

The drilling equipment to be provided by the proposed Grant Aid will be used by the drilling division in the Water Resources Department for constructing boreholes for both Rural Water Supplies and Ranch Water Development Schemes. Drilling crews will be organized and supervised by the Drilling Division. A drilling crew normally consists of 10 to 15 members. A typical make up of a drill crew is shown below:

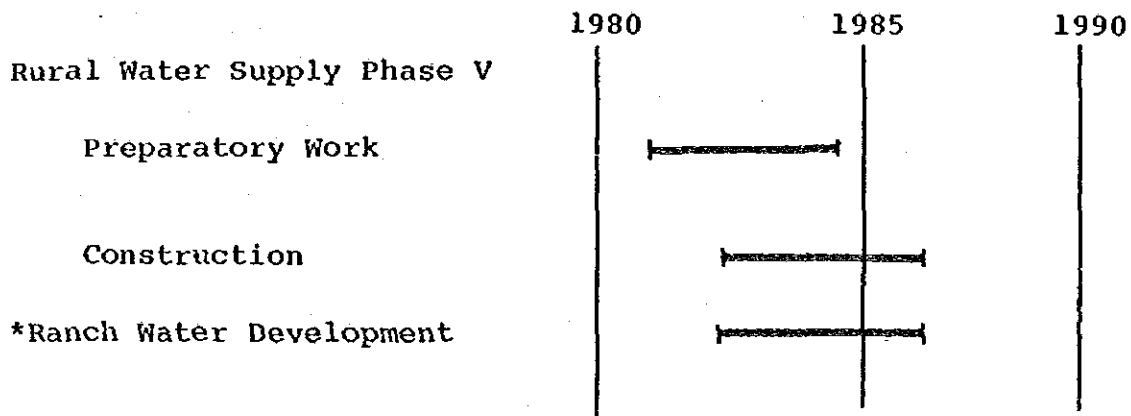
<u>Drilling Crew</u>	
1. Drilling Supervisor	1 person
2. Driller/Operator	2 persons
3. Drilling Assistant	6 persons
4. Drivers	2 persons
5. Mechanic	1 person
6. Watchman	2 persons
<div style="display: flex; justify-content: space-between; width: 100%;"> Total 14 persons </div>	

5-8 Proposed Time Schedule of the Project

According to the implementation schedule of the Ministry construction of schemes for project in Rural Water Supplies Programme Phase IV will start in 1982 and they are scheduled to be completed by the end of 1984. Currently implementation of the schemes of the Ranch Water Development is far behind the initial construction schedule. The Ranch Water Development Branch intends to complete construction as soon as possible.

The following implementation schedule of the project is proposed.

Fig. 17 Proposed Implementation Schedule
of the Project



CHAPTER 6

PROJECT EVALUATION

This project is part of the Rural Water Supplies Programme and Ranch Water Development Programme for Kajiado and Narok Districts.

At present, the total water demand in the project area is estimated at 55,000 m³/day. While the total design capacity of existing facilities and the total yield of all boreholes in the two Districts are only about 8,900 m³/day or 16% of the present demand.

When all 66 proposed sites of this project are completed, an additional 7,600 m³/day of drinking water will be produced. Together with the existing supply of water, the total capacity of water supply in the two Districts will be 16,500 m³/day. This increases the capacity to almost 30% of the present water demand, in effect, doubling the present capacity. In addition a part of this project will be able to contribute to livestock development by supplying water to over 15,000 km² of ranch area.

Although the total supply capacity at the completion of the project (16,500 m³/day) is only 16% of the total water demand expected in target year 2,000, the completion of the project will contribute significantly to the livestock development and can truly be appreciated.

A bi-product of this project is the technology transfer which improves the Drilling Branch by providing equipment and machinery.

Of further importance is the improvement of public hygiene by providing clean and safe drinking water to the local community and cattle. And the savings in labour for carrying water from remote water point should not be forgotten.

For successful project implementation, there are several points which should be considered.

Since a dry climate predominates in the project area, available water sources for rural water supply are limited in many cases to groundwater. The drilling teams will play an important role in the project implementation.

They will be provided with drilling equipment and machinery together with necessary material like screens and casings. As shown in Table 6 (Chapter 3) there are 19 drilling engineers and drilling inspectors in the Water Resources Department. They are experienced personnels in drilling activities and a few of them are to be key personnels in drilling teams to be organized when the Grant Aid is provided. These key personnels however, have experience in general drilling work but no experience in using the machines to be provided by the Grant Aid.

For this reason, training will be required for these key personnel. The training for operation and maintenance of the machines will take at least six months but a period of one year is more desirable.

Another item of importance is financing. The total project cost is estimated at Shs 86 million. Sh 48 million will be provided for machineries and materials, including pumps and engines by the Grant Aid for the construction of bore-holes.

The remaining Sh 38 million is for construction of additional facilities such as storage tanks, cattle troughs, and communal taps.

The appropriation of the final Sh 38 million is the responsibility of the Government of Kenya.

CHAPTER 7

THE ROLE OF GRANT AID FOR PROJECT IMPLEMENTATION

7-1 Required Items for Grant Aid

Based on the Basic Design Study and discussions made with the government officials concerned, the necessary items of the grant aid are identified and proposed as shown in APPENDIX 1.

The proposed items of grant aid consist of the fully equipped drilling units and casings and screens for 60 to 80 boreholes of an average depth of 150 m with 6 inch finishings. In addition, 60 units of monopumps and engines will be needed.

7-2 Specifications and Quantity of Items Required

The time schedule and geological conditions require rotary type drilling machine. Considering the usual lifetime of the machine (4 to 6 years) two units are required assuming the drilling capacity is one hole per machine in a month. Assuming 70% drilling efficiency a set of machines for drilling can complete 8 to 10 holes of 50 m to 150 m deep. With two drilling teams completely equipped, 15 to 20 holes will be constructed in a year. At this rate of borehole construction it will take three to four years to complete the construction of the required number of water sources for the project.

In determining the specifications and quantity of the required items shown in APPENDIX 1, various aspects of the project were carefully considered. These points are summarized below.

Table 19

TECHNICAL SPECIFICATION FOR WATER WELL DRILLING
MACHINES AND EQUIPMENT FOR PRODUCTION WELLS
AND ESTIMATED COST

- CONTENTS -

			¥ x 10 ⁶
01.	Deep Well Drilling Equipment	2 units	204
02.	Operation Accessories for Direct Mud Circulation	2 sets	150
03.	Submersible Type Pumping Test Equipment	2 units	12
04.	Well Logging Test Equipment	2 units	20
05.	Mobile Workshop	1 unit	20
06.	Mud and Foam Materials	1 lot	15
07.	Miscellaneous Materials	1 lot	20
08.	Spare Parts for Four (4) years operation	1 lot	100
09.	Transportation Equipment	1 lot	120
10.	Well Casing and Screen	1 lot	125
11.	Mono-Pump and Engine Unit	60 units	150
12.	Camping Equipment	1 lot	70
13.	Communication Equipment	1 lot	3

¥1,009,000,000 X 110% = ¥1,109,900,000.-

- 1) The numbers of drilling units was determined based on the total volume of work required for the project.
- 2) All necessary items for the drilling units efficient operation should be included.
- 3) Material and spare parts for two sets of drilling equipment for four years of operation are needed.
- 4) Hydrogeological conditions in the project area have been taken into account.
- 5) All the equipment, machinery and material should be products of Japan except items not available from Japan.
- 6) Specifications are needed for the open tender of procurement.
- 7) First priority is given to the procurement of drilling equipment and machinery so work can begin immediately and second priority to the screens and casings.

A list of detailed specifications and quantity of items is shown in APPENDIX 1 of this main text and summarized in Table 19.

7-3 Cost Estimate of Grant Aid

Estimated total cost of C.I.F. price at Mombasa is 48 million shillings (¥1,100,000,000) as shown in Table 19.

7-4 Comments on Procurement

This grant aid project does not require any engineering service, however, the procurement of the complete set of drilling equipment and machinery requires engineering knowledge since different kinds of equipment and machinery are needed depending on the drilling operation.

In similar grant aid projects for Kenya, the procurement was made in the donor country with the assistance of agents of donor countries nationality.

This method may help save time in procuring items, since, the limit for this Japanese Grant Aid is one year but the manufacturer may require five to six months to produce the equipment after receiving an order.

For this reason we recommend the assistance of an engineering consultant for procuring the equipment and machinery to be used in this grant aid project.

7-5 Contribution of Grant Aid to the Project

The rural water facilities to be constructed for the project are generally simple structures. A typical rural water supply facility consists of water source, (in this case a borehole), a storage tank, cattle troughs, and communal taps. The cost of boring the hole is larger than the construction cost of the rest of the facility.

Total construction cost for the project is estimated at Sh 86 million. The grant aid, however, will provide only the equipment/machinery and material for construction of the water source, pumps and engines.

This comes to about Sh 48 million, and brings the contribution of the grant aid to almost 60% of the total cost.

In addition to the supply of equipment, the grant aid will provide for the creation of two fully equipped drilling teams in the Drilling Branch of the Ministry.

CHAPTER 8

CONCLUSION AND RECOMMENDATIONS

The need for this project and the extent to which it will contribute to the improvement of the difference in the water supply levels between urban and rural areas was identified in Chapter 4 and Chapter 5.

Since the project area, Kajiado and Narok Districts, is one of the rural areas which have high potential for future development among these dry areas, a significant benefit to the districts' economy can be expected. Livestock development will directly be affected.

To make the greatest possible contribution, the Grant Aid will be applied the key factor in the project, the construction of boreholes.

For successful results to the international cooperation through the Grant Aid, the following are proposed:

- 1) Assistance of engineering consultants is recommended to complete procurement of necessary equipment machinery and material within the given time allowance.
- 2) Since the type of drilling machines are new to the Ministry and the drilling operation will be carried out with various combinations of equipment and machines, operational and mechanical training for the drillers and mechanics will be necessary. The training to be provided by the supplier of the equipment should be at least 6 months and preferably one year by two operators and one mechanic as requested by the Kenyan Government officials concerned. Further international technical cooperation following this training will be beneficial.
- 3) As discussed in Chapter 4, there are many different kinds of foreign assistance and in many cases a coordinator is dispatched from the donor agency. The coordinator's function is to coordinate the smooth operation of the project.

It is desirable to have Japanese experts for this purpose within the Ministry. A design engineer or a planning engineer of rural water supplies in the Engineering Department is recommended.

It is requested that the Ministry organize two drilling teams with key personnels to be selected out from the drilling inspectors of the Drilling Branch and make necessary arrangements for fund allocation for the design and construction work necessary to implement the project.

Finally, one problem common in this type of project is determining appropriate pump and engine specification in advance. Specifications are normally decided on after precise pumping tests determining the yield of each borehole. For the Grant Aid Project, however, the specifications need to be decided on at this time.

Specifications therefore, have been determined mainly on the results of hydrogeological studies, reviews of records, and discussions made with the government officials concerned. The mono-pump was finally selected due to its adjustable pump capacity and easy maintenance.

APPENDIX 1

SPECIFICATION AND QUANTITY OF THE
GRANT AID ITEMS

KAJIADO - MAROK UNDERGROUND

WATER DEVELOPMENT PROJECT

TECHNICAL SPECIFICATION

FOR

WATER WELL DRILLING MACHINES AND EQUIPMENT

FOR

PRODUCTION WELLS

TECHNICAL SPECIFICATION FOR WATER WELL DRILLING
MACHINES AND EQUIPMENT FOR PRODUCTION WELLS

-- CONTENTS --

01.	Deep Well Drilling Equipment	2 Units
02.	Operation Accessories for Direct Mud Circulation	2 Sets
03.	Submersible Type Pumping Test Equipment	2 Units
04.	Well Logging Test Equipment	2 Units
05.	Mobile Workshop	1 Unit
06.	Mud and Foam Materials	1 Lot
07.	Miscellaneous Materials	1 Lot
08.	Spare Parts for Four (4) Years Operation	1 Lot
09.	Transportation Equipment	1 Lot
10.	Well casing and screen	1 Lot
11.	Borehole Pump Unit and Diesel Engine	60 Units
12.	Camping Equipment	1 Lot
13.	Communication Equipment	1 Lot

S P E C I F I C A T I O N

0.1. Deep Well Drilling Equipment 2 Units

Quantity Required: two(2) complete units

1.1.1 General: The equipment shall be truck mounted rotary type drilling rig and used for water well drilling in alluvial and hard formations.

The equipment shall have drilling capacity of:

Drill pipe	Drill Depth
2 - $\frac{7}{8}$ "	750 (m)
3 - $\frac{1}{2}$ "	600 (m)
4 - $\frac{1}{2}$ "	Min. 250 (m)

All accessories for the satisfactory operation of the equipment shall be furnished whether or not the details are given herein.

The bidder shall submit the accurate layout drawings of the equipment to be offered.

1.2. Rig Frame: The rig frame independent from the truck chassis shall be fabricated with the shaped and structural steel and suitably reinforced. The frame shall be covered with a suitable nonslip plates where needed. All equipment, two large tool boxes for carrying hand tools and spare parts shall be separately supplied in two large and two small boxes with handle. All moving parts such as torque tubes, chain drive, etc. shall be covered with safety guards.

1.3. Pull Down: The mechanism of pulling up and down is driven by hydraulic cylinder combined with roller chains, having sufficient maximum thrust capacity, feed stroke, feed speeds for drilling purpose and necessary quick pull down is also required.

1. 4. **Drawworks:** Drawworks shall be equipped with free-falling mechanism to enable quick lowering the drill strings and automatic rock is required.
- Main Drum:** Single line pull shall have maximum capacity of more than 5 ton and line speeds shall be 0 - 60 m/min.
- Sand line:** Single line pull shall have maximum capacity of more than 2.5 ton and line speeds shall be 0 - 60 m/min. or equivalent capacity of air lift system for functional borehole cleaning.
1. 5. **Mud Pump:** The mud pump shall be double duplex reciprocating mud pump having a rated capacity of not less than 800 L/min. at maximum working pressure of 20 Kg/cm².
- The pump shall be driven from the main transfer case through clutch and mechanical drive. The pump shall be equipped with surge chamber, check valve, relief valve and pressure gauge.
1. 6. **Mast:** The mast shall be fabricated with the shaped and structural steel and electrically welded with rigid structural sections. The mast shall have a rated capacity of 25,000 kg. and hook load capacity of 12,500 kg. respectively, and a minimum clearance above the rotary table of 10.0m. The mast shall be raised and lowered by two double acting hydraulic cylinders with safety devices.
1. 7. **Power Unit:** An independent deck mounted diesel engine or truck diesel take off, driving mud pump, hydraulic pump for drawworks or power swivel in case of top drive type, 4 cycle, 6 cylinders, water-cooled continuous output shall not be less than 200 PS at 1,800 rpm. for use at 1,500 to 2,000m altitude.
1. 8. **Breakout System:** Hydraulic cylinder type breakout system operating with tubing tongs.
1. 9. **Levelling Jacks:** The equipment shall be fitted with preferably mechanical four levelling jacks fully equipped with safety devices and fully capable of lifting the equipment. The jacks shall be enclosed in housing to prevent dirt from damaging rod chromed surfaces.
1. 10. **Controls:** All the controls and gauges required for the drilling and rig operation shall be grouped and fitted at the driller's control panel and platform.
1. 11. **Lightings:** The equipment shall be arranged with the lightings, on the mast, rig frame and working areas required for the night operation.
1. 12. **Truck:** The truck to be mounted with the rig shall be 6 x 6 drive, heavy duty, right hand drive with hydraulic booster, and bonnet type truck with cab of latest model of common make available in Kenyan market for easy services and spare parts.
- GVW shall be not less than 21,000 kg. Towing jacks are necessary on front and rear.
1. 13. **Engine:** The truck shall be powered by a suitable water-cooled, 6 cylinders, 4-cycle diesel engine having a sufficient maximum output capacity not less than 200 HP. The radiator, oil filters and air cleaner shall be designed in consideration of the severe conditions at the working site.

- 1.14. Clutch: Dry single plate with damper springs, clutch disc and hydraulic with air booster control type.
- 1.15. Transmission: The truck shall be equipped with a transmission with at least 5 speeds forward and 1 reverse.
- 1.16. Brakes: The truck shall be equipped with service brakes acting on all wheels by compressed air and parking brake.
- 1.17. Rear Axle: Full-floating, double-reduction single speed by hypoid and helical gearings, tandem axle, dual drive.
- 1.18. Front Axle: Full-floating, double-reduction single speed by spiral bevel gearings with constant velocity universal joints.
- 1.19. Steering: Recirculating ball, with hydraulic booster assisting linkage.
- 1.20. Springs and Shock Absorbers: The heavy duty leaf springs and shock absorbers shall be provided.
- 1.21. Tires: The truck shall be equipped with 6 wheels with off-the-road tires and one complete spare wheel with tire and tubs.
- 1.22. Cab and Accessories: The cab of truck shall be fabricated with steel with full vision safety glass and equipped with driver's seat, doors with locks, gauges and meters, windshield wipers, outside rear view mirrors. Other manufacturer's standard accessories and instruments such as lights, signals, lamps, horn, batteries, etc. shall be furnished with.
- 1.23. Standard Accessories: Each 1 set of standard tools for drill unit, pump engine and truck. 1 No. of jet hopper mixer with 75 mm hose connection. 1 set of guy line cable with accessories. Each 2 sets of parts list and operation manuals.
- 1.24. Injection System: Displacement 3.9 to 6.4 GPM. pressure 500 to 600 psi Lubricator for the hammer adjustable capacity 0 to 2 liters/hour for 10 hours operation with level indicator.
- 1.25. Portable Air Compressor: Screw type 250 psi, 750 cfm, trailer mounted type equivalent to XHP 750 - SGM. Ingersoll-Rand.

02.	OPERATING ACCESSORIES FOR DIRECT MUD CIRCULATION (DIRECT MUD CIRCULATION DRILLING)	2 SETS
	The manufacture shall supply the following accessories for operation of direct mud circulation or approved equivalent to the satisfaction of the engineer.	
2.1	Flush joint drill pipe, 4-1/2" O.D. with tool joints and thread protectors on both ends, approx. 3m long	200 nos. (300m/unit)
2.2	Drive, rod, 3-1/2 IF x 120mm x 2.5m or Kelly, round 3-3/4" with 3 flutes and 1" drive pin, 23ft long, lame hardend.	2 nos.
2.3	Drill collar, 6-1/4 O.D. 3m long, approx. 405 kg. with 4" IF box to pin connections and thread protectors	10 nos.
2.4	Three cutter rock roller bit, size 6 with 3-1/2 REG pin joint, for hard formation	10 nos.
2.5	- do - size 7-7/8" with 4-1/2 REG pin joint, for hard formation	30 nos.
2.6	- do -, size 9-7/8" with 6-5/8 REG pin joint, for hard formation	15 nos.
2.7	Three cutter rock roller bit, size 13-3/4" with 6-5/8 REG pin joint, for soft formation	8 nos.
2.8	Subs and adapters:	
	a) Drive rod sub, 3-1/2 IF box to pin connection or Kelly head adaptor	4 nos.
	b) Sub. between drill pipe and drill collar, 3-1/2 IF box to 4" IF pin	4 nos.
	c) Bit sub. 4" IF box to 6-5/8 REG box	6 nos.
	d) Bit sub. 3-1/2 IF box to 3-1/2 REG box	4 nos.
2.9	Heavy duty water swivel, 12 ton capacity, with 3-1/2 IF left hand and 75 mm hose connection.	1 nos.
2.10	Hoisting swivel, telescoping type, with 3-1/2 IF pin connection	4 nos.
2.11	Lifting plug for drill collar, 4" IF pin connection	2 nos.
2.12.	Drill collar spider to be mounted on the drilling rig, with slips for 6-1/4" drill collar and 3-1/2 IF drill pipe.	2 sets
2.13	Break-out tong for 3-1/2 IF drill pipe	2 sets
2.14	- do -, for drill collar	2 sets
2.15	Swing hanger, 3-1/2"	2 nos.
2.16	Hoisting wire rope with safety clevis	2 rolls
2.17	Wire rope with safety clevis for sand line.	2 rolls
2.18	Travelling block, size 380 mm, single sheave.	2 nos.

2.19 Hoses with fittings:

- | | | |
|----|---|--------|
| a) | Suction hose with quick couplings,
150mm x 4.5 m long | 2 nos. |
| b) | Foot valve with flange, 150 mm | 2 nos. |
| c) | Delivery hose, high pressure type,
75 mm x 6 m long | 2 nos. |
| d) | By-pass and mixer hose, high pressure type,
75 mm x 6 m long | 2 nos. |

2.20 Hydraulic jacks, 50 ton capacity 4 nos.

2.21 Taper tap for 3-1/2 IF drill pipe 2 nos.

2.22 Bit breaker for 10-5/8" bit 2 nos.

2.23 - do -, for 12-1/4" bit 2 nos.

2.24 Operating hand tools: 2 sets

- | | | |
|----|---|--------|
| a) | Super tong, ST-2 | 4 nos. |
| b) | - do -, ST-3 | 4 nos. |
| c) | Pipe wrench, 900 mm | 4 nos. |
| d) | - do -, 600 mm | 4 nos. |
| e) | - do -, 450 m | 4 nos. |
| f) | Sledge hammer with handle, 4.5 kg | 2 nos. |
| g) | Engineering tools kit such as steel level, socket
wrench set, files, chisels, etc. | 2 sets |
| h) | Steel tool box with lock and key, large size | 2 nos. |

2.25 Miscellaneous supplies:

- | | | |
|----|------------------------------------|---------|
| a) | Manila rope, 20 mm x 30 m long | 2 rolls |
| b) | Snatch block, single sheave, 200mm | 2 nos. |
| c) | - do -, double-sheave, 200 mm | 2 nos. |
| d) | Hand winch with steel cable | 2 nos. |
| e) | Oil jug | 4 nos. |
| f) | Oiler, jet type | 4 nos. |
| g) | Shovel with handle, round point | 4 nos. |
| h) | - do -, square | 4 nos. |
| i) | Pick with handle | 4 nos. |
| j) | Chain block, 5 ton capacity | 2 nos. |
| k) | Wire sling, 12.5 mm x 6 m long | 4 nos. |
| l) | - do -, 12.5 mm x 3 m long | 8 nos. |
| m) | - do -, 12.5 mm x 1.5 m long | 8 nos. |
| n) | - do -, 18 mm x 1.5 m long | 4 nos. |
| o) | Bench vice, 150 mm | 2 nos. |

2.26 Buckets carrying cans oil containers 2 sets.

2.27 Water tank 5m³ capacity 2 sets

2.28 " " 3m³ " 2 sets

2.29	Hard rock drill hammer and sub. to fit drill collar for 6" equivalent to Mission B53-15	2 sets
2.30	Hard rock drill hammer and sub. to fit drill collar for 8", 10" equivalent to Mission A63-15	4 sets
2.31	Thread compound containing 40 per cent finely powdered metallic zinc. or approved equivalent	1 lot
2.32	6" button drop center	30 nos.
2.33	8" " "	20 nos.
2.34	10" " "	10 nos.
2.35	High pressure air hose 3" I.D. x 10m	2 nos.
2.36	Spare parts for two years complete one lot consists of:	1 lot
	a) Tob sub	
	b) Drive sub	
	c) Check valve dart	
	d) Check valve spring	
	e) Choke	
	f) O - ring for piston and for bit retainer ring	
	g) Piston	
	h) piston retainer ring	
	l) Bit retainer ring.	
3.37	Disassembling tools for hammer	2 sets
03.	<u>Submersible Type Pumping Test Equipment</u>	<u>2 Units</u>
3-1.	Submersible electric motor pump for 150 mm size wells, 15 stages, TDH 100 m, discharge 200 liters/min, 400 volts, 50 Hz, 7.5 KW, 2,900 rpm.,	2 nos.
3-2	Submersible electric motor pump for 200 mm size wells, 4 stages, TDH 50 m, discharge 400 liters/min., 400 volts, 50 Hz, 7.5 KW, 2,900 rpm.,	2 nos.
3-3	Accessories including star-delta switch, electric cable with necessary bundle for cable fixing valves, discharge pipes for 2" flush with attachment and tools for maximum installation of 100m.	2 units
3-4	Measuring box with drain valve, approx. dimension shall be 0.5m x 0.8 m x 1.0 m.	2 nos.
3-5	Portable diesel generator for the test pump, rated output 19 KVA, 50 Hz, 400 volts, and with 20 m captyre cable	2 units

O 4. TESTING EQUIPMENT2 UNITS

4-1 Electric log measuring unit

1 unit

Well logger to include the following items, functioning and capability shall be equivalent to geologger 300:-

- a) Portable well logger with power supply to operate from external 12 volt vehicle battery.
- b) Recorder: Self balancing recorder with acrylic dust cover, synchronized with sheave pulse at scales 1/100. 1/200.
- c) Modularised measurement system to include long and short normal resistivity, temperature and caliper sonde.
- d) Self potential and resistivity probes to facilitate. Long and short normal resistivity. Self potential logging.
- e) Hand winch with measuring sheave and chart synchronization, to take three hundred meters of logging cable.
- f) Three hundred meters of logging vinyl cable with cable header.
- g) All necessary connecting cables complete with plugs and sockets.
- h) Five rolls of chart paper
- i) All necessary surface electrodes.
- j) Well head tripod.
- k) Carrying case for surface equipment.
- l) Operating manual - 2 copies
- m) Maintenance manual - 2 copies.
- n) Other necessary items.
 - Battery (12V, 32A)
 - Battery charger
 - Test tools.

4-2 Electric log measuring unit

1 unit

One complete unit consists of the following items. Functioning and capability shall be equivalent to geologger 3000.

- a) Portable logging system have hard aluminium with air-tight top system case, electric unit, density unit, linear ratemeter unit, measuring unit, recording unit, power unit. depth counter handwinch and necessary probes for resistivity - SP, micro - resistivity, caliper temperature, density and natural gamma.
- b) Recorder: Automatic balance method with 10 cm width of paper, feltpen, input impedance 5 m input sensitivity 10 mV. S. accuracy # 1 % F.S.
- c) Measuring range: 5.10.50.100.500 1K, 5K, 10K -m resistivity is directly displayed by calculating circuit.
- d) Three hundred meters of logging vinyl cable with cable header.

- e) All necessary connecting cables complete plugs and sockets.
- f) Five rolls of chart paper
- g) Carrying case for surface equipment.
- h) Two copies of maintenance/operation manuals.
- i) Battery (120) battery charger, test tools

REMARKS:

The geophysical well logging equipment supplied shall be robust construction but highly portable and capable of operating in ambient temperatures of between 10C and 35C and high humidities common in tropical climates. All electric component boards and soldered connections shall be tropicalized with varnish or other sealant. The equipment is capable of withstanding long journeys over very rough roads.

4-3	Electric conductivity meters, transistorized, with extra conductivity cell	6 nos.
4-4	Water level indicator to measure water level in the borehole, battery operated, with double electric cable, capacity 200 meters.	4 nos.
4-5	Portable water analysis laboratory kit for Fe, Mn, F and PH valve.	2 nos.
4-6	Solar Electric calculator	4 nos.
4-7	Seismic prospecting instruments	1 set
	1) Seismic Amplifier	1 no.
	(Specifications)	
	Amplifier unit:	
	Channels	24
	Gain	90 dB
	Input impedance	215 ohm
	Frequency characteristics	3 to 5 KHz
	Control unit:	
	Oscillator	Frequency 12.5, 25, 50, 100Hz. PU test/leak test, telephone circuit/shot mark circuit.
	Control circuits	DC 12V, Max. 1.5A.
	Power:	
	2) Oscillographs	1 no.
	(Specifications)	
	Channels	32
	Optical arm	200 mm.
	Lamp	Halogen
	Timing	
	Recording width	Whole width
	Lamp	Xenon lamp
	Line	10 m sec, 50 m sec.
	Accuracy	0.1%
	Recording	
	Paper speed	15, 30, 60, 100 cm/sec.

	Auto drive	1 to 10 sec.
	Recording paper	6 in. x 100 ft.
	Power	DC 12V, Max. 5A.
3)	Blaster	2 nos.
	(Specifications)	
	Detonating voltage	200V.
	Attaching circuits	Shot mark circuit/cap test/remote control/battery check.
4)	Take-out cable for 24 channels 10m interval	200m x 2 nos.
5)	Land cable for 24 channels	200m x 1 nos.
6)	Telephone cable	500m x 2 nos.
7)	Connector between amplifier and land cable, land cable and take out cable.	
8)	Cable reel	3 nos.
9)	Geophone 14Hz, Marsh-type	30 nos.
10)	Storage battery 12V	2 nos.
11)	Charger for battery	1 no.
12)	Lead cable for blast	100 m x 3 nos.
13.	Oscillopaper 6 in x 100 ft.	80 nos.
14)	Shading sheet	2 sheets
15)	Spare parts and other consumption material	1 set
16)	Engineering tools	1 set
0 5.	<u>MOBILE WORKSHOP</u>	<u>1 UNIT</u>
5-1	Heavy duty mobile workshop truck, diesel driven 4 x 4 right hand steering.	
	The truck shall have following specifications.	
	Engine:	Diesel, 4 cycle, vertical, 6 cylinders, in-line, over head valve, water-cooled, maximum output of 190 HP at 2,350 rpm. and maximum torque of 65 mkg at 1,200 rpm. or equivalent.
	Transmission:	Five forward speeds and one reverse all constantmesh.
	Rear axle:	Full-floating, single-reduction, single- speed-by spiral bevel gearings.
	Steering:	Recirculating ball with hydraulic booster assisting linkage.
5-2	Diesel engine driven 250A AC welder with 5KVA AC generator	

5-2-1. DC Arc Welder

Type:	Drip-proof type	
Capacity:	8.75 kw	
Voltage:	35 v	
Current:	250 A	
Range of current regulation:	30 A - 250 A	
Revolution:	1,500 rpm. at 50 Hz (1,800 rpm. at 60 Hz)	
Duty cycle:	60%	
Control panel:	Pilot lamp	1 pc.
	DC ammeter	1 pc.
	DC voltmeter	1 pc.
	Welding terminal	1 pair
	Welding current regulator w/handle	1 set
	Filed regulator w/handle	1set
	Polarity change switch	1 pc.

5-2-2 AC Generator

Type:	Static self-excited system revolving armature type.	
Capacity:	5 KVA	
No. of phase:	Three	
Voltage:	200 V	
Frequency:	50 Hz (60 Hz)	
Revolution:	1,500 rpm. (1,800 rpm.)	
No. of pole:	4	
Power factor:	80%	
Control panel:	AC ammeter	1 pc.
	AC voltmeter	1 pc.
	Voltage regulator w/handle	1 pc.
	No. Fuse breaker	1 set
	Distribution switch board:	1 set.

5-2-3. Diesel Engine

Type:	Air-cooled 4 cycle diesel, 3 cylinder.
Output:	36.5/1,800 rpm.

5-2-4. Welding Tools

1)	Electric cord, 20 m.	2 pcs.
2)	Helmet	1 pc.
3)	Leather gloves	1 dozen
4)	Welding holder	2 pcs.
5)	Wire brush	1 pc.
6)	Hammer	1 pc.
7)	Earth clip	2 pcs.
8)	Welding shield, helmet type	2 pcs.
9)	Glass for above	4 pcs.
10)	Plate for above	4 pcs.
11)	Welding rod, 4 mm	10 kg.
12)	- do -, 3.2 mm	10 kg.

5-3. Oxy-acetylene cutting, welding & brazing equipment

1)	Oxygen container, 46 lit	1 pc.
2)	Acetylene container, 41 lit	1 pc.
3)	Pressure regulator for acetylene	1 pc.
4)	Pressure regulator for acetylene	1 pc.
5)	Cutting torch set	1 set
6)	Welding torch set	1 set
7)	Acetylene hose, 20 m	1 pc.
8)	Oxygen hose, 20 m	1 pc.
9)	Welding goggles	1 pc.
10)	Hose band, stainless	4 pcs.
11)	Welding rod, mild steel, 20 Ømm	3 kg.
12)	-- do --, 26 Ømm	3 kg.
13)	-- do --, 32 Ømm	3 kg.
14)	-- do --, cast metal, 6.0 mm	3 kg.
15)	Lighter	1 pc.
16)	Welding gloves	1 pair.

5-4. Lubrication equipment

1)	Grease gun, high pressure level type, 200 cc	1 pc.
2)	Extention pipe, 2" type	2 pcs.
3)	Extention hose, bottom head type	1 pc.
4)	Extention hose, with coupling	1 pc.
5)	Oil measure, 1 lit.	1 pc.
6)	Oil measure, 2 lit.	1 pc.
7)	Rotary pump	1 pc.
8)	Piston oiler	1 pc.
9)	Drum can opener spanner	1 pc.
10)	High pressure grease pump	1 set.

5-5. Electric equipment

1)	Electric drill, 6.5 mm	1 set
2)	-- do --, 13 mm	1 set
3)	-- do --, 20 mm	1 set
4)	-- do --, bench type	1 set
5)	Electric grinder, bench type	1 set
	205 mm w/grinder wheel	
	fine	2 pcs.
	medium	2 pcs.
	coarse	2 pcs.
6)	Electric portable grinder	1 set
	100 mm w/grinder wheel	
	fine	2 pcs.
	medium	2 pcs.
	coarse	2 pcs.
7)	Ignition wrench, metric	1 set
8)	Battery terminal plier	1 pc.
9)	Screw driver, insulated plastic driver	1 pc.
10)	Screw driver, insulated plastic driver	1 pc.
11)	Screw driver, spark testing high tension	1 pc.
12)	Iron, electric soldering iron, 200W	1 pc.
13)	Paste soldering 400 g	1 pc.
14)	Solder 1 kg	1 pc.
15)	Cutting plier, 200 mm	1 pc.
16)	Nipper, 150 mm	1 pc.
17)	Plug gap gauge	1 pc.
18)	Plastic hammer, 450 g	1 pc.

	19)	Hydrometer	1 pc.
	20)	Battery filer	1 pc.
	21)	Tachometer	1 pc.
	22)	Volt ampare meter	1 pc.
	23)	Megger, 500V 1 - 100 Mohm	1 pc.
	24)	Extension cord 25 m w/plug & consent	1 pc.
	25)	Battery charger 50A	1 set
5-6)		Air Compressor	
	1)	Air compressor, 0.4 kw	1 set
	2)	Air hose, 10 meter	1 set
	3)	Spray gun	1 set
	4)	Air gun	1 set
5-7.		Hydraulic press 10 ton	
	1)	Hydraulic press 10 ton	1 set
5-8.		Diesel engine service equipment	
	1)	Nozzle tester	1 set
	2)	Diesel compression gauge	1 set
	3)	Special service tool set for injection pump	1 set
	4)	Adjustable reamer (11 pc./set)	1 set
	5)	Screw extractor	1 set
	6)	Cylinder gauge (50-150m/m) Carl-Mahr type	1 set
	7)	Lapping compound 450 g	1 pc.
5-9.		Gasoline engine service equipment	
	1)	Compression gauge	1 set
	2)	Vacuum gauge	1 set
	3)	Plug service set	1 set
	4)	Timing light	1 set
	5)	Plug wrench set	1 set
5-10.		Tire service equipment	
	1)	Pressure gauge, 10 kg/cm ²	1 pc.
	2)	Tire lever, 450 mm	1 pc.
	3)	Tire lever, 510 mm	1 pc.
	4)	Valve repair	5 pcs.
	5)	Hot pach, 30 pcs./set	5 pcs.
	6)	- do -, 30 pcs./set	5 pcs.
	7)	- do -, 18 pcs./set	5 pcs.
	8)	Clamp	2 pcs.
5-11.		Machinist tools set	
	1)	Hack saw blade, length 250 mm, width 1/2" w.	6 doz.
	2)	Caliper, firm joint, outside 200 mm	1 pc.
	3)	Caliper, firm joint inside 200 mm	1 pc.
	4)	Micrometer caliper outside 0-150 mm	1 set
	5)	Chisel	
		Chisel, cape 7 x 180 mm	1 pc.
		Chisel, flat 10 x 140 mm	1 pc.
		Chisel, flat, 13 x 160 mm	1 pc.
		Chisel, flat, 16 x 180 mm	1 pc.
		Chisel, flat, 19 x 185 mm	1 pc.
	6)	Divider spring, 200 mm	1 pc.
	7)	File set in cloth case w/handle	1 pc.

	File flat bastard, 250 mm	1 pc.
	File flat medium, 250mm	1 pc.
	File flat smooth 250 mm	1 pc.
	File round, bastard, 250 mm	1 pc.
	File round, medium, 250 mm	1 pc.
8)	Needle file, (12 pcs./set)	1 set
9)	Hack saw, adjustable, 200 - 300 mm	2 pcs.
10)	Goggle	1 pc.
11)	Center gauge	1 pc.
12)	Gauge, screw pitch (4 pcs./set)	1 set
13)	Copper, hammer, 1 lb. w/handle	2 pcs.
14)	Ball peen, hammer, 1 lb. w/handle	1 pc.
15)	Ball peen hammer, 2 lg. w/handle	1 pc.
16)	Oil push button	1 pc.
17)	Plier, combination, 200 mm	2 pcs.
18)	Plier, combination, 200 mm	2 pcs.
19)	Combination, punches, in wood case set	1 set
20)	Steel rule, folding 1 m	1 pc.
21)	Steel rule, 600 mm, straight	1 pc.
22)	Screw driver, insulated handle, 150 mm	1 pc.
23)	Screw driver, insulated handle, 250 mm	1 pc.
24)	Screw driver, through type, small, 100 mm	1 pc.
25)	Screw driver, through type medium, 200 mm	1 pc.
26)	Screw driver, through type large, 250 mm	1 pc.
27)	Screw driver, philips type 218 mm	1 pc.
28)	Screw driver, philips type 283 mm	1 pc.
29)	Screw driver, philips type 255 mm	1 pc.
30)	Combination square set	1 set
31)	Oil stone 8" x 2" x 1"	1 pc.
32)	Wrench, adjustable 8"	2 pcs.
33)	Wrench, adjustable 12"	2 pcs.
34)	Wrench, adjustable 450 mm	2 pcs.
35)	Socket wrench 1/2 sq. drive (13 pcs./set)	1 set
36)	Breast drill 1/2"	1 pc.
37)	Scraper 9"	1 pc.
38)	Surface plate, 300 x 450 mm	1 pc.
39)	Surface gauge, 200 mm	1 pc.
40)	Dial indicator w/magnet stand	1 pc.
41)	V block, 100 mm (2pcs./set)	1 set.
5-12	Forge and anvil	
1)	Anvil cast steel 50 kgs.	1 pc.
2)	Tongth blacksmith, round	1 pc.
3)	Tongth, flat	1 pc.
4)	Tongth, straight type flat	1 pc.
5-13.	Machinist vice	
1)	Reed type vice, 100 mm	1 set
2)	Swivel vice, 100 mm	1 set
5-14.	Tap and dies	
1)	Screw plate, 1/4" - 1"	1 set
2)	Screw plate, 6-18 mm	1 set
5-15.	Work bench.	2 sets.

5-16.

Wrench and others

1)	Heavy duty socket wrench 1/2 sq. dr.	1 set
2)	Open end wrench (6 pcs./set)	1 set
	6x7, 8x10, 11x13, 12x14, 17-19, 22x24	
3)	Wrench adjustable 450 mm	1 pc.
4)	Hammer, double face sledge, 10 lbs.	1 pc.
5)	Vice wrench	1 pc.
6)	Screw driver, 200 mm	1 pc.
7)	Screw driver, 300 mm	1 pc.
8)	Feeler gauge in inch	1 set
	.0015 .002 .004 .006 .003 .008 .010 .12 .015	
9)	Feeler gauge in mm	
	04 .05 .06 .07 .08 10 .15 .20 .30	1 set
10)	Thickness gauge, 25 leaves in metric	1 pc.
11)	Pry bar 400 mm	1 pc.
12)	Pinch bar 400 mm	1 pc.
13)	Puller, slider hammer	1 pc.
14)	Offset wrench set	1 set
	8x10, 11x13, 12x14, 17x19, 22x24, 24x27	
15)	Puller, heavy duty bearing	1 set
16)	Torque wrench 1,800 cm-kg	1 set.

5-17.

Light and others

1)	Flod light w/bracket	1 pc.
2)	Garage lamp	1 pc.
3)	Working lamp	1 pc.

5-18.

Fire extinguisher

1 pc.

0 6.	<u>MUD AND FOAM MATERIALS</u>	<u>1 LOT</u>
	a) Full Bentonite,	20 tons
	b) Na-Carboxy methyl cellulose (CMC)	2 tons
	c) Foaming agent for DTH hammer or air-flash drilling (180 liter drum can)	40 nos.
	d) Mud testing equipment including mud balance, funnel viscosity meter, etc.	2 sets.
0 7	<u>MISCELLANEOUS MATERIALS</u>	<u>1 LOT</u>
	Including steel bar, steel plate, bolt and nuts, wire ropes, angles tee, nipple, pipes, valves, welding materials, cement, mission oil, hydraulic oil etc.	
	The providing materials shall be listed up by the supplier.	
0 8.	<u>SPARE PARTS FOR MACHINERY AND OTHERS (FOR 2 YEARS NORMAL OPERATION)</u>	<u>1 LOT</u>
	1. Spare parts for drill unit	2 sets
	2. Spare parts for pump unit	2 sets
	3. Spare parts for truck	2 sets
	4. Spare parts for air compressor	2 sets
	5. Supplies for hoses, fittings, slips, water swivel parts, wires etc.	2 sets
	6. Spare parts for pumping unit	1 lot
	7. Supplies for wrenches	2 sets
	8. Spare parts for vehicles	2 sets
	9. Spare parts for other equipment	1 lot.
0 9.	Transportation equipment	1 lot
	a) a) Station wagon, diesel drive 4x4 right hand driver	2 nos.
	The jeep shall have diesel engine 6 cylinders in line, maximum output of 100 ps at 2,3000 rpm and maximum torque of 20 mkg at 2000 rpm or approved equivalent.	
	Clutch shall have single dry plate with diaphragm springs.	
	Front axle shall be full-floating hypoid gear drive and semi-floating in rear axle. Brakers is front and rear drums with tandem master cylinders and booster or equivalent.	
	b) Heavy duty tank lorry, diesel driven, with 6,000 liters tank 4 x 4 right hand steering.	
	Tank lorry for water transport	2 nos.
	Tank lorry for fuel transport	2 nos.

The tank lorry shall have diesel engine. 4 cycle 6 cylinders in-line over head valve, water-cooled maximum output of 150 HP. at 2000 rpm. with five forward speeds and one reverse transmission. Rear axle shall be full-floating, single reduction, single speed by spiral level gearings. Steering shall be recirculating ball with hydraulic booster assisting linkage or equivalent. Water tank shall be equipped with pumping set valve. Manhole and necessary accessories.

- c) Flat body truck with 3 ton crane diesel driven 4 x 4 right hand steering maximum loading capacity of 7,500 kg. body length 6.5 m with opening on both sides. 2 nos.

The engine shall be diesel 4 cycle 6 cylinders in-line over head valve water cooled and shall have sufficient maximum output and torque capacity.

Transmission shall be in five forward speeds and one reverse, rear axle, full-floating single-reduction single speed by spiral level gearings. Steering shall be recirculating ball with hydraulic booster assisting linkage.

Crane shall have 3 ton capacity at 2 m complete with 2 sectioned fully hydraulic tabscooping 600 m. Hydraulic motor driven winch and hydraulic operated outriggers or equivalent.

- d) 4 wheels-driven tractor with 8 ton trailer 6.5 m length body. 2 nos.

- | | | |
|-------|--|-----------------------------------|
| 10. | <u>Well Casing and screen</u> | <u>1 Lot</u> |
| 10-1. | 10" Well casing pipe
Carbon steel pipe for general
structural purposes with bevel-end and
reinforcement patch.

JIS G3444 STK-41

O.D 267.4mm
Thickness 6.6 mm, Unit length 6.0m | 300 pcs. |
| 10-2. | 8" Well casing pipe
Carbon steel pipe for general
structural purposes with bevel-end and
reinforcement patch
JIS G3444 STK-41
O.D. 216.3mm
Thickness 5.8mm Unit length 6.0m | 300 pcs. |
| 10-3. | 6" Well casing pipe
Carbon steel pipe for general
structural purposes with bevel-end and
reinforcement patch
JIS G3444 STK-41
O.D. 165.2mm
Thickness 5.0mm, Unit length 6.0m | 1,000 pcs. |
| 10-4. | Stainless steel well screen
N.D. 6" JIS G4308
Pipe base wire wrapped screens.
Slot opening 0.3 mm and 0.5 mm
Unit length 3.0 m Effective length 2.5m | 300 pcs. |
| 10-5. | Stainless steel well screen
N.D. 8" JIS G4308
- do - | 50 pcs. |
| 10-6. | Lowering and lifting casings
a) Casing band for 10" casing
b) - do -, 8" casing
c) - do -, 6" casing | 2 sets
4 nos
4 nos
4 nos |
| 11. | <u>Borehole Pump Unit and Diesel Engine</u> | 60 units |
| 11-1. | The pump unit shall have the capacity of
6,000 liters per hour at 100 m total head.
The pump unit shall be equiped with sufficient
power unit to the functional system and with
necessary accessories. | 30 units |
| 11-2. | The pump unit shall have the capacity of
9,000 liters per hour at 150 m total head.
The pump unit shall be equiped with sufficient
power unit to the functional system and with
necessary accessories. | 30 units |

12. CAMPING EQUIPMENT

1 LOT

a) Caravan, trailer mount, for drilling

2 Nos

Type: Single axle trailer mount, with two bed rooms and one locker room.

Trailer: Approx. 6.9 (L) x 2.6(W) x 3.8(H) Max. payload 940 Kg.

Floor: Linoleum, 2.0 mm thickness.

External wall: Aluminium, 1.0 mm thickness.

Interior wall: Decorated plywood, 5.0 mm thickness.

Heat insulator: 100 mm thickness for roof, 50 mm for wall.

Door & window: Aluminium sash.

Electric equipment: 100 or 200V current wiring, embedded in panel.
Illuminator; FL40W x 2 2 Nos. and 20W 1 No.

Accessories: Locker, folding table, one spare tyre and carrier.

b-1) Trailer mounted dining facilities:

2 units

Type: Single axle trailer mount, with one kitchen room.

Trailer: Approx. 6.9(L) x 2.6(W) x 3.8(H) Max. Payload 940 kg.

Floor: Linoleum, 2.0 mm thickness with waterproof plywood.

External wall & roof: Aluminium, 1.0 mm thickness

Interior wall: Decorated plywood, 5.0 mm thickness.

Heat insulator: 100 mm thickness for roof, 50mm for wall.

Door & Window: Aluminium sash.

Electric equipment: The power source shall be 2200 50 HZ 1 phase FL 40 W and FL 20W.

Accessories: Gas table, sink, kitchen table, dining table with chair.

Generator: Diesel generator sound proof type. 19 KTA.

b-2 Camping Tents:

2 ^m H x 2.5 ^m W x 2.5 ^m L	20 nos
b-3 Sheet	
ZK x 3K	6 nos
b-4 Sheet	
3K x 4K	2 nos

13. Communication equipment 3 sets
- 1) For mobile station in field 3 sets

Frequency range	rated frequency	8.018.5 KHZ
Power	13 KW	
Bandwidth and type of emission	16 F 3	

Simplex operation with high gain
antena and installation materials

One set of selective calling unit.

APPENDIX 2

HYDROGEOLOGICAL STUDY REPORT

Hydrogeological Study Report

INTRODUCTION	<u>Page</u>
Chapter 1. General Description of the Area	2
Chapter 2. Outline of Survey	4
Chapter 3. Meteorological Conditions	9
3-1 Temperature	9
3-2 Precipitation	10
3-3 Evapo-transpiration	16
Chapter 4. Topography and Geology	19
4-1 Topography	19
4-2 Geology	23
4-3 Hydrogeology	25
Chapter 5. Aquifers	29
5-1 Classification of Wells	29
5-2 Water Level	46
5-3 Water Quality	46
5-4 Hydrogeological Constants	50
Chapter 6. Geo-electric Resistivity Survey	54
6-1 Method of Survey	54
6-2 Analysis of Results	60
Chapter 7. Conclusion	71

- Table 2-1 Observation Data at Talek
- Table 2-2 Mean Monthly Temperature of
Nairobi
- Table 2-3 Mean Monthly Precipitation
- Table 2-4 (1) Monthly Rainfall 1950 - 1980
(Kajiado)
(2) Monthly Rainfall 1950 - 1980
(Narok)
- Table 2-5 Table of Probable Evapo-Transpiration
- Table 2-6 Table of Geological Classification
of Boreholes
- Table 2-7 Borehole Data (No. 1 - No. 8)
- Table 2-8 Water Quality
- Table 2-9 Estimated Hydrogeological Constants

- Fig. 2-1 Hydrogeological Survey Site Map
- Fig. 2-2 Mean Annual Rainfall
- Fig. 2-3 Topography of Kajiado/Narok Areas
- Fig. 2-4 Catchment Area
- Fig. 2-5 Geological Map of Kenya
- Fig. 2-6 Geological Map of Kajiado/Narok
- Fig. 2-7 Hydrogeological Map of Kajiado/Narok
- Fig. 2-8 (a) Borehole Location Map
(b) Borehole Location Map
(c) Borehole Location Map
(d) Borehole Location Map
- Fig. 2-9 Contour Map of Static Water Level
- Fig.2-10 Groundwater Conductivity Map
- Fig.2-11 Major Patterns of Groundwater Chemistry
- Fig.2-12 Distribution of Yields of Borehole
- Fig.2-13 (a) Geo-electrical Survey Site
(b) Geo-electrical Survey Site
(c) Geo-electrical Survey Site
- Fig.2-14 Geoelectric - Resistivity Section of Oldonyo
Onyokie Site
- Fig.2-15 Geoelectric - Resistivity Section of Selengei
Site
- Fig.2-16 Geoelectric - Resistivity Section of Lengesim
Site

- Fig. 2-17 Geoelectric - Resistivity Section of Kenya
Marble Quarry Site
- Fig. 2-18 Geoelectric - Resistivity Section of Ewaso
Kidong Site
- Fig. 2-19 Geoelectric - Resistivity Section of Nkornkori
Lemek Site
- Fig. 2-20 Geoelectric - Resistivity Section of Ololulunga
Site
- Fig. 2-21 Geoelectric - Resistivity Section of Maji
Moto Site
- Fig. 2-22 Geoelectric - Resistivity Section of Olenkuluo
Site
- Fig. 2-23 Geoelectric - Resistivity Section of Ewaso
Ngiro Site

Basic Studies on Hydrogeological Survey

in Kajiado/Narok Districts

Introduction

During the last two decades, a number of countries have made remarkable progress in developing and making use of groundwater resources. Many countries can now supply a constant amount of high-quality water, with very little temperature change throughout the year. Even groundwater resources which lie underneath vast extents of dry and lifeless deserts have been investigated and developed. The Kenyan government has decided that securing potable water in semi-dry areas is one of the most urgent issues in the Fourth 5-year Plan and is promoting a program for developing groundwater resources.

This survey was conducted south of Nairobi in the Kajiado and Narok districts of the Rift Valley Province at the request of the Kenyan government. The basic study and geoelectric survey was performed from a hydrogeological aspects to help the project proceed more swiftly. Training was also provided for the Kenyan counterparts using two sets of geoelectric resistivity survey equipment.

1. General Description of the Area

Kenya is located in the eastern part of the African Continent. It borders with Somali and Ethiopia to the north-east, with Sudan and Uganda to the west and with Tanzania to the south.

The eastern part of the country faces the Indian Ocean and its quasi-square land is located on the equator, extending between N. Lat. 5°10' and S. Lat. 4°10', and 33°50' W. and 41°50' E.

It has an area of 582,646 km², about 1.5 times that of Japan, while its population is only 15 million.

A plateau of over 1,500 m above sea level covers the south-west part of the country. On the plateau, there is savanna with grass fields and bushes. The average temperature is as mild as 20°C in spite of being located on the equator.

On the other hand, low lands of 300 to 500 m above sea level cover in the north-eastern part, where it scarcely rains.

Kenya is an agricultural country and agriculture is extensively carried on in the areas stretching from the mountain area of the central part of the country to Lake Victoria, where there is relatively abundant rainfall. Its major products are coffee, tea, fruits and vegetables. Kenya is the world second largest coffee producer and exports it all over the world.

In Kenya, numerous kinds of animals live under government protection and attract many tourists to this country.

(about 330,000 annually)

The Kajiado and Narok districts are situated in the savanna in the southern part of Kenya. Cattle breeding is their only industry because of little rainfall.

In these semi-desert like area, no surface water exists except during the heavy rainy season. Thus, groundwater is their main source of water.

The purpose of this project is to promote development of groundwater resources so as to secure potable water for people and cattle in these areas.

2. Outline of Survey

Data collection was made on the following items, meteorology, hydrology, topography, hydrogeology, water quality and existing wells. In this basic survey, field surveys were made in areas where only limited information was available. During the field survey, preliminary assessment of groundwater was made using the two sets of geoelectric survey equipment provided by the Japanese Government and also technical training was given to the Kenyan counterparts on the groundwater survey.

2-1 Delivery and List of the Surveying Equipment and Material

Equipment and material for the survey, which had been air-freighted separately from Japan, were delivered on December 5, 1981 to the Water Resources Department of the Ministry of Water Development after completing required formalities.

The supplied equipment and material are listed on an Internal Memo in Appendix 6.

2-2 Collection and Analysis of Data

Data on climate, topology, and geology, the basic data necessary for making development plans, was collected by relevant ministries, agencies, departments and offices in Nairobi City.

All material concerning topological maps are kept on file by Survey of Kenya but are not currently being utilized. Well drawn maps are available on a scale of 1 : 50,000 to 1 : 250,000 for the southern part of Kenya. However, further studies and surveys are wanted for the northern part and northeastern coastal areas.

Geological maps are also kept on file at the Mine and Ecology Department in Industrial Estate but are not currently being utilized. Data on climate, especially rainfall, which cover about the last 20 years, was available from several meteorological stations located in Kajiado and Narok.

Meteorological material is now being processed by computers for statistics and completion of such processing is anxiously awaited. Various materials on existing wells which play a key roll in clarifying hydrogeological structures, were available at the library of Geology Section and Drilling Section of the Ministry of Water Development. Due to the lack of geological log records information from the drilling data table of each well has been used.

Information on the actual conditions, maintenance and control of the facilities and equipment installed on the existing wells were obtained from Operation and Maintenance Branch.

2-3 Field Survey

The major purposes of the field survey, a geoelectrical survey and technical transfer of survey methods, were carried out during a period of December 9, 1981 and January 19, 1982.

Prior to this survey, several meetings were held with six Kenyan counterparts to sufficiently discuss the methods to be used in the geoelectric survey and other matters necessary for preparing reports on the groundwater study.

(a) Selection of sites for field survey

Five sites out of the previous list of high priority sites for the Ranch Water Development Programme were selected for each district by the development officers after discussion with The Study Team.

(b) Technical transfer

Six counterparts of the Kenyan government are listed below.

1. Mr. Justus Ituli Geologist Geology Section
2. Mr. Simon N. Njoroge Geologist Geology Section
3. Mr. Z.K.O. Onyango Geologist Geology Section
4. Mr. Gilbert M. Barno Senior Groundwater Inspector,
Geology Section
5. Mr. Paul Munba Groundwater Inspector
6. Mr. Julius W. Makindi Groundwater Inspector

Three are geologists with 6 months to a year experience. They are engaged in geological surveys as assistants to senior geologists. Three are groundwater inspectors in charge of investigating and reporting conditions of existing wells to the Geology Section.

The major purpose for technical transfer was to provide training through actual field experience until method of operations, maintenance procedures and control of the machines are thoroughly learned as well as practice. Ten sites were selected for both Kajiado and Narok and sufficient time was taken for training.

The latter half of the survey works at each site was taken over by Kenyan counterparts. They had to select measuring spots, operate the machines, and examine the data obtained. Japanese counterparts remained to assist and advise them.

2-4 Areas Surveyed

Sites for field survey were selected according to agreements reached between district development officers of Kajiado and Narok districts (See Fig. 2-1.).

Kajiado District

No.	Name of Selected Sites
1.	Ewaso Kidong
2.	Kenya Marble Quarry
3.	Oldonyo Onyokie
4.	Selengei
5.	Lengism

Narok District

No.	Name of Selected Sites
1.	Ewaso Ngiro
2.	Olenkuluo
3.	Maji Moto
4.	Olululunga
5.	Nkornkori-Lemek

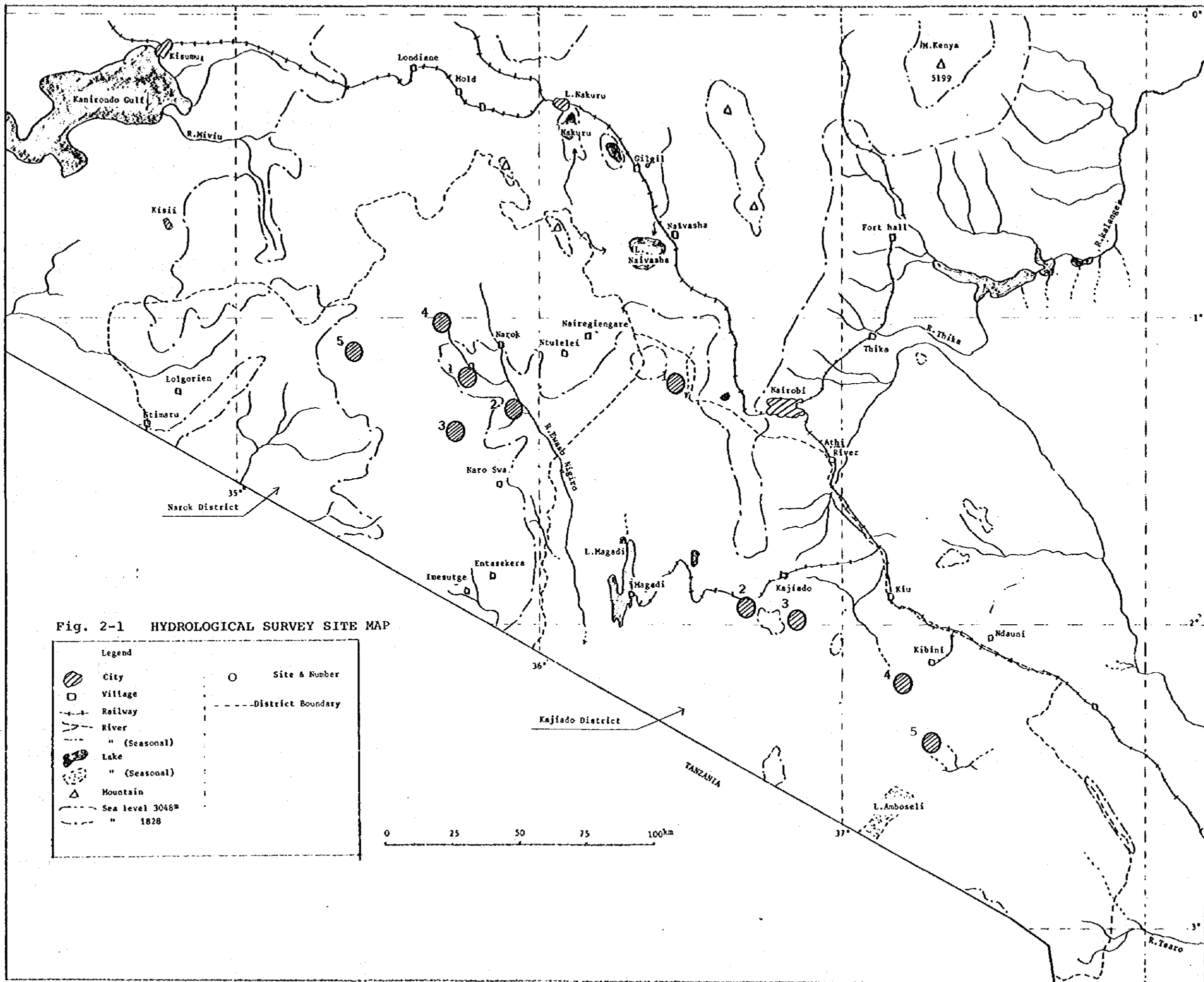


Fig. 2-1 HYDROLOGICAL SURVEY SITE MAP

3. Meteorological Conditions

In spite of the fact that both Kajiad and Narok are situated directly on the equator, their climate is very mild as they are as high as 1,500 m above sea level.

3-1 Temperature

Little data is available on temperature. Even the detailed geological survey conducted between 1951 and 1960 reported only observation data collected at the Town of Talek in Narok. The data is shown in the following table.

Table 2-1 Mean Monthly Maximum and Minimum Air Temperature at Telek

Year		Month													
		1		2		3		4		5		6		7	
		max.	min.	max.	min.	max.	min.	max.	min.	max.	min.	max.	min.	max.	min.
1957															
1958		31.1	11.1	31.1	11.1	29.3	-	29.3	-	26.2	-	27.6	14.5	27.1	12.9
1959		28.2	14.0	28.2	14.5	28.2	15.0	28.2	14.1	28.2	-	28.2	11.6	27.6	12.1

		8		9		10		11		12	
		max.	min.	max.	min.	max.	min.	max.	min.	max.	min.
1957		30.6	11.6	33.2	11.1	33.7	12.1	27.1	12.1	26.6	12.1
1958		28.2	13.4	30.0	14.0	29.3	14.5	31.1	14.1	27.6	15.0
1959											

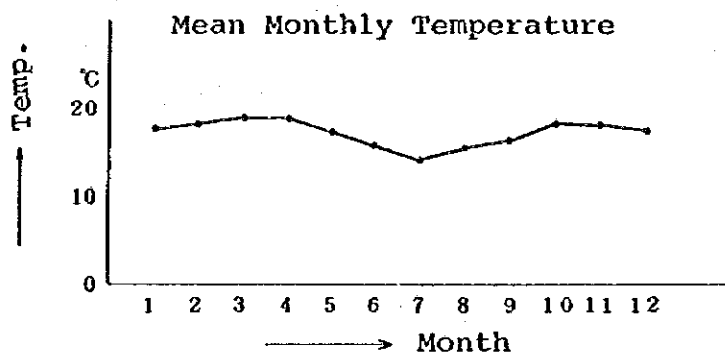
Little variation in temperature is seen throughout the year in the above table. Daytime temperature ranges between 27°C and 33°C, which may be considered somewhat hot. On the other hand, nighttime temperature varies from 11°C to 15°C, which may be considered rather cool.

Temperatures in Nairobi, which is located close to Narok and Kajiado, is cited from the Science Almanac as follows:

Table 2-2 Mean Air Temperature at Nairobi (°C)

Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sept	Oct.	Nov.	Dec.	Mean Annual Temperature
17.8	18.1	18.8	18.8	17.8	16.2	14.9	15.6	16.8	18.6	18.3	17.8	17.5

(From the Science Almanac)



The above table shows that the mean maximum temperature is 18.8°C (during February and March) and the mean minimum temperature is 14.9°C (during July). The mean temperature for the year is 17.5°C. This indicates a very mild climate.

3-2 Precipitation

Observation data on rainfall in the Geological Survey Report (from 1951 to 1960) shows that a maximum rainfall of 1,044 mm was recorded in the vicinity of Mau Escarpment in the central mountain area, followed by 797 mm at Olo'bouge which is closely located to Lake Nivasha and 701 mm in Narok.

The minimum precipitation of 370 mm was recorded in Magadi, followed by 496 mm in Kajiado. In highlands extending from the central part to the southern part of this country, the western part has relatively abundant rainfall while the low lands along the Rift Valley structural line which goes

through the central part of the country have less rainfall part to the Valley shows slightly more precipitation with a rainfall of 600 m. Considering the average precipitation in Japan of between 1,500 mm and 1,800 mm), the figures represent considerably low precipitation.

The following tables and graphs were made based on the data obtained from meteorological stations in Kajiado and Narok.

Table 3 Mean Monthly Precipitation

Unit: mm

Meteorological station	Month													Total
		1	2	3	4	5	6	7	8	9	10	11	12	
Kajiado		48	41	55	127	70	14	6	3	8	20	74	45	511
Narok		91	86	103	163	101	141	19	25	26	28	72	84	939

(Average of 31 years from 1950 to 1980)

Table 2-4 (1) MONTHLY RAINFALL (m/m) 1950-1980

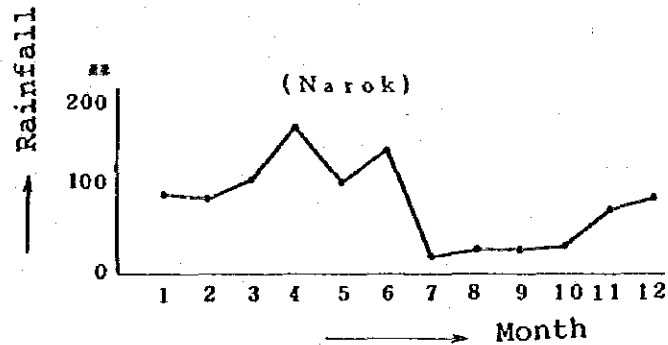
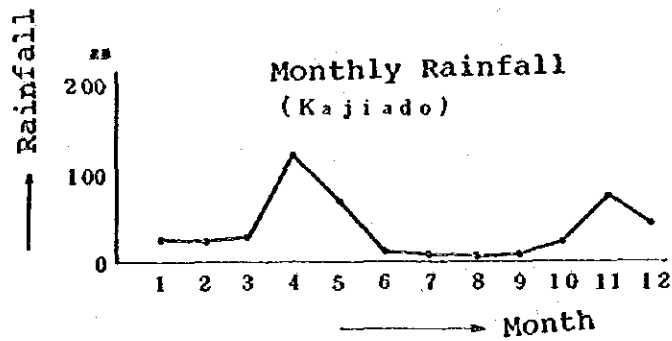
(KAJIADO METEOROLOGICAL STATION D.C.-91.36.39)

	JAN.	FEB.	MAR.	APRIL	MAY	JUNE	JULY	AUG.	SEPT.	OCT.	NOV.	DEC.	TOTAL
1950	25.7	50.8	81.3	85.6	5.1	16.3	NIL	7.6	NIL	26.4	24.9	1.8	325.5
1951	66.8	11.7	100.8	547.9	85.6	8.9	9.6	18.8	8.9	45.2	94	183.1	1181.3
1952	8.1	50.3	68.3	145.5	93	NIL	NIL	1.8	NIL	13.5	41.9	15	437.4
1953	16.5	NIL	10.9	117.9	28.4	1.5	NIL	NIL	5.1	21.6	67	5.1	274
1954	26.9	51.6	4.1	316	167.4	NIL	29	NIL	NIL	18.5	84.8	NIL	698.3
1955	NIL	67.6	48.3	75.2	53.8	NIL	NIL	NIL	10.2	6.4	64	64	389.5
1956	132	39.1	112	27.7	24.1	NIL	NIL	NIL	14	20.1	52.8	10.9	432.7
1957	113.5	NIL	19.3	112	164	5.6	1.3	NIL	NIL	4	84.3	37.5	541.5
1958	67.6	140	58.2	108	76.5	12.7	2	2	NIL	NIL	23.4	50.8	541.2
1959	22.4	35.3	77.5	71.4	70.9	NIL	NIL	21.3	11.2	10.9	97.8	39.9	458.6
1960	14	1.5	62.7	99.8	21.6	1.5	4.8	NIL	3.3	18.5	27.4	22.4	577.6
1961	1.3	9.7	1.5	115.6	35.3	14.2	1	1.3	9.4	53.6	561.6	348.2	1152.7
1962	103.1	8.1	12.4	133.9	113.8	26.9	NIL	2	8.9	45.9	85.9	47.8	588.7
1963	37	47	63.2	138.1	52.3	28.1	NIL	6.3	1	10.7	146.3	80	610
1964	59.2	43.7	60.5	135.6	12.4	39.4	33	NIL	NIL	14	39.4	39.9	477.1
1965	67.2	43.0	40.1	113.2	55.4	10.4	NIL	NIL	3.8	95.0	42.7	37.8	508.6
1966	10.2	87.4	116.0	128.7	37.0	6.6	NIL	5.1	NIL	NIL	26.6	22.0	439.6
1967	NIL	13.2	15.7	148.1	73.7	2.3	6.9	7.6	25.1	66.5	45.3	34.3	438.7
1968	NIL	35.3	150.6	98.0	162.0	N.R	N.R	N.R	N.R	N.R	150.4	17.4	613.7
1969	124.5	37.1	39.0	13.2	94.5	13.1	NIL	NIL	NIL	37.0	63.0	NIL	421.4
1970	107.6	27.0	145.0	118.0	138.5	40.8	NIL	NIL	NIL	NIL	9.4	5.0	591.3
1971	59.7	NIL	7.9	107.5	104.7	NIL	NIL	9.2	NIL	2.0	30.2	1909	512.1
1972	27.4	153.9	25.3	NIL	51.9	50.4	NIL	NIL	24.7	42.7	49.1	11.9	437.3
1973	90.8	101.9	NIL	50.8	11.2	NIL	NIL	5.0	90.2	25.3	34.2	32.3	441.7
1974	1.1	17.8	69.9	261.3	59.5	45.0	29.4	8.3	NIL	1.2	72.0	28.1	593.6
1975	61.2	NIL	87.1	155.9	82.9	NIL	19.5	NIL	17.0	18.9	22.8	33.1	498.4
1976	17.1	3.0	16.6	42.2	4.3	33.5	NIL	NIL	7.1	NIL	12.9	16.3	153.0
1977	51.0	59.2	18.0	222.8	NIL	NIL	NIL	NIL	NIL	NIL	50.2	NIL	401.2
1978	63.8	50.4	98.5	121.8	92.4	NRA	NRA	NRA	NRA	NRA	46.9	NRA	473.8
1979	66.9	56.0	81.1	53.8	112.2	79.6	NIL	NIL	NRA	6.6	57.6	31.8	545.6
1980	48.3	13.1	5.2	63.3	76.2	NIL	58.8	NIL	3.6	10.4	71.6	NIL	350.5
Total	1490.9	1254.7	1697	3928.7	2160.6	436.8	195.3	96.3	243.5	614.9	2280.4	1408.3	15807.5
Mean	48.1	40.5	54.7	126.7	69.7	14.1	6.3	3.1	7.9	19.8	73.6	45.4	509.9

Table 2-4 (2) MONTHLY RAINFALL (m/m) 1950-1980

(NAROK METEOROLOGICAL STATION D.C.-91.36.39)

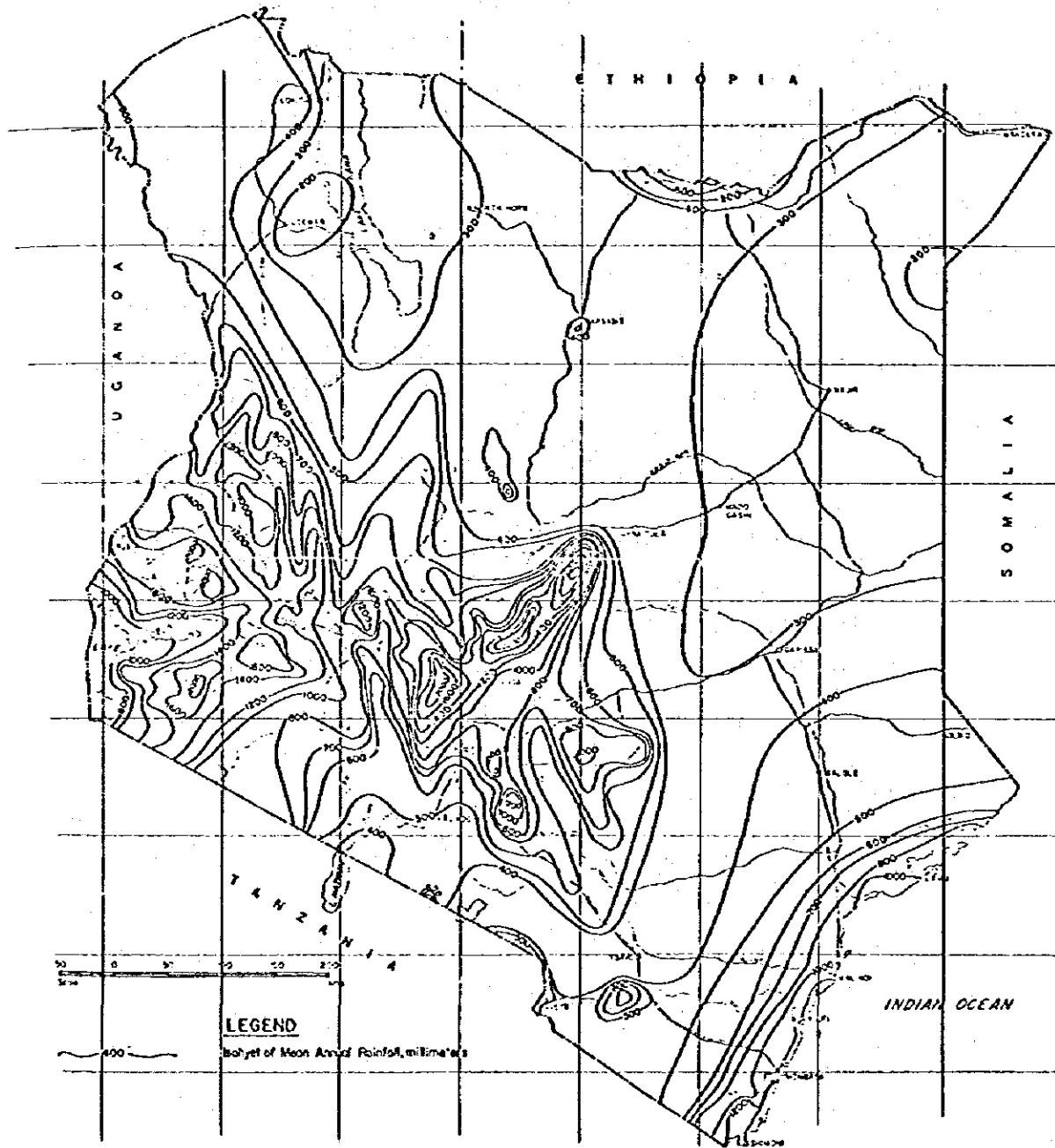
	JAN.	FEB.	MAR.	APRIL	MAY	JUNE	JULY	AUG.	SEPT.	OCT.	NOV.	DEC.	TOTAL
1950	72.4	93.5	223.8	190.5	18.8	24.1	4.6	34.3	17	54.6	9.1	14.2	756.9
1951	140.7	91.2	89.4	419.6	46	39.1	11.2	23.6	17	47.8	63	130	1118.6
1952	33.8	64.8	39.9	202.4	200.6	NIL	29	13.5	24.1	8.4	27.2	7.6	651.3
1953	45.5	10.7	16.3	121.9	27.7	14	1.8	24.6	20.1	24.1	27.4	62.7	396.8
1954	88.4	59.2	3.8	278.9	170.4	17.5	38.4	4.6	13.2	23.4	22	87.1	806.9
1955	14.2	198.4	79.8	99.3	14	18	26.2	105.1	58.2	13.2	68.5	103.4	798.3
1956	208.8	93.5	94.5	128.5	48	20.1	6.9	67.6	20.3	17	100	90.4	895.6
1957	132.8	53.8	93	267.5	250.7	85.3	NIL	NIL	6.4	14.2	44.2	131.3	1079.2
1958	104.6	124.7	130.8	99.1	196.3	24.4	47.2	10.4	10.6	25.4	38.4	141.2	953.2
1959	50.5	56.6	224	25.6	55.6	10.4	8.4	38.9	11.9	15.5	152.7	83.6	733.8
1960	94.5	47.7	212.1	154.2	9.7	7.1	12.7	14.9	59.9	34.5	120.9	38.1	806.3
1961	8.4	46	40.4	70.6	102.4	33.5	0.5	18.8	25.4	25.4	289.3	371.6	1032.3
1962	223	19.6	93.5	182.9	216.9	47.7	1.1	31.5	20.1	104.4	68.1	87.9	1096.6
1963	192.8	59.4	91.7	262.9	243	14.2	41.7	33.8	NIL	1	187.6	231.4	1359.5
1964	66.3	136.6	124.7	230.4	43.9	24.6	47.7	26.2	23.6	35.1	11.4	25.9	796.4
1965	57.9	57.0	59.3	84.5	76.4	20.8	5.9	8.8	43.0	15.8	75.2	64.5	569.1
1966	38.4	191.3	130.9	185.8	18.3	12.7	9.0	42.7	43.5	29.1	45.3	11.7	758.7
1967	4.6	52.5	44.3	153.3	187.0	11.6	18.9	2.8	43.8	32.6	55.4	82.6	689.4
1968	18.7	101.5	177.9	281.2	83.5	61.9	11.2	1.6	6.0	16.6	68.6	54.3	883.0
1969	129.5	152.1	51.1	23.6	101.5	18.8	2.5	5.9	40.1	20.4	74.9	23.2	643.6
1970	328.4	72.0	183.3	135.9	141.5	43.9	26.0	6.7	7.8	23.2	13.8	59.7	1042.2
1971	67.1	34.9	28.2	175.0	104.4	7.9	28.6	129.7	1.5	14.1	6.9	92.1	690.4
1972	82.7	160.1	59.8	36.2	119.0	125.2	1.8	4.6	3.9	79.7	135.2	67.0	875.2
1973	138.4	224.2	6.7	48.0	55.6	66.6	3.4	12.4	109.6	36.5	90.6	42.8	834.8
1974	8.8	18.2	138.6	310.1	53.3	45.1	74.1	3.8	18.3	0.2	35.1	34.7	740.3
1975	40.7	5.9	101.2	80.2	67.9	6.8	54.3	4.1	72.3	60.2	9.4	79.3	582.3
1976	36.4	12.8	16.5	96.3	60.8	60.3	17.1	26.0	29.1	11.1	78.5	38.5	483.4
1977	92.4	96.5	40.7	246.5	126.0	8.8	42.2	45.9	22.9	46.5	130.6	118.8	1017.8
1978	135.3	144.4	368.7	122.9	28.0	13.1	1.3	25.6	17.8	8.3	20.0	125.8	1011.2
1979	86.7	173.9	137.8	162.6	101.0	49.0	22.2	5.5	8.2	4.0	39.4	52.1	842.4
1980	90.4	10.8	91.3	179.0	171.9	11.7	1.8	4.4	12.4	32.6	117.7	39.7	763.7
Total	2833.1	2663.8	3194	5055.4	3140.9	944.3	597.7	778.3	807.7	874.9	2224.4	2593.2	25707.7
Mean	91.4	85.9	103.0	163.1	101.3	30.5	19.3	25.1	26.1	28.2	71.8	83.7	829.4



As indicated in the above table, the heaviest precipitations (Kajiado; 127 mm, and Narok; 163 mm) are observed in a period of March through May which is called the Heavy Rainy Season. Then the 2nd largest precipitation occurs in another period of November and December, which is the Light Rainy Season. The lowest precipitation is recorded during July through September, when Kajiado area has little rainfalls.

Figure 2-2 indicates the rainfall in the whole nation.

Fig. 2-2 MEAN ANNUAL RAINFALL



According to Fig. 2, west places have below 600 mm precipitation except the central mountain areas--the vicinity of Mom basa facing Lake Victoria and Indian Ocean has over 1,000 mm precipitation. Most parts of Kajiado have an annual precipitation of 400 to 500 mm and Narok 800 mm.

3-3 Evapo-Transpiration

Observation and use of evapo-transpiration is not commonly practiced yet. (Only a few Japan's meteorological stations observe evapo-transpiration). Because the difficulties in observation the water surface evapo-transpiration which is normally absorbed at meteorological stations, are quite different from ground evapo-transpiration, satisfactory data has not been obtained so far.

The evapo-transpiration estimated using the Thornthwaite (1948) method is considered fairly acceptable in Japan. This method computes the evapo-transpiration with the following equation, using altitude and mean monthly temperature of the site.

$$E = 16 \left(\frac{10T}{I} \right) a$$

$$\text{where } a = 6.75 \times 10^{-7} I^3 - 7.71 \times 10^{-5} I^2 + 1.792 \times 10^{-2} I + 0.49239$$

$$I = \frac{12}{I} \left(\frac{T}{S} \right) 1.514$$

E : monthly evapo-transpiration value

T : Mean monthly temperature.

Note: The affects of latitude and days of month were compensated for.

Probable evapo-transpiration around the surveyed sites was calculated using this equation (See Table 15).

Table 5. Table of probable evapo-transpiration rate

(1950 - 1980)

Kajiado D.C.

Item Month	1	2	3	4	5	6	7	8	9	10	11	12	Annual average
Temp.	17.8	18.1	18.8	17.8	16.2	14.9	15.6	16.8	18.6	18.6	18.3	17.8	17.5
Rainfall	48	41	55	127	70	14	6	3	8	20	74	45	511
Probable evapo-transpiration volume	69	66	75	73	69	56	50	55	61	73	70	69	786
Estimated surplus water	-	-	-	54	1	-	-	-	-	-	4	-	59

Narok Met. stn.

Item Month	1	2	3	4	5	6	7	8	9	10	11	12	Annual average
Tem.	17.8	18.1	18.8	18.8	17.8	16.2	14.9	15.6	16.8	18.6	18.3	17.8	17.5
Rainfall	91	86	103	163	101	31	19	25	26	28	72	84	829
Probable evapo-transpiration volume	69	66	75	73	69	56	50	55	61	73	70	69	786
Estimated surplus water	22	20	28	90	32	-	-	-	-	-	2	15	209

Note: (1) For temperature, data of Nairobi was used.

(2) " - " represents negative figures

Although the above table was prepared using temperatures of Nairobi, it should give fairly reasonable estimates as Nairobi is close to the surveyed area.

This table explains why many of the rivers in Kajiado are dried up. Assuming that an average of 40% of the surplus water becomes ground water, only 23 mm/year is available for ground water in Kajiado and 84 mm/year in Narok.

These figures amount to only 6% and 32% of the available ground water normally found in Japan and indicate a serious lack of ground water resources in Kajiado.

4. Topography and Geology

4-1 Topography

Kajiado and Narok are located in the southern part of Kenya and are adjacent to Tanzania. Together they are 425 Km long and 125 Km wide, occupying an area of 40,619 Km². (Kajiado: 22,106 Km², Narok: 18,513 Km²)

As is seen in the above topographical map, the surveyed areas are located on a plateau of 1,000 to 3,000 m above sea level extending from the foot of the central mountains to the southern part of Kenya.

The typical treeless plains of this area are so called savanna. They are covered with a scattering of small bushes and grass fields which are green only during the heavy rainy seasons. Without the savanna the area would appear like an endless desert. This area may be remnant of an old desert in different geological era. A large graben called the Rift Valley runs through this area from north down to south. This is a very large graben which starts far north in Syria and runs through the Red Sea, Ethiopia and Kenya, then via Tanzania, Malawi, Mozambique and finally reaches the Indian Ocean. It is 6,000 Km long, 70 Km wide and is as deep as 700 m in some areas.

Lake Magadi and Lake Natron were formed from depressions of low lands in the central part. Mt. Kenya (5,119 m) and Mt. Kilimanjaro (5,895 m) are volcanos which were also formed as the result of this depression. They are the two highest mountains in Africa.

Rivers running through the area are all dried up except some in Narok. They are all rather small. One important river among them is the Ewaso Ngiro River which collects water from the central mountains. It passing through Narok and runs west to the Rift Valley. (Water Catchment Zone).

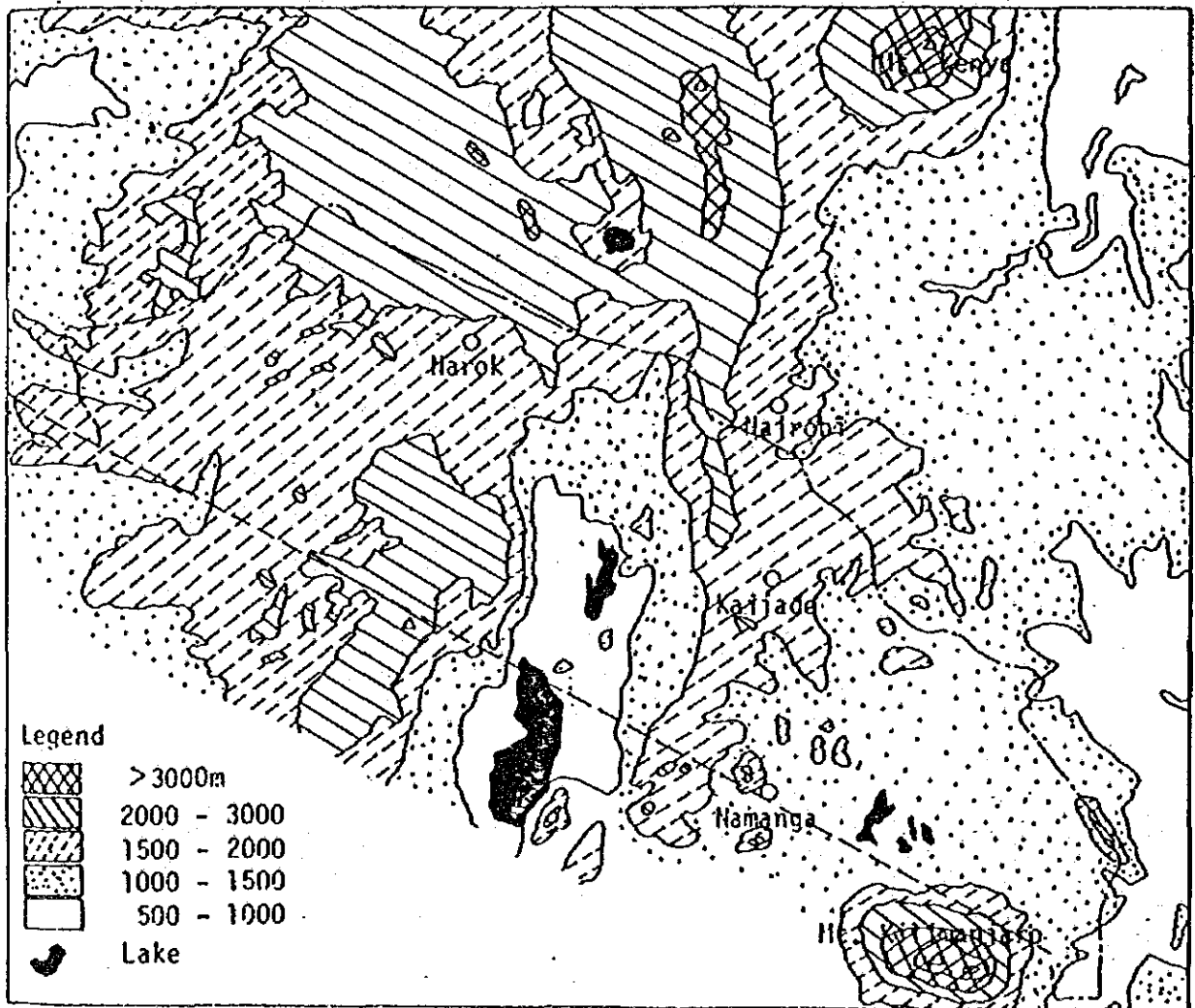
Areas where rainfall gathers are generally good places to look for ground water resources.

Fig. 4 shows the catchment zones around the survey areas. Indicating three large catchment zones in the Rift Valley district eastern and western parts. The Kajiado district is divided into two zones in the Rift Valley district and into four zones in the eastern part, a total of six zones. Rivers in one zone of the Rift Valley and one zone in the south have no outlets.

The Narok district is divided into five zones. With exception of one zone located at the western part, all others run to south to Tanzania.

When studying ground water in these areas, sufficient attention should be paid to catchment zones. Catchment zones should be further subdivided for studies to determine good well sites.

Fig. 2-3 TOPOGRAPHY OF KAJIADO/NAROK AREAS



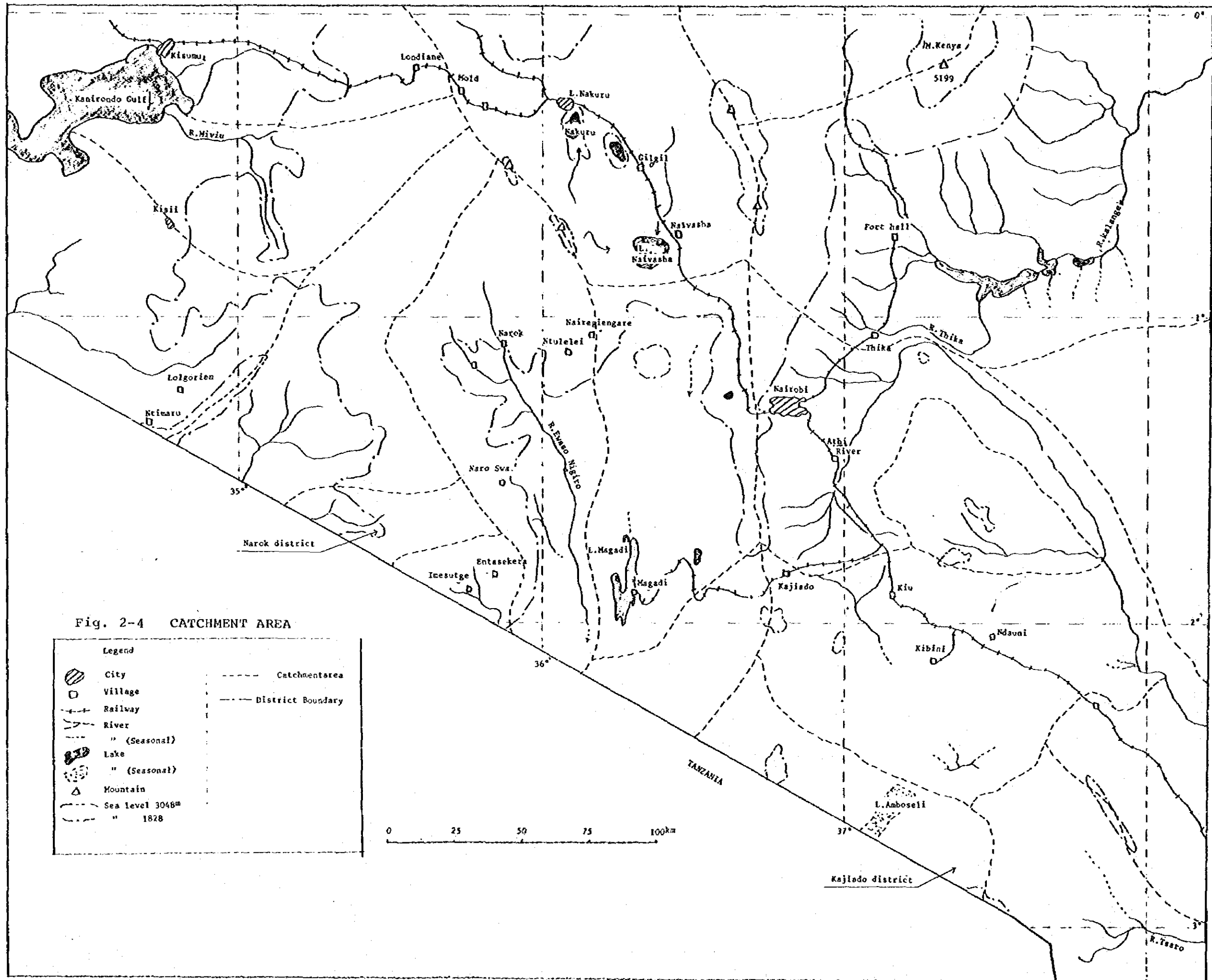


Fig. 2-4 CATCHMENT AREA

4-2 Geology

As shown in Fig. 5 the oldest stratum of the earth of the Pre-Cambrian era, African Shield, covers most of Kenya. Along the coastal line, a small Mesozoic stratum is distributed. The Tertiary formation, the upper layer on the Mesozoic stratum, is found along the Rift Valley and the coastal line. The upper layer of the quarternary formation is found in areas surrounding volcanos and in low land areas.

A detailed report of the geology of the two prefectures was made on a scale of 1:125,000 by a British Geologist based on geological survey during 1951-1960. It is as shown in Fig. 6 (There are some areas left blank on the geological map due to lack of information.) Pre-Cambrian, Tertiary and Quarternary rocks are distributed in the ratio of 4 ; 3 ; 3 in the Kajiado district. From the central to eastern part, basements of Pre-Cambrian rocks are widely distributed. The Tertiary formation spreads along the Rift Valley structural line and the foot of Mt. Kilimanjaro. Thin quarternary formations cover the rest of alluvial plain basins.

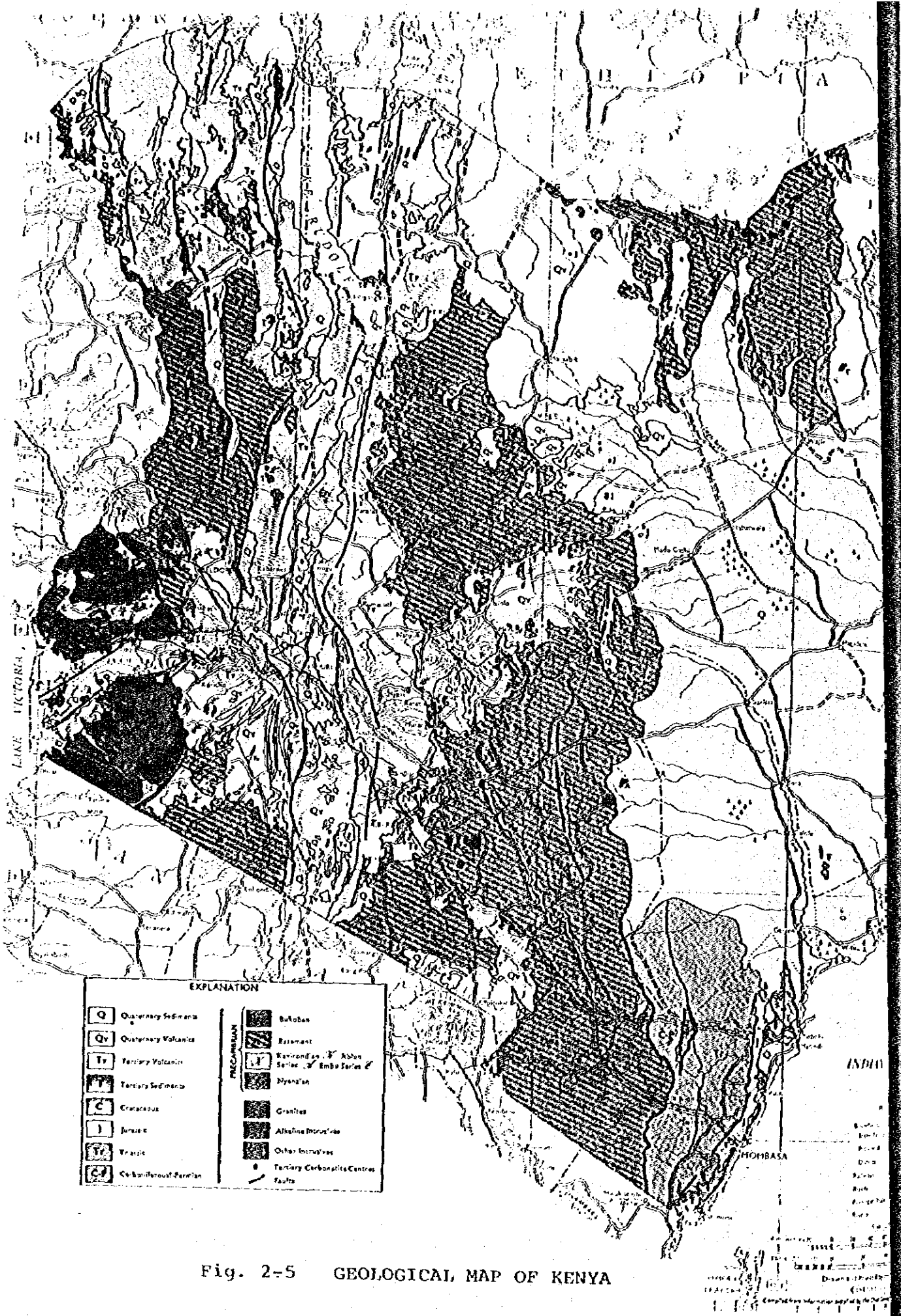


Fig. 2-5 GEOLOGICAL MAP OF KENYA

In Naro, Pre-Cambrian, Tertiary and Quarternary formations are distributed in the ratio of 5 ; 3 ; 2. Pre-Cambrian basements are dsitributed from the central to southern part of the district. Tertiary rock lies along the Rift Valley structural line and in the western side of the district while a wide rangeof the central part is covered by Quarternary rock.

The major part of the Pre-Cambrian layer is composed of gneiss, which is one of the metamorphic rocks, being follwoed by Quartzite, marbles and schist. The Tertiary layer is composed of volcanic rocks such as Basalt, Trachyte, Phonotite, Tuffbreccia and Tuff.

The Quarternary layer was formed by material shot out during volcanic eruptions such as Volcanic sand, agglomerate, and ashes and by other alluvial layers made of clays and sands.

The consolidation of these rocks and layers of the Pre-Cambrian layer is high because this is the oldest stratum of the earth and has been compressed over a long period of time. The Tertiary formation is relatively new and less consolidated. The Quarternary formation is still new and consists of soft stratum not yet consolidated.

4-3 Hydrogeology

Ground water is found in aquifers formed by rainwater which flows or stayes in permeable strata. When the capacity of the permeable stratum is large, a great amount of ground water can be stored. Situation with low permeability cannot store much water. The reason why a large amount is that there are no other readily available sources. In places where there is sufficient rainfall but there is no satisfactory permeable stratum, little or no water can be drawn from wells.

The nature of the underground largely determines the availability of ground water. Because the two prefectures are made

up of highly consolidated Pre-Cambrian formations, it will be difficult to find any aquifers of high permeability.

There is hope however, that small scale aquifers may be found in the weathered zones which have been subjected to considerable weathering over a long period of time.

The Tertiary formation is very likely to have good aquifers since it is less consolidated and is of porous structure. The Quarternary formation is the most promising as it is not yet consolidated. Much can be expected on the foot of volcanos while less is expected on plains of thin layer.

Fig. 7 is the hydrogeology map of the rea based. The following areas are considered to be the most promising ground water basins for this project.

Kajiado District

- o District along the Rift Valley structural line.
Excluding surrounding areas of Lake Magadi, a salt lake, and mountain tops.
- o Foot of Mt. Kilimanjaro
- o Areas south of Nairobi
- o Alluvia around Lake Aboseli. (Except areas close to Amboseli.)

Narok District

- o Districts along the Rift Valley structural line
- o Foot of Mau Escarpment
- o Plains west to Narok

During the basic survey these areas were carefully checked for ground water storage.

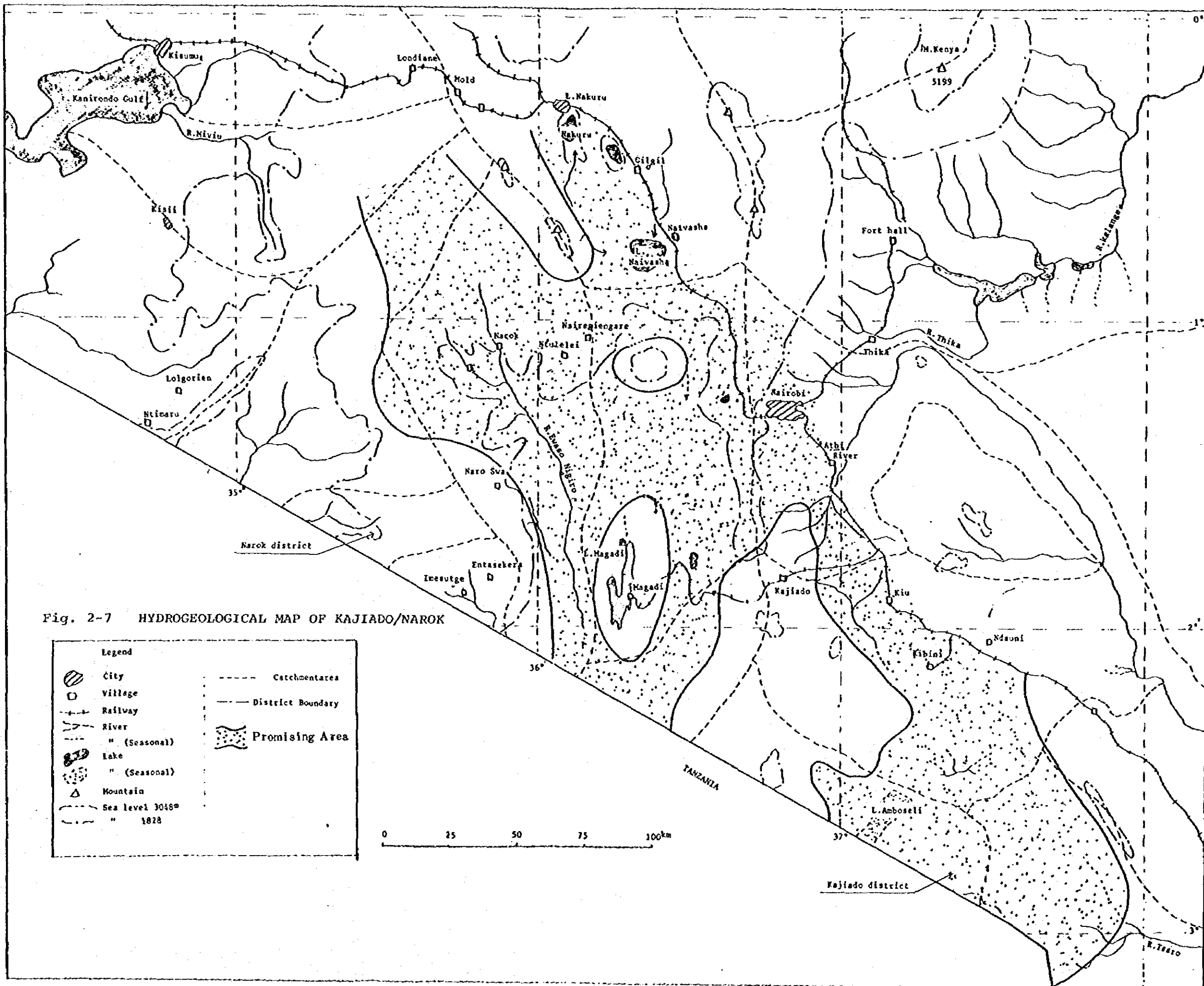


Fig. 2-7 HYDROGEOLOGICAL MAP OF KAJIADO/NAROK

Legend	
	City
	Village
	Railway
	River
	" (Seasonal)
	Lake
	" (Seasonal)
	Mountain
	Sea level 3048m
	" 1828
	Catchment area
	District Boundary
	Promising Area

0 25 50 75 100km

5. Aquifers

Ground water flows through large underground porous mediums and pools in certain geological formations.

When studying aquifer in this area, the survey should focus on the sand and decomposed rock layer in the New Sedimental Rock and coarse sediment layer in the old Rock weathered zone.

As most parts of the surveyed area is composed of Pre-Cambrian basement rock, coarse sediment zone of the weathered zone will be likely around water sources.

Conditions and characteristics of the aquifer in these areas can be judged from the above-mentioned geological conditions and information on 164 existing boreholes. Well prepared but rarely used records are available at the Kenyan Ministry of Water Development. The Summary of this data is shown in the Table title "Borehole Data".

5-1 Classification of Wells

5-1-1 Geological Classification of Water Wells

Aquifers of wells drilled in Kajiado-Narok area are classified by geological era as shown below.

Table 6 Table of Geological Classification of Boreholes

Item Area	New era (The Tertiary, Quaternary)		Sedimental rock		Basement rock (Pre-Cambrian)	
	No. of drilled wells	No. of dry wells	No. of drilled wells	No. of dry wells	No. of drilled wells	No. of dry well
Kajiado	40	7 (18%)	115	21 (18%)	155	28 (18%)
Narok	7	5 (71%)	2	1 (50%)	9	6 (67%)
Total	47	12 (26%)	117	22 (19%)	164	34 (21%)

5-1-2 Drilling details of drilled water wells

o Drilling machines:

Many wells were drilled before the introduction of the rotary drilling machine with all percussion system. This means the casing size differs depending on the machine used.

o Casing sizes:

Diameter (mm)	No. of Wells
100	1
150	93
170	1
200	27
250	1

The majority of wells are 150 mm in diameter and the second largest group 200 mm in diameter.

o Drilling depth

Depth (m)	No. of wells
0 - 50	9
51 - 100	43
101 - 150	69
151 - 200	36
2200m or deeper	7

Wells with depths between 101 and 150 m are the most common.

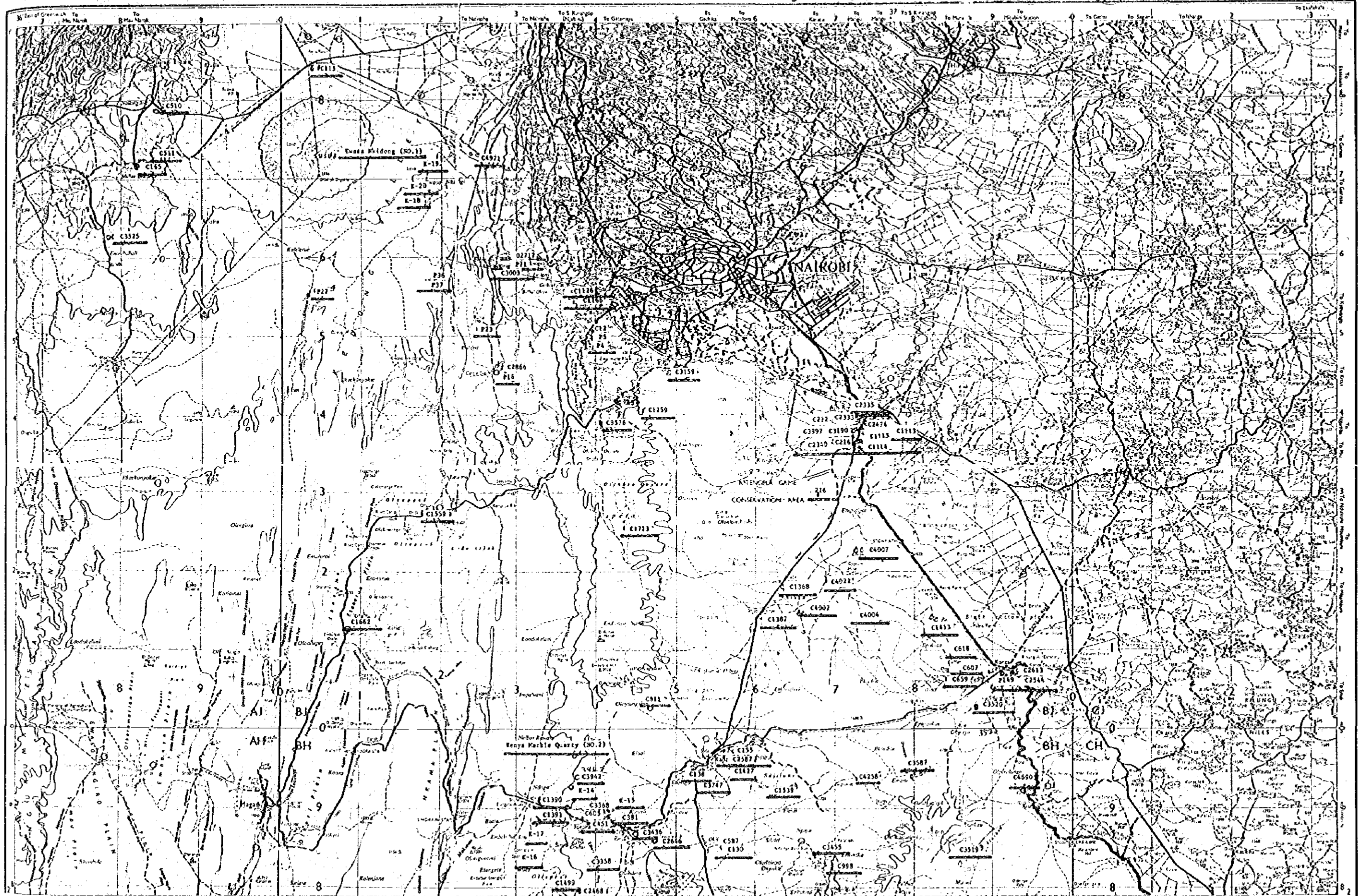
o Thickness of aquifer

Records on the struck depth at which water layer were found are available, but there is no data on the thickness of the water layer.

As shown in the above table, an overwhelming number of wells are drilled on basement rock zones, amounting to 70% of the total. Of these wells, 20 percent in both sedimental rocks and basement rock zones are dry. The talbe shows that there are more dry wells in Narok. As there are less wells drilled in this area, it indicates the search for and production of water from the aquifers is not easy or simple.

NAIROBI

Fig. 2-8(b) BOREHOLE LOCATION MAP

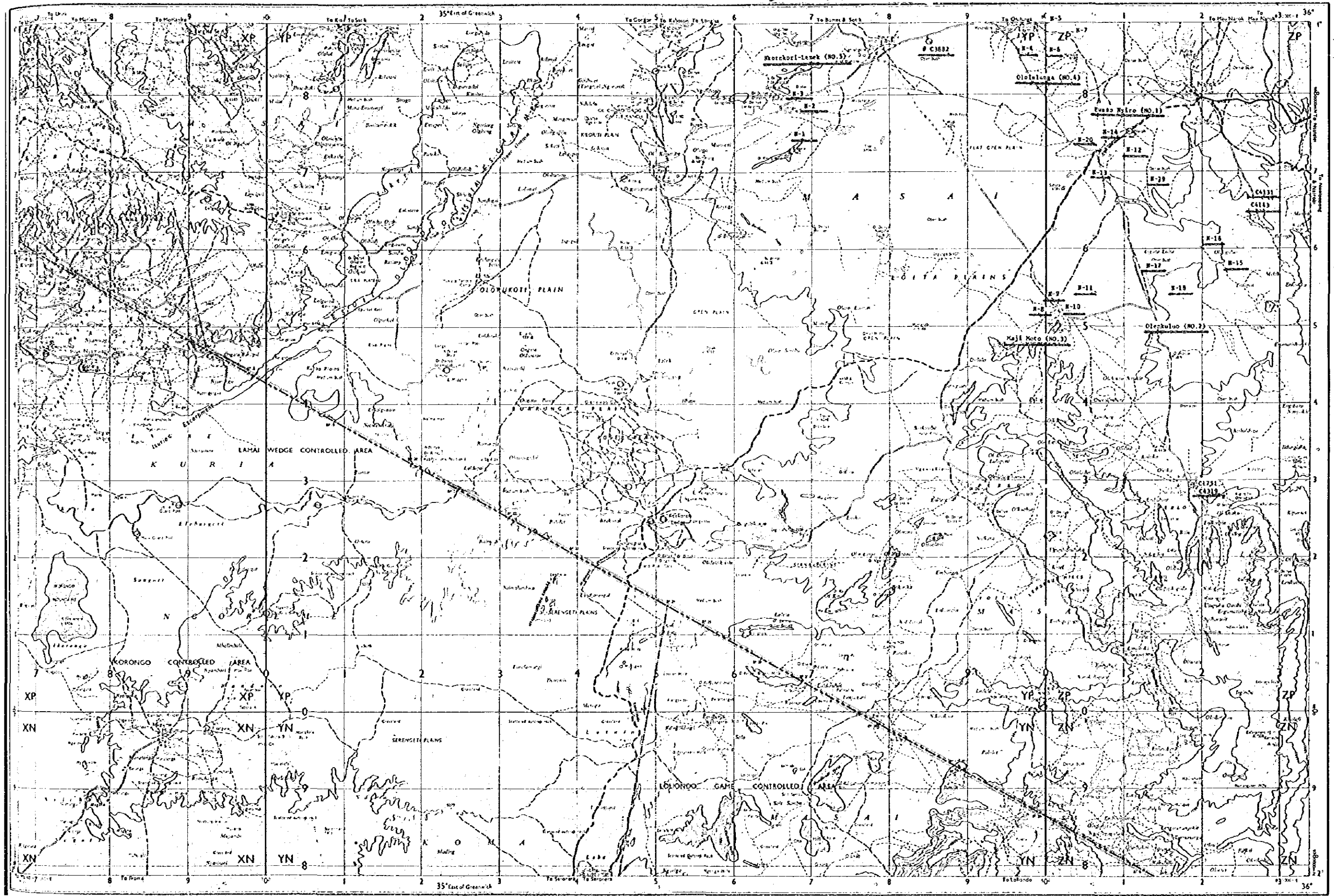


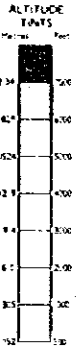
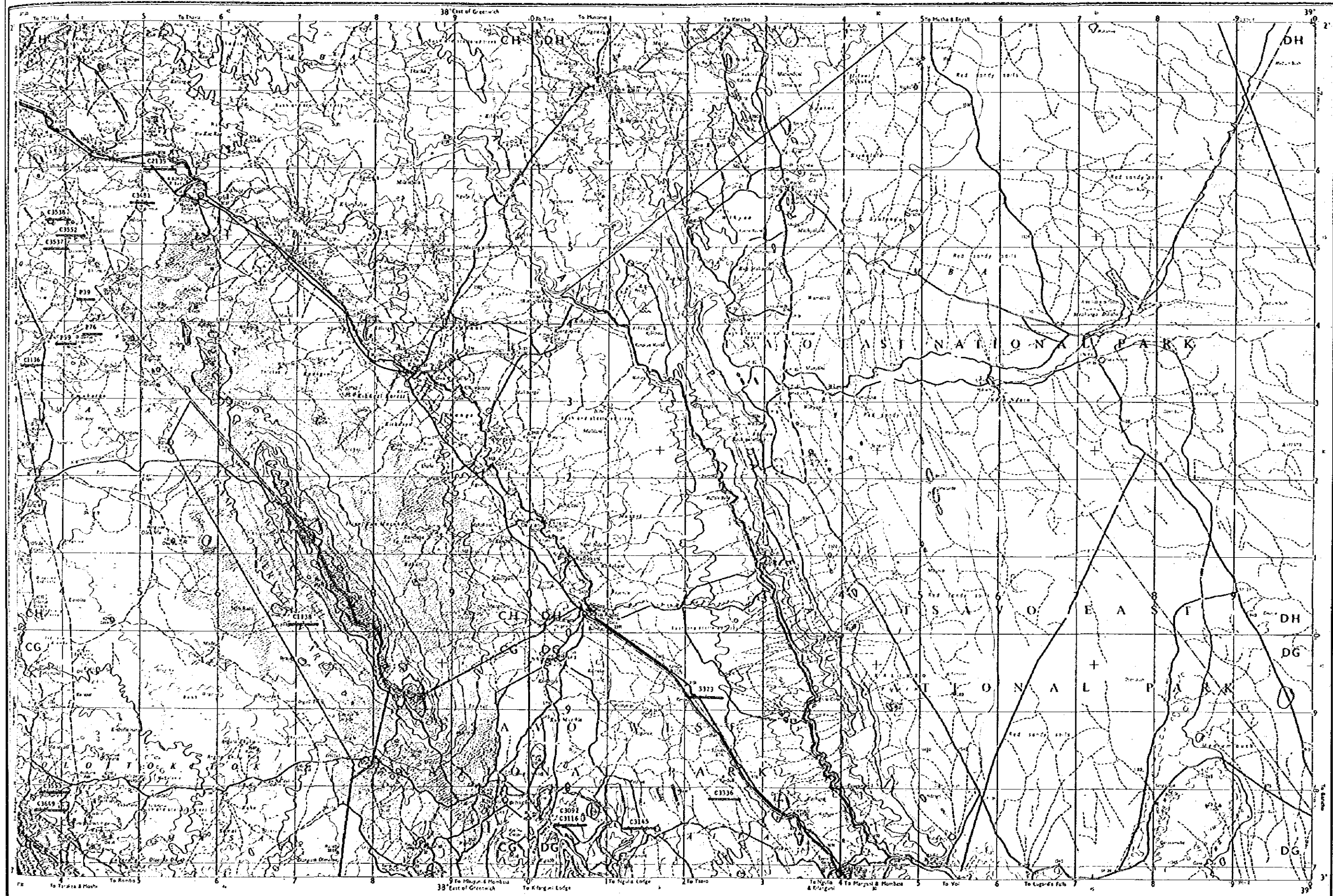
ALTITUDE
METERS

CONVERSION
TABLE

NAROK

Fig. 2-8(c) BOREHOLE LOCATION MAP





CONVERSION TABLE

Feet	Meters
0	0
100	30.48
200	60.96
300	91.44
400	121.92
500	152.40
600	182.88
700	213.36
800	243.84
900	274.32
1000	304.80
1100	335.28
1200	365.76
1300	396.24
1400	426.72
1500	457.20
1600	487.68
1700	518.16
1800	548.64
1900	579.12
2000	609.60

Table 2-7 -7 BOREHOLE DATA

Province Rift Valley

District Kajiado/Narok

Sheet ①

No.1

Borehole	Scale 1:250,000	Total Depth (m)	Water Struck (m)	Rest Level (m)	Tested Yield (m ³ /h)	Date of Completion
C 1499	SA-37-5	129.5	-	-	Dry	27/7/51
C 2468	"	179	155	152	Dry	12/12/55
C 451	"	137.2	110,120 134	44	6.8	28/8/46
C 381	"	128	31	23	4.1	30/10/45
C 1391	"	152	137	111	10.5	31/3/51
C 605	"	149	113,130 136	122	9.1	20/9/47
C 3368	"	65	61	10.9	2.72	1/11/65
C 3436	"	70.2	42.7	42.7	7.2	16/5/67
C 2646	"	91.4	80.8	59.4	1.5	6/3/57
C 130	"	60.9	30.1	23.7	4.54	6/4/41
C 587	"	92	41-56	24	9.1	13/9/47
C 3455	"	167.6	48.8	38.1	1.5	7/9/67
C 998	"	137	120	29.6	0.9	30/11/49
C 3519	"	99.67	53.6 68.6	40.2	8.09	25/5/68
C 4690	"	150	62	26.25	14.44	7/10/79
C 3582	"	96.0	-	-	Dry	7/5/69
C 3587	"	112.7	NIL	NIL	-	7/6/69
C 4258	"	150	106	11.1	9.2	30/1/76
C 1539	"	114.3	15	23	10.51	10/2/51
C 3747	"	85.9	10.7 61.0	6.4	9.0	24/10/70
C 138	"	73.1	36.5	5.1	1.70	11/5/41
C 1427	"	137	101	24	2.65	15/6/51
C 2587	"	182	48,177	22	3.0	11/11/56
C 155	"	55.7	32,50.2	23.7	3.63	19/2/42
C 811	"	129.5	81.3,23.7	17.9	4.45	30/1/49

Table 2-7 BOREHOLE DATA

Province Rift Valley

District Kajiado/Narok

Sheet ①

No.2

Borehole	Scale 1:250,000	Total Depth (m)	Water Struck (m)	Rest Level (m)	Tested Yield (m ³ /h)	Date of Completion
C 3520	SA-37-5	152.4	38.4	15.6	0.2	25/11/68
P 149	"	107.3	67,100.6	57.9	4.87	24/7/31
C 2544	"	97.5	-	55.8	5.2	15/1/47
C 2613	"	121	93,92	58	1.3	6/12/56
C 659	"	138	68	62	3.6	20/4/48
C 607	"	114	40,109	40	9.1	1/11/47
C 618	"	65	42,58	59	5.2	20/12/47
C 1413	"	152	4.8	18	4.70	19/5/51
C 4004	"	152.5	66	6.95	11.683	6/4/74
C 4022	"	152	110	8.36	7.92	13/7/74
C 4002	"	132.5	128	2.51	4.67	25/5/74
C 1387	"	55	48	7	8.2	8/5/51
C 1368	"	183	34,10	24	1.6	13/4/51
C 1662	"	182	107,122	90.8	3.27	6/2/52
C 1559	"	119	94.5	84	12.9	27/10/51
C 1713	"	177	97	55	0.54	4/3/52
C 4007	"	152	-	Dry	NIL	19/6/74
C 3190	"	135	-	39.3	11.67	-/-/43
C 1113	"	120	113,116	42.7	37.8	19/11/49
C 1114	"	139	137,139	56.7	11.4	8/4/49
C 1115	"	137	82,99	55.5	12.7	20/3/50
C 212	"	45.7	21.3,33.5	17.8	2.0	21/2/43
C 234	"	125	70.1-99.1	39.6	6.8	20/9/43
C 2474	"	106.7	68.6 100.6	2.44 9.80	68.1	13/1/56
C 3997	"	214	214	33.5	45.5	6/12/74

Table 2-7 BOREHOLE DATA

Province Rift Valley

District Kajiado/Narok

Sheet ①

No. 3

Borehole	Scale 1:250,000	Total Depth (m)	Water Struck (m)	Rest Level (m)	Tested Yield (m ³ /h)	Date of Completion
C 2333	SA-37-5	106.7	103.3	2.7	18.2	6/2/55
C 3159	"	167	27 122,152	20.4	13.6	8/9/61
P 4	"	92.65	NIL	NIL	NIL	28/11/27
P 5	"	204.2	188.98	94.5	3.60	29/9/55
C 12	"	107	91	44	0.5	22/6/38
C 216	"	70.1	36-39	18.6	14.8	3/4/43
C 1166	"	237	176	174	4.1	28/11/50
C 1126	"	215	207	204	1.14	28/7/50
P 16	"	147.5	96.9, 147.5	48	1.8	9/8/28
C 2866	"	147.5	133.5 147.5	89	4.7	5/3/59
P 23	"	83	74, 67	70.1	1.575	6/10/28
P 37	"	21.33	NIL	NIL	NIL	23/2/29
P 36	"	34.13	NIL	NIL	NIL	2/2/29
P 27	"	36.88	NIL	NIL	NIL	18/12/28
C 3525	"	143	88.1	86.6	7.1	19/10/68
C 165	"	155	-	-	0.07	16/4/47
C 511	"	171	-	-	NIL	7/2/47
C 510	"	183	-	-	NIL	28/2/47
C 115	"	249	-	-	NIL	17/7/41
C 1390	"	171	-	-	NIL	6/3/51
C 1259	"	138	18	9.14	6.37	2/5/50
C 3576	"	137.16	17	4.5	0.46	21/5/69
C 3942	"	152.4	106.7	100	6.4	6/10/73
C 3358	"	182	124	-	NIL	15/8/65

Table 2-7 BOREHOLE DATA

Province Rift Valley

District Kajiado/Narok

Sheet 34

No.4

Borehole	Scale 1:250,000	Total Depth (m)	Water Struck (m)	Rest Level (m)	Tested Yield (m ³ /h)	Date of Completion
C 4562	SA-37-9	227	95	89.25	1.84	21/1/80
C 3485	"	182.8	11.8 172	91.4	9.20	27/4/68
C 3044	"	100.3	73.2, 74.4	62.2	10.1	4/6/60
C 3046	"	131.1	112.8	111	10.1	8/7/60
C 2794	"	190.9	100.6 179.8	85.6	16.3	17/5/58
C 3043	"	46.3	27.4	27.1	11.37	August/60
C 2839	"	27.4	-	8.23	18.16	7/6/58
C 3045	"	24.4	12.5	10.66	10.1	20/2/60
P 66	"	157	118 149	92.4	NIL	13/11/29
C 1009	"	55	33	-	4.54	20/12/49
C 116	"	37.1	24.3	19.2	4.18	6/3/41
C 3757	"	106.7	50.3, 74.7 99.1	39.3	4.5	27/3/71
C 3836	"	114.3	34.7	30.4	10.9	19/5/72
C 142	"	76.2	55.4	53.3	NIL	18/8/41
C 2804	"	74.7	38.1	32	16.3	4/6/58
C 999	"	100	23	17.4	12.7	3/12/49
C 3826	"	109.7	35.8	32.0	10.9	17/4/72
C 1231	"	107	40	37	4.1	30/11/50
C 3816	"	100.5	41.1	34	10.5	18/2/72
C 1221	"	77	70	20	9.8	31/10/50
C 1136	"	191	79	28.3	10.9	8/6/50
C 1151	"	105	38.63 91	34	13.6	30/8/50
C 1183	"	122	38.82 116	23	3.6	27/9/50
C 3581	"	138.3	-	Dry	-	14/3/69
C 3532	"	121.92	100.88	45.08	1.82	19/12/68

Table 2-7 BOREHOLE DATA

Province Rift Valley

District Kajiado/Narok

Sheet (34)

No.5

Borehole	Scale 1:250,000	Total Depth (m)	Water Struck (m)	Rest Level (m)	Tested Yield (m ³ /h)	Date of Completion
C 3580	SA-37-9	108.5	43.5	32.9	14.6	19/3/69
C 2695	"	107.9	102	61.84	11.4	29/7/57
C 1071	"	96	46.72 91	41	3.2	19/4/50
C 3339	"	106	88.9	33.8	8.01	7/4/65
C 3	"	95	82	15	16.4	17/7/38
C 1923	"	154	27,102	50	3.86	21/3/53
C 2975	"	95.4	85.9	85.3	9.09	31/11/59
C 3578	"	152.7	56.3	41.15	1.04	18/6/69
C 3579	"	141.7	-	44.5	1.82	7/5/69
C 975	"	137.2	22.9,67.1	38.1	5.2	4/11/49
C 3311	"	62	40.5,45.7 51.8	35	11.3	28/9/64
C 3839	"	100.5	46.3	40.5	10.2	16/6/72
C 1534	"	63.3	39.3	20.7	14.55	29/9/51
C 3688	"	91.4	85.3	37.5	3.9	10/7/70
C 1290	"	94.5	39	37	9.2	10/1/50
C 139	"	53.3	32.3	29.2	2.36	5/6/41
C 3748	"	77.4	39.6 61	31	11.6	5/9/70
C 2435	"	108	29.48 103	24	4.7	5/11/55
C 3474	"	58.2	31.2	28	8	15/2/68
C 3835	"	114.3	34.7	30.4	10.9	19/5/72
C 2942	"	167.6	29,87	25.9	1.36	17/11/59
C 3392	"	122	58	21.3	0.48	5/7/66
C 3742	"	89.9	35.9,89.9	28	7.4	12/12/70
C 3394	"	137	-	-	NIL	17/8/66
C 3743	"	155.4	24.4	14	3.9	31/8/70

Table 2-7 BOREHOLE DATA

Province Rift Valley

District Kajiado/Narok

Sheet (34)

No.6

Borehole	Scale 1:250,000	Total Depth (m)	Water Struck (m)	Rest Level (m)	Tested Yield (m ³ /h)	Date of Completion
C 926	SA-37-9	121.9	89	21.3	2.9	15/8/49
C 3451	"	122	19.2 73.2	14.9	3.3	30/6/67
C 3337	"	138	121.9	61.8	4.95	24/5/65
C 3744	"	108.8	85.3	71.6	0.3	28/11/70
C 942	"	128	125	42.4	0.2	17/9/49
C 987	"	158	38,113	41.5	2.2	5/11/49
C 875	"	152	103	73	0.02	31/5/49
C 824	"	183	138	137	0.02	7/3/49
C 2468	"	179	155	152	Dry	12/12/55
C 1499	"	129.5	-	-	NIL	27/7/51
C 2647	"	103.6	91.4	18.3	4.2	24/3/57
C 3759	"	196.7	-	-	Dry	10/6/71
C 3756	"	106.7	-	-	Dry	1971
C 3776	"	167.6	19,142.6 164	3.0	5.4	17/4/71
C 2510	"	189	182.9	68.6	5.0	1/6/56
C 2365	"	76	67	55	Dry	22/3/55
C 552	"	122	91,116 118	94	11.36	14/6/47
C 315	"	59.4	50.3	47.5	6.83	17/8/44
C 359	"	60	46	50	9.1	28/3/45
C 875	"	152	103	73	0.02	31/5/49
C 3741	"	107.9	36.6,91.4	30.5	3.0	30/10/70
C 3338	"	137	49 84,125	39.3	5.9	15/1/65
C 1523	"	131	-	-	Abandon	7/9/51