1-2 truck(s) for equipment and material transportation. The test pumping teams shall be provided with truck-mounted test pumping equipment, 1 pick-up truck and 0-1 truck for material transportatiaon.

A total of 4 trucks with cranes shall be provided for these teams instead of the requested 2 trucks. However, repair equipment mounted on a mobile workshop truck and a water tank installed on a water tank lorry can be replaced by adding cranes to the trucks to be provided and the provision of a mobile workshop truck and a water tank lorry has been rejected. These 4 trucks will be used not only for such limited purposes as water and repair equipment transportation but also for the transportation of fuel, cement, sand and casings, etc.

The provision of the requested truck-mounted borehole servicing machine has also been rejected in view of the fact that the necessary work can be adequately performed by the truck-mounted test pumping equipment. The motorcycles will be used for borehole maintenance work and the provision of 2 motorcycles to patrol 160 borehoels, i.e. the number of boreholes to be constructed in the first 2 years of the construction work, is decided.

(6) Communication Equipment

This equipment will be used for communication between the base camp (Ntaja) and the construction site (mobile station) and should be capable of being used over a distance of some 100km in view of traversing a mountain range of around 400m above sea level.

The number of sets to be provided shall be 1 set for the base camp, 2 sets for the borehole construction teams, 2 sets for the test pumping teams and 1 set for the mobile base camp.

(7) Pump

The foot pump has been selected in view of its maintenance, operation, pumping volume and the contents of the original request. 160 pumps shall be provided for the first 2 years of the construction work.

(8) Casing and Screen

The casings and screens will be FRP pipes with screws which allow the work to be easily carried out and which have strong resistance to deformation. The amount to be supplied is 7,200m (160 x 45m) and the details are as follows.

Screens : 160 x 12m = 1,920m
Casings : 160 x (45 - 12) = 5,280m

(9) Repair Equipment

The repair equipment shall include an engine welder, drill press, grinder, pipe cutter and measuring tools, etc. and will be used for the repair and processing of other equipment and materials.

(10) Equipment, Materials and Spare Parts

The standard quantities of the equipment, materials and spare parts to be provided are calculated based on the requirements for the construction of 160 boreholes in the first 2 years.

5-3 List of Machines, Equipment and Materials

The Government of the Republic of Malawi will be provided with the machines, equipment and materials required for the implementation of the Project through the grant aid of the Government of Japan. The specifications and quantities of the mchines, equipment and materials are decided based on the examination results and the basic policy and are as follows.

(1) Drilling Rig 2 units

Truck-Mounted Rotary-Air Hammer Combined Type Truck
Specifications: Water-Cooled Diesel Engine, Right-Hand Drive, 4 x 4
Drilling Rig Capacity: Bottom Hole Diameter of 6 1/2" (165mm) and Maximum Drilling Depth of some 100mm (Air Hammer)
Muddy Water Capacity: Discharge Volume of 600ℓ/min, Pressure of 20 kg/cm^2 or more, with Standard Accessories and Expendables

(2) Air Compressor 2 nos.

Capacity: 17.5 kg/cm^2 x 20 m^3/min or more with Standard Accessories

(3) Test Pumping Equipment 2 units

1) Truck-Mounted Borehole Development Unit (with Mast and Winch)
   Truck Specifications: Water-Cooled Diesel Engine, Right-Hand Drive, 4 x 4

2) Air Lift Tools
   Compressor: 7 kg/cm^2 x 3.5 m^3/min or more

3) Generator : 50Hz, 220V, 20KVA

4) Water Pump: Lift of 50m, Discharge Volume of 100ℓ/min or more, with Accessories

5) Groundwater Level Measuring Apparatus: Upto a Depth of 100m

6) PH Meter

7) Electric Conductivity Meter (with Thermometer)

(4) Electric Prospecting Equipment: Maximum Prospecting Depth of 200m or more — 2 sets

(5) Electirc Logging Equipment — 2 sets

Type : Automatic Recording with 100m Cord
Logging Items: Natural Electric Potential, Resistivity (Micro, with Log)
Accessories : Battery and Recording Paper, etc.

(6) Vehicles

1) Cargo Truck with Crane

Specifications: Water-Cooled Diesel Engine, Right-Hand Drive, 4 x 4

Crane Capacity: 5 tons for 7 Ton Truck — 2 nos.
3 tons for 5 Ton Truck — 2 nos.

2) Station Wagon — 2 nos.

Specifications: Water-Cooled Diesel Engine, Right-Hand Drive, 4 x 4, Long Body

3) Pick-Up Truck — 2 nos.

Specifications: Water-Cooled Diesel Engine, Right-Hand Drive, 4 x 4, Loading Capacity of 500kg

4) Motorcycles — 2 nos.

Engine Capacity: 100 - 125cc for Off-Road Use

(7) Water Tank — 1 no.

Specifications: $4m^3$ (can be loaded on truck) with Water Pump

(8) Communication Equipment — 1 unit

Specificaitons: 50W Output with Antenna Set for Base Camp

(9) Pump — 160 sets

Foot Type

(10) Casing and Screen

FRP Casing with Screw 4" x 4m	1,280 nos.
FRP Screen with Screw 4" x 4m	480 nos.
(Pore Ratio of 5% with Horizontal 1mm Slits)	
FRP Bottom Plug with Screw 4" x 1m	160 nos.

(11) Repair Equipment

1)	Generator, Welder and Accessories	1 set
2)	Drill Press and Accessories	1 set
3)	Grinder and Accessories	1 set
4)	Pipe Cutter and Accessories	1 set
5)	Screw Cutter and Accessories	1 set
6)	Sander and Accessories	1 set
7)	Pipe Vice	1 no.
8)	Bench Vice	1 no.
9)	Measuring Tools	1 set
10)	Gas Cutter	1 no.
11)	Hydraulic Jack	2 nos.
12)	Grease Supplier	1 no.
13)	Speed Change Cutter and Accessories	1 set
14)	Others	1 lot

(12)	Spare Parts, etc. (for the initial 2 years' construction work of 160 boreholes)	1 lot
(13)	Base Camp Equipment	1 set
(14)	Muddy Water Agent and Blowing Agent	
	1) Bentonite	80 tons
	2) CMC	4 tons
	3) Blowing Agent	8 tons
(15)	Materials for Civil Work	1 set

5-4 Basic Policy for Borehole Construction

The following basic policy shall be followed for smooth borehole construction using the provided machines, equipment and materials.

(1) The borehole construction work will extend over a 3 year period, i.e. 80 boreholes in the first year, 80 boreholes in the second year, and 79 boreholes and 16 rehabilitated boreholes in the third year. The initial 2 years' construction work will be carried out by a Japanese contractor.

(2) Of the 80 boreholes to be constructed in the first year, 40, 22 and 18 will be distributed in MGA 9, 10 and 11 respectively. Locations of the 80 boreholes to be constructed in the second year will be decided through consultations with the Department of Water.

(3) Malawi engineers will participate in on-the-job training during the initial 2 years' construction work in view of the transfer of technologies. In the third year, the construction work will be carried out by Malawi engineers.

(4) Prior to the selection of the locations of the 160 boreholes to be constructed in the initial 2 years, a field survey (including electric prospecting) will be carried out. The fianl selection of the borehole locations will be made by the Department of Water through consultations with the local inhabitants based on the data provided by this field survey.

(5) The average borehole drilling depth will be 45m in view of the results of the fields survey which has already been conducted.

(6) The borehole finishing diameter will be 100mm and foot pumps will be installed. A water receiving apron, drainage channel and washing area will be provided at each borehole as auxiliary facilities.

(7) The target service population and the target water supply volume per borehole are 250 and 27ℓ/capita/day respectively.

(8) The yield of the boreholes to be constructed will be 10ℓ/min or more and their water quality will be not exceeding the Proposed Standards' numerical value in Malawi (see Table 3-10).