JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)
THE MINISTRY OF WATER,
THE GOVERNMENT OF THE UNITED REPUBLIC OF TANZANIA

THE STUDY ON THE GROUNDWATER DEVELOPMENT FOR HANANG, SINGIDA RURAL, MANYONI AND IGUNGA DISTRICTS IN THE UNITED REPUBLIC OF TANZANIA

FINAL REPORT

VOLUME TWO : SUPPORTING REPORT

AUGUST, 1998

SANYU CONSULTANTS INC. (JAPAN)
JAPAN ENGINEERING CONSULTANTS CO. LTD. (JAPAN)

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CHAPTER ONE: HYDROGEOLOGY AND GROUNDWATER

1.1 Introduction

In order to identify the hydrogeological feature and groundwater resource in the Study area, various hydrogeological and groundwater surveys were conducted in the Study.

They were;

- collection and review of the existing records on geomorphology, geology, borehole, meteorology, hydrology and others,
- compilation of hydrogeological maps,
- water quality survey,
- geophysical soundings,
- test drilling of boreholes; and
- others.

The findings of said surveys and the evaluation of groundwater resources in the Study area are concluded in this chapter.

1.2 Geography and Geomorphology

1.2.1 Geography

The Study area lies in Central Plateau of the country between South Latitude 4°05' and 7°50' and between East Longitude 33°20' and 35°40'. Total study area is approximated to 52,000 sq. km.

1.2.2 Geomorphology

The Study area consists mainly of vast undulating peneplain made during mid-Tertiary called "African Surface", and which makes up the greater part of Central Plateau extending from Lake Victoria to Mbeya Rang. Another distinct topographic feature is some ranges of rift valleys formed by faulting during the Neogene deforming this peneplain surface.

The Study area is classified into the following topographical units:

- Low-lying Plain, Rift Valley (Swamp, Mbuga, Flood plain, Lakebeds);
- Peneplain (Peneplain with inserberges, Pediment, Depositional surface of Kilimatinde cement);
- Fault Escarpment and Mountain; and
- Volcano (Volcanic cone, Volcanic crater, pyroclastic cone)

(1) Low-lying Plain, Rift Valley

(a) Wembre basin and Bahi basin

Most developed low-lying plains are formed along Wembre and Bahi basins which are formed peneplains covering Igunga, Singida Rural, Manyoni and Dodoma districts. The Wembre basin is extended from Lake Eyasi rift valley. These low-lying plains consist of swamps, mbugas and flood plains.

(b) Lake-bed

Lake-bed consists of lacustrine deposit of proto-Victoria Lake and extends to the Manonga and Wembere basins north of Igunga district forming a flat low terrace.

(c) Rift Valley

The ranges of rift valleys are located on Hanang and north of Singida Rural district extending NE-SW direction such as Bassotu-Lake Singida, Balangida-Singida Fault and Balangida Lelu-Turu. Along another continuous rift fault, alluvial plains are formed such as Ititi swamp-Nkuhi-Manyoni Fault in Singida and Manyoni districts and Nzega Fault in Igunga district.

(2) Peneplain (Peneplain with Inserberges, Pediment, Depositional Surface of Kilimatinde Cement)

(a) Peneplain underlain by Synorogenic Granitic Rocks

A huge area is occupied by undulating peneplain formed a part of African Surface. There was formed thick weathered crust on the surface of granitic rocks. Inserberg is ranged parallel to direction of rift valleys. Characteristics of river patterns which are engraved on peneplain surface controlled by geological structures are interpreted on the satellite imagery and aerial photographs especially on the northwest of Igunga district, the northern and eastern parts of Singida Rural district, the south and southeast of Hanang district and the middle and south of Manyoni district.

(b) Peneplain underlain by Metamorphosed Sedimentary Rocks

The northern part of Igunga district which is underlain by Nyanzian system shows some different landform from an area underlain by granitic rocks characterised by steep rock hills overtopping on flat undulating peneplain. The southern half of Manyoni district; which is underlain by Dodoman Systems composed of metamorphosed sedimentary rocks, gneiss and migmatite; is also characterised by a range of steep rock hills.

(c) Depositional Surface of Kilimatinde Cement

Kilimatinde cement is terrestrial sediment of Neogene overlain Precambrian basement rocks expanding from south of Singida Rural district to north of Manyoni district. Depositional surface of Kilimatinde cement makes flat or slightly undulating topographic feature and on which drainage pattern has not been developed. On satellite image Kilimatinde surface can be distinguished as dark coloured spot.

(3) Fault Escarpment and Mountain

Fault escarpments were formed along boundaries between peneplain and rift valley. Typical escarpments are located on Nzega Fault, a continuous fault from Lake Eyasi to east of Wembre basin in Igunga district and Basotu-Lake Singida rift valley, Balangida rift valley, Singida Fault and Balangida Lelu-Turu rift valley in Singida Rural district, and Kilimatinde Fault and west escarpment of Bahi basin in Manyoni district. Steep mountains underlain by hard basement rocks overtopping on peneplain are located in the north of Igunga district and the southern part of Manyoni district.

(4) Volcano (Volcanic cone, Volcanic crater, Pyroclastic cone)

Mt. Hanang which raise to an elevation of 3,678 m overtops on the peneplain of Africa Surface in an elevation of some 1,700 m. There are many volcanic and pyroclastic craters surrounding the volcanic cone of Mt. Hanang. Along Basotu Fault, many volcanic craters in a small size are also spread out.

1.2.3 Drainage Pattern

The drainage pattern of the Study area is characterised with Wembere - Manonga river system, Mponde - Bubu river system and Ruaha river system. Every rivers in Igunga district flow into to

Wembere or Manonga river and river of western Singida district flow into Wembere river. Durmo river flows from north Singida to north and join Lake Eyasi - Wembere river system. There are closed river systems along in rift valley of Hanang district such as Basotu, Balangida and Balangida Relu. Mponde river flows to south along Turu rift valley and gathering tributaries flows into Bahi basin. Bubu river also gathering tributaries from southeast plateau oh Hanang district flows into Bahi basin. Rauha river flows from plateau of south of Manyoni district gathering tributaries to east toward Indian Ocean.

1.3 Soils, Vegetation and Land-use

(1) Soils

The soils in the Study area can be divided broadly into the following four groups:

(1) A complex of plateau soils on the highest ground, non-calcareous plains soils on the lower ground and black calcareous clay in the depressions.

(2) A complex of red earth passing through yellow and grey sands on granite on the higher ground, to black, calcareous clays in the bottom lands.

(3) Non-lateritised red earth on volcanic and doleritic rocks.

(4) A complex of calcareous plains soils with calcareous black clays in the low-lying lands, characteristic of the Wembere Steppe.

(2) Vegetation

Larger tracts of the area are virtually open plain or grasslands, with patches of stunted thicket, commonly thorny. Low land such as Wembere and Bahi depressions is characterised either by open grassland or semi-open acasia-baobab bush. The broad area located from the south of Singida district to the north of Manyoni district underlain by Kilimatinde Cement formation is covered relatively dense thorny thicket. More luxuriant forest is found some forest reserved areas.

(3) Land-use

Large tracts of land are cultivated and are planted mainly maize. Grazing of cattle, sheep and goats are common through the Study area.

1.4 Meteorology and Hydrology

1.4.1 Meteorology

The meteorological stations in the Study area are at Singida Airport (Station No.2K/R10) and Manyoni (Station No.2RR12) in Singida Region, and Sekenke (Station No.2K/R11) in Igunga District. No station is available in Hanang District.

The daily records on rainfall, air temperature, relative humidity, pan evaporation, sunshine hour and wind-run are available from the stations covering period since 1970 to date.

The meteorological features of the Study area are as follows:

(1) Rainfall

The rain in the Study area falls concentrately in six month period from November to April. An averaged annual rainfall at three stations above are 626 mm, 612 mm and 876 mm respectively (refer to Appendix-1, Table 1.4.1-1(1)-(3)).

(2) Temperature

The annual mean, maximum and minimum monthly mean daily temperature at Singida are 22.5°C, 24.6°C (March) and 20.6°C (August) respectively. Those at Manyoni are 22.1°C, 24.4°C (November) and 19.3°C (July). Those at Sekenke are 24.2°C, 24.2°C (April) and 22.8°C (August) (refer to Appendix-1 Table 1.4.1-2 (1)-(3)).

(3) Relative Humidity:

The annual mean, maximum and minimum monthly mean daily relative humidity at Singida are 74.6%, 80.7 % (March) and 61.7 %(October) respectively. Those at Manyoni are comparatively high ranges showing 80.6 %, 86.0 % (February) and 73.4 % (July). Those at Sekenke are relatively low range showing 66.6 %, 76.0 % (February) and 55.2 % (October) (refer to Appendix-1 Table 1.4.1-3 (1)-(3)).

(4) Pan Evaporation:

An averaged annual pan evaporation is 2,400 mm at Singida, 2,144 mm at Manyoni and 2,488 mm at Sekenke. The maximum and minimum monthly mean daily evaporation are; 8.7 mm/day (October) and 5.5 mm/day (July) at Singida; 6.9 mm/day (November) and 5.3 mm/day

(January) at Manyoni; and 10.3 mm/day (October) and 5.1 mm/day (April) at Sekenke (refer to Appendix-1 Table 1.4.1-4(1)-(3)).

(5) Sunshine Hour:

Averaged annual sunshine hours in three stations are 7.7 hr/day at Singida, 7.9 hr/day at Manyoni and 7.1 hr/day at Sekenke. The maximum and minimum monthly mean daily sunshine hours at three stations are; 9.2 hr/day (July) and 6.2 hr/day (December) at Singida; 9.2 hr/day (September) and 6.5 hr/day (January) at Manyoni; and 8.7 hr/day (July) and 5.6 hr/day (November) at Sekenke (refer to Appendix-1 Table-1.4.1-5(1)-(3)).

(6) Wind-run:

The wind-run record at Singida shows 220 km/day (2.5 m/sec) as an annual averaged daily mean; 380 km/day (September) and 108 km/day (January) as the monthly maximum and minimum respectively. Windy seasons, which exceed 150 km/day (1.7 m/sec), cover from March to November.

The wind-run record at Manyoni shows a very gentle wind-run as 94 km/day (1.1 m/sec) of an annual averaged daily mean; 140 km/day (September) and 53 km/day (February) as the monthly maximum and minimum respectively. Windy seasons, which exceed 100 km/day (1.2 m/sec), cover only from August to December.

The wind-run record at Sekenke shows 104 km/day (1.2 m/sec) as an annual averaged daily mean; 172 km/day (September) and 48 km/day (March) as the monthly maximum and minimum respectively. Windy season which exceed 100 km/day (1.2 m/sec) covers from July to November (refer to Appendix-1 Table 1.4.1-6(1)-(3)).

1.4.2 Hydrology

The drainage system of the Study area is characterised by the Wembere-Manonga system, the Mponde-Bubu and the Ruaha systems. Every rivers in Igunga district flow into the Wembere or the Manonga river and river of western Singida district flow into the Wembere. Durmo river flows to the north from northern Singida and joins with Lake Eyasi-Wembere system. There are closed river system along in the rift valley of Hanang district such as Basotu, Balangida and Balangida Relu. The Mponde flows, gathering flows in tributaries, down to southward along Turu rift valley and pour into the Bahi basin. The Bubu also flows from the southeast plateau of

Hanang district into the Bahi basin. The Rauha flows from plateau of south of Manyoni district down to east toward the Indian Ocean. All the rivers are seasonal, and form closed basins.

Three gauging stations for river runoff observation are operated at Kirondatal on the Karonda River, one of tributary of the Wembere, since 1955, Msememlso on the Msememlso River (Bahi system) since 1968 and Makuru on the Maduma River (Bahi system) since 1969.

The annual average runoffs at Karonda, Msememlso and Maduma stations are 56 MCM or 230 mm, 9 MCM or 8 mm and 14 MCM or 14 mm respectively. The runoff coefficients are variable in 0.26 at Karonda, 0.01 at Msememlso and 0.02 at Maduma.

1.5 Geology

1.5.1 A summary of geology of Tanzania

The oldest rocks of the territory of Tanzania are those belonging to Dodoman System. They occupy the west-central region. They are coarsely crystalline metamorphic rocks of sedimentary volcanic origin, as well as migmatites. Granite occupies large areas.

In the northwest and probably deposited upon a rigid shield of Dodoman rocks are the volcanics and quartzite of Nyanzian System. The characteristic rock is "banded ironstone". The volcanics have suffered low-grade metamorphism. Associated with these are rocks of the Kavirondian System consisting principally of conglomerates, grit, quarzites and volcanics. There has been large-scale emplacement of "younger" granite into the area of Nyanzian and Kavirondian rocks.

In the east are rocks of the Usagaran System, which belong to orogenic belt extending northward into Kenya and south ward into Mozambique. On the west is a complementary belt, parallel to Lake Tanganyika, consisting of rocks of the Ubemdian System, believed to be same age as the Usagaran. The rocks of these two systems have close resemblance to those of the Dodoman System. The boundary is in place obscure by migmatisation. The rocks of these tree systems belong to Archaean group.

The Karagwe-Ankolean System is located along western border of the territory and consists of phyllite and quartzite with granite intrusion. The Bukoban System is made up of sandstone, shale and basalt and extends in a belt from Uganda border to Lake Tanganyika. The age of the system is from late Precambrian to Paleozoic.

Following the close of the Bukoban times, there appears to have been a long interval before the deposition of the rocks of Kaloo age (Upper Carboniferous - Lower Jurassic). These are principally terrestrial sediment consisting of sandstone, shale, conglomerate and limestone.

Marine rocks, chiefly marl, limestone, sandstone and shale of Jurassic, Cretaceous, Tertiary and Quaternary age, made up a disconformable sequence occupying a belt of limited width adjacent to the present coast-line. Contemporaneous with marine sediment in the east, there was accumulation inland of terrestrial deposit of various kinds. During the late Cenozoic, in the more stable areas of the centre and north, bed of limestone, silt and terrestrial sediments were accompanied rift-faulting movement. The Pleistocene lake-bed of Olduvai Gorge are famous for remains of early man.

Commencing probably in late Cretaceous times, there was volcanic activity, associated apparently with rift-faulting movements, which produced the Tertiary-Recent volcanics. In the north it extended from Hanang Mountain to Kilimanjaro and northward into Kenya.

1.5.2 Geological Formation of the Study Area

The majority of the Study area is underlain by granitic rocks of Archean Group. The rest part of area is underlain by metamorphosed sedimentary rocks of Archean Group such as Nyansian System in the northern Igunga district and the northern Singida Rural district, and Dodoman System in the southern Manyoni district. Lower plains located on Wembere and Bahi basins and others extending in another rift valleys and Kilimatinde surface are underlain by younger sediments in Pleistocene-Holocene age.

A geological map of Study area is shown in Figure 1.5.2 and stratigraphy and rock facies of the Study area is shown in Table 1.5.2

(1) Granite

Almost 61 % of the Study area is underlain by the "Granites" made during Archean age. It's composed of granite, granodiorite locally foliated, migmatitic and porphyroblastic. During the peneplaination, granites were weathered deeply and thick superficials have been formed, especially they were crushed and weathered strongly along fault.

The southern half of Igunga district is underlain by granite forming undulating peneplain. There are predominant lineaments in the southwest-northeast direction.

Except the northern part, whole district of Singida Rural and the east of Hanang are underlain by granites. It's supposed that granites are crushed and weathered deeply along the rift fault, especially from northeast of Singida Rural to the east of Hanang district. A flat and slightly undulating peneplain spreads out in the western part of Singida Rural district on which lineaments run but these are not so remarkable than the northern part of the district. Over an area covered by Kilimatinde Cement from the southern part of Singida Rural to the northern part of Manyoni district, granites are only exposed along river courses and fault escarpment.

(2) Bubu Cataclasite

Eestern and southern peneplains of Hanang district are underlain by Bubu Cataclasite composed of sheared and granulated granites, migmatites and gneisses. Predominant lineaments which range parallel to the direction of rift fault along the Balangida Lelu Lake control the courses and patterns of river engraved on the peneplain.

(3) Nyanzian System

The north of Igunga district is underlain by Nyanzian System composed of banded ironstone, metamorphosed volcanic rock and schist. Some limited areas in the north and south of Singida Rural and the northwest of Hanang district are also underlain by the system. The structure of Nyanzian System follows with the east-west and northwest-southeast direction.

(4) Dodoman System and Bukoban System

A wide and undulated peneplain with overtopping hills located in the south of Manyoni district is underlain by Dodoman System accompanied by Bukoban and Nyanzian Systems. The Dodoman System is composed of granite, gneiss and migmatite, and Bukoban System is composed of shale, sandstone and phyllite.

(5) Dyke rocks

Dyke rocks are located along faults especially nearby a rift fault. The types of dyke rock are mainly dolerite, porphyrite and kimberlite which is mother rock of diamond and located north of Igunga and Singida Rural. Usually dyke rocks are fractured and being excellent aquifers.

(6) Kilimatinde Cement

Kilimatinde Cement underlies about 1.3 km^2 or 8.5% of the Study area. The area spreads out along the boundary between Singida Rural and Manyoni districts. It is hard, sometimes porous, composed largely of sand, cemented either by clay or lime or silica, and often contains sub-angular relics of granite and gneiss. Its thickness may be 30 m or more.

(7) Manonga-Wembere Lake Deposit

A wide area extended the north of Igunga along with the Manonga river and Wembere basin is underlain by Manonga-Wembere Lake-beds of Pliocene-Pleistocene age. It consists of lacustrine limestone, clay, sand and gravel. Its thickness may be 100 m or more.

(8) Hanang Volcanics

Volcanic activities were associated with the rift fault such as Balangida and Basotu fault. The main cone of Hanang Volcano consists of nephelinitic lava. Volcanic craters and pyroclastic cones consist of calcareous crystal tuff and tuffaceous agglomerate.

(9) Alluvial Deposit

Flood plains, mbugas and alluvial fans which are located on Wembere and Bahi basins, rift valleys and another alluvial plains are underlain by superficial deposit consisting of clay, silt and fine sand.

1.6 Hydrogeology and Groundwater

1.6.1 Existing Borehole Record

Some 287 borehole records related to the target villages are available from Regional Maji Offices. Out of them, the locations and current situations of 137 boreholes were confirmed by the Study Team through the inventory survey on the existing water supply facility. Out of boreholes confirmed, only 46 boreholes are still working. The borehole inventories with the location map are compiled in Volume Three of the present report.

The numbers and situation of recorded boreholes by district are summarised in the following Table 1.6.1-1, inventory of boreholes is shown Appendix-1 Table 1.6.1-2 (1)-(4) and location of them is shown Appendix-1 Figure 1.6.1-1(1)-(4).

Table 1.6.1-1 Numbers and Situation of Recorded Boreholes by District

District	No. of BH Recorded	Location Confirmed	No. of Working BH	Averaged Dimensions		
				Depth (m)	S.W.L (m)	Yield (m^3/hr)
Hanang	14	9	1	65.3	12.4	8.7
Singida rural	111	60	14	86.0	22.4	8.8
Manyoni	138	49	27	106.1	24.4	5.8
Igunga	24	19	4	60.9	14.8	8.8
Total/Ave.	287	137	46	93.5	22.5	7.0

1.6.2 Geophysical Soundings

(1) Methodology

In order to obtain general hydrogeological information of the Study area and to identify possible borehole sites in the pilot villages and some target villages, the geophysical soundings were conducted by the Study Team adopting the electro-magnetic (EM) and resistivity methods. The EM sounding was mainly applied to detect the fracture zone in bed-rocks and the resistivity sounding was adopted to identify aquifer structures.

The general methodology and specification are as below:

Electro-magnetic (dual loop) sounding

- System : MAXMIN I-6 EM System
- Observatory interval : 10 m
- Frequency : 3520 Hz and 880 Hz

Resistivity sounding

- Electrode configuration : Wenner method
- Observatory depth : 150 - 250 m
- Interval of observatory point : 70 - 150 m.

The observatory lines and points were selected to cross over the geological structures such as faults and lineaments identified through the integration of interpretation aerial photographs, hydrogeological maps, the existing boreholes records and field inspection. Total number of observatory points were amounted to 12,016 for EM and 701 for resistivity respectively (EP).

List of village and number of observatory point is shown Table 1.6.2-1 (1)-(2) and location map of observatory village by districts are shown Appendix-1 Figure 1.6.2-1 (1)-(4).

Electrical resistivity of earth materials is a function of the lithology and the character of the pore fluid. Electrical Prospecting measures the variation of electrical resistivity (the mathematical inverse of electrical conductivity) of the subsurface, either vertically or horizontally. It means subsurface resistivity by passing a DC current through outer two electrodes planted into the ground and measuring the resulting potential field with inner two electrodes. Among numerous different electrodes geometry which have been developed, the Wenner and Schlumberger are the most common for investigations. Surveys conducted to determine changes in resistivity with depth are called 'vertical electrical soundings (VES) or depth soundings' and to measure the lateral changes in conductivity to approximately the same depth are called profiles.

EM sounding is applied a mobile transmitter and receiver coil which are horizontally oriented on the same plane to be maximum coupled for coils. Subsurface conductivity measurements are made by generating an alternating EM field with transmitting coil (the primary EM field). The filed penetrates the surface and induces electrical currents to flow the bunch of lines of the magnetic field. The strength of induced currents is a function of the conductivity of the material and induced currents generate EM fields of their own (called the secondary field) which propagate toward the surface of the ground. The field observed at the receiver coil is a product of both the primary and secondary fields. The secondary field can be compared to the primary field by measuring both of magnitude and phase lag and the response of these parameters, which measurements are usually reported in % of the primary field strength, is a function of the resistivity of the material and the frequency of the transmitted EM field. In general, the depth of penetrating to the ground is depend on a frequency of transmitted field.

(2) Sounding for test drilling siting

Geophysical characteristics of each drilling site of the pilot study village are as follows. Refer to Appendix-1 for following figures; Location of survey lines and points of EP and EM survey for the each pilot villages attaching outline of water supply facilities of the pilot study are shown on Figure 1.6.2-2 (1)-(13). Typical resistivity profile and ρ- a (apparent resistivity - electorode interval relation) curve are shown on Figure 1.6.2-3 and Figure 1.6.2-4. Typical plot sheets of EM sounding are shown on Figure 1.6.2-5.

[Bassodesh]

Drilling point was identified on Point C5 of resistivity sounding aiming aquifer of crushed and deeply weathered granite along supposed Basuto fault.

Resistivities of the bottom layer shows low in the middle of survey lines on Resistivity Sounding, which considers distributing of fracture zones perpendicular to survey lines. On EM Sounding, C line shows typical and stronger changes of OP and IP values, crossing point of both OP and IP appeared between 750 m and 3520 m. The resistivity of expected aquifer ranges 100 - 200 ohm.m along C line. Drilling was assumed 150 m in depth from the result of soundings.

[Ishponga]

Point A11 was selected aiming a lineament interpreted by aerial photograph. Depth of drilling was assumed 140 m deep. The resistivity of exposed aquifer is relatively high and showed in the range of 300 ohm.m or more.

Resistivity distribution of the deepest layer shows high through every survey lines, however, the second bottom layer, which is obtained around 300 ohm.m, is widely spread along A line. From the result of EM sounding, it is difficult to distinguish a fracture zone from a tendency and strength of amplitudes of IP and OP on both frequencies.

[Mara]

Point A3 was selected aiming crushed and deeply weathered granite along supposed faults ranging to the south of Hanang volcano. Drilling depth was assumed 110 m.

On EP result, resistivities of the deepest layer are obtained reciprocally high and low, which means a distribution of some fracture zones across survey lines. From EM result, amplitude of data along A line is greater than that of B line and the first half of data on A line is less than the latter half of it. Expected low resistivity fractured zone could not be distinguished by both Ep and Em sounding.

[Masqaroda]

Point A5 was selected aiming same hydrogeological character with Mara.

Resistivity distribution around Masqaroda shows quite low, several to some ten ohm.m for the surface, several to ten ohm.m for medium layers and hundreds ohm.m less 200 ohm.m in most points along A line. However, for resistivity of the deepest layer along B line shows several thousands ohm.m at a few points.

For EM sounding, the result shows greater in B line than A line for changing of an amplitude, which is expected frequent distributions of fracture zones across B line.

The resistivity of an expected aquifer is considered around 100 to 150 ohm.m, and drilling depth was assumed 110 m.

[Choda]

Point D3 is selected aiming deeper crushed and weathered zones of granite. It is analysed by EP sounding that superficial Kilimatinde cement layer covers granite up to 20 to 30 m in depth. The depth of drilling is assumed 110 m and resistivity values of an expected aquifer is considered to range of 60 to 120 ohm.m.

On EP sounding, the resistivity of an expected aquifer can be seen in the medium depth along B, D and E lines and a resistivity of the deepest layer shows a large difference between D2 and D3. On EM result, from the beginning of the line (E1) to 1500 m (A1), an amplitude of all data indicates big changes up to 75 %, and then quite small change is observed along final quarter half of the line. It supposed based on both sounding that some fractured zone are located long first (northern) half of the survey line, and it disappears gradually towards the end of the line (to south).

[Nkuhi]

Point A11 was selected to expect aiming fractured zone which extends along a remarkable fault ranging from Ititi – Ihanja – Nkuhi to Manyoni. Drilling depth was assumed 150 m and a resistivity of an expected aquifer ranges 35 to 85 ohm.m. It is analyzed by EP sounding also like as Choda that superficial Kilimatinde cement layer covers granite up to 30 or 50 m in depth.

A long survey line was planned from existing borehole crossing supposed fault fractured zone. Excellent aquifer was expected because of law resistivity, which ranges from 35 to 85 ohm.m and distributes from 50 to 120 m in depth around A10 to 12.

EM result says that a difference of amplitudes of Q line is greater than that of A line, however, the amplitudes of data shows small but clearly changes near A9 in P line profile.

[Mpapa]

Point B7 is selected aiming crushed zones of granite which is supposed in lineaments interpreted by aerial photograph. Drilling depth was assumed 100 m and a resistivity of an expected aquifer had been considered in high ranges of 250 to 400 ohm.m.

On EP profiles, high resistivities layer was analyzed from shallow parts of the ground along A line, however, resistivity along B line is lower than that of A line valued 350 or less ohm.m. The existing dry well locates near A7, and a resistivity of the deepest layer shows slightly low from others. On EM result, amplitudes of data changes clearly around 1000 m between A5 and A6. Along Q line, amplitudes of data is not so clear, but a geological lineament can be expected from an aerial photograph interpretation along Q line.

[Chikola]

Point B7 was selected aiming crushed and deeply weathered zones of granite, which is supposed to be located along the river course. Drilling depth was assumed 150 m and resistivity of expected aquifer ranges 150 to 250 ohm.m.

Among all EP points, resistivity of the deepest layer shows the smallest at B8 ranging from 120 to 250 ohm.m which expects an aquifer is obtained in a medium depth around B7 to B9.

On EM sounding, slightly fractured zone is analyzed on the latter half of P line and the middle of Q line is firmer than both sides of the line. On R line profile, amplitudes of both frequencies indicates strongly fractured from the beginning to 1600 m, around C10 on EP, close to the end of the line comparing with other parts of EM sounding.

[Igurubi]

Point A7 was selected aiming an aquifer of Manonga-Wembre Lake-beds and crushed zones along the fault interpreted by aerial photograph. Drilling depth was assumed 150 m and a resistivity of an expected aquifer considers very low, in ranges of 10 to 20 ohm.m reflecting a low resistivity in the superficial saline condition.

Sounding lines have been planned to across interpreted a major fault. Remarkable change of distribution of resistivity of layer between northern side and southern side of the fault is analysed along every survey lines. A7 sites just close to the north side of the fault. EM result shows also clear distinguish between both sides of the fault. Because, a difference of both sides of the fault is so deep, which is obtained more than 80 m, EM data were influenced strongly. Therefore, it can be guessed that the coil interval and lower frequency for observation should have been changed wide and lower.

[Nguriti]

Point B3 is selected among crushed and deeply weathered zones of granite by an aerial photograph interpretation. The depth of drilling is assumed 100 m and a resistivity of expected aquifer is relatively high in the range of 250 to 500 ohm.m.

EP sounding lines are located parallel each other and low resistivities of the deepest layer shows lower just close to lineaments which indicate on aerial photos. EM result shows a weak change from amplitudes.

(3) Comparison of Geophysical Soundings and Test drilling results

Comparison of Geophysical Soundings and Test drilling results is made with Figure 1.6.2-6 in which analysed resistivity is put down with summary of borehole lithological logging and geophysical logging by each drilling.

[Maskaroda]

Superficial very low resistivity layer is distinguished up to 27 m by EP, coincided well to lithological logging of the test drilling and then it is followed by high resistivity layer of 130 ohm.m correspond to fractured and weathered basement rock observed by the test drilling.

[Bassodesh]

Superficial deposit is distinguished to lay up to 9 m by EP, corresponded well to volcanic pyroclastics observed from lithological logging and then it is followed by relatively high resistivity layer of 220 ohm.m corresponded to fractured and weathered basement rock of the test drilling.

[Ishponga]

The ρ - a (apparent resistivity - electorode interval relation) curve draws a typical "high-low-high" type. Superficial deposit is distinguished to lay up to 10 m by EP, coincided well to lithological logging and then it is followed by very high resistivity layer of 3500 ohm.m correspond to weakly weathered granite. It is difficult to distinguish weathered part and fresh granite by EP.

[Mara]

The ρ - a curve draws a typical "high-low-high" type. Superficial deposit is distinguished to lay up to 14 m by EP sounding, coincided to volcanic pyroclastics observed on the test drilling. Resistivity measured by geophysical logging of the test drilling is 100 - 170 ohm.m but resistivity analysed by EP is 450 or more.

[Nkuhi]

Superficial low resistivity layer of 20 - 50 ohm.m is analysed to lay up to 50 or 85 m depth refracting Kilimatinde Cement formation observed on the test drilling, coinciding also low resistivity of geophysical logging. But it is difficult to distinguish boundary of basement rock by EP.

[Choda]

Superficial lower resistivity layer of 73 ohm.m is analysed refracting clayey alluvial sediment of the test drilling and then, it is followed by slightly higher resistivity layer of 150 ohm.m from 10 to 31 m depth refracting Kilimatinde Cement formation observed on the test borehole. From 31 m to 100 m depth, Low resistivity layer of 60 ohm.m is analysed refracting weathered and fractured granite of the borehole. Finally, high resistivity layer of 600 ohm.m is analysed from 100 m refracting intact granite.

[Chikola]

The ρ - a curve draws a typical "high-low-high" type. First high-low portion of 50 ohm.m resistivity is corresponded well to highly weathered granite of the test drilling. The continuous low-high portion divided two portions by interpretation of the curve. From 11 m to 50 m, slightly high resistivity layer of 140 ohm.m is distinguished and then high resistivity layer is analysed. But it is difficult to subdivide clearly the low-high portion by EP.

[Mpapa]

The ρ - a curve draws a "low-high" type. Only to first 5 m very low resistivity layer is distinguished refracting salty superficial alluvial sediment, and then it is followed by relatively high resistivity layers. It is difficult to distinguish boundary between weathered portion and fresh intact portion of granite by EP.

[Igurubi]

Analysed resistivity is very low totally. Superficial very low resistivity layer of 6 – 30 ohm.m are analysed to 31 m depth refracting clayey and possibly salty alluvial and lacustrine deposit observed from cuttings of the test drilling, and then it is followed by relatively high resistivity layer of 12 ohm.m which is corresponded to sand and gravel layer of lacustrine deposit, and fractured basement rocks. A hidden fault escarpment is clearly analysed by EP but it is difficult to distinguish boundary between basement rock and soft alluvial and lacustrine deposit by EP.

[Nguruti]

Low resistivity layers of 10 - 25 ohm.m are analysed to 28 m depth refracting superficial sediment observed from cuttings of the test drilling and then it is followed by high resistivity layer of more than 450 ohm.m corresponded to weathered and fresh and intact granite.

(4) Geophysics sounding for the Target villages

Geophysical characteristics of selected target village are as follows. Refer to Appendix-1 for following figures ; Typical resistivity profile and ρ - a (apparent resistivity - electorode interval relation) curve are shown on Figure 1.6.2-7 and Figure 1.6.2-8. Typical plot sheet of EM sounding are shown on Figure 1.6.2-9.

<Singida Rural district>

[No. 13 Ujaire]

On EP sounding, the surface layer shows various resistivities which are 40 to 5000 ohm.m, with a thickness of 20 to 30 m. Then, middle layer is obtained partly with resistivities of 100 to 250 and a thickness of 40 to 50 m at A5 to A6 and B3 to B5. The bottom layer' resistivity shows more than 1000 ohm.m except A3 and B2 with resistivities of 600 and 750 ohm.m. P line's EM data show typical response from the ground. Large and sharp difference and changes of amplitudes of both frequencies on the first half of line, which are assumed to exist structures around A3 and A4, and a small flat change from 700 to 1000 m, which is considered a sound rocks, and small sharp changes at the end of line, a small disturbance of the ground. On Q line of EM shows no clear changes at 150 m, B2 on EP, however, amplitudes of the first half of the line is slightly greater than that of the latter half. It means a geological structure is assumed to exist through A3 and B2.

[No. 44 Ighombwe]

On EP result, resistivities of the surface layer show various values, from around 10 to 8500 in maximum, the next layer, distributed from 10 to 60 m in depth, shows also wide resistivities but values are smaller than the upper layer. The bottom layer's resistivity is obtained more than 1000 ohm.m in many sites except A3, A7, B5 and B9 for low value of less 600 ohm.m. Therefore, geological structures are considered to exist beneath these 4 sites, especially low resistivity structures of A3 and B9 can be the same one.

Unfortunately, as both P and Q lines of EM result are assumed to be interrupted by noise, it is hardly to obtain an information.

[No. 50 Mwastiyanga]

Resistivity structure is divided in three parts, the beginning is from A1 to A4, the centre is from A5 to A7 and final is A8 to A9. Both ends show high resistivities for the deepest layer and the central part shows low value for the bottom layer. For EM sounding, the result is not so clear as EP analysis. Though amplitudes of 880 Hz is observed slightly large difference on the beginning and getting small on the end, that of 3250 Hz show parallel along the line.

Therefore, from the contrast of resistivity distribution of the bottom layer of A line, a geological structure is assumed to cross near the centre of EP line.

[No. 58 Ikiwu]

Except a part of the surface for low resistivity, less than 100 ohm.m, resistivities are obtained high on both A and B lines for EP sounding. The deepest layer distributes at the shallow of the ground and the value itself shows more than 1200 ohm.m. As EM sounding result shows sharp peaks toward the line, small structure are assumed to exist but considered small on both lines.

[No. 73 Madamigha]

Sounding sites and lines are located two places, A, B of EP and P, Q for EM are east of Irongero Town, where is just close to Mrama sites, others are west of the town.

(East of Irongero)

EP result shows low resistivities on the deepest layer of A1, A2 and A5, but no low value are obtained for the deepest layer along B line. For the middle depth of the ground, a resistivity structure of the quarter half of A line is different from others. From the surface of the ground to 50 m deep, less than 50 ohm.m in resistivity are distributed, however, other sites show more than 100 ohm.m at the same depth except thin layers just under the surface, which is less than 100 ohm.m. On EM data, amplitudes show the largest difference at 300 m, close to A1, and the smallest is obtained at 1700 m, around A8 on P line. Amplitudes of both frequencies change all along the line. Around 900 m to 1200 m, near A4 to A6, amplitudes of 880 Hz and 3520 Hz differs large, and that of the low frequency show greater than that of the high. It is considered some fracture zones are assumed at the beginning, the middle and the end of the line, A1 to A2, A5 and beyond A8. Along Q line, as same as B line of EP, which distributes high resistivities from the surface, that means sound or hard rock, amplitudes of both frequencies show a small difference mainly. However, as sharp peaks of amplitudes are observed at 150, 350 and 550 m, small structures are expected around there.

(West of Irongero town)

Two lines are observed for C and D of EP, and EM lines, R and S, are overlapped them.

At the surface of the ground, swamp deposits are obtained for low resistivities, less than 80 ohm.m, and weathered layers are considered for a distribution of 130 to 400 ohm.m. The deepest layer's resistivity shows more than 2000 ohm.m except C1 and C5, where have been analysed less than 600 ohm.m. R line of EM result shows almost same parallel distribution of amplitudes for both frequencies, however, sharp changes are observed around 300 m, between C2 and C3 on EP, for 3520 Hz. It means that geological structures are considered to exist around C1 and C5.

Along D line of EP sounding, the thin layers are obtained at the surface and the deepest layer is appeared for high resistivities, such as more than 1000 ohm.m, except D4 and D7, where show 600 and 400 ohm.m. S line of EM says amplitudes of 880 Hz are observed that of a parallel trend, but that of 3250 Hz shows an intersection around the middle of the line. Therefore, geological fracture zones are assumed around D4 and D7 but considered weak.

[No. 74 Mrama]

As same as in Mwakiti, EM sounding's data show parallel here. Therefore, it is difficult to distinguish a geological structure from EM. However, the deepest layer of EP profile shows low resistivities in some sites, A2,A3, A5 to A7 and A9, geological structure can be assumed to exist there.

[No. 77 Mwakiti]

Both profiles of EM sounding show parallel distributions of amplitudes along survey lines, however, various kind of resistivities are obtained on EP sounding. EP sites along A line is perpendicular to a fault escarpment and the second half of the line is crossed a river to a swamp. The beginning of B line on EP sounding also comes to meet the river.

Therefore, low resistivities, which are around 500 to less than 800 ohm.m, of the deepest layer on EP profiles are considered to obtain geological structures.

[No. 84 Igauri]

Dried up layer is obtained at the surface of the ground, but some ten to around 200 ohm.m layers are also seen at the shallow parts, which is assumed to be swamp deposit. Resistivities of the deepest layer show quite high toward A1, however, at the end of the line, it comes lower such as 600 ohm.m. On EM profiles, paralleled amplitudes of both frequencies come to intersect at the end of the line, around 1450 m.

The low resistivity of the deep layer at A6 and the cross of amplitudes at the end of the line of EM are considered to exist a geological structure toward the end of the line.

[No. 85 Ntonge]

Low resistivities are distributed near the surface of the ground on both EP profiles. However, though the deepest layer's resistivities show high along A line, that of some sites are obtained less or around 1000 ohm.m, which can be considered comparatively lower than that of others on B line. On EM profiles, it is difficult to get some anomalies along P line, because of parallel tendency of amplitudes, but the amplitudes of IP and OP of 3520 Hz are intersected each other at 600 m and B6.

Therefore, when sites of low resistivities of the deepest layer for EP and locations where amplitudes are crossed on Q line of EM soundings are considered, it can be assumed to exist geological structures across them.

[No. 103 Mgori]

From the surface to the middle depth, around 50 to 80 m, very low resistivities, such as less 50 ohm.m partly several ohm.m, are analysed along the EP survey line. Lowest layers also show 50 to 200 ohm.m at many sites. According to EM profile, amplitudes of both frequencies show a small difference at the beginning, the middle and the end of the survey line. A difference of amplitudes of 1150 m to 1600 m is greater than that of the first half of the survey line. Then, an interval along the line, which shows the large difference of amplitudes, seems to correspond to EP's low resistivity of deepest layers. Therefore, some geological structures are considered to exist to across A2 to A6 and A9 to A11.

[No. 106 Unyampanda]

On EP result, 100 to 250 ohm.m layer is developed deeper toward A3 to A1 and B5, meanwhile, a several ten ohm.m, 30 to 70 ohm.m, can be seen B1 to B4 and A4 around 10 to 40 m in depth. As resistivity distribution of the deepest layers is high for all sites, no geological structures such as faults is considered around this area. EM profiles, very weak and parallel data for both frequencies, show the same conclusion of EP sounding.

<Manyoni district>

[No. 1 Manyoni]

Along A line for EP sounding, a middle depth of the ground, below the shallow part of the ground to less about 50 m in depth, shows lower resistivities on the first half of the line and resistivities of the deepest layer of A2 to A4 show different from that of others. For B line, the profile shows the same as the first quarter of the line for the middle depth. The deepest layer's resistivities are considered an existence of structures at the both sides of the line.

A disposition of amplitudes of both frequencies on EM data tend the same, a difference of 5 to 10 percents of amplitudes are continued from the beginning to 1700 m and disappears.

It means that some geological structures can be existed around beneath the first quarter of A line.

[No.4 Mhalala]

On EP result, several to less 20 ohm.m layer is distributed close to the surface of the ground, partly it shows deep, and high resistivities are analysed at the beginning and the later half of the line, which means a distribution of comparatively lower resistivities, on the deepest layer. On EM profile, amplitudes of 3250 Hz data show widening for its difference at A6 and that of 880 Hz crossed each other. It is considered that a geological structure extends around A5 and resistivity distribution of the deepest layer shows the structure of a swamp area.

[NO. 7 Mkwese]

EP profiles show a distribution of high resisitvity layers from the surface of the ground except the later quarter of B line, in which low resistivity layers is analysed close to the surface. On EM results, as all amplitudes show parallel each other, it is difficult to distinguish anomalies for geological structures on it. However, the deepest resistivity of the later of B5 shows the lowest value among others, then, it can be assumed a weak structure.

[No. 16 Itigi]

Resistivities of the lowest layer at A2, A3, A7 and A9 show decreasing of value, and low resistivities are analysed at shallow parts of A2 and A3. Therefore, three geological structures are considered to exist across A2 to A3, A7 and A9. A crossing of amplitudes of P line on EM data show the same result. However, the structure which passes through A2 and A3 are regarded it as the largest among three.

High resistivity distribution of the bottom layer among B sites on EP sounding and small changes for EM profiles along Q line show difficulties of existence of structures across them.

[No 21 Kitopeni]

Two parts, A5 to A6 and A8 to A10, along the EP survey line, distributions of resistivity of the lowest layer show that geological structures are considered to exist. EM result shows the same result of bigger amplitudes in the first half than the latter half along the line, however, the small ratios of changing of amplitudes are considered weak structures.

[No.64 Saranda]

On EP profile of A line, low resistivities are distributed from the surface to medium depth of the ground, and the deepest layers also show low value, a several ten to less 200 ohm.m, except both ends of the line, which show more than 500 ohm.m. However, it is very difficult to get an information from EM sounding, because, data have been interrupted by noise. Therefore, this line is considered to obtain one of geological structures ranging along remarkable rift fault.

Along B line for EP sounding, the profile shows a distribution of lower resistivity layers from the surface to a shallow part of the ground. For the deepest layer, B2, B5 to B7 and B9 to B11 show a low resistivity. These resistivities also show some geological structures across the sounding line. EM profiles is interfered by noise, then, it is hardly to have a conclusion.

[No. 68 Solya]

Along A line of EP sounding, the surface of the ground is covered with a quite thin high resistivity layer and a several ten to hundred layers are underlain by it. Resistivities of the lowest layer show small at A4 and A11 among high. On P profile of EM, amplitudes of 3520 Hz show parallel but a difference of that of 880 Hz is assumed a geological structure from the beginning to 1700 m, especially at A5, A9 and A11.

On B line of EP, a thick medium resistivity layer, which shows some ten to hundred ohm.m, can be seen along the first half of the line and it disappears to thin toward the end of the line. The lowest layer shows high on the profile, however, it considers resistivities of the lowest layer distributes lower at the first half and higher at the second half. On EM result along Q line, a narrow but high peak is obtained at 675 m (around B5 of EP), on 3520 Hz. 880 Hz data show an existence of geological discontinuities at 550 m and 700 m (nearby B4 and B5 of EP).

[No. 71 Sasajila]

On EP result, resistivity distribution of the surface and shallow depth of the earth shows quite low. That of the deepest layer is obtained different value, 20 to 1000 ohm.m, and it comes high resistivity, 1000 ohm.m, around the end of the line. The maximum interval of EP sounding point is enough to detect more than 100 m deep, therefore, low resistivity of the deepest layer is distributed widely and it can be considered that a large geological structure is underlain below the sounding line.

As the sounding line of EM is considered to locate in a geological structure, data show a distribution of small and parallel amplitudes for IP and OP each other along the line. Toward the end of this line, a difference of both amplitudes of 880 Hz comes larger gradually, however, that of 3520 Hz keeps parallel. It means that shallower part of the earth is stable by 3250 Hz but deeper parts of the ground are changing toward the line end.

The reasons of a small difference of amplitudes of both frequencies is considered that an electromagnetic field can not penetrate enough into the earth, because of the low resistivity distribution from the shallow of the ground.

<Igunga district>

[No. 1 Matinje]

On EP result, geological structures, where the lowest layers show small values in resistivity, are supposed at sections of B1 to B2, B8 to B9 and B11 to B12. At the distance of around 400 m and 800 m to 1000 m, (nearby B4 and B7 to B8 on EP sites), amplitudes of IP and OP shows contrary each other on EM result.

[No. 34 Itunduru]

Resistivities of the deepest layers along EP profile show lower numbers of 100 to 200 ohm.m in main parts, where some distributions of geological structures is considered, and higher value such as more than 300 ohm.m distributes A4, A6, A11 and A14 only. Meanwhile, on EM result, great changes of amplitudes show in the middle of the survey line and the distance of 1550 m to the final end of the line. The change of the latter shows continuously along the profile.

[No. 37 Mwauynge]

Resistivity distribution shows very low values on EP profile. Characteristics of resistivities say less than 100 ohm.m along the surface of the ground in main parts, some ohm.m in shallow to middle depth and 10 to 100 ohm.m, 20 to 30 ohm.m are dominated, on the lowest distribution. From EM data, the contrast of a distribution of amplitudes of IP and OP can be seen around the end of the line. An edge of large scale of geological structure is considered form the ratio of amplitudes in there.

[No. 42 Kaumbu]

On EP result, according to resistivity values of the lowest layer, some geological structures are considered to distribute on the first half (A1 to A4), A6, A8 and A10 along the survey line. The value of the first half is greater than that of others. Meanwhile, amplitude of the first half of the line shows largest on EM profile.

[No. 46 Ipumbulya]

According to the distribution of resistivities of the lowest layer on EP result, a geological structure can be considered to pass around the middle of the survey line. However, EM analysis says that a large changing of amplitude is obtained along the first half of the line only.

(2) General Outcome of Soundings

Regardless the specific resistivities which could be identified by the resistivity borehole logging, the apparent resistivity of layers are, in general, very low ranging several to several hundreds ohm.m reflecting a low resistivity in the superficial saline condition over the area.

The majority of ρ- a (apparent resistivity - electorode interval relation) curve draws a "high-low-high" type. The first "high-low" portion indicates the superficial formations; and the break point of "low-high" curve clearly indicate the bed-rock surface. The last high curve which indicates the bed-rocks in weathered or fresh condition goes linearly upward in a magnification of 30 to 50 times. In fact, some existing boreholes, as well as the test-boreholes drilled under the

Study, stroked water in a depth of 100 m or more at around the bottom of weathered zone of bed-rock formation. It is deemed to be difficult to identify weathered or fresh zone by the resistivity sounding.

The EM sounding was effective to detect a low resistivity fracture zone where is covered by thin superficial sediments. Due to low signal output and limited range of frequencies, it is not so effective in an area where covered by thick superficials.

It is concluded that a more effective manner, such as Time-Domain Electro-Magnetic (TDEM) sounding, is to be introduced to identify specific hydrogeological structures in depth.

1.6.3 Test Drilling

(1) Outline of Test Drilling

The test drilling of boreholes was conducted in the Study by a local drilling contractor for purposes of confirming the groundwater potential under the framework of the pilot study. Borehole sites were selected in 10 pilot villages within four districts.

The outline of the test drillings is given Table 1.6.3-1.

(2) A Summary of each Test Drilling

A summary of each test drilling is as follows : refer to Appendix-1 Figure-1.6.3-1(1)-(10) lithological and geophysical logging of each borehole.

[Bassodesh]

The lithology is sandstone of Nyanzian system and porphylite intruded into sandstone layer. Both rocks are fractured and form excellent aquifers. EC of water is relatively high as 338 mS/m. A high yield of 8.0 m^3/hr at drawdown of 5.14 m was measured by pumping test.

[Ishponga]

The lithology of borehole is composed of granite which shows almost intact and hard rock facies. The hole was drilled to 110 m depth but was dry. The electric resistivity of granite by logging is as high as 1,500 to 2,000 ohm.m.

[Maskaroda]

The lithology of borehole is composed of alluvial sediments and underlying gneiss and schist of Bubu Cateclasite. The bed-rocks are weathered and fractured. 54 m depth and below is remarkably fractured, and the hole was collapsed frequently. The EC of water is somewhat high as 140 mS/m. A high yield 9 m^3/hr at drawdown of 25.5 m was measured by pumping test.

[Mara]

The lithology of borehole consists of volcanic ash and underlying gneiss of Bubu Catacrasite that remarkably weathered and fractured. The hole was collapsed frequently. Water quality is good for drinking (EC = 58.6 mS/m, pH = 7.34). High yield of 9 m^3/hr at drawdown of 0.33 m was measured by pumping test.

[Nkuhi]

The lithology of borehole is composed of Kilimatinde Cement and underlying siltstone and sandstone of Nyanzian System. Kilimatinde Cement consists of loose and impervious limestone, calcareous mud and conglomerate showing very low resistivity of 10 to 120 ohm.m. Water was stricken at 73 m depth. Crushed and weathered siltstone and sandstone form excellent aquifers. Borehole was drilled up to 134 m and casing was installed to 100 m depth. Water quality is good for drinking (EC = 65.5 mS/m, pH = 6.64). High yield of 7.2 m^3/hr at drawdown of 13.32 m was measured by pumping test.

[Choda]

The lithology of borehole is composed of loose limestone or calcareous mud of Kilimatinde Cement to 28 m depth and then granite and intruded dolerite. Water strikes were at 44 m and 46 m depth. Main aquifers are fractured granite and intruded dolerite dikes. Water quality is good for drinking (EC = 84.4 mS/m, pH = 7.18). High yield of 9 m^3/hr at drawdown of 2.79 m was measured by pumping test.

[Mpapa]

The lithology of borehole is composed of weathered and fresh granite. Though water strikes were at 54 m, 66 m and 77 m depth, a small yield was observed by pumping test (0.15 m^3/hr at drawdown 11.4 m).

[Chikola]

The lithology is composed of highly weathered granite to 16 m depth, then slightly weathered granite. Some weathered and fractured part were found in various thickness of 1 to 6 m. Fresh and hard granite appeared from 110 m to bottom. Water strikes were at 28 m, 50 to 53 m and 71 to 72 m. Water quality is good for drinking (EC = 172 mS/m, pH = 7.54). A small yield of one m^3/hr at 55.6 m drawdown was measured by pumping test.

[Igurubi]

The borehole was drilled up to 144 m and struck a high water yield. The hole, however, could not be cased by pipes due to high water head and collapsing hole wall. The contractor tried several times to prevent collapsing of hole, but it was hardly beyond their technology and outfits. Finally borehole was called off due to washing out of access road by flood taken place on December 1997.

The lithology of borehole was composed of loose silt, sand and gravel of Manonga-Wembere Lake-beds up to 83 m depth and then metamorphosed igneous rock of Nyanzian System. Sand and gravel layers and fractured weathered igneous rocks form an excellent aquifer. Water strikes were at 54 m, 70 m and 88 m depth. Water quality relatively good while conductivity a little high as 284 mS/m.

[Ngruti]

The lithology was composed of superficial sediments to 23 m, and then weathered granite to 43 m depth. From 43 m almost intact and slightly fractured granite continues to bottom. The hole was almost dry.

(3) Pumping Test

Pumping test was conducted for 7 completed boreholes. A process of pumping test is as standard:

- Preliminary test : 4 hour test
- Step draw-down test : draw-down 4 step and recovery 2 step
- Constant discharge test : 24 hour

- Fluctuation of water level during constant discharge test is shown by each borehole on Figure 1.6.3-2 and Appendix-1 Table 1.6.3-2(1)-(7). Capacity of each boreholes can be summarised as Appendix-1 Table 1.6.3-3 and can be characterised as follows:
- Boreholes hit excellent aquifer in rift valley and/or remarkable fault such as Maskaroda, Nkuhi, Basodesh and Choda are expected high yield from 7.5 to 70 m^3/hr at draw-down of 20 m. Especially borehole drilled Mara is expected very high yield more than 100 m^3/hr at draw-down of less than 10 m.
- Boreholes did not hit aimed fault such as Chikola and Mpapa show small capacity of 0.25 - 0.5 m^3/hr at drawdown of 20 m.

Water quality of the test boreholes are shown on Table 1.6.3-4, and are more or less good for drinking and bellow allowable value of Tanzanian standard. Colour and muddiness is clear without in case of Basodesh pumped up by handpump observed muddiness. pH is ranged between 6.99 to 7.56. EC is ranged between 58.6 to 171 mS/m without basodesh observed 450 mS/m. F is almost more than 5 ppm refracting characteristic of groundwater in granite zone. Colon Bacillus is not detected.

Table 1.6.3-1 Summary of Test Drilling

District	Village		Borehole No. *	UTM Grid		Completed Depth	Dia.	Total screen	Depth to soft formation	Static Water Level	Yield **	Draw-down	EC	pH	Aquifer System
	No.	Name		X	Y	m	inch	m	m	m	m³/hr	m	mS/m		
Hanang	7	Basodesh	AR.257/97	736586	9524469	87	6	29.00	9	13.74	8.0	5.14	338.0	7.01	Nyanzian(sandstone), porphyrite
	20	Ishponga	AR.258/97	736586	9524469	110			10	dry					Granite
	32	Maskaroda	AR.259/97	784726	9516784	78	6	34.80	27	0.00	9.0	25.25	140.0	6.99	Bubu Cataclasite(gneiss)
	21	Mara	AR.260/97	778500	9507706	40	6	14.50	19	7.30	9.0	0.33	59.0	7.34	
Singida	11	Nkuhi	SG.255/97	696390	9409621	100	6	17.40	82	39.80	7.2	13.32	66.0	7.18	Nyanzian(sandstone)
Rural	9	Choda	SG.256/97	695466	9391879	102	6	35.90	27	25.62	9.0	2.79	84.0	7.2	Granite, Dolerite
Manyoni	58	Mpapa	SG.251/97	721298	9283150	120	6	40.60	12	17.52	0.2	18.99			Granite
	49	Chikola	SG.252/97	703593	9326867	150	6	49.30	16	18.81	1.0	36.16	172.0	7.5	Gramite
Igunga	23	Igurubi	TA.253/97	578827	9558632	--***			83				284.0		Manonga L Beds (gravel), Nyanzian
	50	Nguruti	TA.254/97	563954	9507371	110			23	dry					Granite
Total						897		320.10							
Average						100		31.64	30.8	17.54	6.2	14.57	163.2	7.20	

* Borehole No. registered in the Ministry of Water

** Borehole No. registered in the Ministry of Water

*** Drilling was called off due to wash out of access road by flood in December 1997

1.6.4 Hydrogeological Map

In order to compile all the hydrogeological and groundwater data and information into a map, hydrogeological maps by target district and target village.

Four (4) satellite imageries were provided by JICA covering whole Study area. Some 2,300 sheets of aerial photographs in scales of 1/30,000 and 1/50,000 (taken during 1990 to 1995) along 48 flight courses were procured from the Service and Mapping Division of Ministry of Land.

The basin-wide hydrogeological structures were detected through the interpretation of the satellite imageries, and the local hydrogeological structures on the pilot villages and target villages were detected by interpreting aerial photograph.

Two kinds of hydrogeological maps were prepared in the Study. One is a hydrogeological map of target districts in a scale of 1/100,000 as summarised in Figures 1.6.4-1(1) to (4). The map was compiled basing on the existing geological maps called the "quarter degree sheet" and the result of interpretation of satellite imageries and aerial photographs. They give geological data and information inclusive of the hydrogeological units, geological structures such as faults and rift valleys, the location of existing and test boreholes, statistic level and quality of groundwater and others.

Another is a hydrogeological maps by target village in a scale of 1/25,000, show the local hydrogeological structures being compiled on the basis of the interpretation of aerial photographs and the field inspections. The map gives the data and information on the hydrogeological units, faults, lineaments and dyke rocks, location of existing and test boreholes, dug wells and water sampling and other information obtained through the field inspection.

1.6.5 Productive Aquifers

The aquifer systems in the Study area are summarised as Figures1.6.4-1 (Hydrogeological Maps of District) and Table1.6.4-1 (Summary of Groundwater Potential). The major productive aquifers by district and by the hydrogeological unit are as described in below:

(1) **Hanang District**

[Unit A];

The unit is located in Hanang Volcano and it's southern slope and classified into A-1 and A-2 sub-unit. Main aquifer of A-1 is Hanang Volcanics composed of lavas and phyroclastics. Fractured lava is expected to form the potential aquifer. Some springs are found on the mountain-foot and used for domestic purpose. A-2 unit is located between rift valley faults and aquifers composed of volcanics and underlying fractured gneiss of Bubu Catacrasite.

The borehole depth may be required to 100 to 150 m. The expected borehole yield of the unit is high and the static water level is 20 to 30 m below the ground. The successful rate of borehole of the unit is deemed to be 70 to 75%.

[Unit B];

The unit occupies the eastern and southern parts of the district and classified into B-1 and B-2 sub-units. Main aquifer is fractured gneiss and granite. Two test boreholes were drilled in Mara and Maskaroda villages belonging to B-1 sub-unit, and high yield were hit at the both sites. A high groundwater potential is expected in B-1 sub-unit along the rift fault. The borehole depth in the unit may be required to 80 to 100 m. The expected borehole yield is high and the static water level is to 15 m below the ground. The successful rate of borehole of the unit is deemed to be 70 to 80%.

[Unit C];

This is located in the east and northeast part of the district and classified into four sub-units. C-1, C-2 and C-3 sub-units are located on high land and C-4 is located in the rift valley. Relatively high groundwater potential is expected in C-4 sub-unit in the fractured granite and/or Nyanzian system. A test borehole was drilled at Bassodesh village belonging to C-4 sub-unit and hit high yield. On the other hand, another test borehole was drilled at Ishponga village belonging to C-2 sub-unit but this was dry.

The borehole depth in the unit may be required to 100 m. The expected borehole yield is one to five m^3/hr and the static water level is to 25 m below the ground. The successful rate of borehole of the unit is deemed to be 70 to 80%.

(2) Singida Rural District

[Unit A];

The unit occupies the northern part of Bassotu fault escarpment and classified into A-1 to A-3 sub-units. Main aquifers are fractured and weathered granite and Nyanzian system. Groundwater potential is relatively high in A-1 and A-3 units, while A-2 unit is not so high. The borehole depth in the unit may be required to 80 to 100 m. The expected static water level is 10 to 30 m below the ground. The successful rate of borehole of the unit is deemed to be 70 to 75%.

[Unit B];

The unit is located in the rift valley between Bassotu fault and Singida fault escarpment and classified into B-1 to B-4 sub-units. High groundwater potential is expected in the units except B-4 unit which situates on the hilly area above Singida fault escarpment. B-3 unit is located around Singida Town and many boreholes are sunk for the urban water supply. The expected borehole depth is about 100 m. Static water level is estimated relatively shallow in B-1, B-2 and B-3 units, while it may be deeper in B-4 unit where is nearby the fault escarpment. The successful rate of borehole of the unit is deemed to be 75 to 80%.

[Unit C];

This is located in Turu rift valley. High groundwater potential is expected in this unit. The expected borehole depth is about 100 m. Static water level is estimated at deeper horizon in a strip along the fault escarpment. The successful rate of borehole of the unit is deemed to be 70 to 75%.

[Unit D];

The unit is located in the east of C unit and the outside of rift valley. Groundwater is expected only the area along lineament running SW-NE direction.

(3) Manyoni District

[Unit A];

The unit occupies an area in Bahi basin, the eastern part of the district, and classified into A-1 to A-4 sub-units. A-1 and A-4 sub-units are located nearby the fault escarpment and high groundwater potential is expected. A-2 unit is located along A-1 sub-unit and relatively high groundwater potential could be expected. A-3 sub-unit is located in Bahi basin and hydrogeological structure of granite is hidden by overlying Kilimatinde Cement formation. The expected borehole depth is some 70 to 80 m. Static water level is estimated at 35 to 45 m in A-1 sub-unit. The successful rate of borehole of the unit is deemed to be 70 to 80%.

[Unit B];

The unit is located along the Kilimatinde fault escarpment and classified into B-1 and B-2 sub-units. B-1 unit is confined an area below the escarpment and there is a borehole supplying water to Manyoni Town. B-2 sub-unit is located in an area between two fault escarpments along Bahi basin. High groundwater potentials are expected in both sub-units. Static water levels are estimated at a large depth (35 to 55 m). The expected borehole depth is around 110 to 150 m. The successful rate of borehole of the unit is deemed to be 75 to 80%.

[Unit C];

This is spread out on the slightly undulating hill underlain by Kilimatinde Cement and classified into C-1 to C-4 sub-units. C-1 sub-unit is located along the fault escarpment through Manyoni Town and high groundwater potential is expected. C-3 sub-unit is located in the low and flat area along the railway to Tabora and along an assumed fault zone. Relatively high groundwater potentials are expected from the sub-unit. It is difficult to estimate groundwater potential on C-2 and C-4 sub-units because hydrogeological structure of granite is hidden by overlaying Kilimatinde Cement. The EC of groundwater in the unit shows sometimes relatively high affected by groundwater from aquifer of Kilimatinde Cement. The successful rate of borehole of the unit is deemed to be 70 to 75%.

[Unit D];

This is located on the plateau extending over the south of the district, underlain directly by granite, and classified into D1 to D3 sub-units. Groundwater potentials are relatively high in a strip along distinct faults in D-1 sub-unit. A test borehole was drilled in Chikola village in D-

1 sub-unit but a small yield was measured. D-2 sub-unit is located in the plateau extending in the east of Bahi basin. A test borehole was drilled at Mpapa village in D-2 sub-unit but small yield was met as well. C-3 sub-unit is located in the western end of the district. The expected borehole depth is 70 to 80 m and the static water level is estimated at 10 to 30 m depth in the unit. The successful rate of borehole of the unit is deemed to be 70 to 75%.

(4) Igunga District

{Unit A};

The unit is located in the southern half of the district and classified into A-1 to A-4 sub-units. Main aquifer is weathered and fractured granite along the fault and lineament running SWW-NEE direction. The target villages are concentrated A-1 sub-unit. A test borehole was drilled in Nguruti village but was dry. Relatively high groundwater potential may be expected along with the relatively distinct lineament in A-1 sub-unit and the fault running NS direction in A-4 sub-unit. The expected borehole depth is 70 m and the static water level is 20 to 30 m. The successful rate of borehole of the unit is deemed to be 70 to 75%.

[Unit B];

This is located in the northwest part of the district and classified into B-1 to B-3 sub-units. Main aquifer is fractured and weathered part of Nyanzian System composed of schist and metamorphosed volcanic rock. B-1 sub-unit is located along faults and is expected a relatively high groundwater potential than B-2 sub-unit. The expected borehole depth is 70 m and the static water level is 30 m. The successful rate of borehole of the unit is deemed to be 70%.

[Unit C];

The unit is located in the northeast portion of the district and classified into C1 to C3 sub-units. Main aquifers are formed in Manonga Wembere Lake-beds and fractured rock of Nyanzian System. C-1 sub-unit is located along with a distinct fault. A test borehole was drilled at Igrubi Village and met an excellent aquifers but the borehole construction was failed due to heavy collapse of layers. C-2 sub-unit is located along a distinct fault, and high groundwater potential is expected in aquifers within Manonga Wembere Lake-beds and fractured granite along the fault. The groundwater in aquifers may be saline. The successful rate of borehole of the unit is deemed to be 70 to 80%.

Consideration of possible borehole yield to adopt L-2 system is made for some 16 villages based on hydrogeological feature. The expected yield of borehole for L-2 system is 6 cu.m/hr (100,000 lpd/16 hr) on target year 2001 and 2006 in case of service population of 4500. Evaluation for expected yield, static water level and well depth of adopted 12 village until 2016 (9 village until 2001) is shown Table-1.6.5-2.

1.6.6 Groundwater

(1) Groundwater Level

In accordance with the borehole record, the static water level in the Study area are, in general, 12 m to 24 m below the ground (refer to Table 1.6.1-1). The level is appropriate in term of application of deep-well type handpump which is practically effective to a water level to 40 m or less.

In some villages located on the following hydrogeological units (refer to hydrogeological map by district), the static water level in borehole is supposed to be 40 m or more:

[Hanang district]:
C-1, C-2 and C-3 units located on the plateau between rift valley.

[Singida district]:
B-4 and E-4 units located nearby the fault escarpment.

[Manyoni district]:
A-1, B-1, B-2, C-2, C-3 and C-4 units located nearby the fault escarpment.

As a result of detailed identification in the hydrogeological map on the target villages and the existing borehole record of 22 villages located on above mentioned hydrogeological units, the static water level for eight villages are to be deeper than 45 m; and one of powered pump such as engine-pump, wind-pump or solar pump is to be adopted to those villages (refer to Table1.6.6-1).

(2) Groundwater Quality

(a) Water Quality Survey

The water quality survey was carried out over 284 target villages. The Study Team collected 734 water samples from different water sources such as boreholes, dug-wells, water-holes and others. In situ and laboratory analysis were conducted to cover the items of colour, muddiness, smell, temperature, electric conductivity (EC), pH, F, NO_2, NO_3, NH_4 and colon bacillus. Number of water sample by district and water source, and water quality test by survey item are shown on Table1.6.6-2 and Table1.6.6-3. The inventories of water quality survey by target village are shown on Appendix-1 Table1.6.6-4 (1)-(4).

(b) Comparison of Water Quality for Different Water Source

Water quality of different water sources were compared in four items of EC, Colon bacillus, F and Colour as a result of water quality survey for whole target villages. Water sources were classified into borehole (BH), dug-well which is manually dug shallow well lined by concrete ring (DW), water-hole which is traditional dug hole without any lining (WH) and charco dam which is simple small water-pond. Water quality of household containers was also measured.

Results of analysis are shown in Table-1.6.6-5, Figure 1.6.6-5 and Figure-1.6.6-6, and as described in below:

(Colour)
60 % of water-hole and 40% of charco dams showed milky or turbid colour. On the other hand boreholes water was very clean. 20% of dug-well show milky colour. About 30% of stocked water in household showed milky colour.

(Colon bacillus)
Colon bacillus was undoubtedly observed over 59 % of water-holes and 42% of charco dams (undoubted number means more than 11 number of colony of colon bacillus). On the other hand, they were observed over 33 % of dug-wells and 15 % of boreholes.

(F)
F (fluorine) was observed relatively high over the granite area, but the difference between water sources was not so clear.

(EC)
EC value of boreholes was higher than that of other water sources. 67% of boreholes showed

more than 100 mS/m. While, dug-well, water-hole, charco dam and household container shown EC over 100 mS/m were 25%, 13%, 12% and 20% respectively.

(NO_2)

NO_2 was observed over 70 % of household container. On the other hand observed in 32 % of borehole, 24 % of dug-well and 43 % of water-hole.

(NO_3)

NO_3 was observed over 80 % of household, 85 % of borehole, 72 % of dug-well and 55 % of water-hole.

(NH_4)

NH_4 was observed over 60 % in every water sources even in borehole. NH_4 originated in organic matter in general, and change to NO_2 and NO_3 in successively, therefore they reduce in deeper aquifer as usual. But there are not distinct difference of them between borehole and other sources compare with clear differentiation observed on colon bacillus, so trace of organic material originated from excreta analysing NH_4, NO_2 and NO_3 was not made succeeded during the study.

As a result of the survey, about 40 % of villagers are depending on turbid or unhealthy water sources contaminated with colon bacillus. On the other hand, the water from boreholes and dug-wells showed better water quality.

(c) **Water Quality of Boreholes**

Typical values of EC and pH are shown on Figure1.6.6-7.

(EC)

The allowable value of EC is 200 mS/m in accordance with the Standard of Tanzania shown in the design criteria of the Ministry of Water (refer to Table 1.6.6-6).

High EC value are, however, supposed to be in some hydrogeological units especially those units within the Manonga-Wembere basin, Bahi basin and some of rift valleys. About 10% of boreholes in the units show high EC value of more than 300 mS/m.

(pH)

73 % of borehole water show pH values within the allowable value of Tanzanian Standard

(6.50 to 9.20). 27 % of borehole water show pH between 5.01 to 6.49, especially in Manyoni district, 41 % of borehole show lower than 6.5 (but higher than 5.0).

(d) Water Quality of Household Container

Water quality of 453 household containers in whole Study area were measured. 58% of water in household container were collected from water-holes and charco dams. 34% of water were from dug-wells and 8 % from boreholes.

A comparison of number of colon bacillus between household container and those original sources is shown in Figure 1.6.6-8 and as described as follows:

- 57% of water kept in household containers are contaminated with colon bacillus.
- 47% of water kept in household containers are collected from borehole contaminated with colon bacillus although only 14% of original water of boreholes contaminated.
- 50% of water collected from dug-wells and 44% from water-holes are contaminated by colon bacillus although the original water are contaminated by 32% and 62% respectively. This rate shows almost same percentage as water from boreholes.
- In conclusion, it is important to keep household container clean and proper hygiene habit to prevent water contamination by colon bacillus during collection and stock of household water.

1.6.7 Groundwater Resource

As stated in the foregoing sections, the groundwater potential in the Study area is, in general, in an excellent category in terms of yield, depth and successful rate of borehole and groundwater quality.

The extent of groundwater resource is examined in view of the areal water balance in this section.

The rate of annual groundwater recharge is, in general, not less than 1 % of annual rainfall even in arid regions where annual rainfall reaches around 100 mm. The rate in a monsoon region reaches, in general, to 10% or more. The rate in a savannah region is not known well. It is, however, believed to be not less than few %, might be in between those rates in the arid and monsoon regions.

Assuming that the rate of annual groundwater recharge of the Study area is 1 % of the annual rainfall (say 600 mm/a), the groundwater is rechargeable to some 312 MCM/a (0.01 x 0.6 m x 52,000 km^2).

Supposing the annual runoff coefficient of river flow at 2 %, the total hydrological balance of the Study area is made as shown in the following table:

Table 1.6.7-1 Hydrologic Balance of the Study Area

Factors	Water Amount (MCM/a)	Remarks
Rainfall	31,200	600 mm/a x 52,000 km^2
Evapo-transpiration	30,264	97% of annual rainfall or 25% of pan evaporation of 2,400 mm/a
Surface Runoff	624	2% x 600 mm x 52,000 km^2
Groundwater Recharge	312	1% x 600 mm x 52,000 km^2

Whereas, the water demand of the Area in the year of 2016 is estimated at 57 MCM/a (18% of above annual groundwater recharge) as shown in the table below:

Table 1.6.7-2 Future Water Demand of the Study Area

Purpose	Water Demand in 2016 (MCM/a)	Remarks
Domestic	18.6	Projected popul'n of 1.7 million x 30 lcd x 365 day
Livestock	18.3	Livestock unit of 2.0 million x 25 lcd x 365 day
Others	20.0	For industires and others
Total	56.9	

The groundwater resource of the Study area seems to be good enough for the socio-economic use in foreseeable future.

Figure 1.5.2

Geological Map of the Study Area

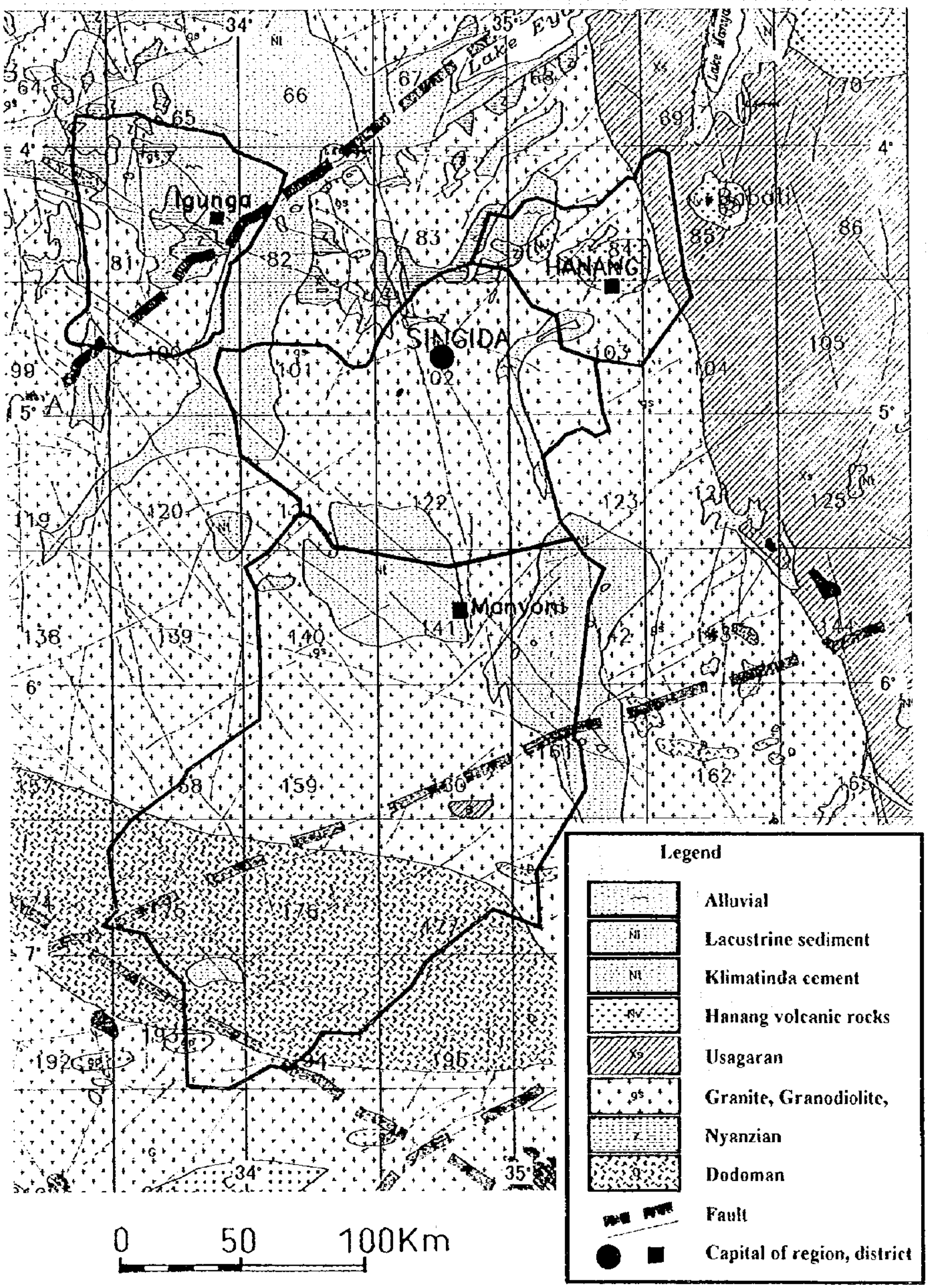


Table 1.5.2 Stratigraphy and Rock Facies of the Study Area

Geological Age		Geological name	Rock facies	Igunga	Singida Rural	Manyoni	Hanang
Neogene	Holocene – Pliestcene	Aluvial deposit	Clay, silt, sand	Alluvium	Alluvium	Alluvium	Alluvium
	Pliestcene – Pliocene	Manonga – Wembere Lake Beds	Lacustrine limestone, clay, sand, gravel	Manonga – Wembere Lake Beds			Rift valley deposit
	Pieistcene	Kilimatinde cement	Clay, silt, sand, limestone		Killimatinde cement		
	Pleistocene – Neogene	Hanang volcanics	Tuff, lapilly tuff, tuff breccia lava		Hanang volcanic		Hanang volcanics
Paleozoic Proterozoic	Dyke rock	Dyke rock	Dolerite, Porphyroite, Kimbarite	Dolerite, Porphyrite, Kimbarite	Dolerite, Porphyrite		
	Metamorphosed sedimentary rocks	Bukoban	Shale,Sandst,Phyllite			Limestone,shale, Sandst	
Archaen		Nyanzian	Banded ironstone, meta-volcanic rocks, chlorite schist	Banded ironstone, schist, metamorphosed volcanic rock		Metamorpfosed sandstone, siltstone,quartzite, schist,	
		Dodoman	Granitic gneiss, migmatite, schist			Granite gneiss migmatite, schist	

Proterozoic	Plutonic – metamorphic rocks	Bubu Cataclasite	Sheared (cataclastic) synorogenic granite porphyroclastic gneiss, migmatite				Sheard (cataclastic) granite gneiss
Archean		Granite	Granite, granodiolite	Granite & granodiorite (ocally foliated and porphyroblastic)			

Table 1.6.2-1 (1) List of Line and Point for Geophsical Survey on the Pilot and the Target Village

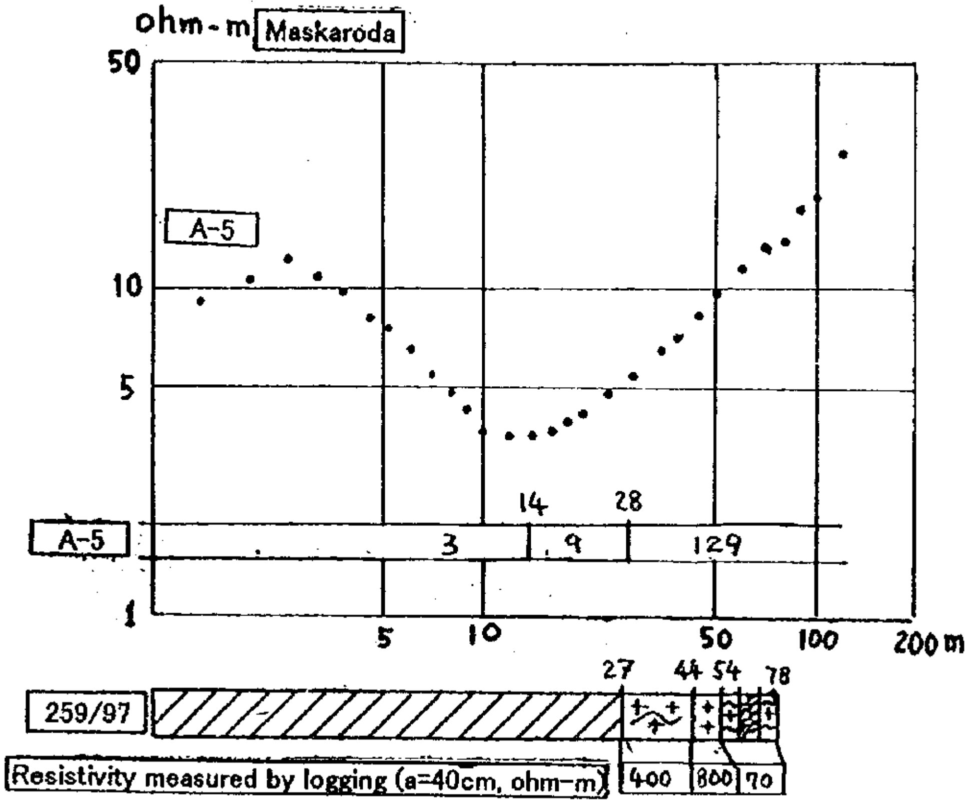
	Village No.	EP		EM		
		Line No.	Pnt. No.	Line No.	Length (m)	Pnt. No.
Pilot Village	13	31	293	27	51,710	5,171
Target Village	29	43	389	44	67,390	6,739
Total	42	74	682	71	119,100	11,910
Singida Town*	2	5	36	4	2,800	280
Total *	44	79	718	75	121,900	12,190

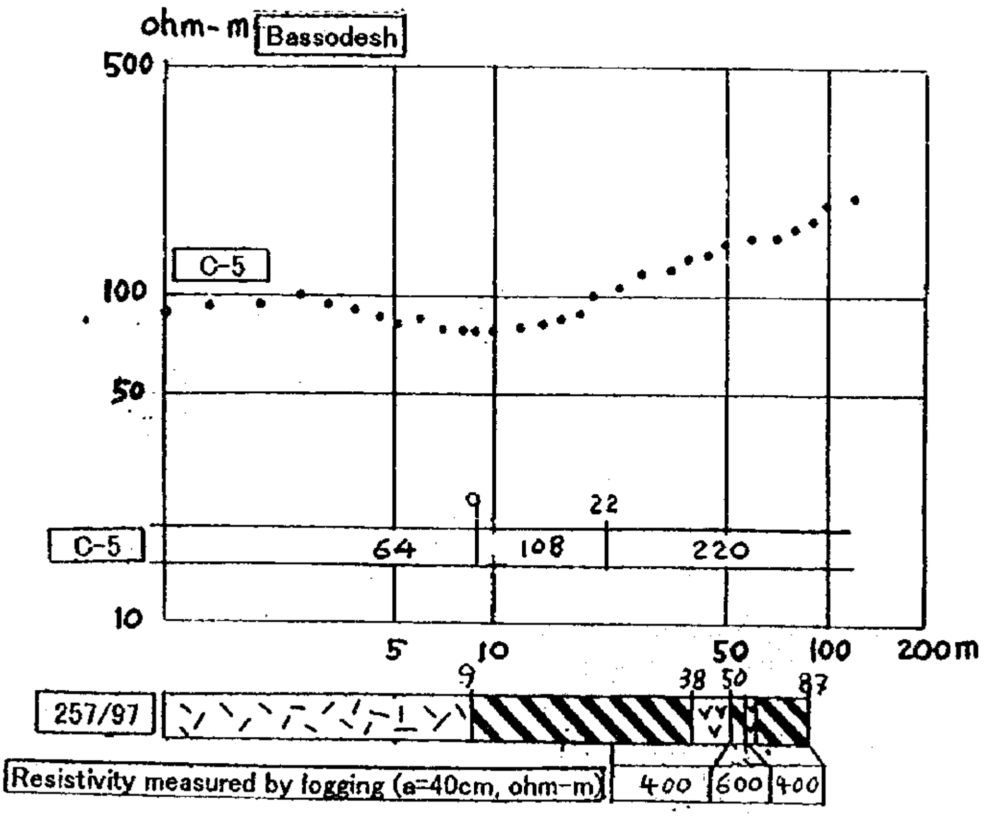
Table 1.6.2-1 (2) List of Line and Point for Geophsical Survey on the Each Pilot and the Target Village

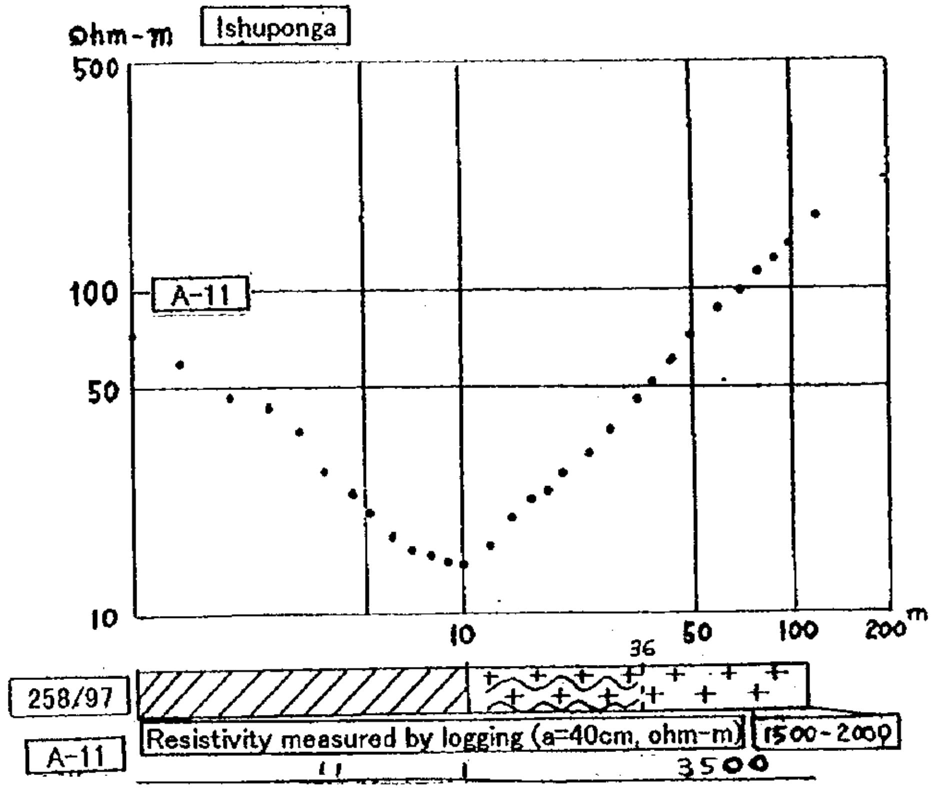
District Name	Village		EP				EM			
	Name	No.	Line	pnt.	Total	G-Total	Line	Dst.(m)	Total	G-Total
Pilot Village										
Hanang	Bassodesh	7	A	11			P	1,600		
			B	9			Q	1,600		
			C	8	28		R	1,600	4,800	
	Ishponga	20	A	15			P	2,400		
			B	10	25		Q	1,800	4,200	
	Mara	21	A	12			P	2,600		
			B	8	20		Q	1,400	4,000	
	Masqaroda	32	A	12			P	1,800		
			B	13	25	98	Q	2,000	3,800	16,800
Singida Rural	Choda	9	A	12			P	2,640		
			B	4			Q	1,000		
			C	5						
			D	5						
			E	2	28				3,640	
	Nkuhi	11	A	23			P	3,860		
			B	5			Q	1,960		
			C	5	33				5,820	
	Mang'onyi	16	A	5	5	66	P	1,000	1,000	10,460
Manyoni	Droto	17	A	5	5		P	1,800	1,800	
	Chikola	49	A	11			P	1,400		
			B	8			Q	1,400		
			C	10			R	2,100		
			D	5	34				4,900	
	Mpapa	58	A	10			P	2,300		
			B	6	16	55	Q	1,500	3,800	10,500
Igunga	Ndembezi	14	A	5	5		P	1,500	1,500	
	Igurubi	23	A	16			P	2,450		
			B	13			Q	1,500		
			C	8			R	1,300		
					37		S	1,500	6,750	
	Nguriti	50	A	19			P	3,700		
			B	13	32	74	Q	2,000	5,700	13,950
						293				51,710
Target Village										
Hanang	Dajamet	3	A	11	11		P	1400	1400	
	Gawidu	5	A	11	11		P	1500	1500	

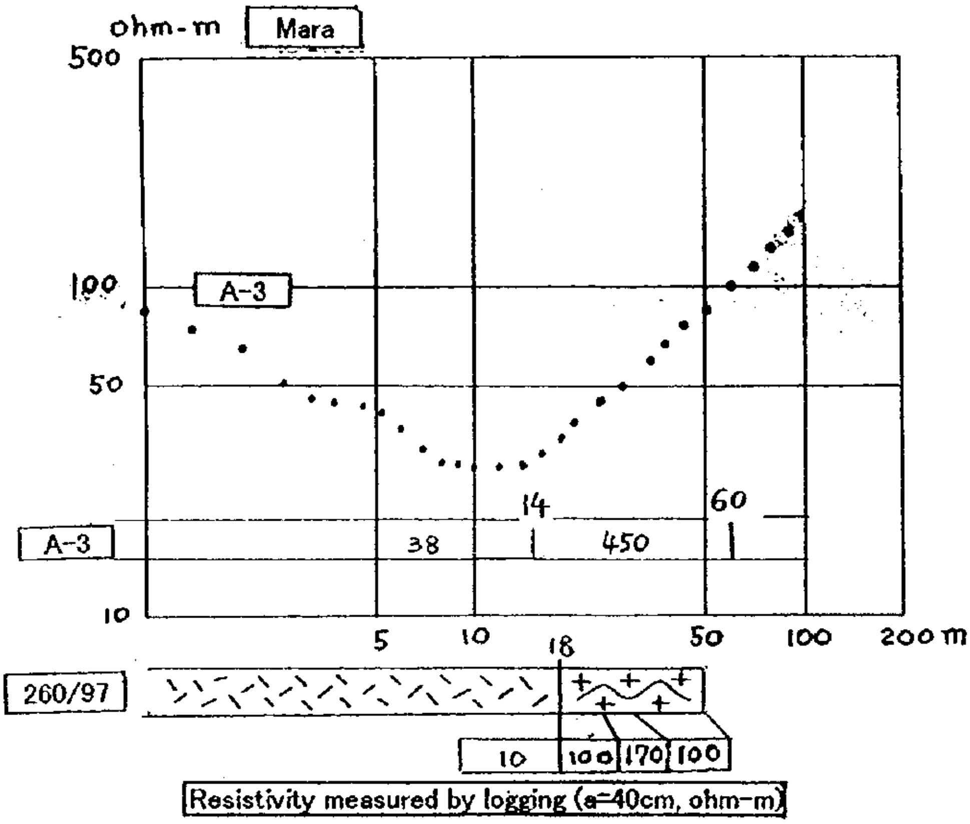
District Name	Village		EP				EM			
	Name	No.	Line	pnt.	Total	G-Total	Line	Dst.(m)	Total	G-Total
	Dinna	14	A	11	11		P	1500	1500	
	Murero	17	A	12	12		P	1650	1650	
	Masakta	30	A	4	4	49	P	1600	1600	7,650
Singida Rural	Ujaire	13	A	7			P	1250		
			B	5	12		Q	750	2000	
	Ighombwe	44	A	8			P	2000		
			B	9	17		Q	2200	4200	
	Mwastiyanga	50	A	9	9		P	1250	1250	
	Ikiwu	58	A	8			P	1600		
			B	9	17		Q	1600	3200	
	Madamigha	73	A	8			P	2000		
			B	5			Q	1500		
			C	6			R	1000		
			D	9	28		S	1500	6000	
	Mrama	74	A	9	9		P	1800	1800	
	Mwakiti	77	A	7			P	1000		
			B	6	13		Q	1500	2500	
	Igauri	84	A	6	6		P	1500	1500	
	Ntonge	85	A	7			P	1250		
			B	7	14		Q	1500	2750	
	Mgori	103	A	12	12		P	2000	2000	
	Unyampanda	106	A	4			P	750		
			B	5	9	146	Q	750	1500	28,700
Manyoni	Manyoni	1	A	12			P	1950		
			B	4	16		Q	590	2540	
	Mhalala	4	A	12	12		P	1500	1500	
	Mkwese	7	A	9			P	1500		
			B	9	18		Q	1800	3300	
	Saranda	64	A	9			P	1000		
			B	11	20		Q	1500	2500	
	Solya	68	A	9			P	2500		
			B	10			Q	1500		
					19		R	1000	5000	
	Sasajila	71	A	11	11		P	1750	1750	
	Itigi	16	A	10			P	1500		
			B	8	18		Q	1200	2700	
	Kitopeni	21	A	9	9	123	P	1500	1500	20,790
Igunga	Matinje	1	B	17	17		P	2400	2400	
	Itunduru	34	A	16	16		P	2250	2250	
	Mwayunge	37	A	16	16		P	2250	2250	
	Kaumbu	42	A	10	10		P	1700	1700	
	Ipumbulya	46	A	12	12	71	P	1650	1650	10,250
*Singida Town	Utemini *		A	10			P	500		
			B	4	14		Q	300	800	
	Kititimo *		A	12			P	1200		
			B	8			Q	800		
			A'	2	22	36			2000	2,800
Total						425				70,190

Figure-1.6.2-6 Comparison of ρ - a curve and Geology of Borehole






ohm-m
Ishuponga
500
100
50
10
A-11
10
36
50
100
200 m
258/97
A-11
Resistivity measured by logging (a=40cm, ohm-m)
1500-2000
11
3500


ohm-m
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60
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5
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18
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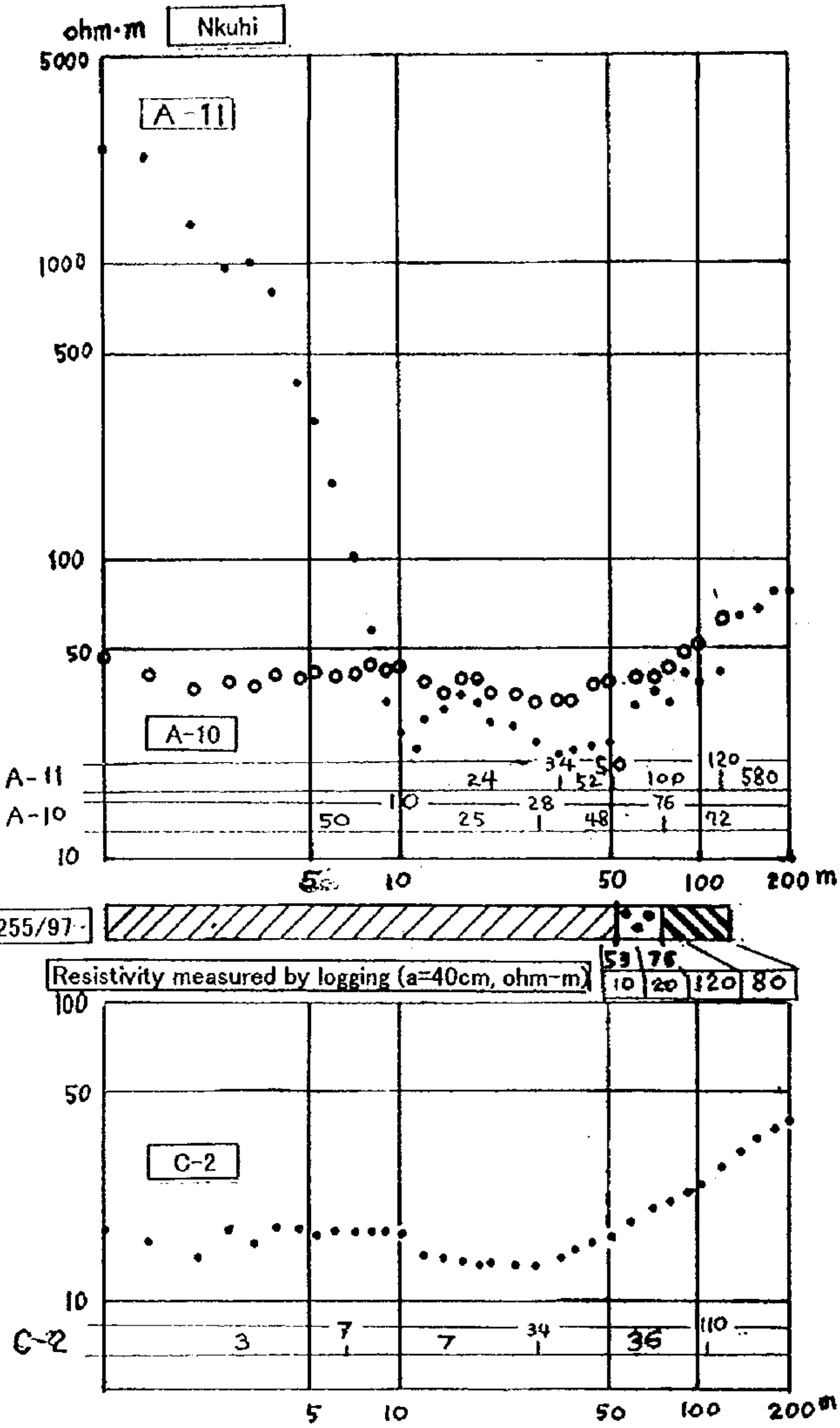
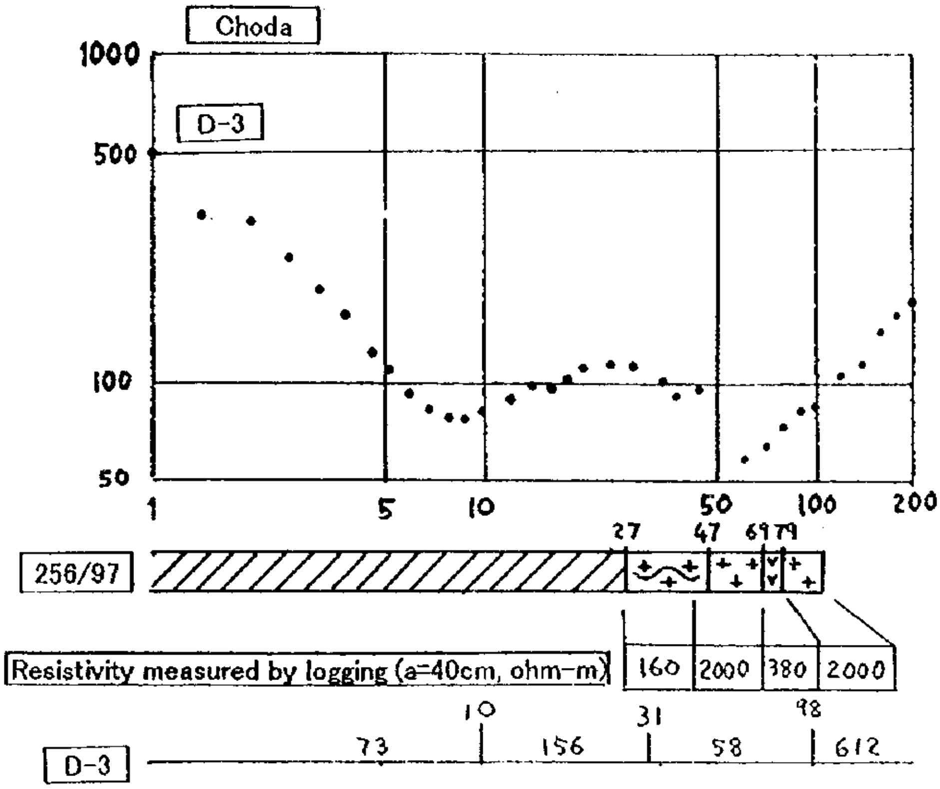
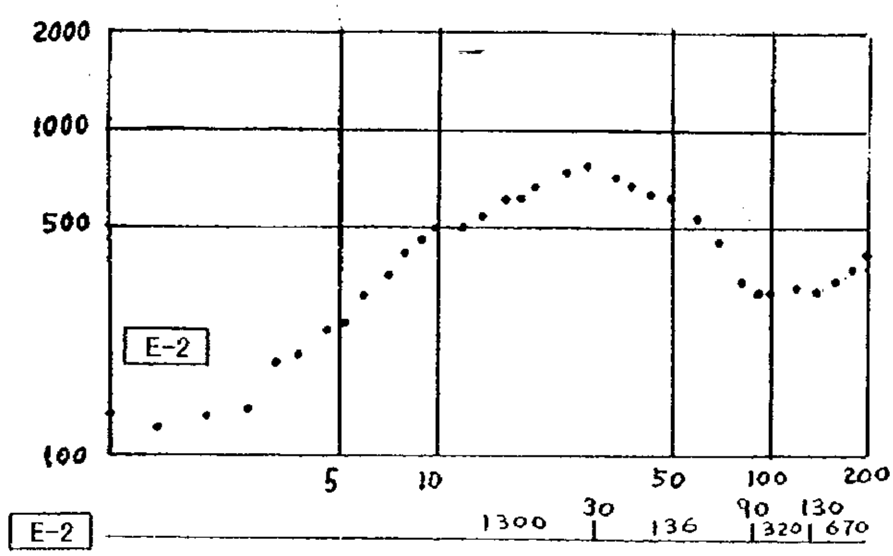
100
200 m
260/97
10
100
170
100
Resistivity measured by logging (a=40cm, ohm-m)

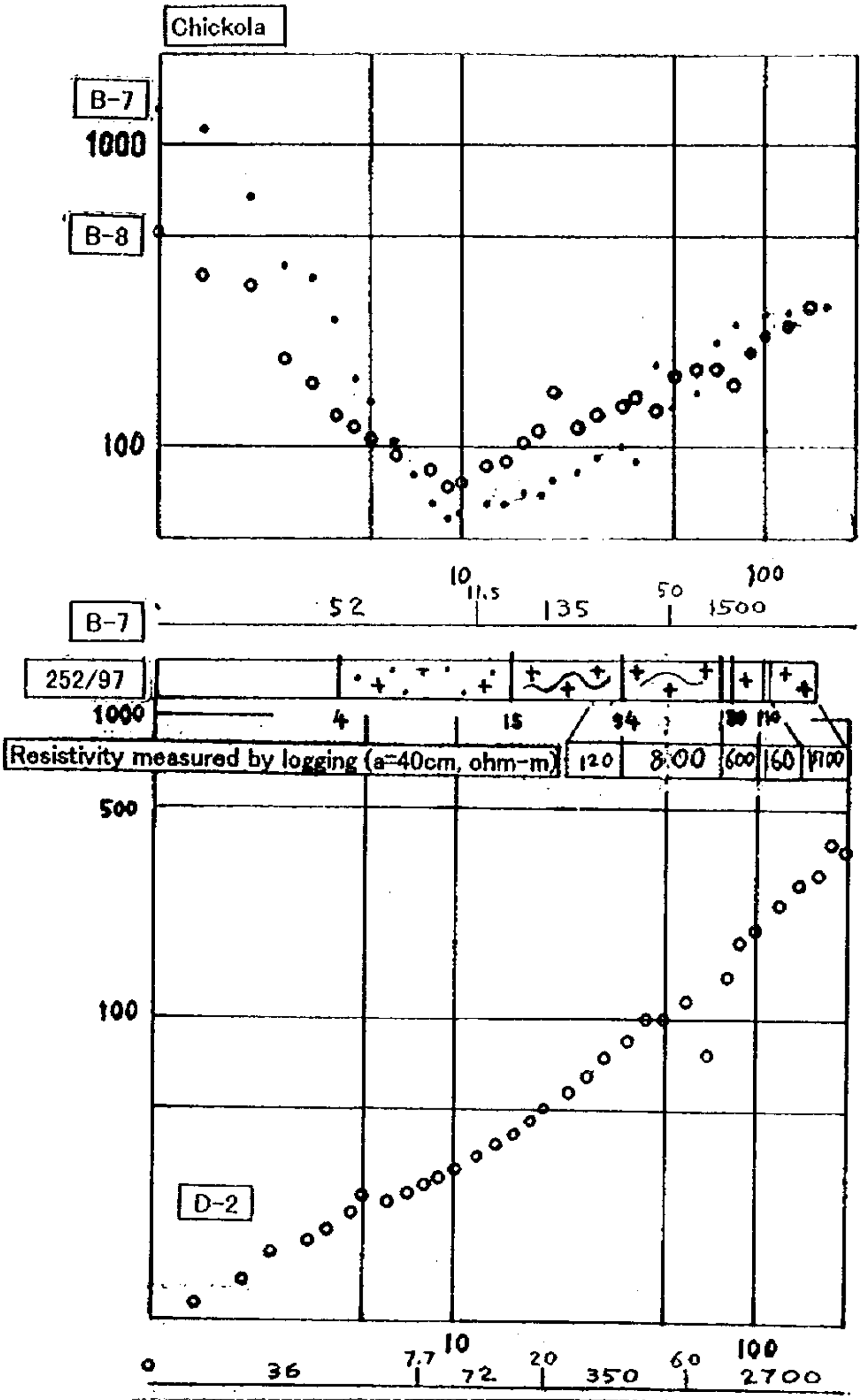


C-2 point compare to BH 109/73 Q = 8.1 m3/hr



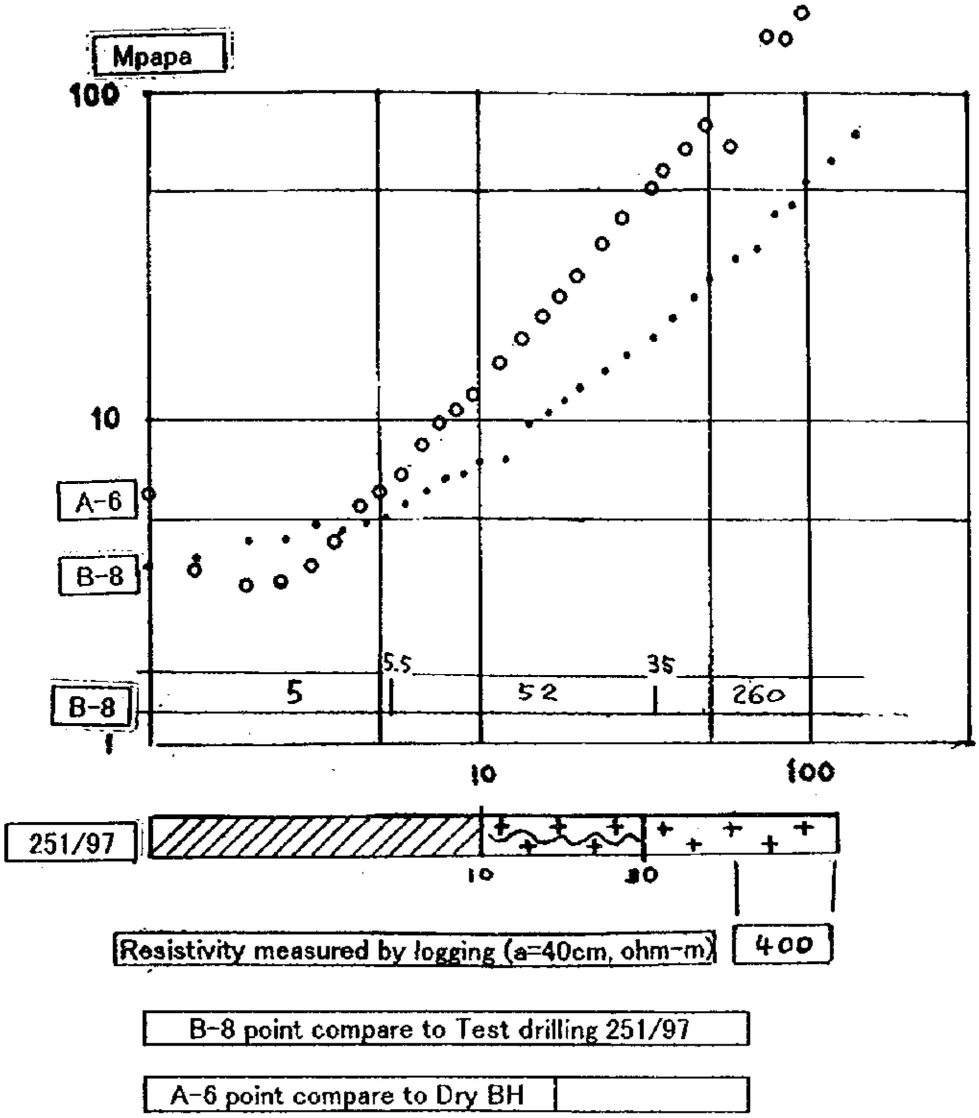


E-2 point compare to BH 12/62 Q = 2.5 m3/hr

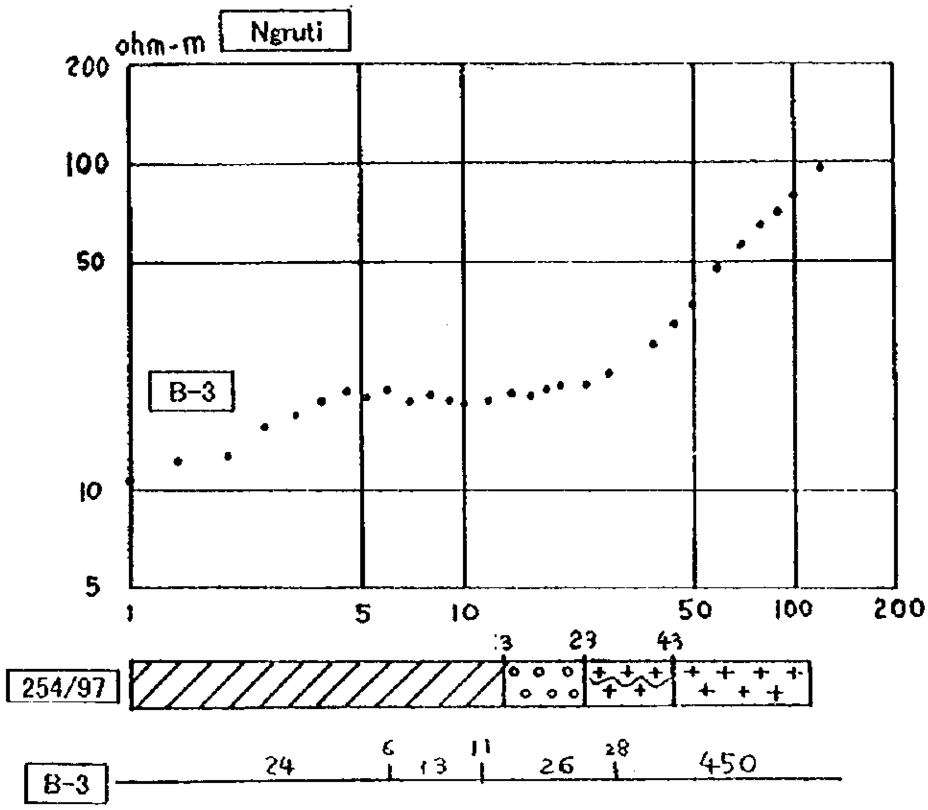


B-7 point compare to Test drilling 252/97

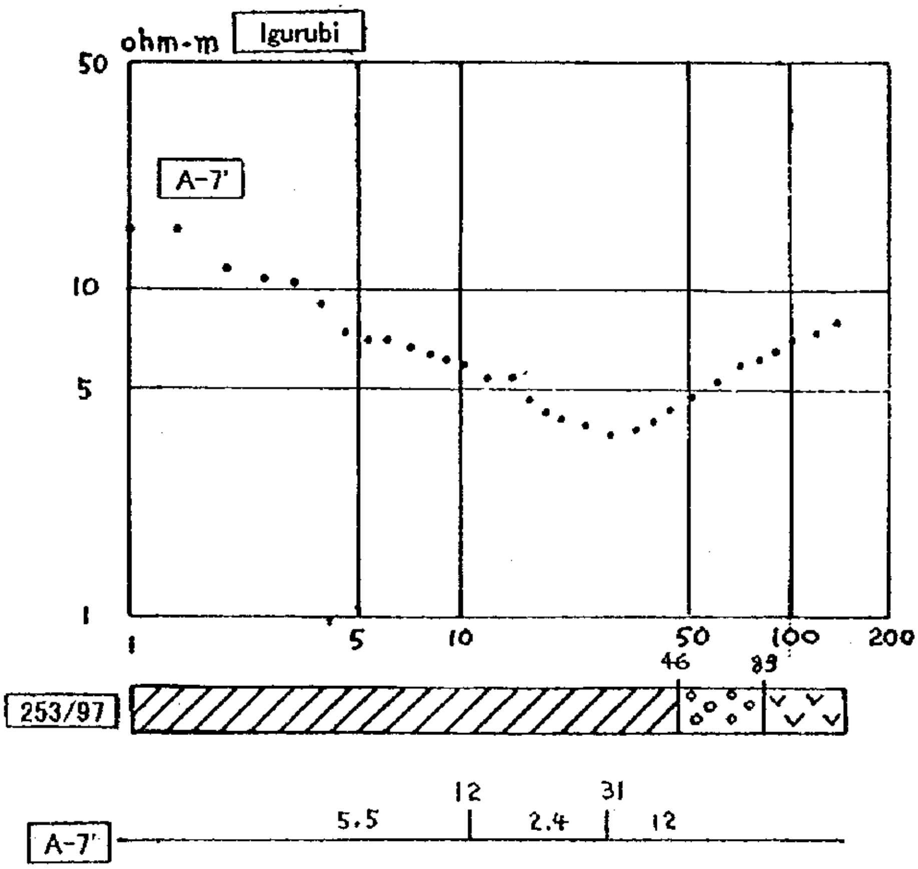
D-2 point compare to BH 40/73 Q = 4.5 m3/hr



Mpapa
100
10
1
A-6
B-8
B-8
5.5
35
5
52
260
10
100
251/97
10
30
Resistivity measured by logging (a=40cm, ohm-m)
400
B-8 point compare to Test drilling 251/97
A-6 point compare to Dry BH

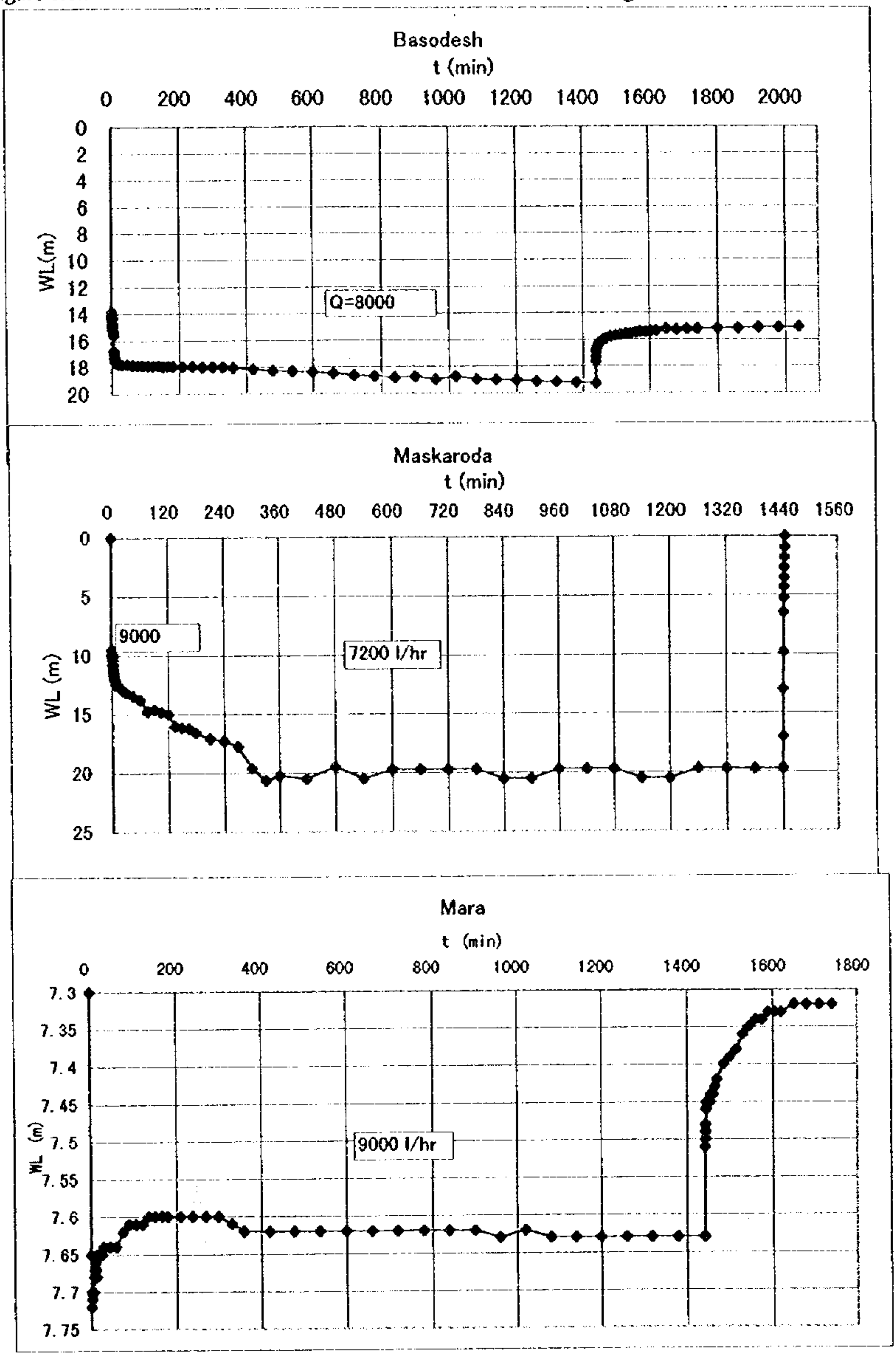


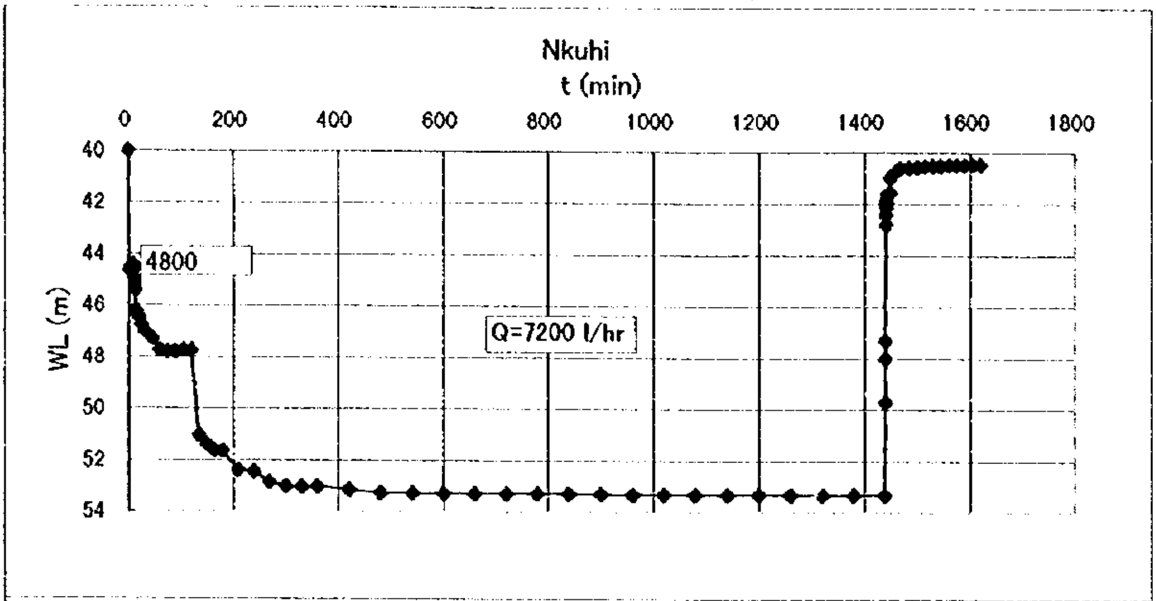
ohm-m
Ngruti
200
100
50
10
5
B-3
1
5
10
50
100
200
13
23
43
254/97
B-3
24
6
13
11
26
28
450



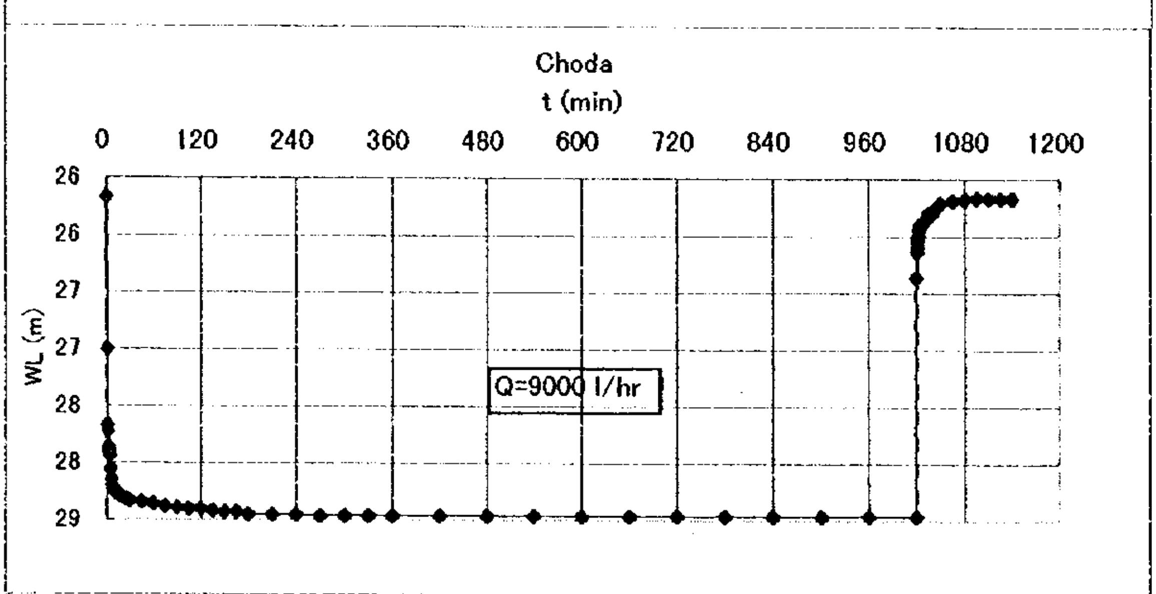
ohm-m
Igurubi
50
10
5
1
A-7'
1
5
10
50
100
200
46
89
253/97
A-7'
5.5
12
2.4
31
12

Figure 1.6.3-2 Fructuation of Water Level with Constant Discharge Test

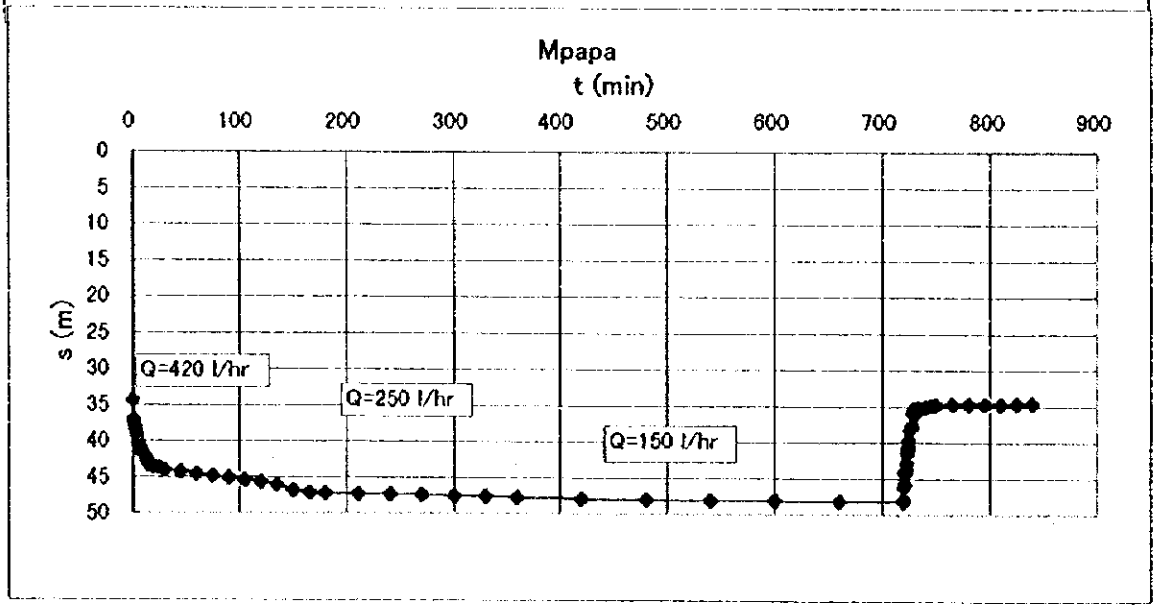




Nkuhi
t (min)
WL (m)
4800
Q=7200 l/hr



Choda
t (min)
WL (m)
Q=9000 l/hr



Mpapa
t (min)
s (m)
Q=420 l/hr
Q=250 l/hr
Q=150 l/hr

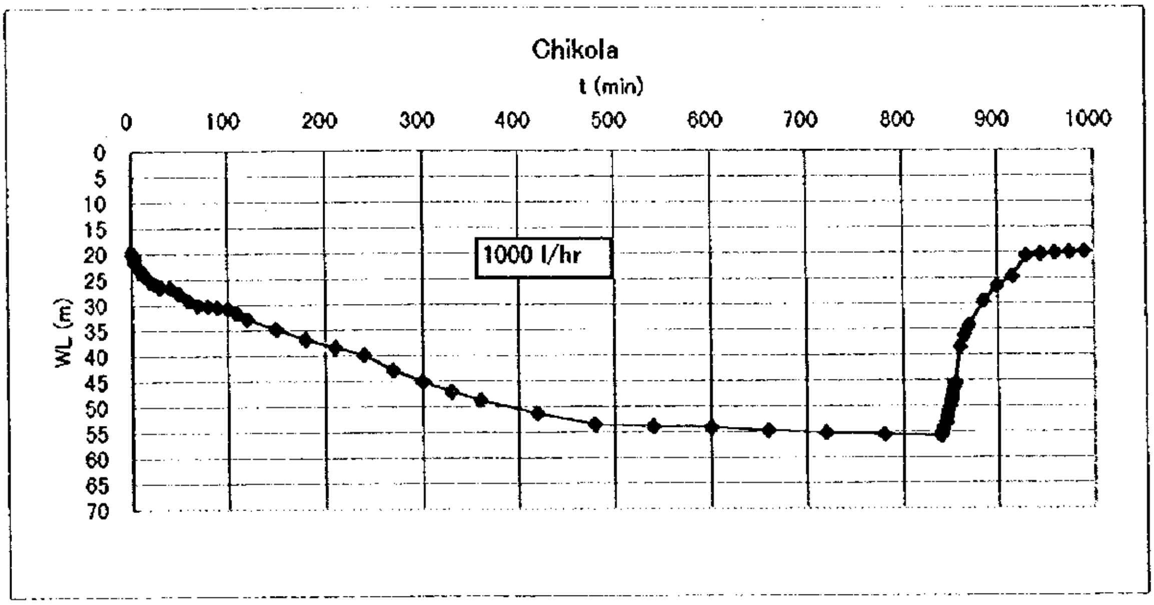

Chikola
t (min)
0 100 200 300 400 500 600 700 800 900 1000
WL (m)
0 5 10 15 20 25 30 35 40 45 50 55 60 65 70
1000 l/hr

Table-1.6.3-3 Pumping Discharge (Q) and Draw-down (s) drawdown (m)

Pilot Village	Pumping Discharge (littr/hr)											
	150	240	250	1000	3600	4200	4800	6000	6200	7200	8000	9000
Maskaroda					8.80			15.30		19.73		25.25
Mara												0.33
Basodesh					2.75	3.10			4.20		5.14	
Nkuhi					6.15		8.30	11.02		13.32		
Choda					1.21			2.05		2.40		2.79
Chikola		10.63		36.16								
Mpapa	11.37		18.99									

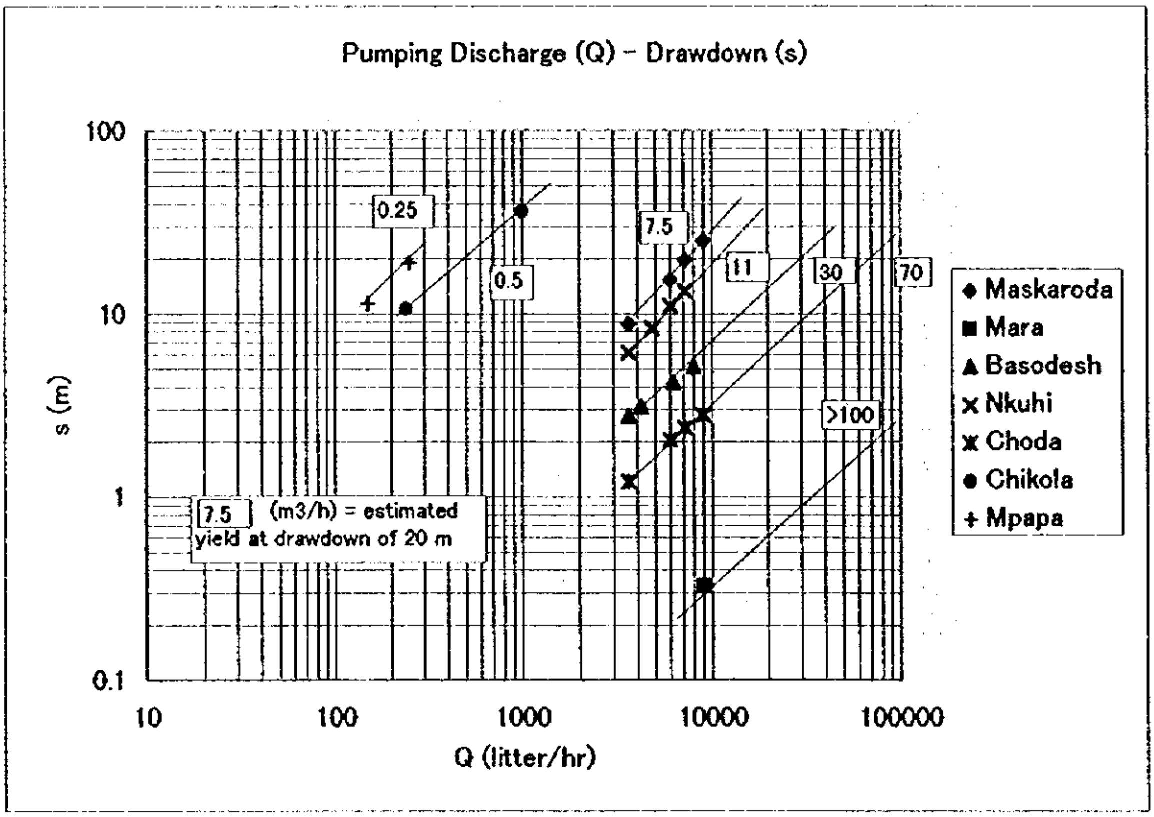


Table-1.6.3-4 Water Quality of Test Borehole

District	Ward	No.	Village	Sample		Gride		Color	Muddiness	Smell	Temperature	pH	EC	F	NO3	NO2	NH4	Colon Bacillus Paper	Colon Bacillus No. W Sp.	Remarks
		No.	Name	Point	Source	X	Y				C		(mS/m)	ppm	ppm	ppm	ppm			
Hanang	Basodesh	7	Basodesh	Borehol	PT	736586	9524469	0	0	0	22.30	7.01	450.00	5	0	0.05	0		0	
	Basodesh	7	Basodesh	Borehol	HP	736586	9524469	1	1	1	26.20	6.99	462.00	5	0.05	0.05	0.5		0	
	Mara	21	Mara	Borehole		778500	9507706	0	0	0	23.60	7.34	58.60	5		0.1	0	0		
	Maskaroda	32	Maskaroda	Borehole		784726	9516784	0	0	0	25.20	7.56	139.50	5		0.1	0	0		
	Maskaroda	32	Maskaroda	Borehol	HP	784726	9516784	0	0	0	25.10	7.69	140.90	5		0.1	0	0		
Singida	Issuna	9	Choda	Borehole		695466	9391879	0	0	0	27.00	7.20	69.20	2		0	0	0		
Rural	Issuna	11	Nkuhi	Borehole		696390	9409621	0	0	0	25.70	7.18	84.40	5	5			3		
Manyoni	Chikola	49	Chikola	Borehole		703593	9326867	0	0	0	23.00	7.50	171.00	2	45	1	0		5	
	Isseke	58	Mpapa	Borehole		721298	9283150													

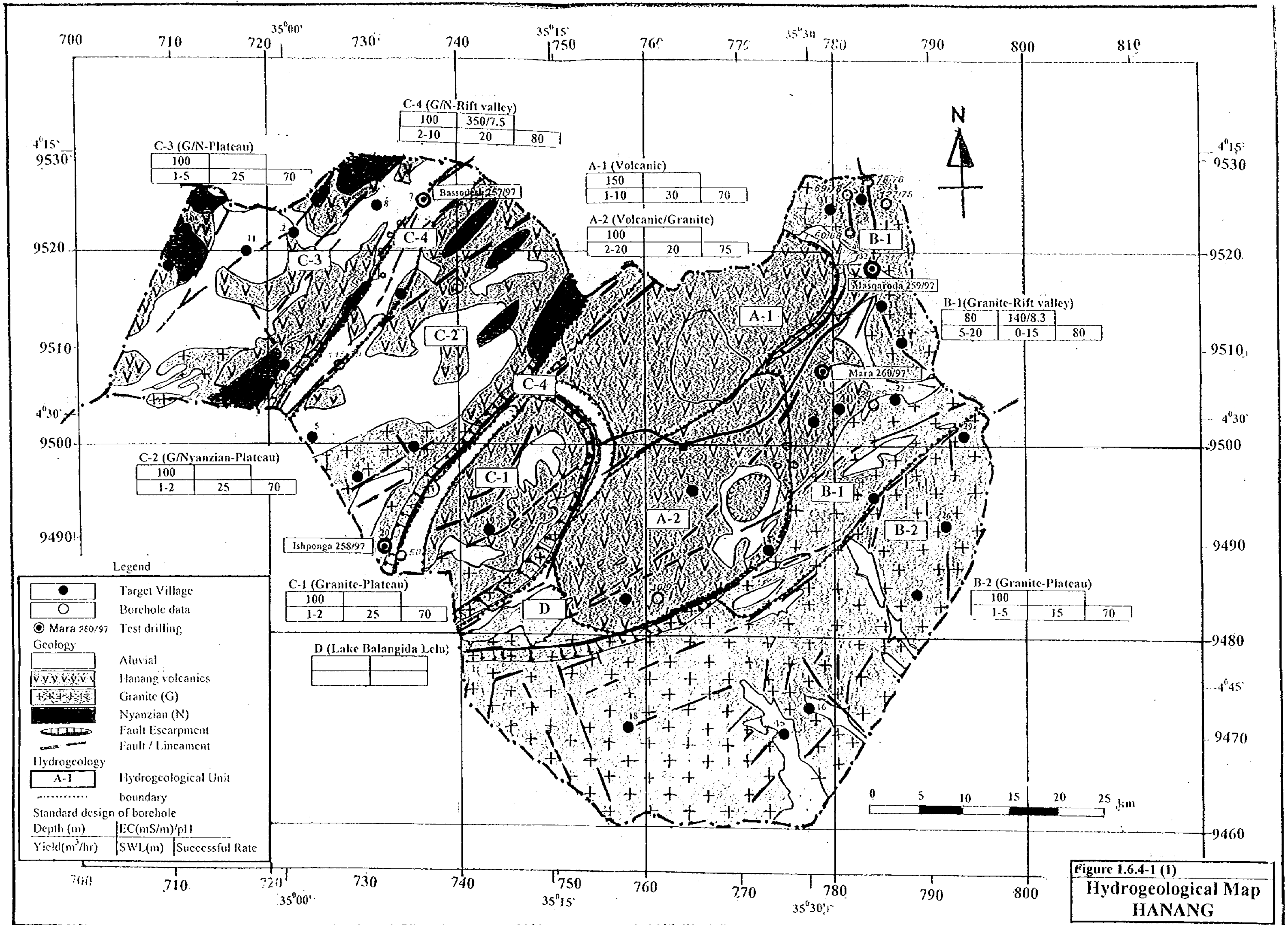


Figure 1.6.4-1 (1)

Hydrogeological Map HANANG

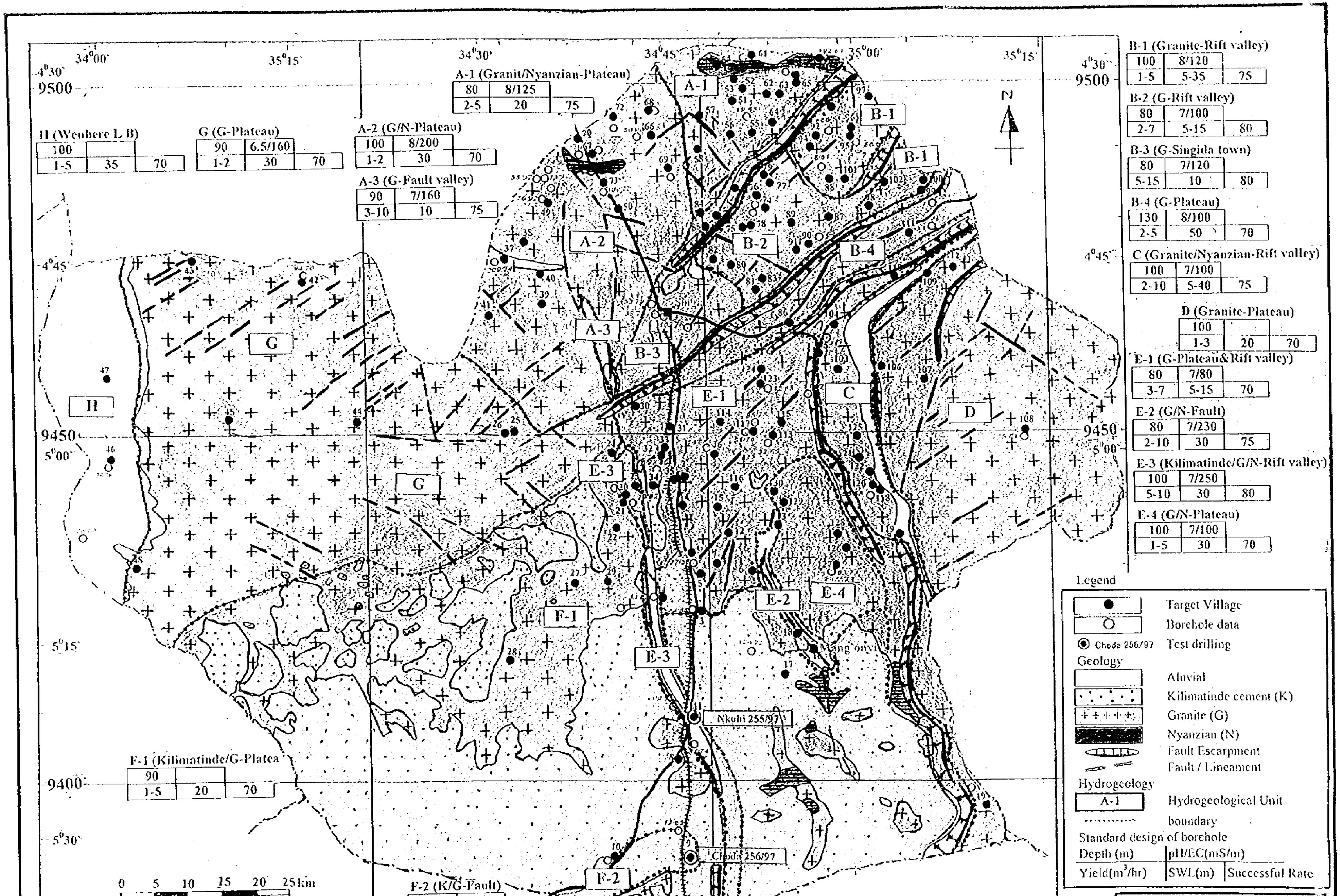


Figure 1.6.4-1 (2)
Hydrogeological Map SINGIDA RURAL

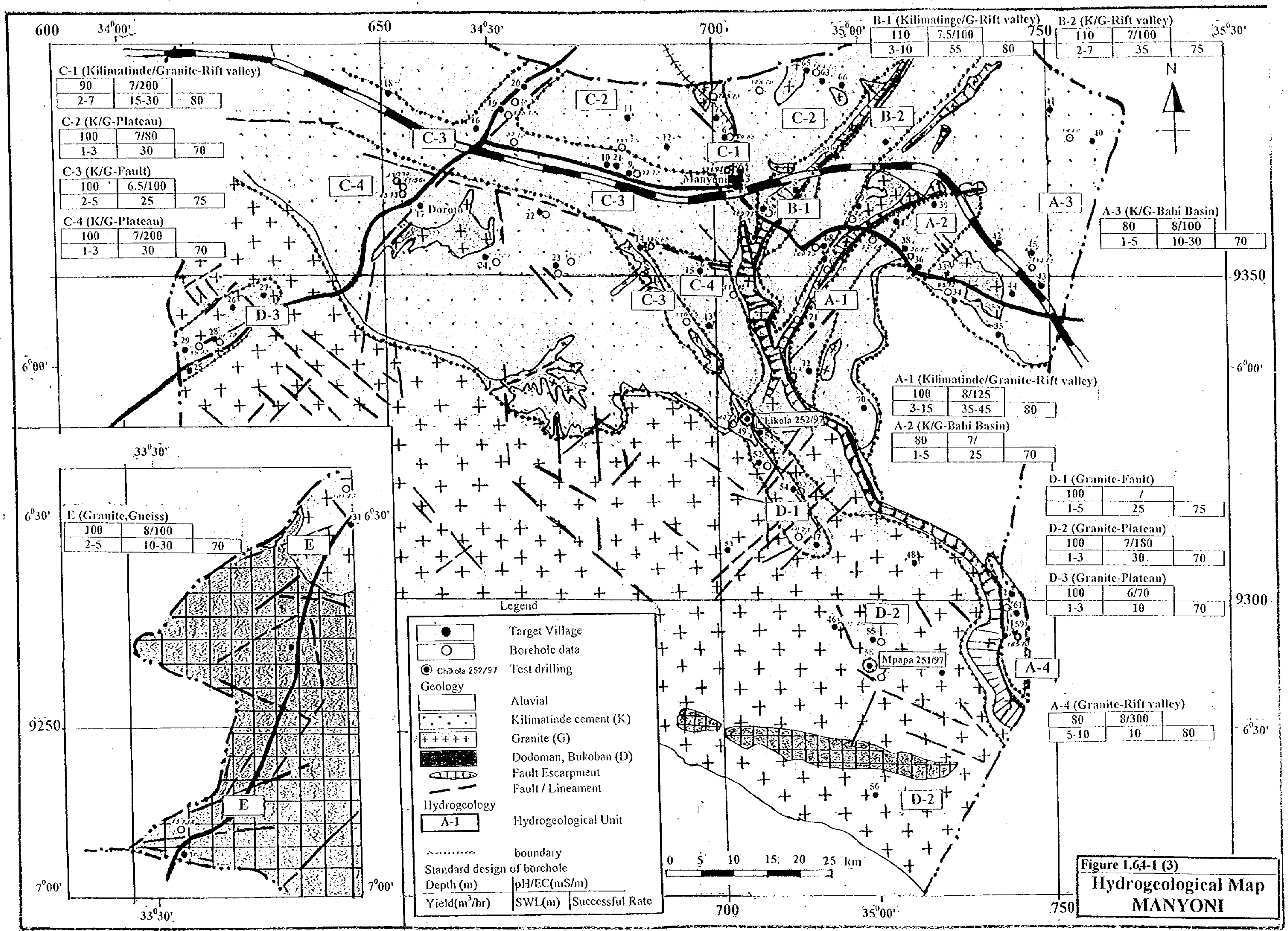


Figure 1.64-1 (3)
Hydrogeological Map MANYONI

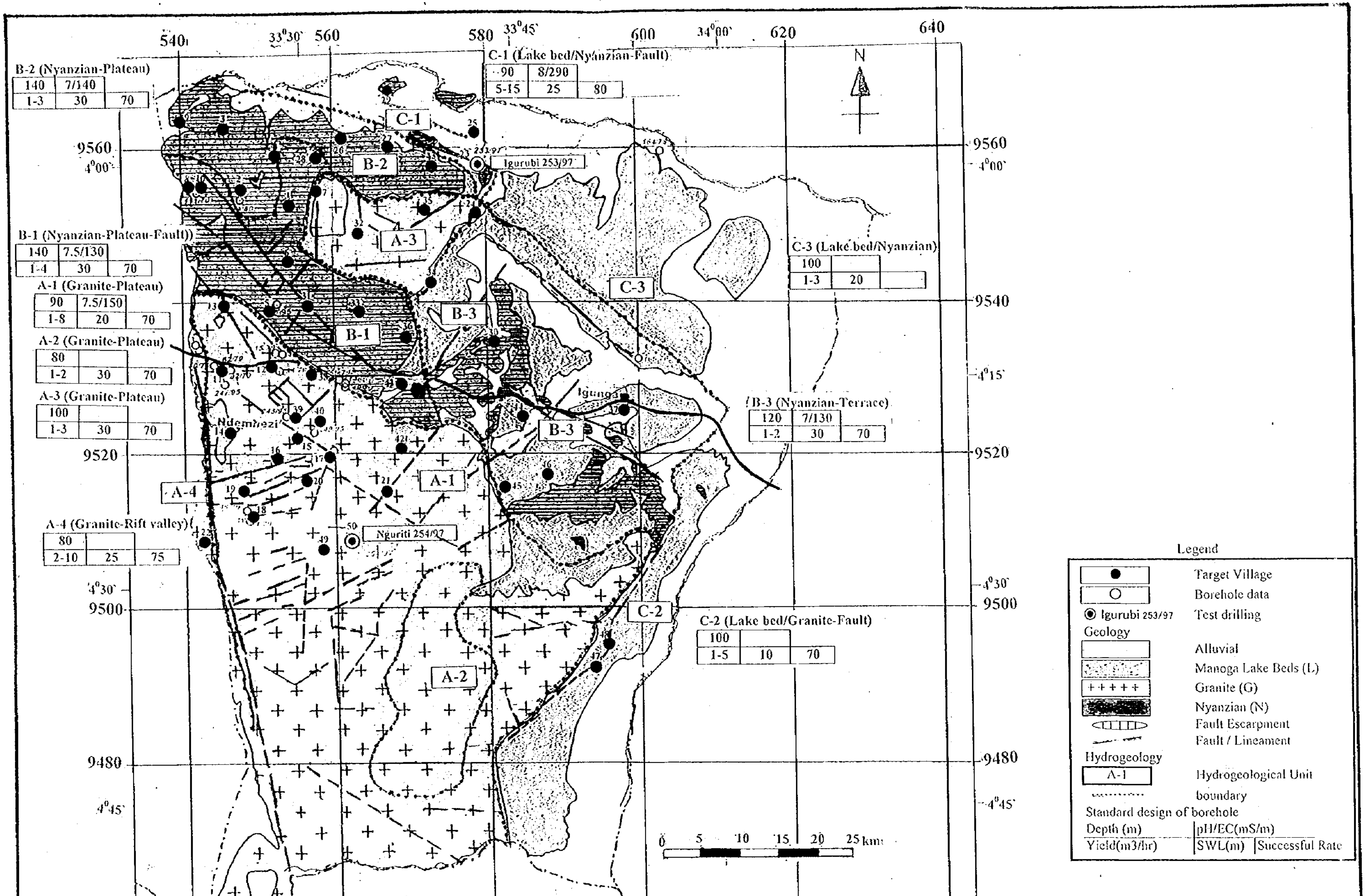


Figure 1.6.4-1 (4)
Hydrogeological Map IGUNGA