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Republic of Kenya
Lake Basin
Development Authority

Kingdom of the Netherlands
Ministry of
Foreign Affairs

RURAL DOMESTIC WATER SUPPLY AND SANITATION PROGRAMME

RURAL DOMESTIC WATER RESOURCES ASSESSMENT
SIAYA DISTRICT

December 1988

DHV

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SUMMARY
AND
WATER SUPPLY PLAN

CONTENTS SUMMARY AND WATER SUPPLY PLAN

S U M M A R Y

A INTRODUCTION

This report gives information about the occurrence, use, exploration techniques, water potential and exploitation possibilities of the water resources in Siaya District.
It presents a plan for improvement of rural water supply in the District (Water Supply Plan) as well as recommendations for implementation of this plan.

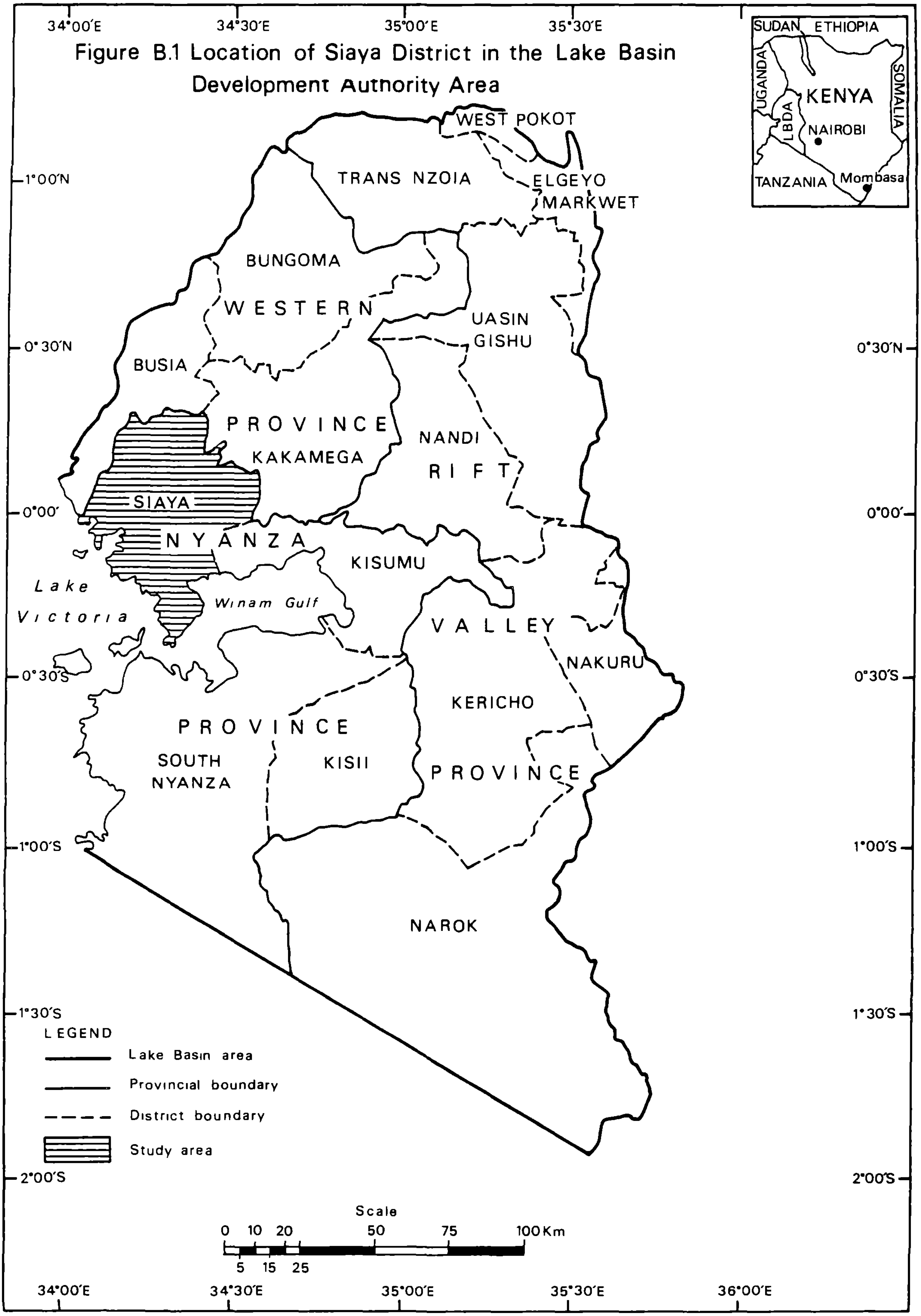
The report is mainly based on the results of the systematic and detailed water resources assessment studies carried out in the District during 1987 and 1988 as a part of the Lake Basin Development Authority's Rural Domestic Water Supply and Sanitation Programme (RDWSSP), which have subsequently been published in five comprehensive Divisional Reports.

The primary aim of the RDWSSP is to improve the water supply situation in the rural areas of Nyanza Province.

Siaya District is an area with tremendous contrasts in water resources. The western and southern parts are very dry areas with almost no perennial water points, while the northern and eastern parts have abundant surface and ground water resources.

The Water Supply Plan for Siaya District is based on point sources water supply. Only in the western and southern parts of the District piped systems are planned. Piped water supply systems are needed in these areas because of the complete absence of suitable ground water sources. Preconditions for piped water supply are a decentralised operation and maintenance set up, including full responsibility and power for the piped water supply staff, and supply of water at a cost-effective basis.

Figure B.1 Location of Siaya District in the Lake Basin Development Authority Area



B GENERAL FEATURES OF SIAYA DISTRICT

Siaya District forms the northern part of Nyanza Province, located in the southwest corner of Kenya. It is bordered by Busia District to the west and north, by Kakamega District to the northeast, Kisumu District to the east and Lake Victoria to the south.

The area is roughly situated between latitudes 00^{o} 25′ South and 00^{o} 18′ North (UTM-grid: 9955-0035) and longitudes 34^{o} 00′ East and 34^{o} 35′ East (UTM-grid: 0610-0675).
The total surface area is about 2,500 (km^2), which is 20 % of the total land surface of Nyanza Province (12,500 km^2).

Siaya District is characterized by a smooth gently undulating landscape with altitudes ranging from 1140 (m) along the Lake Victoria shores to about 1500 (m) in the north and northeastern part of the District.

Climatological conditions vary dramatically from the south with a mean annual rainfall of less than 700 (mm) towards the north where the mean annual rainfall exceeds locally 2000 (mm). Evaporation which is very intense in the southern part, over 2000 (mm/year), steadily decreases towards the northeast of the area (1600-1800 (mm/year).

The present total population amounts to about 690,000 resulting in an average population density of around 276 people per (km^2).

Distribution of population per Division and population projections for 1995 and 2005 are given in Table B-1.

TABLE B-1. SUMMARY OF DISTRICT POPULATION PROJECTIONS.

DIVISION NAME	POPULATION 1987	1995	2005
BONDO	109,000	138,000	186,000
RARIEDA	109,000	138,000	186,000
BORO	157,000	199,000	267,000
YALA	139,000	176,000	237,000
UKWALA	176,000	223,000	300,000
SIAYA DISTRICT	690,000	874,000	1,176,000

Remarks; 3 % growth rate is assumed based on "Integrated Regional Development Master Plan" JICA, 1987

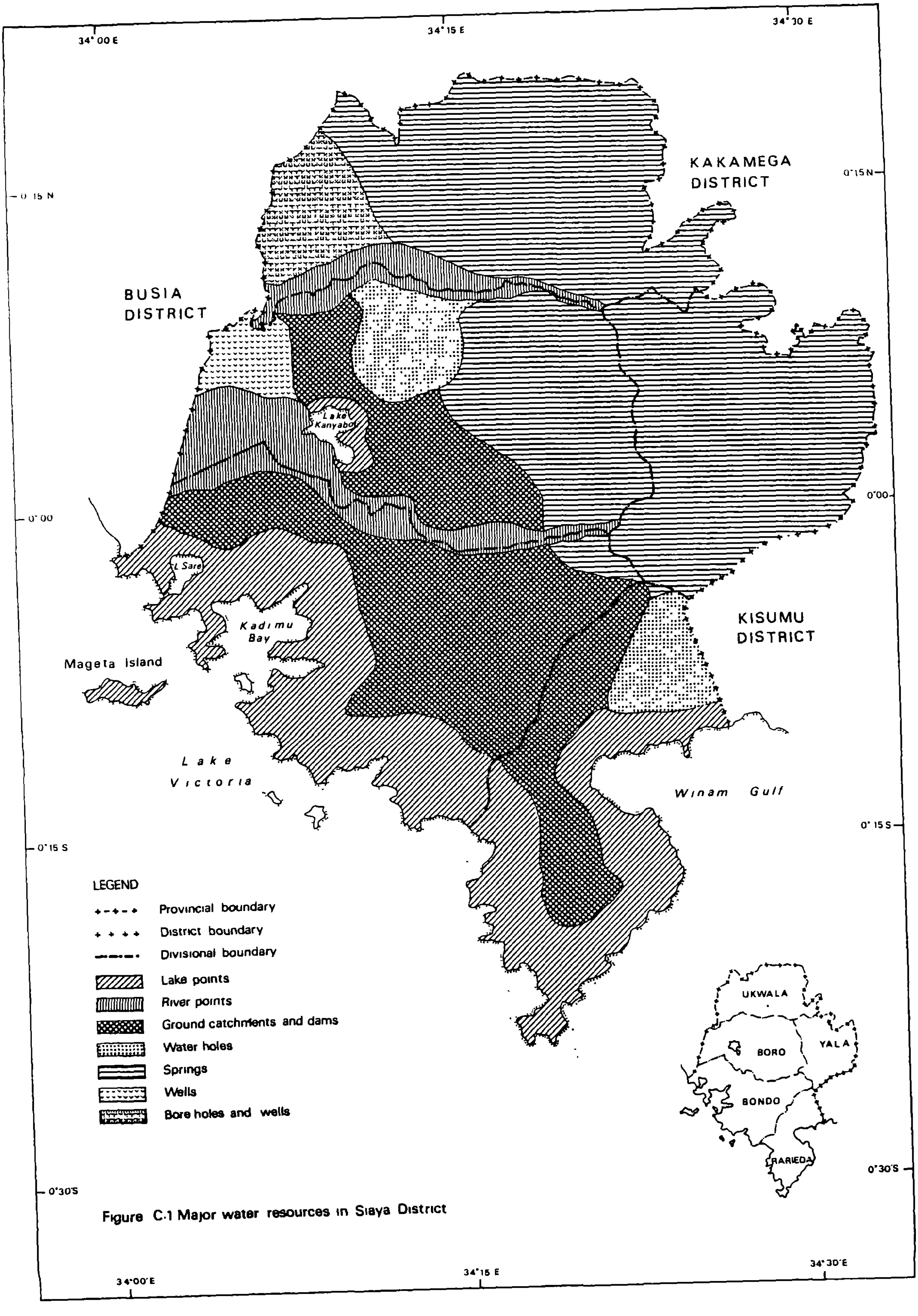


Figure C.1 Major water resources in Siaya District

C EXISTING WATER SUPPLY SITUATION

C-1 *Introduction*

As part of the RDWSSP a comprehensive inventory survey has been carried out, with the aim to assess and evaluate the use and condition of all water sources in the District.

It was found that in total 4,308 different water points are used for domestic water supply, including : springs, river points, lake points, water holes, wells, boreholes, roof catchments, ground catchments and dams. In addition to these point sources, 38 piped water supplies are used on a limited scale.

A summary of existing water sources used for domestic purposes in the District is given in Table C-1.

TABLE C-1. SUMMARY OF EXISTING WATER SOURCES IN SIAYA DISTRICT, USED DURING THE WET AND DRY SEASON.

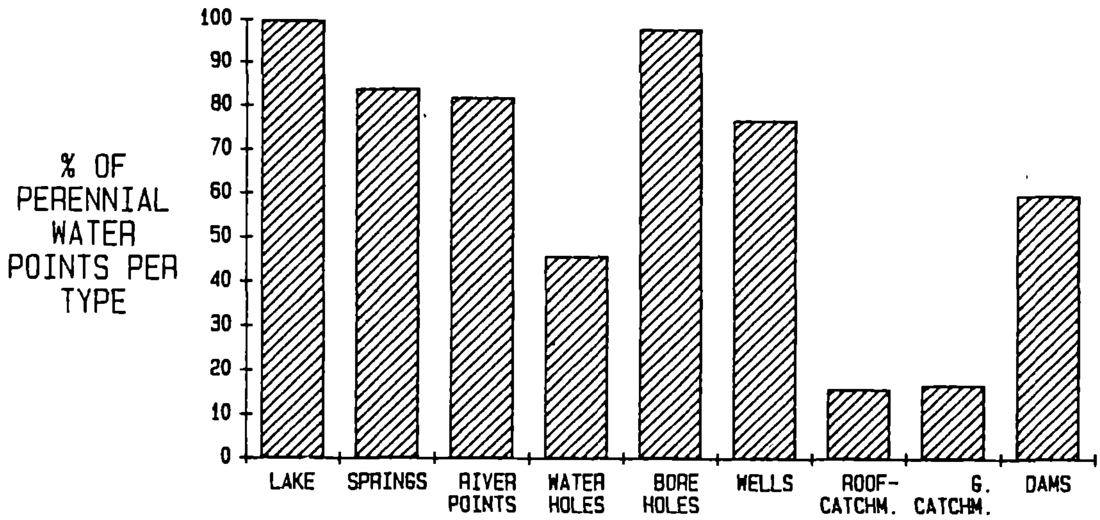
	WET SEASON		DRY SEASON	
TYPE OF WATER SOURCE	NR. OF SOURCES	% OF CONSUMERS	NR. OF SOURCES	% OF CONSUMERS
SPRINGS	1.601	33.8	1,346	33.7
WELLS	492	7.7	379	7.8
BOREHOLES	112	3.6	110	3.7
ROOF CATCHMENTS	525	2.2	82	0.3
RIVERS	622	13.3	507	15.6
LAKE VICTORIA	112	5.8	112	14.5
WATER HOLES	259	5.9	118	4.1
DAMS	109	7.4	65	9.1
GROUND CATCHMENTS	476	16.1	82	6.4
PIPED SUPPLIES		4.2		4.8
TOTAL	4,308	100.0	2,801	100.0

C-2 *Point sources*

The rural population of Siaya District mainly use point sources for their domestic water supply.
On an average about 2 water points per (km^2) exist, but tremendous differences in water point density occurs within the District. The southern part (Bondo and Rarieda Divisions) have less than 1 water point per 2-5 (km^2), while the north, north-eastern part has a water point density of more than 3 per (km^2).
Springs are the most widespread type of water point, but occur mainly in the northeastern part of the District.
Furthermore a large number of water points (1507) can not be used during the dry seasons, because of drying up of the water.

The quality of the water collected from most of the point sources is very poor. With the exception of boreholes, springs and wells (only if they are properly improved or constructed) all existing water points are polluted.
Many springs which essentially supply good water are contaminated due to lack of a proper drainage of the water. Wells without a cover, lining and hand pump were all found to be contaminated.

FIG. C.2 PERCENTAGES OF PERENNIAL WATER POINTS PER TYPE



C-3 *Piped water supply systems*

There are 38 piped water supply systems in Siaya District (Fig. C-5), of which:

- 21 systems regularly supply water;
- 7 systems are irregularly functioning;
- 7 systems are out of order
- 3 systems are under construction.

Out of the 21 systems which are regularly supplying water, there are 7 from which part of the distribution system is operational. As a result only 14 schemes are effectively used.
In total only a small part of the rural population is presently served by the piped water supply systems (4.5 %).

FIG. C.3 WATER POINTS USED FOR DRINKING AND WATER POINTS WHICH ARE NOT USED FOR DRINKING

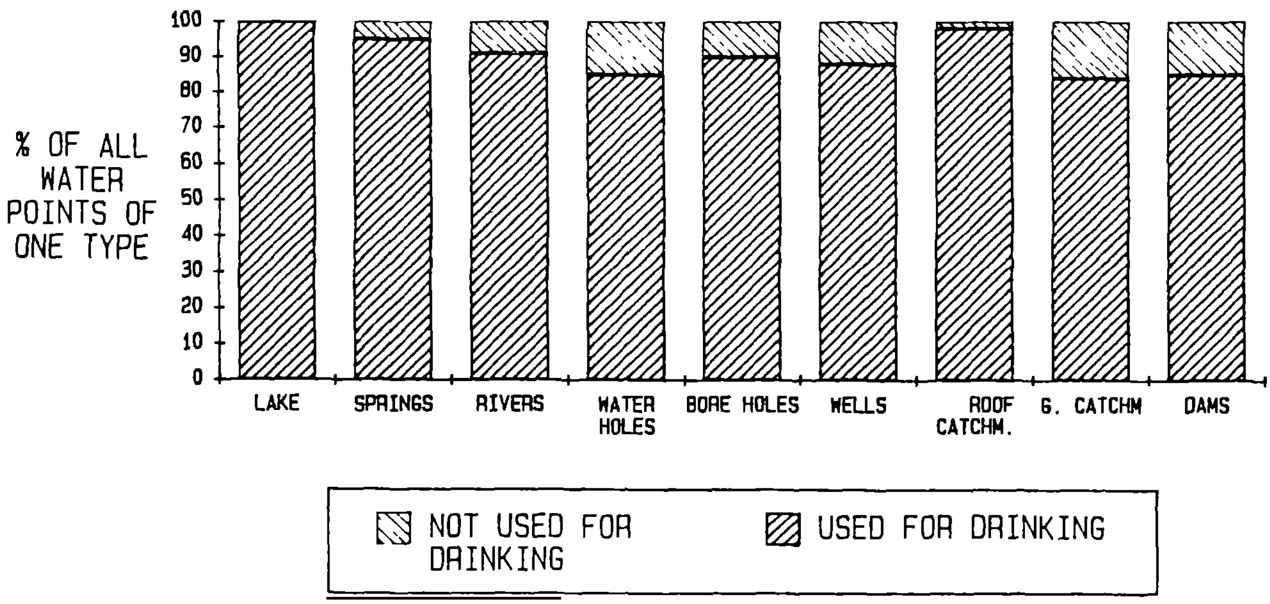
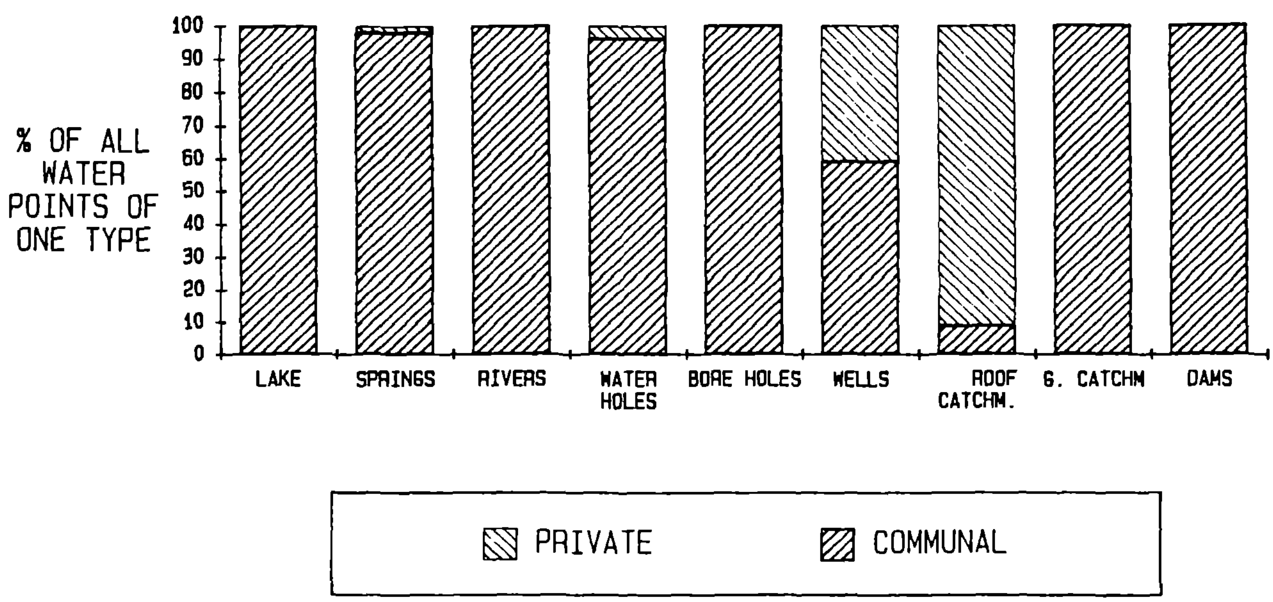


FIG. C.4 PRIVATE AND PUBLIC USE OF WATER POINTS



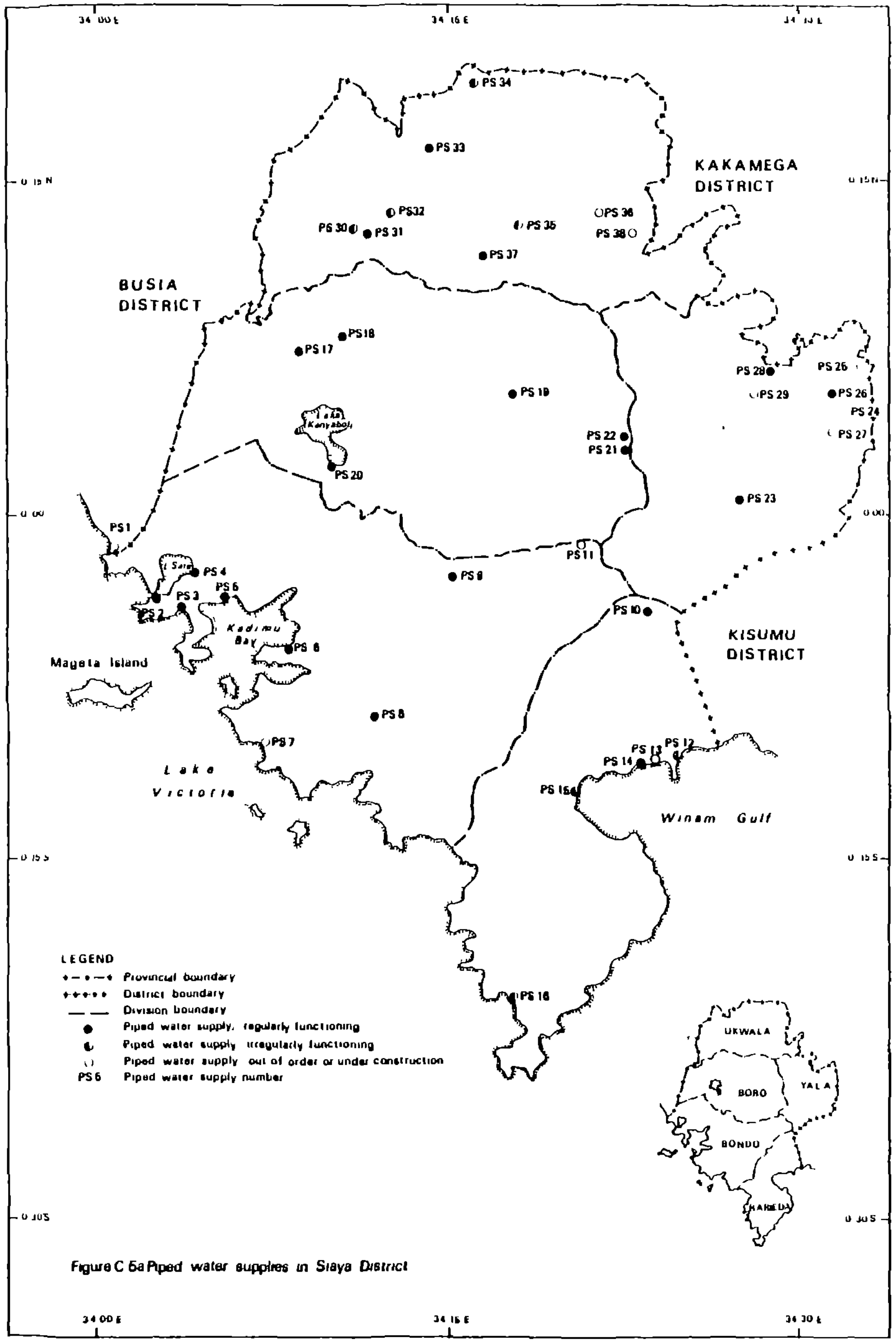


Figure C 5a Piped water supplies in Siaya District

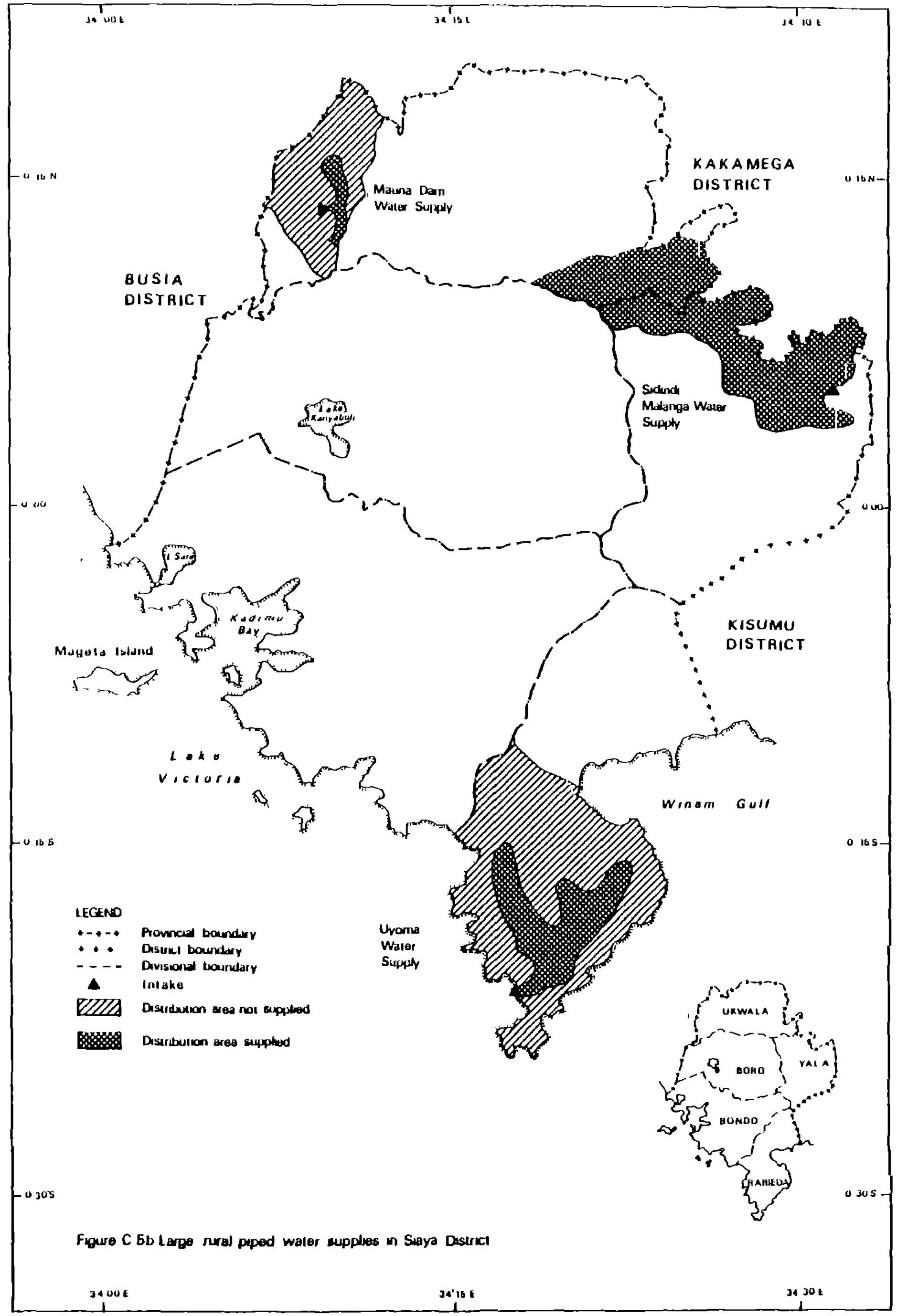


Figure C 5b Large rural piped water supplies in Siaya District

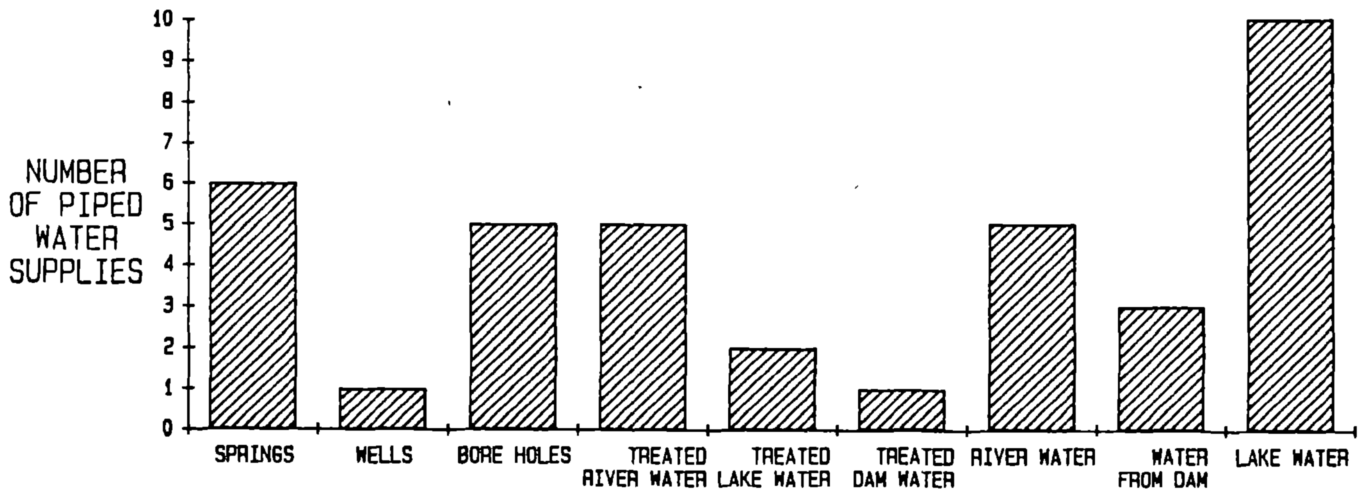
The major sources used for the piped water supply systems are as follows (Fig. C-6):

- 12 schemes use Lake Victoria
- 9 schemes use river water
- 6 schemes use springs
- 5 schemes use dams
- 5 schemes use boreholes
- 1 scheme uses a well.

Most piped water supply systems use diesel driven pumps (33 schemes), while the remaining 5 schemes use electrical driven pumps.

From the 5 schemes with electrical driven pumps, one is out of order, but the remaining 4 regularly supply water.

FIG. C.6 WATER SOURCES OF PIPED WATER SUPPLY; A BREAKDOWN PER NUMBER



Non or irregularly functioning of the piped water supplies mainly occurs on the schemes with diesel driven pumps.
The main reasons for non or irregularly functioning is caused by:

- lack of diesel supply
- removal of (parts of) the diesel engines
- pump breakdowns.

There are 3 large piped water supply systems in Siaya District.

- Uyoma Water Supply
- Mauna Dam Water Supply
- Sidindi-Malanga Water Supply

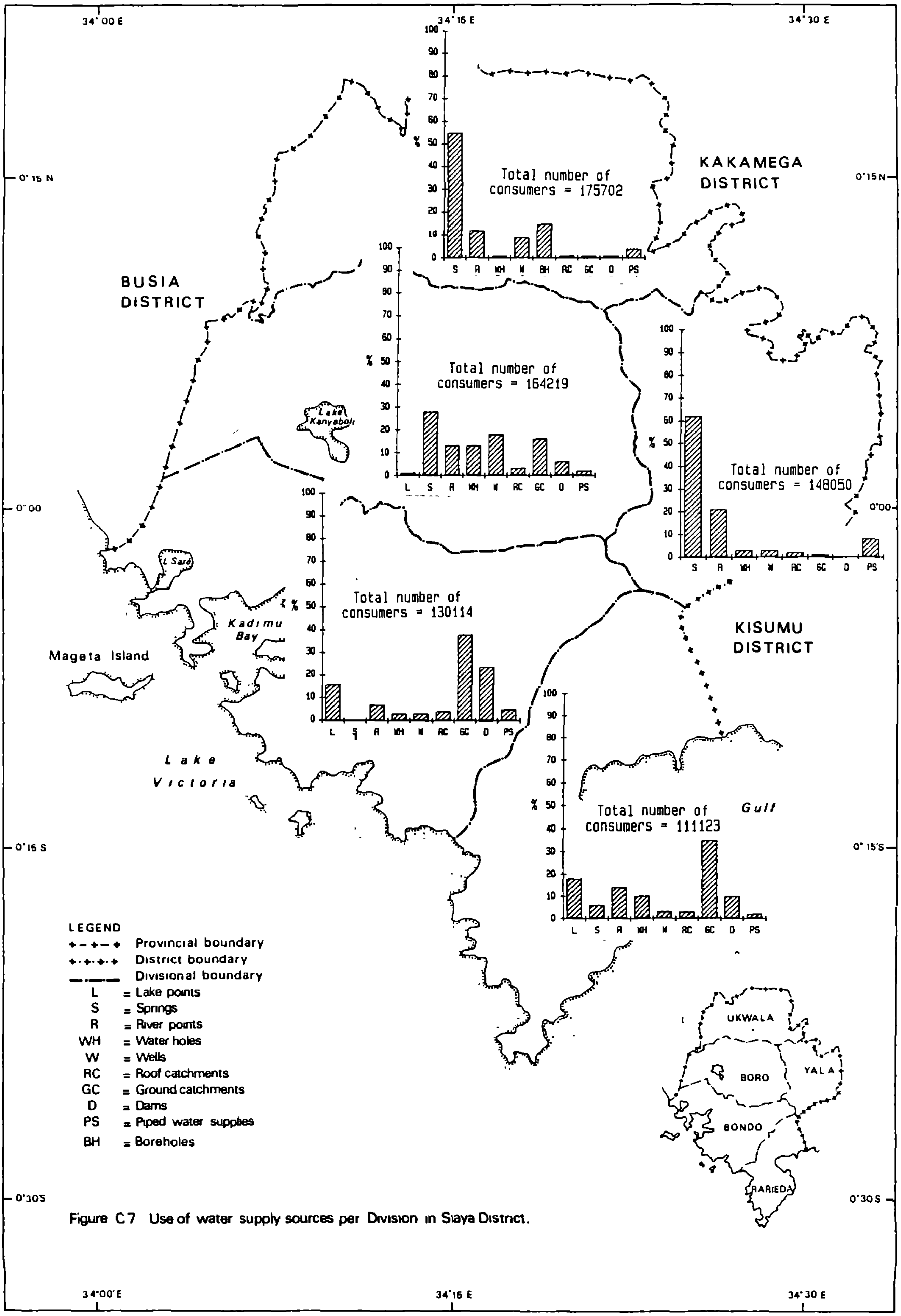


Figure C 7 Use of water supply sources per Division in Siaya District.

C-4 *Use of different water supply resources*

As shown in Table C-1, a large variety of different water points are used in Siaya District. However, the type of water point used by the rural population differs substantially from place to place.
In the southern part, in a wide zone along the Lake Victoria shore, people fetch their water mainly from Lake collection points, while further inland most commonly used water points are dams, ground catchments and water holes.
In the northern and eastern part of the District the most frequently used water points are springs and wells (Fig. C-7).
Water collected from the Lake, springs and roof catchments is almost everywhere used for drinking, but water from dams, ground catchments and water holes are only for less than 80 % used for drinking (Fig. C-3).
Striking is the relatively high percentage (10-12 %) of boreholes and wells not used for drinking, because of a bitter taste of the water (probably caused by a high manganese and/or iron concentration).

A large percentage of wells (40 %) and roof catchments (90 %) are private facilities (Fig. C-4).
Springs, dams, rivers, boreholes and ground catchments are almost exclusively considered as communal water supply facilities.

D GROUND WATER RESOURCES

Siaya District is for 90 % underlain by hard rocks of mainly volcanic and volcano sedimentary origin. The rocks are intensively jointed, fractured and faulted and covered with a layer of weathered rock material. The remaining 10 % of the District is covered with Recent alluvial sedimentary deposits.

Consequently ground water can be present in

- the weathered layer
- fault and fracture zones
- sedimentary deposits

D-1 *Ground water within the weathered layer*

The relatively high amount of annual rainfall in the north and northeastern parts of the District causes a reliable and steady recharge into the weathered layer. The ground water level varies between 5 - 15 (m-gl), which makes the ground water easily accessible through hand dug wells.
In the southern part however, little or no ground water is found within the weathered layer due to a very low recharge in this part of the District.

Because of the rather clayey weathering of the volcanic rocks, the well yields generally are low, but are sufficient for hand pump use (1-2 m^3/hr).
The weathered material of the Kavirondian rock types generally produce slightly higher well yields (2-5 m^3/hr).

D-2 *Ground water in fault and fracture aquifers*

From the results of the ground water survey and the on-going borehole drilling programme in Nyanza Province it appears that relatively high yield wells (10-50 M^3/hr.) can be constructed in major fault zones while the surrounding areas have only a moderate or no ground water potential at all.

Well construction in this type of aquifer can only be done through machine drilling of boreholes. For successful borehole location in this aquifer type special exploration techniques are warranted.
The Programme has developed a combination of survey techniques based on remote sensing, aerial photograph interpretation and ground geophysical survey.

D-3 *Ground water in sedimentary deposits*

About 10 % of Siaya District is covered by sediments, mainly Pleistocene to Recent in age, and consisting of lacustrine and fluviatile deposits. Relatively thick deposits of sediments are found near the mouth of the Yala and Nzoia Rivers (Yala Swamp area).
Ground water generally is present in the coarse layers at a relatively shallow depth (5-8 m-gl).

Ground water presence and quality in these sedimentary deposits are explored by means of the drilling of hand auger survey holes.

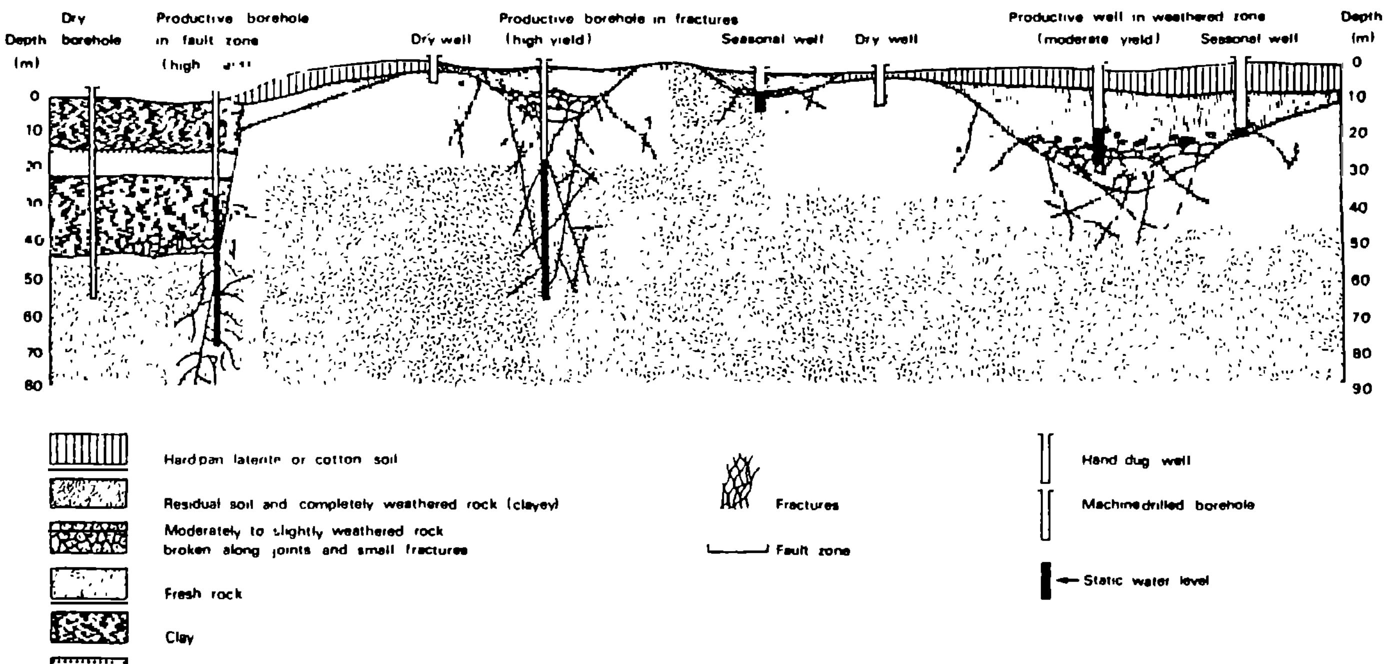


Figure D 1 Aquifer types

D-4 *Ground water potential*

Based on rainfall, runoff and evaporation data the amount of recharge per catchment area was estimated (Table D-1). In total a fair amount of recharge takes place in Siaya District of about 110 x 10^6 (m^3/year). Comparing this total amount with the demand of the total population of Siaya District, on an average 436 (litres/capita/day) is presently available.
However, ground water recharge takes place mainly in the northern and northeastern part of the District, while hardly any recharge takes place in the southern part of the area.
Hence based on ground water potential in Siaya District 3 zones have been distinguished (Fig. D-2).

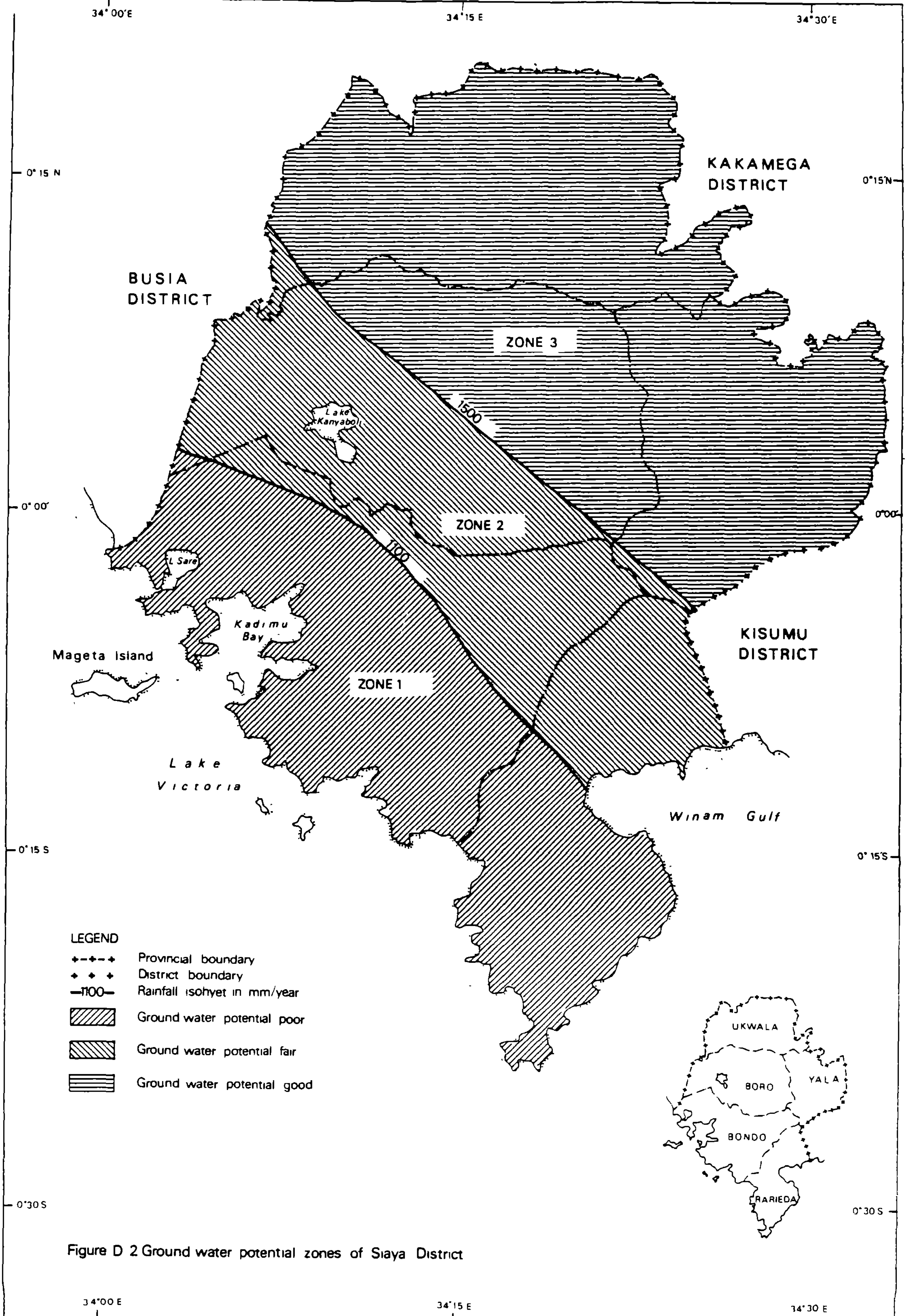


Figure D 2 Ground water potential zones of Siaya District

- Zone 1, with a low ground water potential covering the southern part of Siaya District.

- Zone 2, with a intermediate ground water potential, covering the central area of the District.

- Zone 3, with a good ground water potential located in the north and northeast part of the District.

TABLE D-1 GROUND WATER POTENTIAL PER CATCHMENT

CATCHMENT NAME	CATCHMENT CODE	SURFACE AREA IN (KM^2)	TOTAL VOL. GROUND WATER 10^6 (M^3/YEAR)
LAKE VICTORIA E.	1HB	177	4.9
LAKE VICTORIA W.	1HC	615	1.8
YALA	1FG	887	45.2
NZOIA	1EE	233	24.5
SIYOGA	1EF	238	10.5
WUOROYA	1EG	337	23.3
SIAYA DISTRICT		2487	110.2

D-5 *Ground water quality*

Water analyses carried out on a large number of ground water samples showed that the physical and chemical quality of the water is generally good and can be used without any treatment in most parts of the District. Occasionally the ground water may contain high concentrations of iron and/or manganese which gives a bitter taste to the water, and may cause stains on laundry. In large areas along the Lake Victoria shore and in and around Yala Swamp area saline ground water is found (Fig. D-2. Locally ground water was found to be contaminated (faecal coliforms) which is caused by surface pollution near the collection point, or due to the absence (or bad condition) of a spring or well cover. The ground water originating from properly protected water points however can safely be used.

E SURFACE WATER RESOURCES

A surface water survey was implemented with the aim to investigate the opportunities for piped water supply in Siaya District.

Main conclusions of the surface water survey are:

- Lake Victoria can be used for piped water supply.
  Severe contamination or pollution of the water has not been found.
  The chemical constituents of the water are within Kenyan Standards for domestic water supply. The iron and manganese concentrations which are incidentally found to be too high can be reduced by sedimentation and filtration. It is advised to build raw water storage basins to bridge periods in which an intake of water is impossible due to for instance algae blooms.
  The colour and turbidity figures are rather low and do not fluctuate much. Pre-treatment of the water can be rather simple if a proper intake site is selected. The need for coagulation should be investigated on the spot. Chlorination of the water is always needed.

- Lake Kanyaboli is not suitable for piped water supply. The lake water is getting brackish because there is no replenishment of the water via River Yala and a large evaporation surplus.
  Desalination of the water is not feasible. Ground catchments , dams and water holes will continue to be used because their water tastes better

- Most rivers in Bondo, Rarieda and Boro Divisions are seasonal and therefore unsuited, for piped water supply.

- The minimum flows of most perennial rivers in Yala and Ukwala enables to use them for small scale piped water supplies (<10,000 consumers).

- River Wuoroya could be used as a source for a medium scale piped water supply (up to 30,000 consumers).

- River Yala is suitable for piped water supply. No severe pollution has been found. Using the river water requires a full treatment, including coagulation, filtration and chlorination.

- River Nzoia is unsuitable for piped water supply.
  The river is severely polluted, causing low oxygen levels. The risk of anaerobic conditions causing harmful reductions of nitrate and sulphate is manifest.
  Cadmium and phenol concentrations were found to be too high. A long time sustainable treatment of the water to reduce these substances is not feasible.

F ON-GOING CONSTRUCTION OF POINT SOURCES

Upto the present only a limited number of point water supplies have been constructed in Siaya District. Besides the RDWSSP (with an expected total of 90 water points completed by the end of 1988), several governmental and non-governmental organizations have been active in the implementation of water points in the District.

Most of the activities are concentrated on the construction of hand dug wells, but on a limited scale spring protections, boreholes and rain catchment systems have been constructed as well.

In total 527 improved water points have been made till so far in Siaya District by the following organizations:

- KEFINCO (289)
- MINISTRY OF HEALTH (119)
- FGCSP/IFAD (32)
- RURAL DEVELOPMENT FUND (35)
- CARE (7)
- DIOCESE OF MASENO WEST (5)
- RDWSSP (45)

According to the planning of the above mentioned organizations it is expected that not more than 150-200 water points will be constructed in Siaya District during (1989).

WATER SUPPLY PLAN

G WATER SUPPLY PLAN

G-1 *The RDWSSP policy to improve rural water supply in Siaya District*

The RDWSSP favours to improve rural water supply in Siaya District in 2 phases.
The first phase aims at reaching a water supply level , indicated as Level I , on which the entire rural population of Siaya District has ***access to good quality drinking water.*** The amount of water available has to be sufficient for safe drinking and cooking.
The second phase aims at reaching a water supply level II.
Level II is defined as: the entire rural population of Siaya District is supplied with ***sufficient and good quality drinking water***, enough to use the water at home for all domestic purposes including washing and bathing.

Level I implies, the presence of a dense network of safe and reliable communal water points.
Level II can only be achieved by constructing piped water supplies with private house or yard taps.

The present Water Supply Plan for Siaya District describes what is needed to achieve Level I. Developments aimed at reaching Level II are supported if the conditions for a long time sustainable piped water supply system are fulfilled.

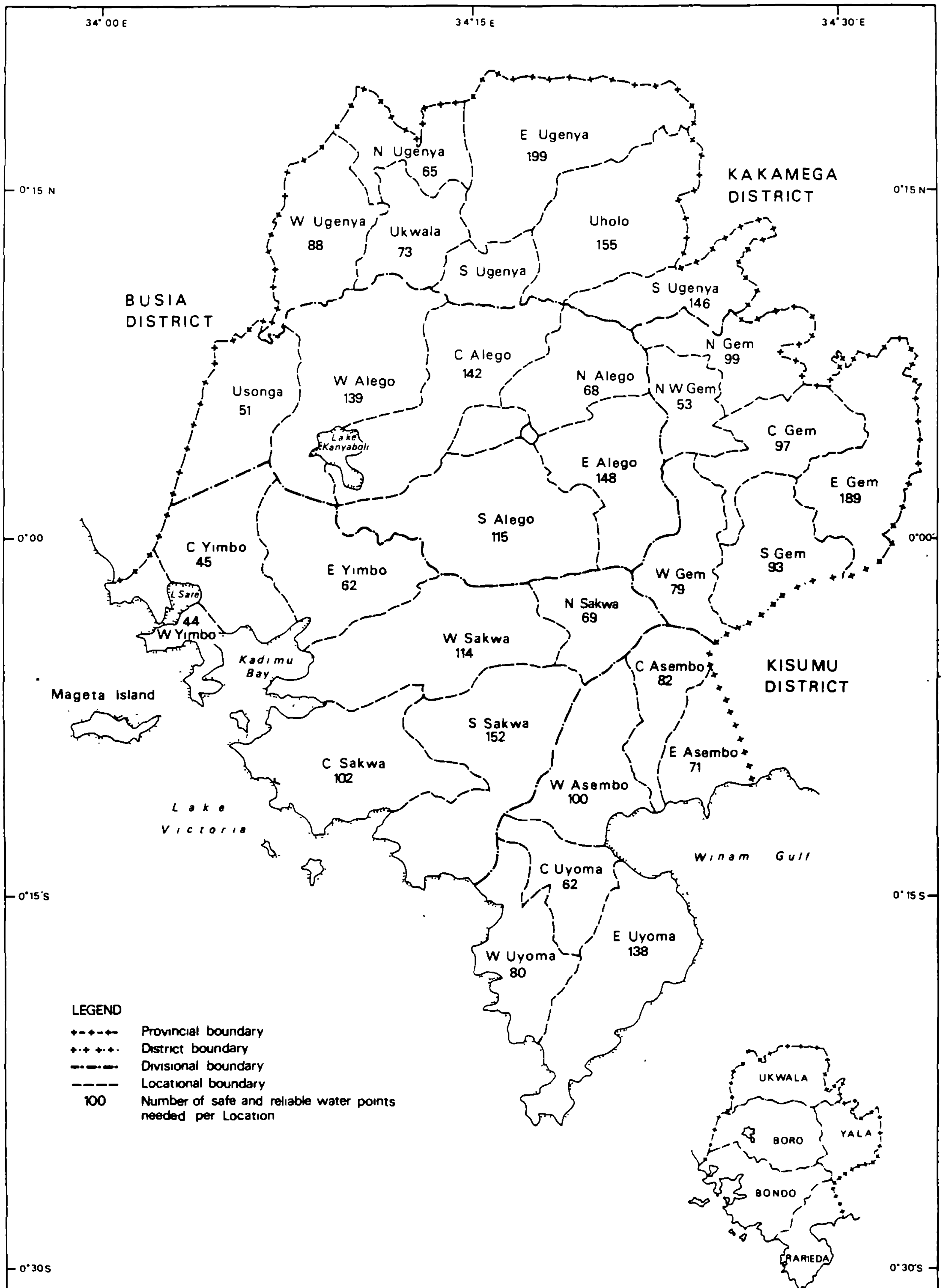


Figure G 1 Required number of safe and reliable water points

G-2 *Targets*

A dense network of safe and reliable communal water points is needed to give everybody access to good quality drinking water. The target set by the RDWSSP is to have an improved communal water point within 500 (m) from each home.

Assuming that each improved water point will cover a circular area with a radius of 500 (m), the required number of improved water points is calculated using formula (G-1).

$$N = \frac{A_i}{0.785} \qquad \text{(G-1)}$$

N = Required number of safe and reliable water points.

A_i = Inhabited area (km^2).

Most of the water points needed in Siaya District are hand dug wells.
The water supply capacity of such a well is limited. Most of the hand dug wells can supply up to 250 consumers.
This figure of 250 consumers per water point, is therefore used as a maximum.

$$N >= \frac{P_s}{250} \qquad \text{(G-2)}$$

P_s = Actual population having no private good water points.

Fig. G.1. shows how many safe and reliable public water points are needed in each Location of Siaya District using both formulas (G.1) and (G.2). The total number of water points needed equals to 3,120.

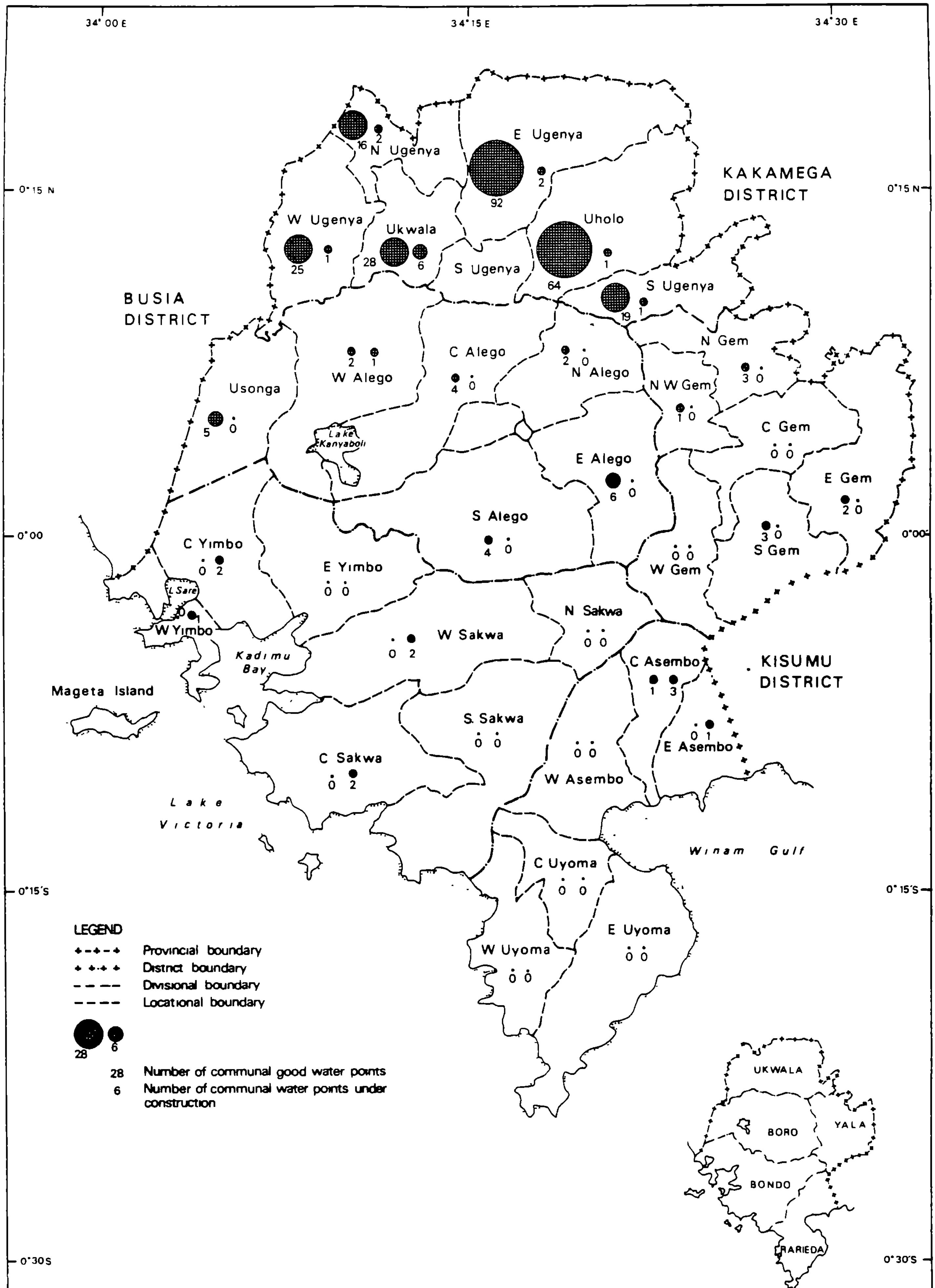


Figure G-2 Good water points and water points under construction in Siaya District

G.3. *Water supply plan*

Good water points and water points under construction

The first step in preparing the Water Supply Plan was to identify which existing communal water points are already safe and reliable.
During the inventory survey , part of the water points were found to be "good". A good water point fulfills the following requirements:

- It is used for drinking
- It's general condition is "good".
- It does not dry up.
- It is not contaminated.
- It has a slab (wells and boreholes) which is in a good condition as well as a working hand pump.
- It has a cover (springs) which is in a good condition, a proper drainage and no possibility of upstream pollution.
- It has gutters and a storage tank (roof catchments) which are in a good condition.

A total number of 333 good water points were found. Out of these 333 good water points, 259 are used as communal water points, do not need improvement and have been included in the water supply plan.

During the inventory survey also a number of wells, and roof catchments were found to be under construction. Part of these water points will be used as communal facilities. With due support e.g. technical advice, delivery of pump equipment, etc. these water points will be safe and reliable in future.
Twenty five (25) communal water points were found to be under construction. The communal water points under construction have also been included in the Water Supply Plan
Fig. G.2 shows the numbers of good water points and water points under construction per Location.

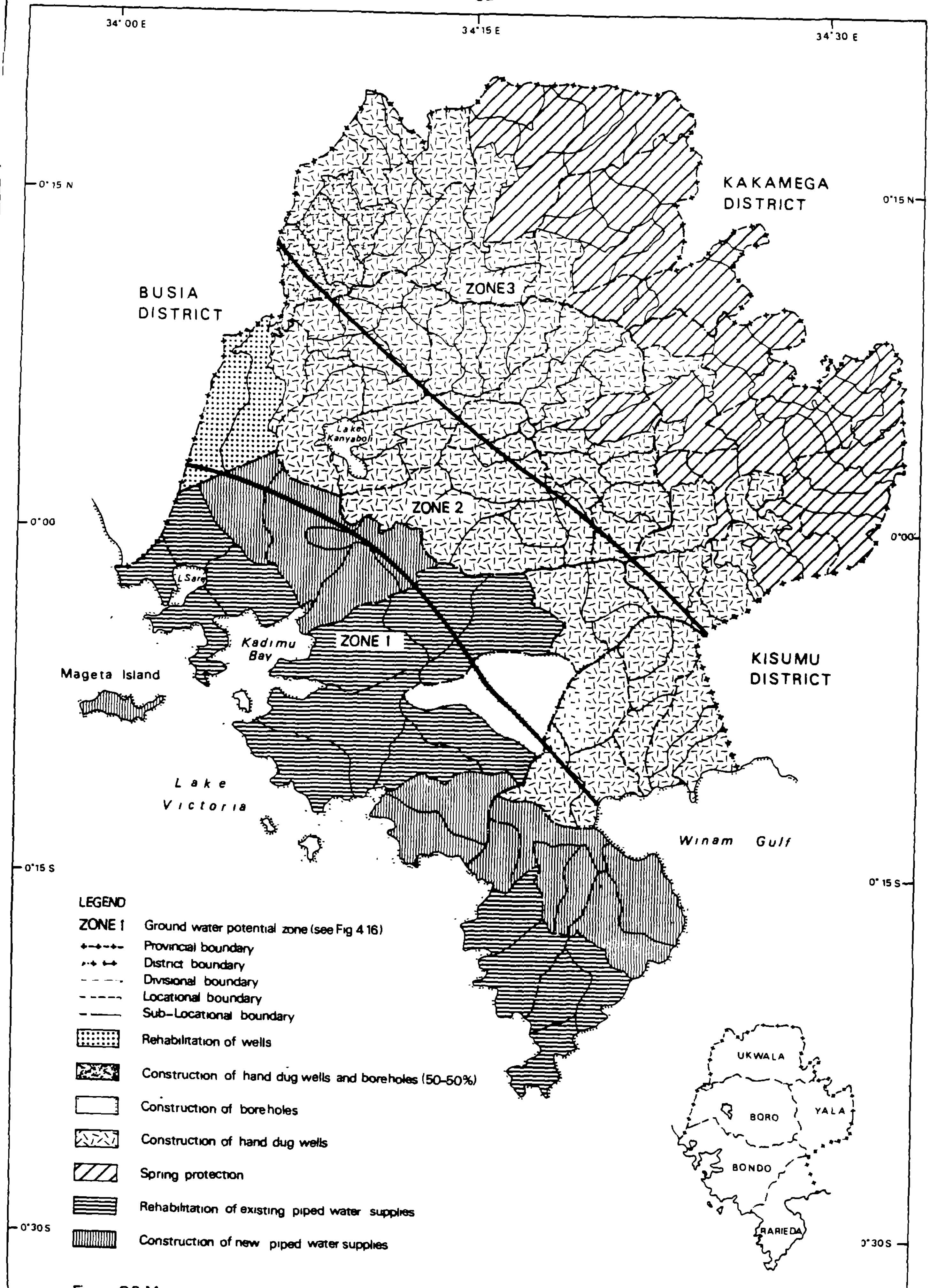


Figure G3 Major improvements works per Sub-Location

Improvement of existing water points; major improvement works per zone

Siaya District has been subdivided into 3 different zones.
The area south of the 1100 (mm) mean annual rainfall isohyet (Bondo, Rarieda and part of Boro Division) is indicated as zone 1. Zone 1 has a poor ground water potential. Springs and wells are hardly found in this zone 1. People use ground catchments and dams or walk to Lake Victoria.
The area between the 1100 (mm) and 1500 (mm) isohyets, indicated as zone 2, has a fair ground water potential. Many people living in zone 2 use ground catchments and dams. Wells and water holes however are also frequently found.
The area north of the 1500 (mm) isohyet, zone 3, has good opportunities for using ground water. Most frequently used water sources are wells and in particular springs.

Based on this subdivision into ground water potential zones as well as the results of the inventory survey describing the existing water supply resources, the major improvement works for each zone are different. Fig. G.3 shows this in detail.

In Bondo and Rarieda Divisions, existing piped water supplies have to be improved. New piped water supplies are needed at Mageta Island, in the northwestern part of Bondo Division and in the central part of Rarieda Division.
Rehabilitation of existing wells will be the major activity in the western part of Boro Division (Usonga Location).
The rest of zone 2 and a large part of zone 3 will be covered by making hand dug wells.
Spring protection will be the most important activity in the eastern part of zone 3 (Ukwala and Yala Divisions).

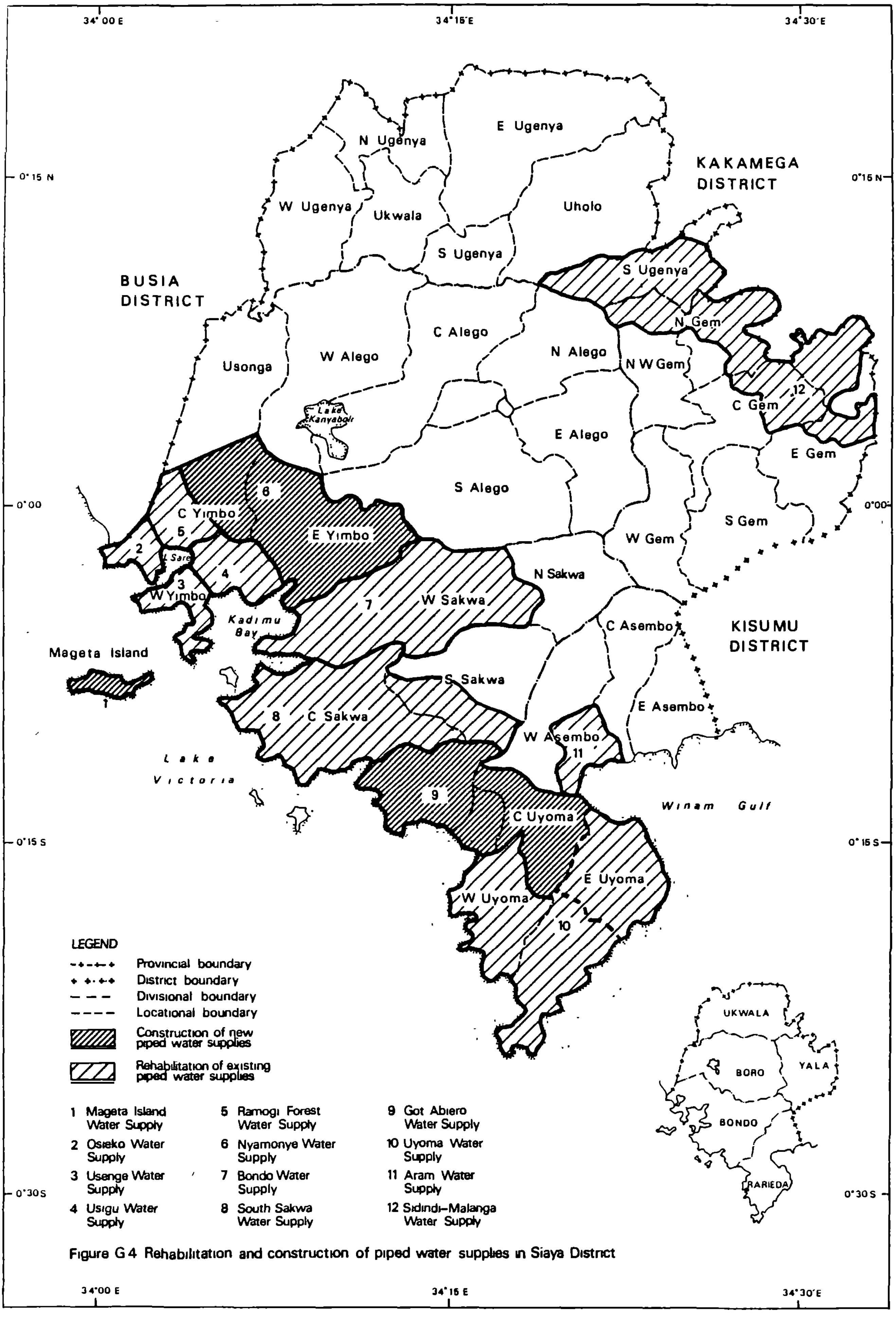


Figure G 4 Rehabilitation and construction of piped water supplies in Siaya District

Piped water supply

Fig. G.4 shows which existing piped water supplies have to be improved and where new piped systems have been planned. A total number of 12 different piped water supply projects have been identified.

Rehabilitation of the following existing schemes is planned:

- Osieko Water Supply
- Usenge Water Supply
- Usigu Water Supply
- Ramogi Forest Water Supply
- Bondo Water Supply
- South Sakwa Water Supply
- Uyoma Water Supply
- Aram Water Supply
- Sidindi-Malanga Water Supply

Construction of 3 new piped water supplies.

- Mageta Island Water Supply
- Nyamonye Water Supply
- Got Abiero Water Supply

Rehabilitation of ground catchments and dams

An adequate sanitary improvement of existing ground catchments and dams is hard to realize.
Rehabilitation, as planned in Bondo, Rarieda and Boro Divisions is therefore considered to be of second level, subordinate to rehabilitation and construction of piped water supplies in these areas.
Nevertheless it should be realized that most people living in Bondo and Rarieda Divisions, use ground catchments and dams for domestic water supply.
Also in future this type of water points will be frequently used.

Fig G5 Design for rehabilitation of ground catchments and dams

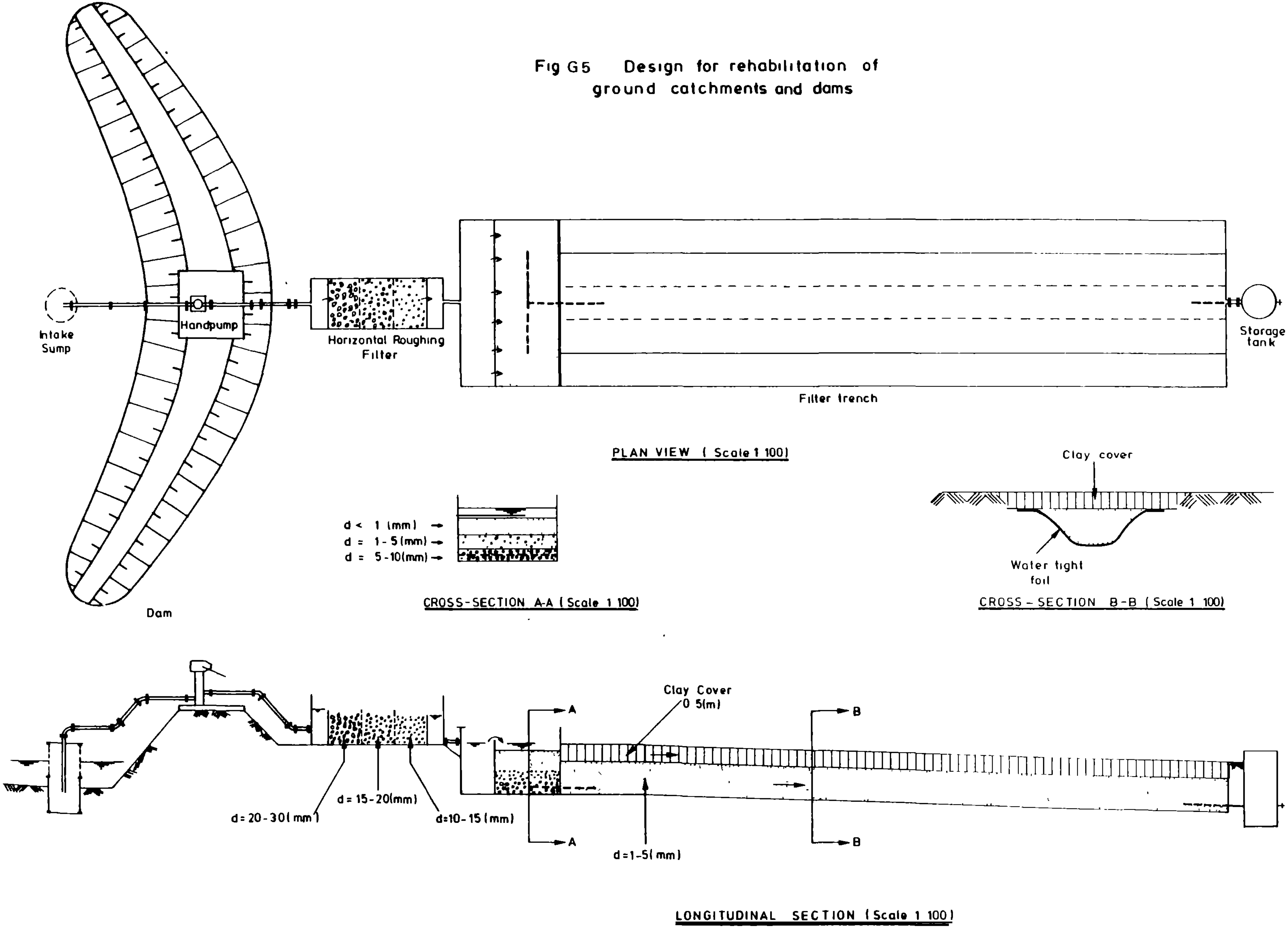


Fig. G.5 shows a tentative design for rehabilitation of ground catchments and dams. It is based on 2 basic ideas.

- The water stored in a ground catchment or a dam is always polluted and there are no ways to exclude or prevent this pollution.
  The water should therefore be treated.

- Underground storage of water after treatment reduces the water losses due to evaporation and enables to use the water for drinking and cooking.
  Polluting activities as cattle watering and washing can be done at the open upstream reservoir.

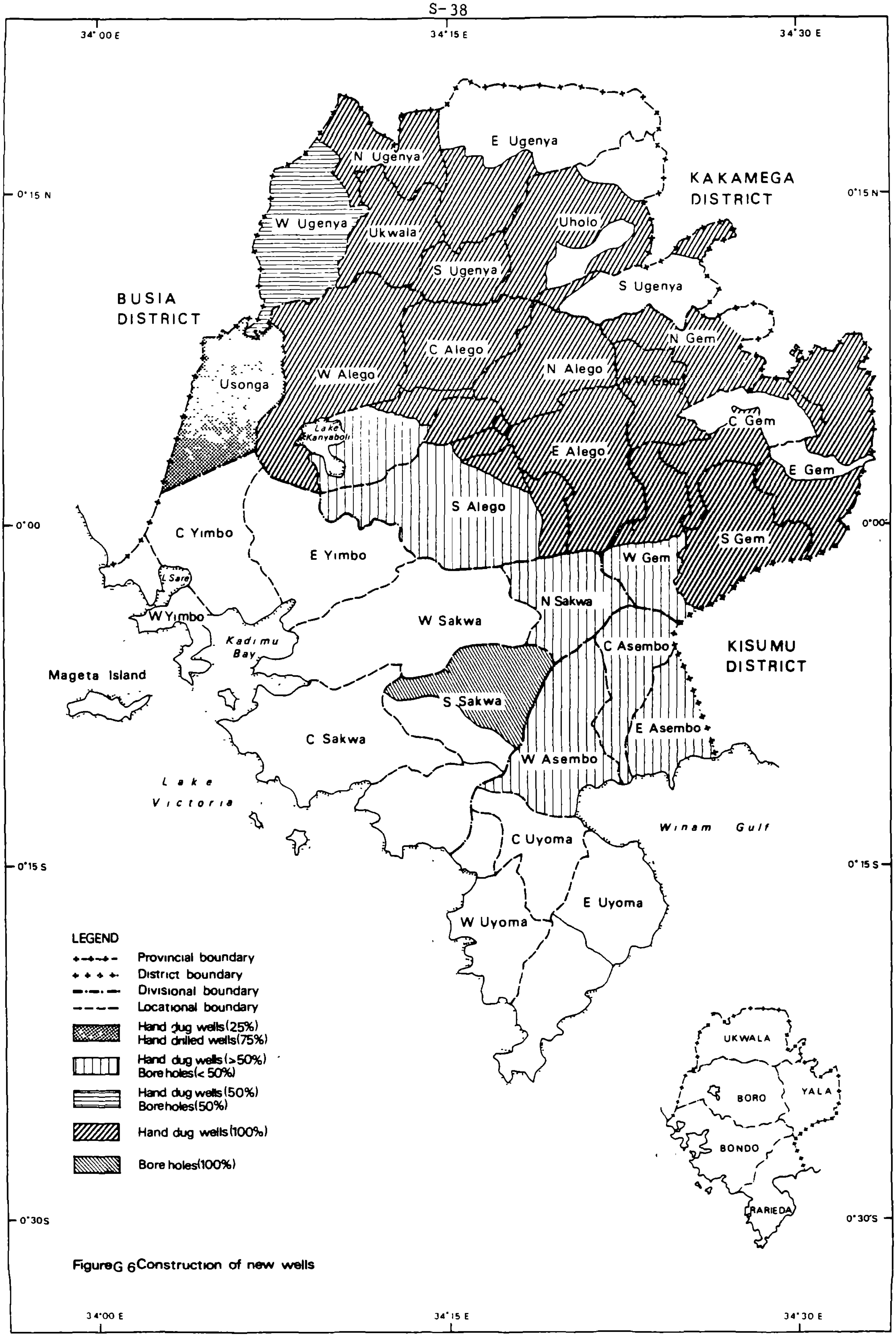
Water is pumped or sucked via a siphon from a culvert intake and flows to a horizontal roughing filter followed by a trench filter. The first part of this trench filter consists of a small slow sand filter. Passing the trench filter the water is stored in a small tank from which it can be abstracted with a pump or a tap.

Rehabilitation of existing roof catchment supplies

Roof catchment water supply is considered to be an appropriate rural water supply system which however can only be used by a small group of consumers. Construction of new roof catchment systems has proved to be rather expensive. A large system including a 50 (m^3) storage tank costs about Ksh 200,000/-
RDWSSP therefore only plans to rehabilitate existing roof catchment systems of schools, churches, health centres etc., which have a limited number of consumers and sufficient roof size to supply these consumers.
Rehabilitation works aim at taking bottlenecks away; bottlenecks, which block the effective use of a roof catchment system.

Some of these bottle necks are:

- gutters which are missing
- gutters which have to be aligned
- pipe connection between gutters and storage tank which is missing
- leaking storage tanks.



FigureG 6 Construction of new wells

Rehabilitation and construction of wells and boreholes

Rehabilitation of existing wells and boreholes is in particular needed in zone 2 and the northern part of zone 3. (see Fig. G.3).

A total number of 116 wells are planned to be rehabilitated. Most of the wells to be rehabilitated (72 %) are located in Boro Division. More than 55 % of the wells recommended for rehabilitation have a lining, about 40 % have a slab and 25 % have a pump of which however only a few are working.

In Ukwala Division 11 existing boreholes are recommended for rehabilitation. Rehabilitation works include fencing, improved drainage, repair of a slab, construction of a cattle trough and/or washing facilities, repair of a pump and installation of a pump.
Repair of the pump or installation of a pump are the most frequently indicated problems.

Fig. G.6 shows in which Locations new wells have to be made.
In most areas all wells can be made by hand digging.
Boreholes are only needed in West Ugenya, the southern parts of Central and South Alego, North and part of South Sakwa, the southern part of West Gem and West, Central and East Asembo Locations.
In Usonga Location it is possible to make hand drilled wells.

Fig. G.7. shows the RDWSSP hand dug well design.
Most characteristic of this design is the top culvert which rises up to 0.60 (m) above the surrounding ground level. Buckets are put besides the covering slab to better protect the well against surface runoff from entering into the well and exclusion of water splashing on the cover and anchor bolts.
A manhole in the concrete cover gives access to the well in case down hole activities are needed.
The well site is fenced with barbed wire and cedar poles. SWN-80 hand pumps are installed at all hand dug wells.

It is common practice to install in all hand dug wells a lining. The presence of a lining increases the life time of a well considerably. It also offers a better protection against polluted surface and sub-surface runoff from entering into the well.(the upper part of the lining is impermeable).

Fig. G.8. shows the RDWSSP design of machine or hand drilled wells.
Slotted PVC pipes are used as a screen. The screen is surrounded by gravel pack. Diameter of the casing and screen pipes is 110 or 125 (mm). The slot size used is about 0.6-0.8 (mm). Gravel pack is sieved between 1.2 (mm) and 4.6 (mm) sieves. A wooden plug is inserted in the bottom of the filter pipe. The aquifer is sealed using clay or concrete, after which the borehole is back filled.
A barbed wire fence is constructed around the well.
SWN-80 hand pumps are installed at all hand or machine drilled wells.

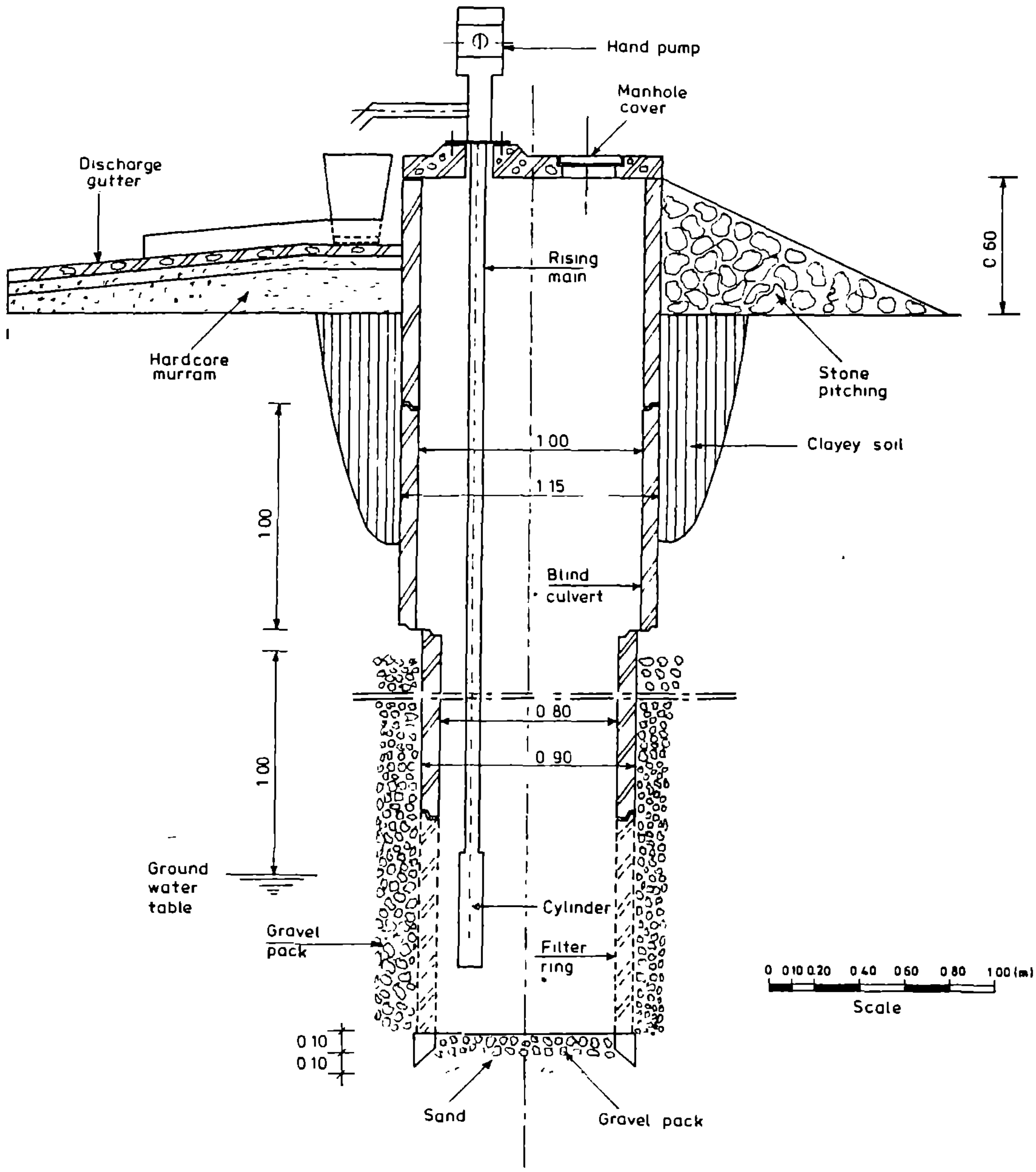


Figure G.7 RDWSSP HAND DUG WELL DESIGN

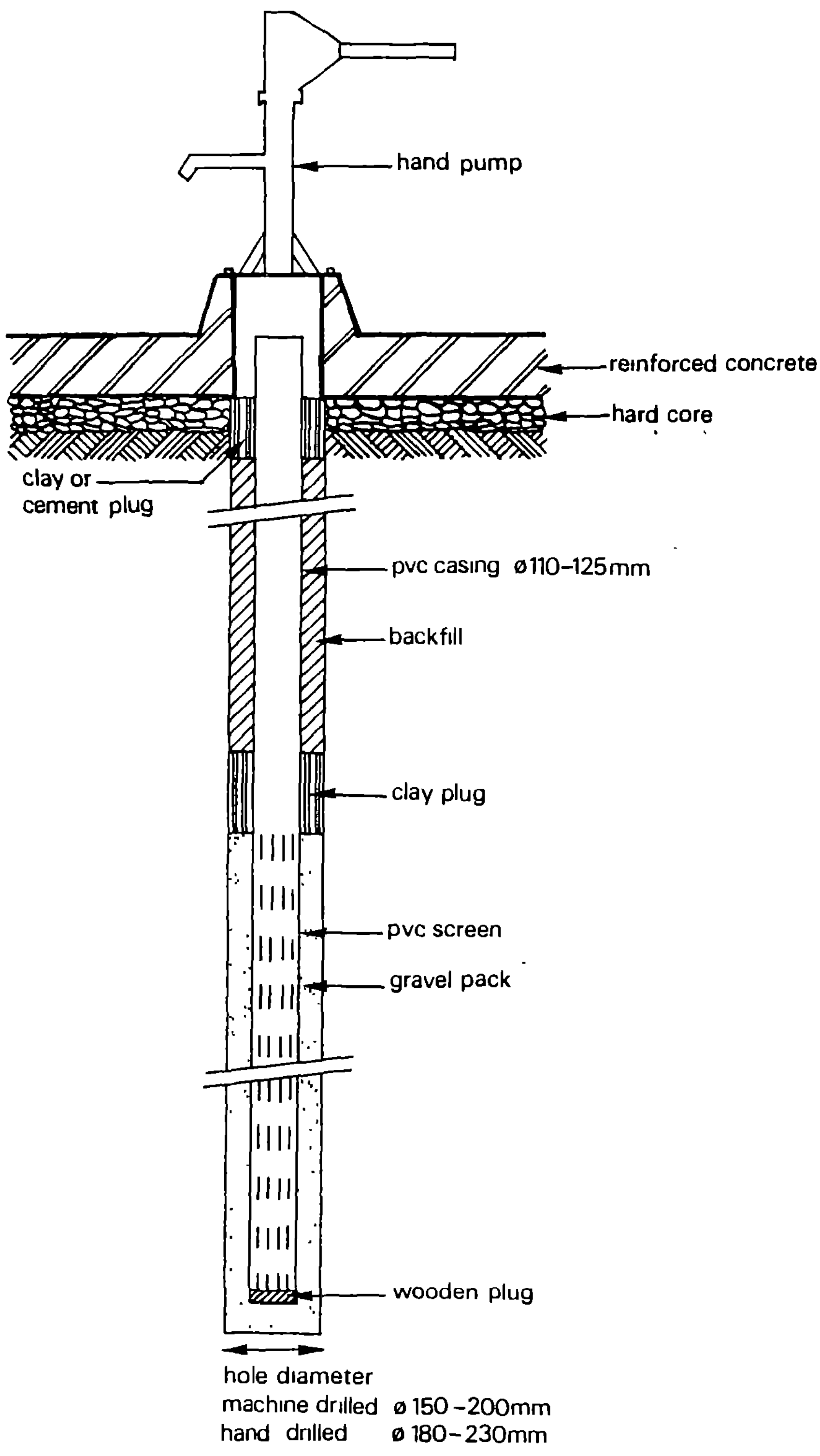


Figure G.8 RDWSSP hand drilled well and bore hole design.

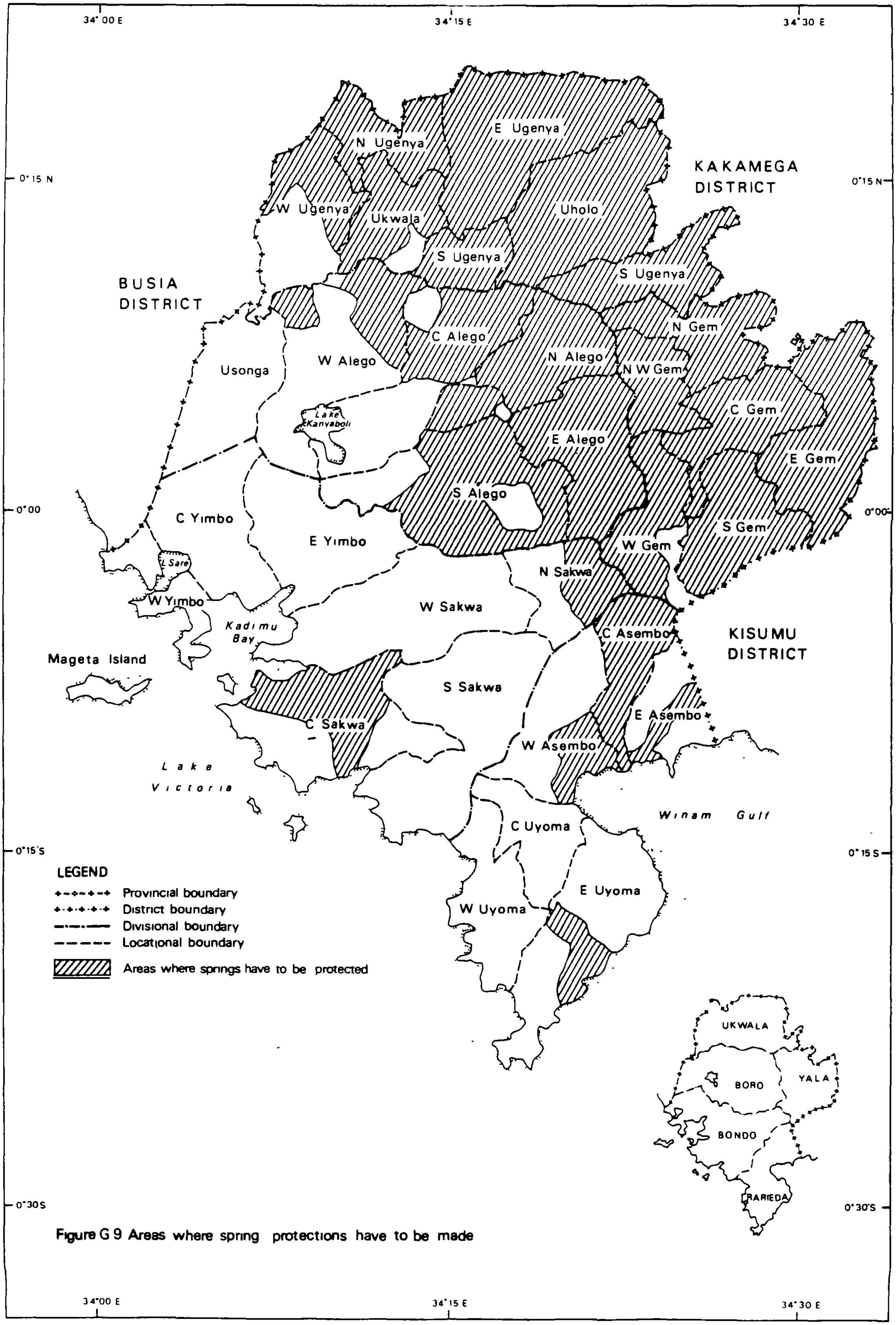


Figure G 9 Areas where spring protections have to be made

Spring protection

Fig. G.9. shows that spring protections are almost exclusively planned in zone 3, having good opportunities for using ground water.

Fig. G.10. shows the RDWSSP design which is used in case of good drainage opportunities.
The overflow pipe and draw off pipe are made at almost the same height. A scour pipe is installed to flush away any blockages of the pipes.
Hardcore, natural stones are embedded in the bottom slab to prevend that the slab is worn out by the water flowing from the pipes.
The area upstream is fenced with cedar poles and barbed wire. A drainage trench prevents polluted surface runoff from reaching the spring water.
Puddled clay is used to exclude that the concrete wall is undermined.

It is estimated that about 36 % of all springs to be improved, can be protected by making a gravity flow protection as indicated in Fig. G.10. At 64 % of the spring sites a shallow well has to be made or there should be good opportunities for piping the water to a site with better drainage opportunities.

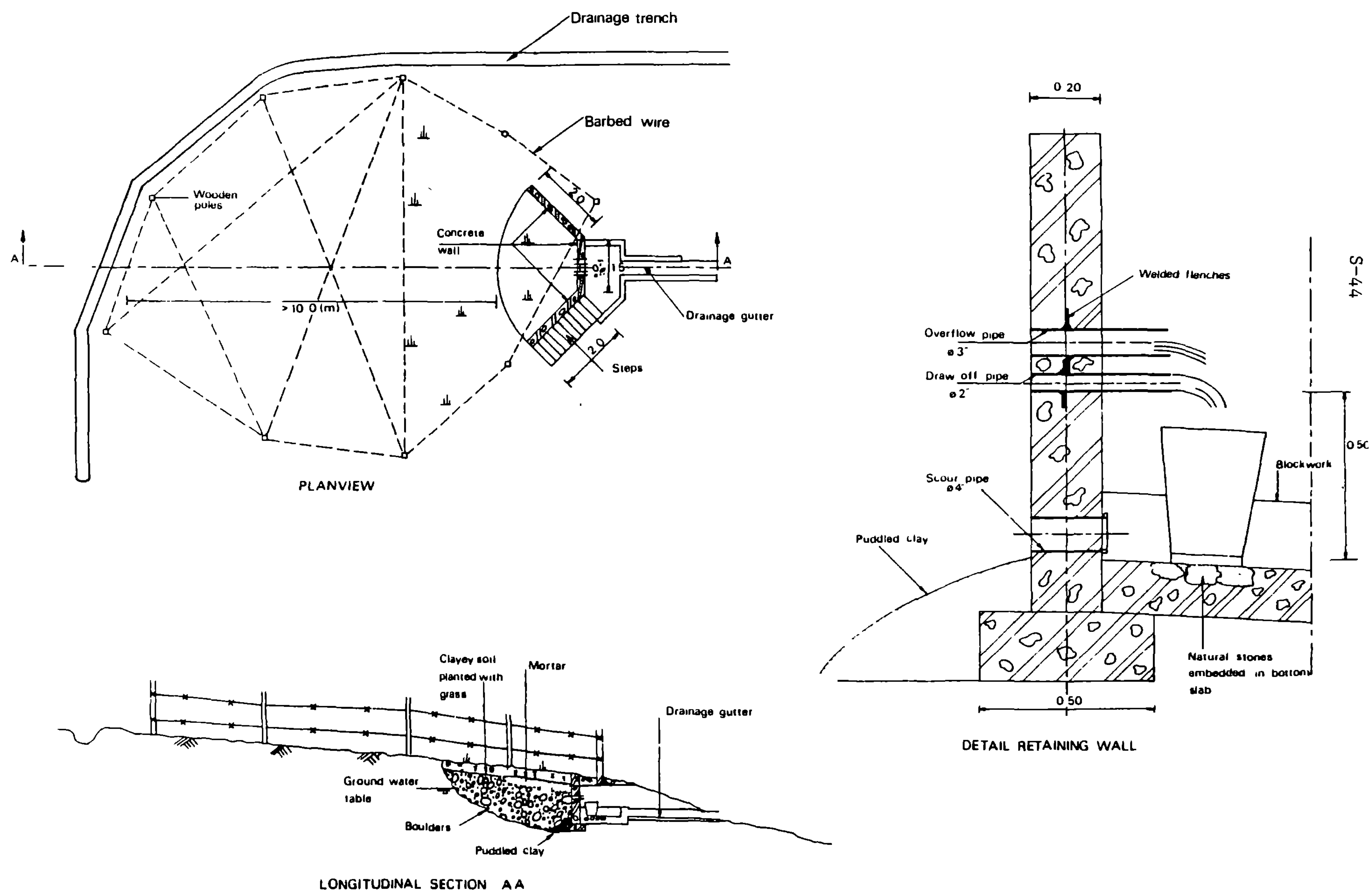


Figure G.10 SPRING PROTECTION RDWSSP
GOOD DRAINAGE OPPORTUNITIES

Table 6.1 Water Supply Plan

Area	Required number of safe and reliable water points	Good water points and water points under cons.	Remaining number of water points to be improved or newly constructed	PIPED WATER SUPPLIES	RAIN WATER: Ground catchm.	RAIN WATER: Dams	RAIN WATER: Roof catch.	WELLS: HAND DUG WELLS: Rehab of wells	WELLS: HAND DUG WELLS: New wells	WELLS: HAND DUG WELLS: Water holes	WELLS: HAND DUG WELLS: Shallow well spring protect.	WELLS: HAND DRILLED WELLS	WELLS: BOREHOLES: Rehab of bore holes	WELLS: BOREHOLES: New bore holes	SPRINGS: Springs gravity flow protect.	TOTAL
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)
Bondo	588	7	581	410	20	30	9	3	32	2	2	0	0	67	6	581
Rarieda	533	5	528	273	15	14	5	7	165	19	11	0	0	19	0	528
Boro	663	18	645	0	4	9	4	84	368	31	101	15	0	25	4	645
Yala	610	13	597	37	0	0	0	8	184	16	252	0	0	11	89	597
Ukwala	726	241	485	20	0	0	2	14	162	3	87	0	11	26	160	485
Siaya District	3,120	284	2,836	740	39	53	20	116	911	71	453	15	11	148	259	2,836

Review of rehabilitation and construction works

Table G.1. presents a breakdown per Division and type of water supply facilities of the rehabilitation and construction works which are needed. Column (4) shows show many safe and reliable water points are needed after subtraction of the existing good water points and the water points under construction.
Column (5) shows that rehabilitation and construction of piped water supplies is almost completely concentrated in Bondo and Rarieda Divisions.
This also applies for rehabilitation of rain and surface water systems as ground catchments, dams and roof catchments. (column 6, 7 and 8).
Construction of wells is concentrated in Boro Division where 624 wells are planned (94 % of all water points needed in Boro).
Most boreholes are needed in Bondo Division.
Only in Ukwala Division existing boreholes have to be rehabilitated (pump repair and installation of pumps).
Spring protection is the major activity in Ukwala and Yala Divisions.

Table G.2. Construction costs of piped water supplies planned to be rehabilitated or newly constructed in Siaya District

Piped water supply	Works needed	Unit costs (Ksh)	Total costs (Ksh)
Mageta Island Water Supply	New scheme	Kshs 300,000/km^2	2,100,000
Osieko Water Supply	Rehabilitation	Kshs 150,000/km^2	1,950,000
Usenge Water Supply	Rehabilitation	Kshs 150,000/km^2	3,000,000
Usigu Water Supply	Rehabilitation	Kshs 150,000/km^2	3,450,000
Ramogi Forest Water Supply	Rehabilitation	Kshs 150,000/km^2	2,700,000
Nyamonye Water Supply	New scheme	Kshs 300,000/km^2	30,000,000
Bondo Water Supply	Rehabilitation + major extension	Kshs 300,000/km^2	33,900,000
South Sakwa Water Supply	Compl. of scheme under constr.	Kshs 225,000/km^2	28,125,000
Got Abiero Water Supply	New scheme	Kshs 300,000/km^2	48,600,000
Uyoma Water Supply	Rehabilitation	Kshs 150,000/km^2	13,650,000
Aram Water Supply	Rehabilitation	Kshs 150,000/km^2	1,050,000
Sidindi-Malanga Water Supply	Rehabilitation	-	4,420,000
		Total	172,945,000

G-4. *Construction cost*

The water supply plan as described in section G-3 includes:

- construction and rehabilitation of piped water supplies;
- rehabilitation of roof catchments;
- rehabilitation of ground catchments and dams;
- rehabilitation and construction of wells;
- spring protection.

The RDWSSP only has a wide experience in rehabilitation and construction of wells and protection of springs.
There is no detailed information available about the costs of construction and rehabilitation of piped water supplies, roof catchments, ground catchments and dams.

Piped water supplies

From literature, estimated construction costs of new piped water supplies were gathered. The cost figures were updated using a price index figure for civil engineering works of 13.5 %.
For 1988, the average costs per (km^2) of distribution area were found to be Kshs 300,000/-.
Based on this unit figure per (km^2) the construction costs of all planned piped schemes were estimated (Table G.2.).

Table G.3 Cost estimates for improvement of groundcatchments and dams

	Ground catchment	Dam
Culvert intake sump (3 culvert rings)	4,500	4,500
Low lift hand pump	15,000	15,000
Horizontal roughing filter		
Filter tank	18,000	18,000
Filter material	3,000	3,000
Slow sand filter		
Filter tank	15,000	15,000
Filter material	5,000	5,000
Filter trench		
Water-tight foil	1,500	1,500
Filter material + clay cover	5,000	5,000
Storage tank (2 blind culvert rings)	7,500	7,500
Piping materials	5,000	5,000
Sub-Total - Water treatment system	79,500	79,500
Planting catchment area	5,000	10,000
Deepening of dam reservoir	75,000	150,000
Improvement or construction of spillway	0	50,000
Sub-Total - Additional works	80,000	210,000
Contractors profit (15 %)	24,000	43,500
Design, supervision and administration (25 %)	39,900	72,400
Total	224,000	406,000

Remarks : Trench digging , planting
deepening (as far as done by hand)
are done by the community

Roof catchments

Improvement of roof catchment systems aims at taking bottle necks away. Technical advises and small repairs are assumed to be given or done by the project. It is estimated that the "non owner" component paid by the project is about Kshs 5000/- per roof catchment system.
All other costs are paid by the owner of the roof catchment system.

Ground catchments and dams

Table G.3. presents cost estimates for rehabilitation of existing ground catchments and dams.
Rehabilitation includes deepening of the reservoir, planting the upstream catchment area, deepening and protection of the spillway (dams) and construction of the water treatment system as described before.
The costs for improving a ground catchment are estimated at Kshs 224,000/-.
The costs for improving a dam are estimated at Kshs 406,000/-.

Table G-4. Construction costs of hand dug , hand drilled and machine drilled wells
(in Ksh ; price level June 1988 ; based on RDWSSP experiences)

Description		HAND DUG WELLS			HAND DRILLED WELLS	BOREHOLES		
		Well depth (m)				Borehole depth (m)		
		10	15	20		50	60	70
WELL	. Digging or drilling	5,000	8,100	11,700	5,000	65,000	78,000	91,000
	. Transport of hand dug or hand drill equipment	3,000	3,500	4,500	3,000	0	0	0
	. Lining (transport + installation)	12,900	17,900	22,900	2,000	10,000	12,000	14,000
	. Supervision	7,000	7,000	7,950	1,000	4,950	4,950	4,950
SUB TOTAL WELL		27,900	36,500	47,050	11,000	79,950	94,950	109,950
SUPER STRUCTURE	. Site clearance + excav.	5,200	5,200	5,200	5,200	5,200	5,200	5,200
	. Concrete works	5,000	5,000	5,000	5,000	5,000	5,000	5,000
	. Fencing	2,800	2,800	2,800	2,800	2,800	2,800	2,800
	. Mobilisation and transport slab/wall mould	1,500	1,500	1,500	1,500	1,500	1,500	1,500
	. Supervision	5,500	5,500	5,500	5,500	5,500	5,500	5,500
SUB TOTAL SUPERSTRUCTURE		20,000	20,000	20,000	20,000	20,000	20,000	20,008
PUMP *	. Pump head + stand	5,297	5,297	5,297	5,297	6,000	6,000	6,000
	. Pump cylinder	3,536	3,536	3,536	3,536	2,470	2,470	2,470
	. Rising main + pump rod	3,285	5,110	6,935	3,285	10,950	14,600	18,250
	. Various small items	400	400	400	400	400	400	400
	. Installation (incl.transp.	1,000	1,250	1,500	1,000	3,000	3,500	4,000
	. Supervision	700	700	700	700	700	700	700
SUB TOTAL PUMP		14,218	16,293	18,368	14,218	23,520	27,670	31,820
TOTAL COSTS		62,118	72,793	85,418	45,218	123,470	142,620	161,770

* Based on duty free imported equipment

* 1 Survey costs (Ksh 4000.- per site) not included
* 2 Costs of expatriate staff not included
* 3 Succes rate of well construction not included

Rehabilitation and construction of wells

Table G.4. gives a review of the costs for making hand dug, hand drilled or machine drilled wells of different depths.
The figures are based on the ongoing RDWSSP construction programme.

All RDWSSP construction works for making a hand dug well are done by local contractors.
The unit prices as indicated in Table G.4, therefore include a contractor's profit.
RDWSSP is responsible for design, supervision and administration. Supervision includes training of the contractor to fulfill the required construction and installation standards. Also this has been taken into account.

The costs for making machine drilled boreholes are based on drilling and testing of the holes by a qualified contractor, and comprise the following activities: set-up of equipment, drilling of an 8" borehole, inserting of casing and gravel pack, top grouting, development and test pumping.

Survey costs, for well siting are not included in Table G.4. On an average the survey costs equal about Kshs 4,000/- per site. Figures as indicated in Table G.4. apply for successfully constructed wells. The success rate of well construction is not taken into account.

Prices of the superstructure and pump installation are based on rates of Kenyan contractors. Prices of pump equipment and PVC casing are based on tax free imported materials.

Depreciation of means of transport e.g. motor bikes used by supervisors and the costs of expatriate staff are not included.

Construction of a hand dug well costs between Kshs 62,000/- and Kshs 85,000/-.
For a hand drilled well an amount of about Kshs 45,000/- is needed.
Borehole drilling is between Kshs 123,000/- and Kshs 162,000/-.

Table G-5. Construction costs of spring protections
(in Ksh ; price level June 1988 ; based on RDWSSP experiences)

Description		Gravity flow protection	Shallow well protection
WELL	. Digging (labour)	-	2,700/-
	. Transport of equipment (Tripod, Dewatering pump)	-	3,000/-
	. Lining (transport + installation)	-	9,830/-
	. Supervision	-	4,000/-
SUB TOTAL WELL		-	19,530/-
SUPER STRUCTURE	. Site clearance + excav.	3,600/-	5,200/-
	. Concrete works	7,000/-	5,000/-
	. Fencing	1,400/-	2,800/-
	. Mobilisation + transport slab/wall mould	1,500/-	1,500/-
	. Supervision	5,500/-	5,500/-
SUB TOTAL SUPERSTRUCTURE		19,000/-	20,000/-
PUMP *	. Pump head + stand	-	5,297/-
	. Pump cylinder	-	3,536/-
	. Rising main + pump rod	-	1,460/-
	. Various small items	-	400/-
	. Installation (incl.transp.)	-	750/-
	. Supervision	-	700/-
SUB TOTAL PUMP		-	12,143/-
TOTAL COSTS		19,000/-	51,673/-

* Based on duty free imported equipment   * 1 Costs of expatriate staff not included

Springs

Table G.5. gives a review of the costs for making spring protections.
A so called gravity flow protection is rated at Kshs 19,000/-. This figure is based on the ongoing spring protection works in Kisii District.
If drainage opportunities at the spring site are insufficient a shallow well is made. The construction cost are assumed to be equal to a well with a maximum depth of 5 (m).
The costs of such a well are about Kshs 52,000/-.

Like hand dug wells, also spring protections are made by local contractors.
Works range from transport of construction materials like sand, stone chippings and ballast to in situ casting of the retaining wall and cover of the spring.
RDWSSP is responsible for design, supervision and administration. Supervision includes training of the contractor to fulfill the required construction and installation standards.

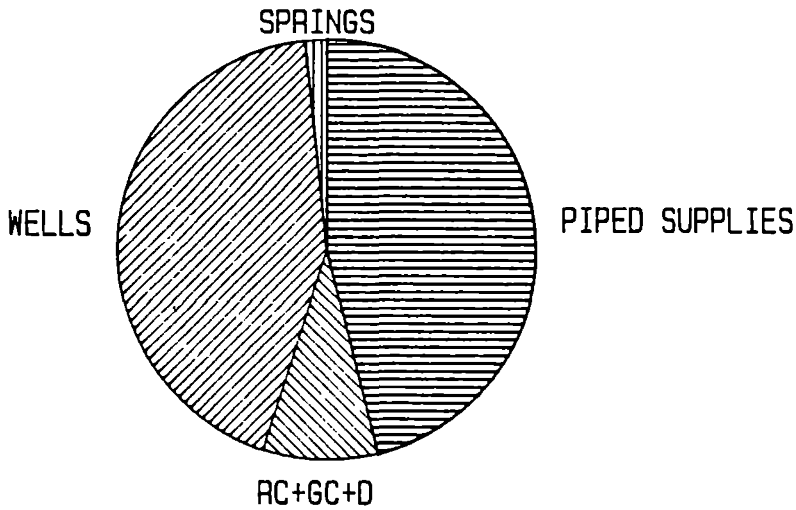
Depreciation of means transport e.g. motor bikes used by supervisors is not included in the costs figures.

The costs of expatriate staff are not included.

Table G-6 Review of construction costs

Area	Construction costs (Ksh*1000)						
	Piped water supplies	Roof catch ments	Ground catch ments	Dams	Wells	Spring protec tions	Total
Bondo	119,925	45	4,480	12,180	17,431	114	154,175
Rarieda	48,600	25	3,360	5,684	21,667	0	79,336
Boro	0	20	896	3,654	47,757	76	52,403
Yala	4,220	0	0	0	30,562	1,691	36,473
Ukwala	200	10	0	0	20,855	3,040	24,105
Siaya District	172,945	100	8,736	21,518	138,272	4,921	346,492

FIG. G.11a CONSTRUCTION COSTS
PER TYPE OF WATER POINT



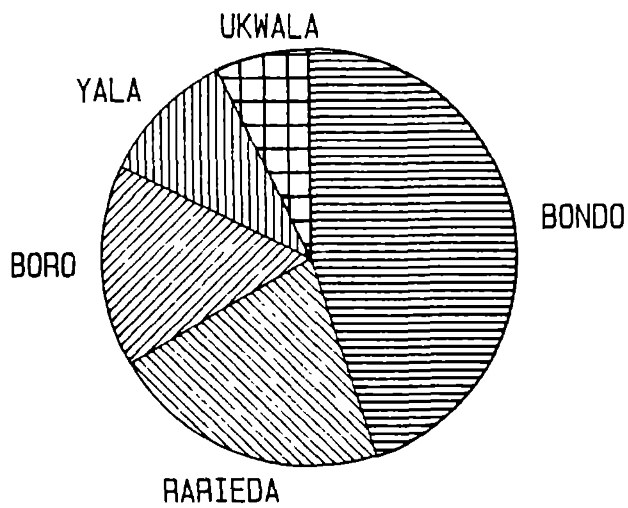
Review of costs

Table G.6. presents a review of the construction costs.
A breakdown is given per Division and type of water supply.

The survey costs and the success rate of well construction have been taken into account. Also the fact that part of the wells are to be rehabilitated which makes them less costly, (no survey) is considered.

The total costs of the Water Supply Plan are estimated at Kshs 346,000,000.
Construction of wells and boreholes and construction of piped water supplies are the most expensive components of the Water Supply Plan (see Fig. G.11. A).
About 45 % of the total costs have to be spend in Bondo Division (see Fig. G.11. B).

FIG. G 11b CONSTRUCTION COSTS PER DIVISION

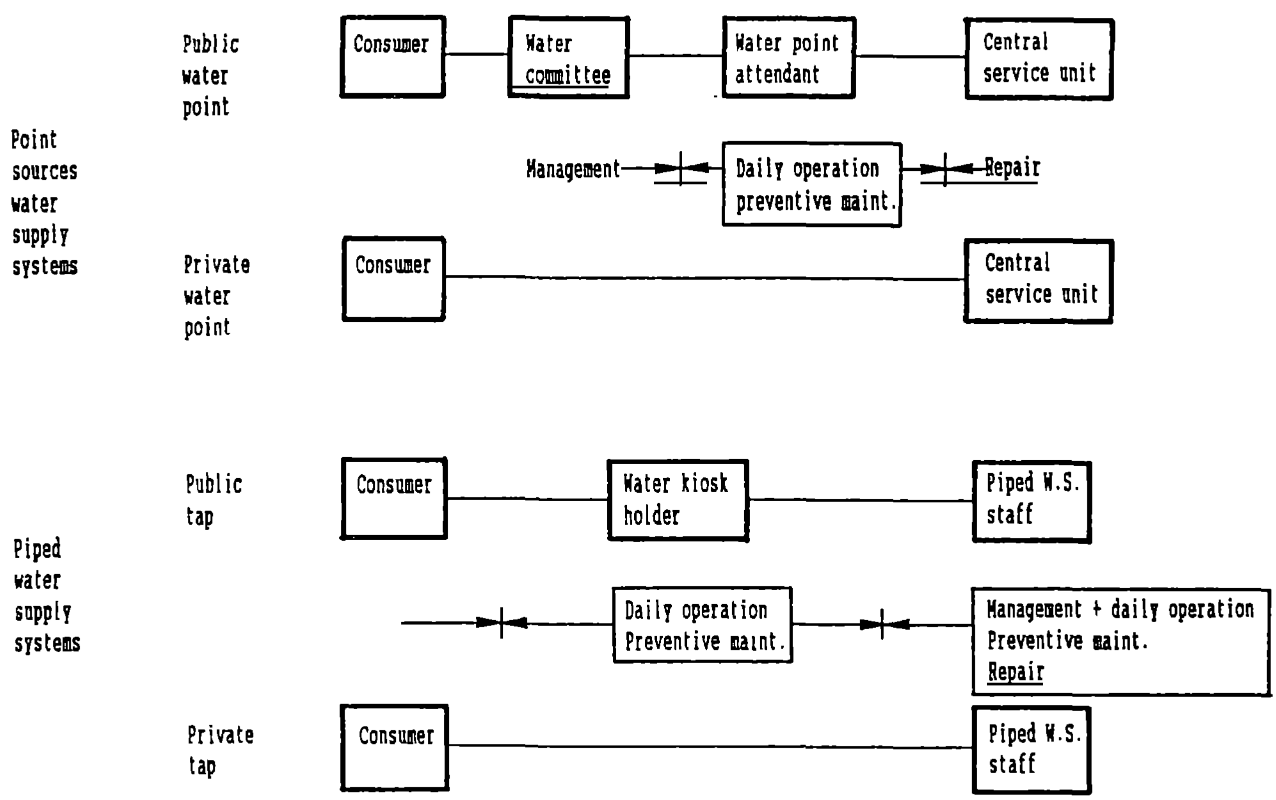


G.5. *Operation and maintenance*

Organizational set-up

Fig. G.12. shows how operation and maintenance of point source water supplies and piped water supply systems can best be organized.
For private water points or private connections both systems are identical and consist of the user at one hand and a central service unit or a central operation and maintenance unit at the other hand.
For communal point sources and public taps there are differences. Point sources have a water point attendant who is responsible for small repairs and a proper use of the water point. The attendant is supervised and paid by a water committee consisting of user representatives.
Each public tap of a piped water supply system has a water kiosk holder who is infact a third party. Like a water point attendant , he is also responsible for small repairs and maintenance of the public tap, however he does not receive any salary. Each user of a public tap has to pay a certain amount of money to the kiosk holder for collecting water. The kiosk holder in his turn has to pay for each (m^3) of water supplied to him via the distribution system.

Fig. G.12 Management of operation and maintenance of rural piped water supplies



Point sources

Proper operation and maintenance of point sources requires :

- Community mobilisation
- Community participation
- Daily operation, preventive maintenance
- Repair

Community mobilisation

Community mobilisation starts with selecting which spring, dam or ground catchment has to be improved or where a new well has to be made.
Having selected the most appropriate site, the RDWSSP survey crew has to approve the chosen site or to recommend a better one.

Once the construction site has been selected, the community is mobilized to participate in the construction works. Apart from cost savings, the aim of this approach is to create the awareness that the community will be the owner of the water point and will be responsible for operation and maintenance.

Community participation

Prior to the start of the construction works a number of preconditions have to be fulfilled.

- There are no disputes about the land where the water point is made. The community has free access to the water point.

- There is a water committee, registered by the Ministry of Culture and Social Services.

- The water committee has raised and banked a prescribed minimum amount of money for maintenance of the water point.
  For a gravity flow protected spring a minimum amount of Kshs 1000.- is required. For water points having a pump this minimum amount has been fixed at Kshs 2000.-

Construction works are done in close cooperation with contractors which are supervised by RDWSSP. The community is involved in the following activities.

- Construction of a proper access road to the water point to enable transport of construction materials and equipment.

- The construction site should be cleared.

- The community brings local construction materials as stones used for back filling and stone pitching to the construction site.

- The community assists in finding accommodation for the construction crew.

- The community is responsible for trench digging and ground level excavation works (ground catchments and dams).

All other construction works are done by local contractors.

Before construction works are completed, the water committee has to appoint a water point attendant who will be responsible for daily operation, preventive maintenance and small repairs.

When the water point is completed the people are instructed to keep the water point and its surroundings clean and in a good state. A fence is placed around the wells and springs. It is the community's responsibility to keep the fence in good condition and to plant euphorbia or any other hedges around it as additional protection of the site.

The upstream catchment area of ground catchments and dams has to be protected against soil erosion. Conservation requires a constant awareness to plant trees and to sow grass at places which have become bare.
The dam or ground catchment will soon be silted if these measures are not taken.

Daily operation and preventive maintenance

The water committee is responsible for management of the water point which includes:

- management of the maintenance fund
- supervision of the water point attendant
- organizing community maintenance works.

Programme extensionists advice the water committee about these management aspects.
Daily operation and preventative maintenance are done by the water point attendant.
Some of his tasks are:

- To open and to close the water point in case the water committee decides upon restricted use.

- To control people using the water point. Only those who contribute to the operation and maintenance fund are permitted to use the water point.

- To control upon the proper use of the water point (a correct pumping technique and use of taps, exclusion of vandalism).

- To keep the water point clean. (clearing of drainage gutters etc.).

- Preventative maintenance.
  Small repairs of the slab. Prevention that the slab is undermined. Trimming of the natural fence.

It is the projects experience that a well trained and motivated water point attendant is crucial for a proper functioning of the water point.

<u>Repairs</u>

From the day the community starts using the new water point a six months "guarantee" period commences.
Any failure, shortcoming or breakdown which occurs during these 6 months , is solved or repaired by the RDWSSP without charging the community.
At the end of this period the new water point is officially handed over to the community by signing a certificate of ownership.

After 6 months, a breakdown or failure of the water point has to be reported to a field maintenance officer stationed at the central service unit in Siaya Town (DWE's office).

These maintenance officers are responsible for

- proper repair of the water point
- financial control of repairs done
- training of water point attendants

Additionally the maintenance officers inspect the quality of pump installation activities.

When a breakdown occurs, the steps taken towards repair basically are as follows:

- The water point committee reports a breakdown to the maintenance officer.

- The maintenance officer makes a visit to the site within 2 days.

- The maintenance officer diagnosis the breakdown, estimates the cost and hands over an order note for spares and tools to the well committee.

- The water point committee arranges transport of the tools and spares from the central spares depot to the water point site.

- The water point committee informs the maintenance officer that tools and spare parts are on the site and that a minimum of 3 labourers will be available.

- The maintenance officer carries out the repair within 2 days.

- The maintenance officer mails the invoice to the water point committee.

- The water point committee pays the invoice from their bank account.

At present the maintenance officers are employed by the RDWSSP. A maintenance system involving the private sector is not yet feasible, because of the relatively small number of water points to be maintained in the District, the limited number of breakdowns and the low density of new water points. In future when the number of water points has increased to a few hundred per Division, such a set-up might be feasible.

Piped water supplies

Operation and maintenance should be done by the piped water supply staff.
Operation and maintenance of different schemes from one central point (e.g. delivery of diesel via DWE's office) fails, while on the other hand communities lack means and skills to maintain and repair e.g. pumps.
The piped water staff can only do their work in a proper way if they have full control over money and means of transport as well as the authority to take measures of disconnection, water rationing etc. if needed.
The piped water supply system should be headed by a project director who is controlled by local authorities.

The only way to create a long term sustainable operation and maintenance set-up is to run a piped water supply system which is cost effective . Everybody has to pay for the water which is delivered. Charges should be in accordance with the costs for operation and maintenance of the water supply system.
In planning, design and construction of a piped water supply one should be fully aware of the fact that the consumers have to pay for the running costs of the new scheme.
Coagulation, sedimentation and filtration of water might be too expensive for a small community, while on the other hand even supply of raw water might be of great importance for a community.

The most sensitive part of a piped water supply system is the distribution net work. In particular public taps are vulnerable for vandalism and mis-use which often leads to either no supply of water or a massive spillage of water.
At these public taps it is needed to have people who have an economic interest in the proper functioning of the water point.
It is therefore advised to work with water kiosk holders acting as a third party which are paid by the consumers for the water delivered. The kiosk holder pays to the piped water supply for getting water.
Such a system of water vending will only work if it is profitable for both consumers and kiosk holders to use the system.
The kiosk holder is responsible for daily operation of the public tap. He opens and closes the water point at prescribed times. He checks on proper use of the taps. He implements small repairs.
The kiosk holder, reports cases of no supply (no income) or leakages (loss of income) immediately to the project director of the piped water supply, who has to take action in order to exclude that his water revenues will decrease.
Some aspects are not covered by the proposed kiosk holder set-up. Such an aspect is the quality of the delivered water.
The consumers should organize themselves in a water committee which can discuss preventing problems with representatives of the MoWD (as a consulting agency) or with local authorities in order to take adequate measures.

H RECOMMENDATIONS

Comparing, the Water Supply Plan with the ongoing construction activities it is concluded that there is a sincere need for proper coordination of design and implementation activities.

* All efforts aimed at improvement of rural water supply in Siaya District should be coordinated.
  The Water Supply Plan includes different kind of activities implemented by MoWD, NGOs, LBDA, private contractors etc.

  A proper coordination of activities is needed.
  It is advised to assign a Technical Coordinator under the District Water Engineer.

* Nine (9) piped water supplies have to be rehabilitated. In most cases, rehabilitation includes a complete renewal or a major extension of the existing water supply system. In addition 3 new piped schemes have to be built.
  The works needed are beyond the capacity of the existing district organizations involved in piped water supply (MoWD, NGOs and communities).

  It is therefore advised to work with private contractors which are fully responsible for the implementation of the required rehabilitation and construction works. Design and supervision of implementation works have to be done by a well experienced Water Supply Engineer assisted by water technicians of the DWEs office. The Water Supply Engineer should work directly under the Technical Coordinator.

* Construction of 259 spring protections, 1551 hand dug wells and 15 hand drilled wells necessitates to enlarge the capacity of the existing RDWSSP District Implementation Unit. Well construction should be intensified and a spring protection unit should be started.

* About 150 boreholes have to be made. Borehole drilling is and will be done by local contractors.
  Borehole siting and supervision of drilling works require the input of a Hydrogeologist of the Survey and Design unit of RDWSSP.

* Part of the Water Supply Plan is to rehabilitate existing roof catchments and to improve ground catchments and dams.

More research is needed to improve the roof catchment design.
Short duration rainfall analyses should be made to find better design criteria for the roof gutters and pipe connection to the storage tank. Self registrating rainfall recorders should be installed at some strategic points to measure 5 min. rainfall amounts. High rainfall intensities should be analysed to draw up design rules for roof gutters applicable for Siaya District.

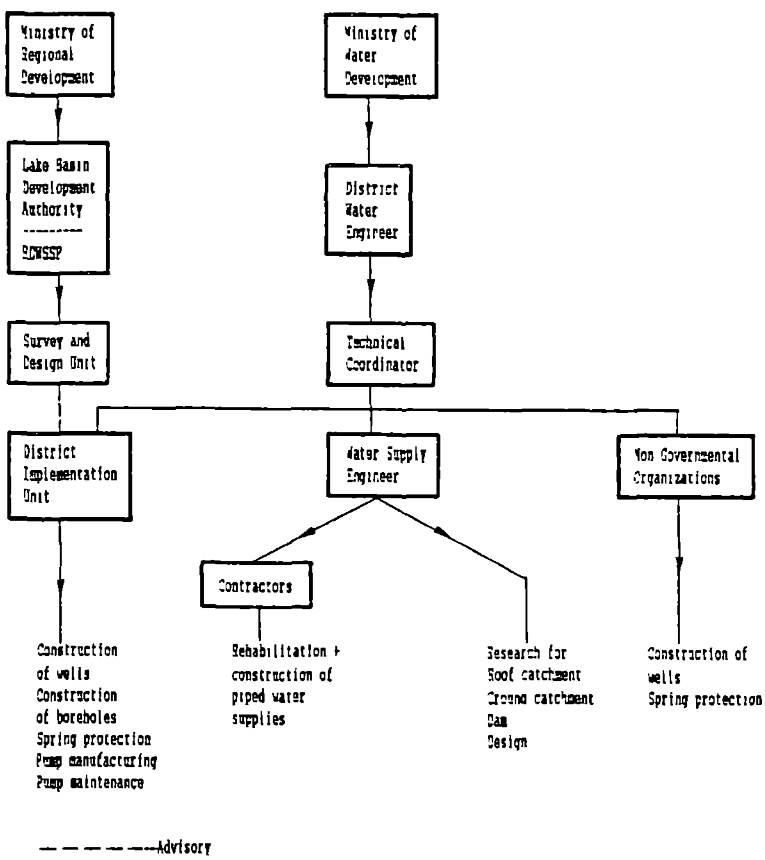
Long series of real time daily rainfall amounts should be analysed to improve the storage tank design.
The existing network of rainfall stations (daily recording) should be checked and improved.

Fig. G.5. shows a preliminary design for improvement of existing ground catchments and dams.
This design should be further elaborated and tested.

The Water Supply Engineer who will be in charge of the piped water systems should also be responsible for this research work.

Fig. G.13. presents a diagram showing the position of the Technical Coordinator, the Water Supply Engineer , the contractors, the District Implementation Unit and the advisory role of the RDWSSP Survey and Design Unit.

FIG G.13 Organization of implementation works
Siaya District Water Supply Plan



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5.2. River gauging stations, Siaya District, station characteristics and minimum flows
5.3. Water quality data, Siaya rivers

PART I

INTRODUCTION

1.1. INTRODUCTION

1.1.1. Purpose and contents of the report

This report on rural domestic water supply in Siaya District gives a review of information about subjects, such as; the occurrence, use, potential, exploration and exploitation possibilities of the water resources in the District.
It is the last of four District Reports which together cover the whole of Nyanza Province.
The report is aimed at District development planners, water supply implementing agencies and donors, as a basis for the feasibility and cost analyses of water supply programmes in Siaya District.

The report is based mainly on the results of the systematic and detailed water resources assessment studies carried out in the District during 1987 and 1988, as part of the Lake Basin Development Authority's Rural Domestic Water Supply and Sanitation Programme (RDWSSP) , which were subsequently published in five comprehensive reports.

Bondo	Division	-	December	1987
Rarieda	Division	-	January	1988
Boro	Division	-	June	1988
Yala	Division	-	July	1988
Ukwala	Division	-	September	1988

In the Divisional Reports the data, results and conclusions of the water resources surveys are presented down to the level of Sub-Locations. For technical information more detailed than presented in this report, is referred to these Divisional Reports.

Relevant information presented and evaluated in this report includes:

- general information about the District's population, socio-economic situation, physiographic characteristics and administration;
- a detailed evaluation and description of the present water supply situation in terms of the sources used, their quality and reliability, with special attention to the improved water supply systems, piped supplies and improved springs;
- an assessment of the available water resources; both ground water as well as surface water;
- ground water exploration, well siting techniques developed and used by the RDWSSP;
- a review of construction activities undertaken by various governmental and non-governmental organizations.

Based on this information a Water Supply Plan for Siaya District is compiled. This report is complemented with five thematical maps (scale 1:100.000).

1.2 THE LBDA'S INVOLVEMENT IN WATER SUPPLY

Siaya District is one of the 4 Districts of Nyanza Province, which forms part of the development area of the Lake Basin Development Authority (LBDA). The LBDA is a statutory organization established by an Act of Parliament in 1979, which empowers the Authority to undertake overall planning, coordination and implementation of programmes and projects in the region.

Since its inception, the LBDA has initiated a series of projects and programmes aimed at the maximum utilization of human, water, animal, land, power and other resources, together with a programme of monitoring and evaluation.

Of the many functions delineated in the Act of Parliament establishing the LBDA, seven specifically refer to development of the water resources.
This emphasizes the importance the Authority attaches to the management and development of this most valuable of natural resources.
Since 1981 a number of water projects have been executed, which culminated in the creation in 1984 of the Rural Domestic Water Supply and Sanitation Programme in Nyanza Province.

1.3. THE RURAL DOMESTIC WATER SUPPLY AND SANITATION PROGRAMME

During the past 20 years numerous Governmental and non-Governmental organizations have been involved in rural water supply activities, but despite of all their efforts the situation has not significantly improved. The main reasons are the rapidly growing water demand, a lack of maintenance of all types of constructed water supplies and the tendency to design mainly large scale supplies, which so far have proved to be difficult to manage and sustain in the rural areas.

In 1984 only 10 % of the rural population in Nyanza Province had access to a properly constructed water supply. The reliability of these water supply systems in most cases was far from satisfactory. The vast majority of the rural population has to carry water over considerable distances, from natural sources, which are often polluted, insufficient or unreliable.

It is against this background that in 1984 the LBDA initiated the Rural Domestic Water Supply and Sanitation Programme with the primary aim to provide safe and reliable water to the rural areas of Nyanza Province.

1.4. HISTORY OF THE PROGRAMME

1.4.1. The Shallow Wells Pilot Project (1982-1983)

In 1981 the Lake Basin Development Authority initiated a Shallow Wells Pilot Project with the objectives to investigate the feasibility of shallow well construction in the rural areas of Nyanza Province and to study the most appropriate methods, equipment and materials to be used.
The Government of the Netherlands under a bilateral aid programme subsidized the project, which was implemented during 1982 and 1983.

Information was gathered on the physiography, demography and water supply situation of the area. Knowledge was gathered on the potential, methods of exploration and abstraction of the ground water.
During the project a total of 41 hand drilled and hand dug wells were constructed and fitted with hand pumps.

1.4.2. The Shallow Wells Workshop (1983)

Early in 1983 a Netherlands Government Evaluation Mission concluded that the feasibility of the abstraction of safe drinking water by means of hand pumps in the region had been established. At the same time the mission emphasized the need for a viable maintenance system, community mobilization and the relationship between safe water and sanitation in the improvement of health. The mission called for a Shallow Wells Workshop, which was held in October 1983.

The principal objectives of the Workshop were:

- to establish the preferred basis and methods for the continuation of a wells construction programme, taking due account of technical, social, cultural, organizational and financial aspects

- to create the opportunity for presentation and exchange of information between organizations which are and may be involved in the provision of water supply in the Lake Basin Area.

Findings and conclusions were written down in the proceedings of the Workshop (Ref.21).

1.4.3. The Interim Project Phase (1984)

On the basis of the recommendations of the Workshop, two survey activities were started early 1984; a water resources survey and a socio-economic survey.

Water resources survey

The comprehensive water resources survey started in Ndhiwa and Mbita Divisions of South Nyanza District. Both Divisions were marked as very poor developed in terms of water supply.
The main objectives of this technical survey were:

- to set up a systematic survey in preparation of a Rural Domestic Water Supply Plan for the entire Nyanza Province;

- to identify all rural domestic water supply possibilities as a basis for future construction or improvement of the rural water sources.

The activities carried out during the Interim Project Phase as well as the results and recommendations of the various surveys undertaken were recorded in the Final Report which consists of three volumes; Main Report, Ndhiwa and Mbita Survey Reports (Ref.11).

Socio-economic survey

The primary aim of the socio-economic survey was, to identify target communities on the basis of the selection criteria established as a result of the Workshop.

The survey consisted of:

- a literature review of documents dealing with the selection criteria;

- administration of a formal questionnaire to household heads and key informants;

- collection of socio-economic data on Sub-Locational level;

- collection and evaluation of data about health aspects.

During the Interim Project Phase, in 1984, two Districts were covered: South Nyanza and Kisii District.

1.4.4. The Rural Domestic Water Supply and Sanitation Programme; Phase 1 (1985-1988)

The findings of the Pilot Project, the recommendations of the Shallow Wells Workshop and the preliminary results of the surveys carried out during the Interim Project Phase, formed the basis for the formulation by the LBDA of the Rural Domestic Water Supply and Sanitation Programme (RDWSSP) in Nyanza Province. The Programme is sponsored by the Netherlands Government for the period 1985-1988 (Phase I).

1.5. OBJECTIVES OF THE PROGRAMME

The primary aim of the RDWSSP is to improve the water supply situation in the rural areas of Nyanza Province.

This is achieved in a direct way by:

- Providing safe water, easily accessible in quantities adequate for domestic use at a cost in accordance with the economic level of the communities and through facilities which can be easily operated and maintained at the local level;

- providing health education with emphasis on safe disposal of human excreta through low cost and easily maintained facilities with the explicit aim of protecting the health of the people from water related diseases;

In an indirect way by:

- establishing the required organizational framework and self-sustaining structures, which can take care of the implementation and maintenance of water supply and sanitation schemes;

- making available to other implementing organizations the results and recommendations of the surveys, carried out, and assisting and advising such bodies on all matters concerning water supply, sanitation and health education.

1.6. ACTIVITIES OF THE PROGRAMME

In order to achieve the objectives of Phase I (1985-1988) of the Programme, a defined series of activities are being undertaken.

- A systematic and comprehensive water resources survey, to form the technical basis for rural domestic water supply programmes.

- A socio-economic survey to form the non-technical basis for rural domestic water supply and sanitation programmes.

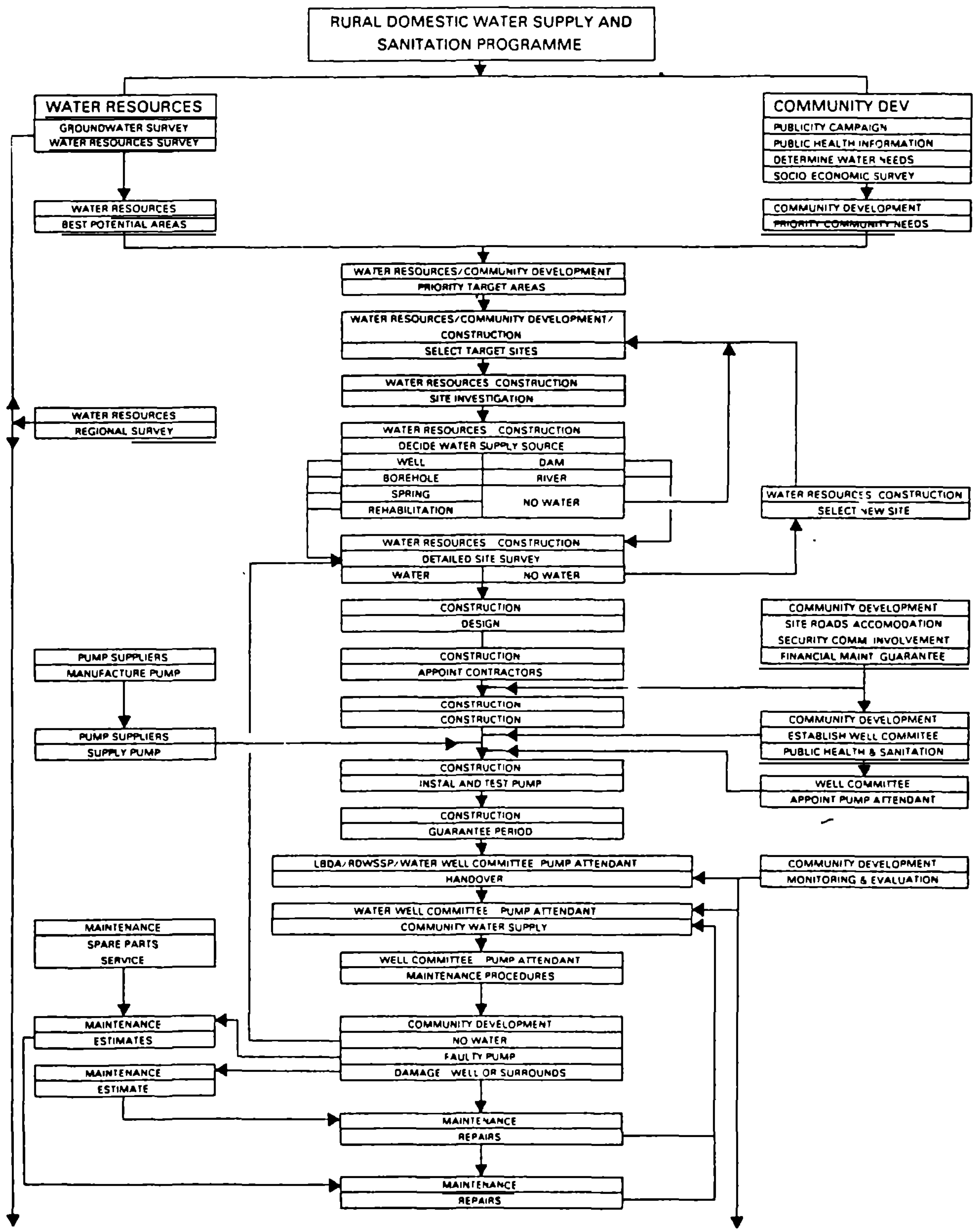


Fig 11 Flowsheet of Programme activities towards the construction and maintenance of water points

- A construction programme which aims at developing approximately 500 water points, executed mainly by local contractors with community involvement.
- The provision of 1800 slabs and vent pipes for the construction of communal sanitary facilities.
- A comprehensive community development programme including information campaigns about the benefits of safe and potable water, sanitation and public health.
- An institution building programme with the aim of establishing self-sustaining structures to take care of construction and maintenance of water supply and sanitation.
- A training and manpower development programme to support both the technical and non-technical departments of the RDWSSP as wells as the institution building operations.
- The establishment of a production line in Kenya, which will manufacture hand pumps, spare parts and related equipment, and to set up a distribution network of the manufactured goods.

1.7 ORGANIZATION AND COORDINATION OF THE PROGRAMME

The activities are being undertaken by two major departments within the Programme: the Community Development Department and the Technical Development Department. Both departments, which have an integrated approach towards the targets of the Programme, are supported by two service departments for accountancy and administration.

The Community Development Department is responsible for the following Programme components:

- socio-economic survey;
- community development and mobilization;
- sanitation and health education;
- construction of sanitary facilities;
- monitoring, evaluation and reporting.

The Technical Development Department is responsible for:

- detailed mapping of the existing water supply situation
- systematic and comprehensive water resources survey
- source identification and design
- construction of water points
- training of technical staff
- monitoring, evaluation and reporting.

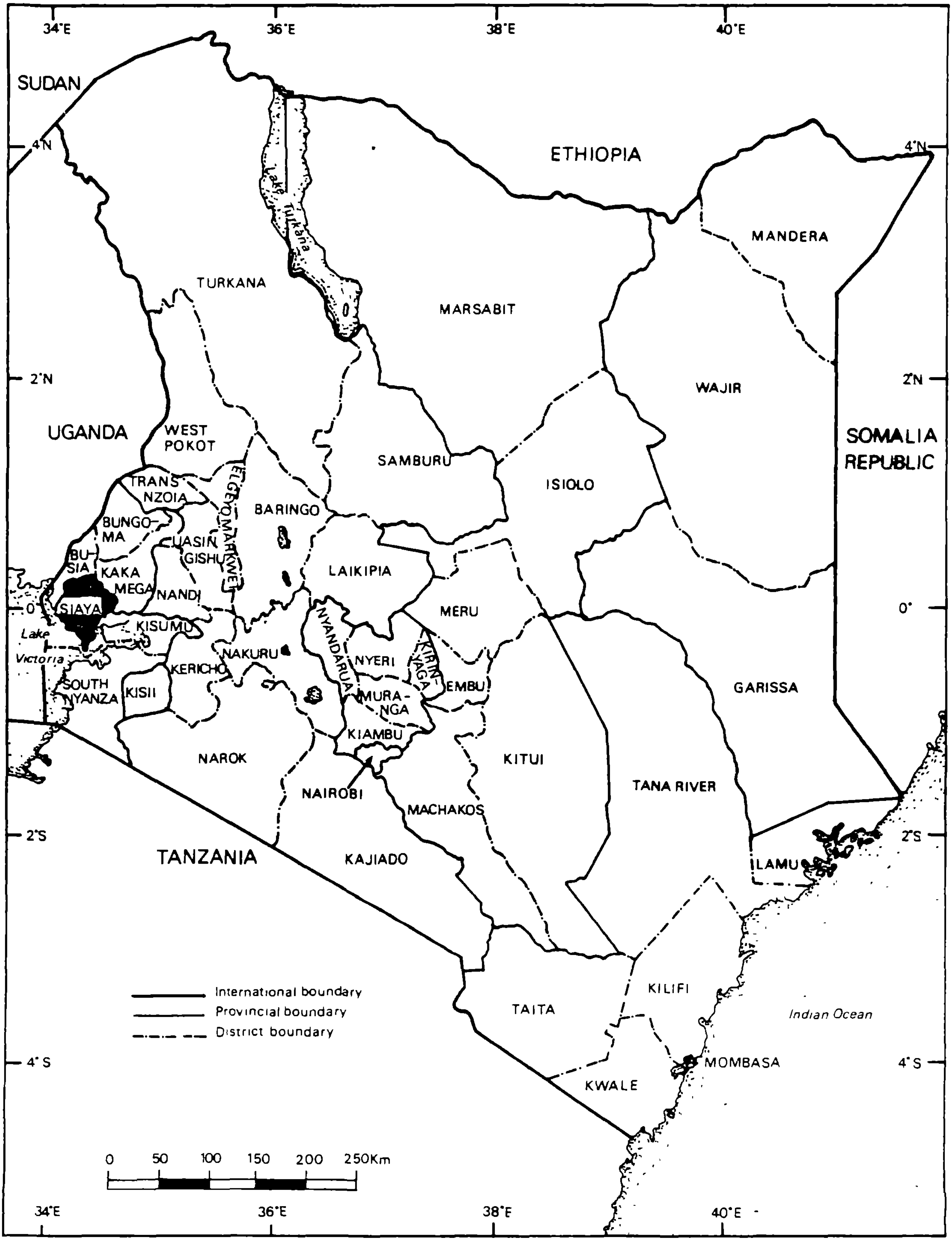
The overall management of the Programme is with the Programme coordinator, who reports directly to the Steering Committee, which is composed of experts of the LBDA, representatives of the Ministry of Water Development, Health, Social Services and Agriculture as well as representatives of the District Development Committees.

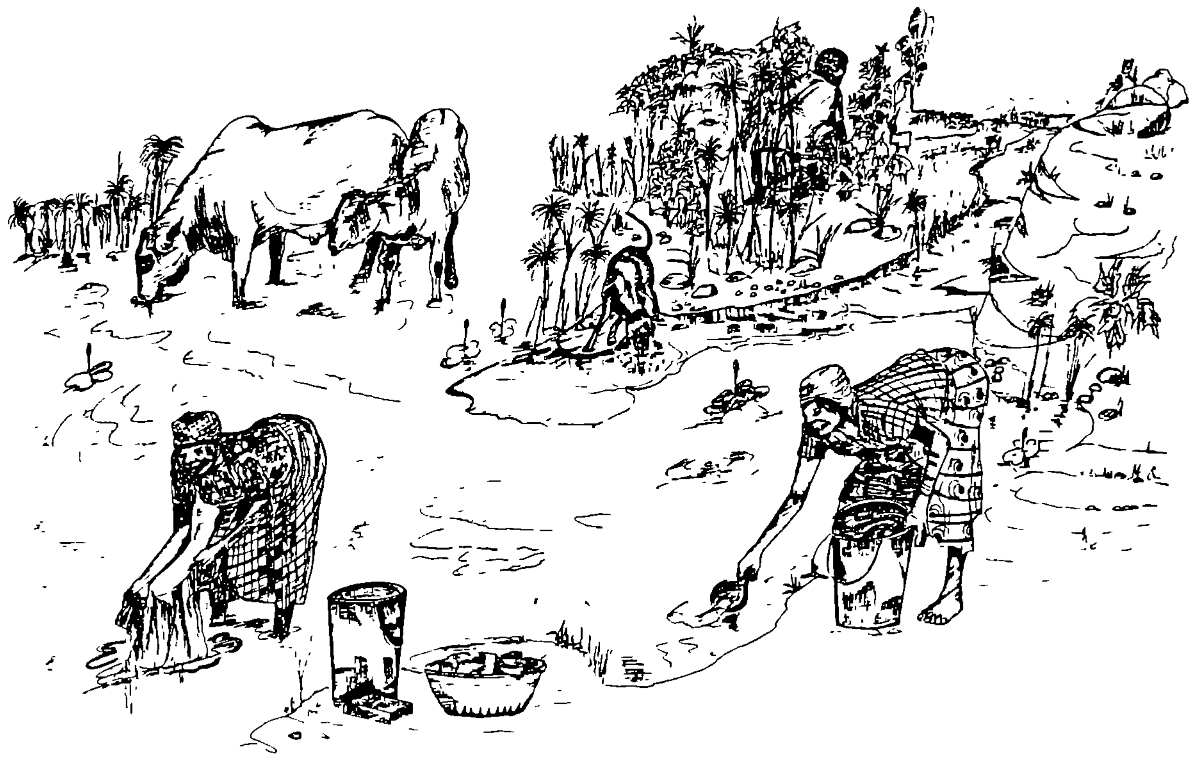
The LBDA has engaged DHV Consulting Engineers of the Netherlands to Provide professional services to the technical activities of the Programme and to train its personnel and staff.

PART II

GENERAL INFORMATION

Figure 2.1 Location of Siaya District in Kenya





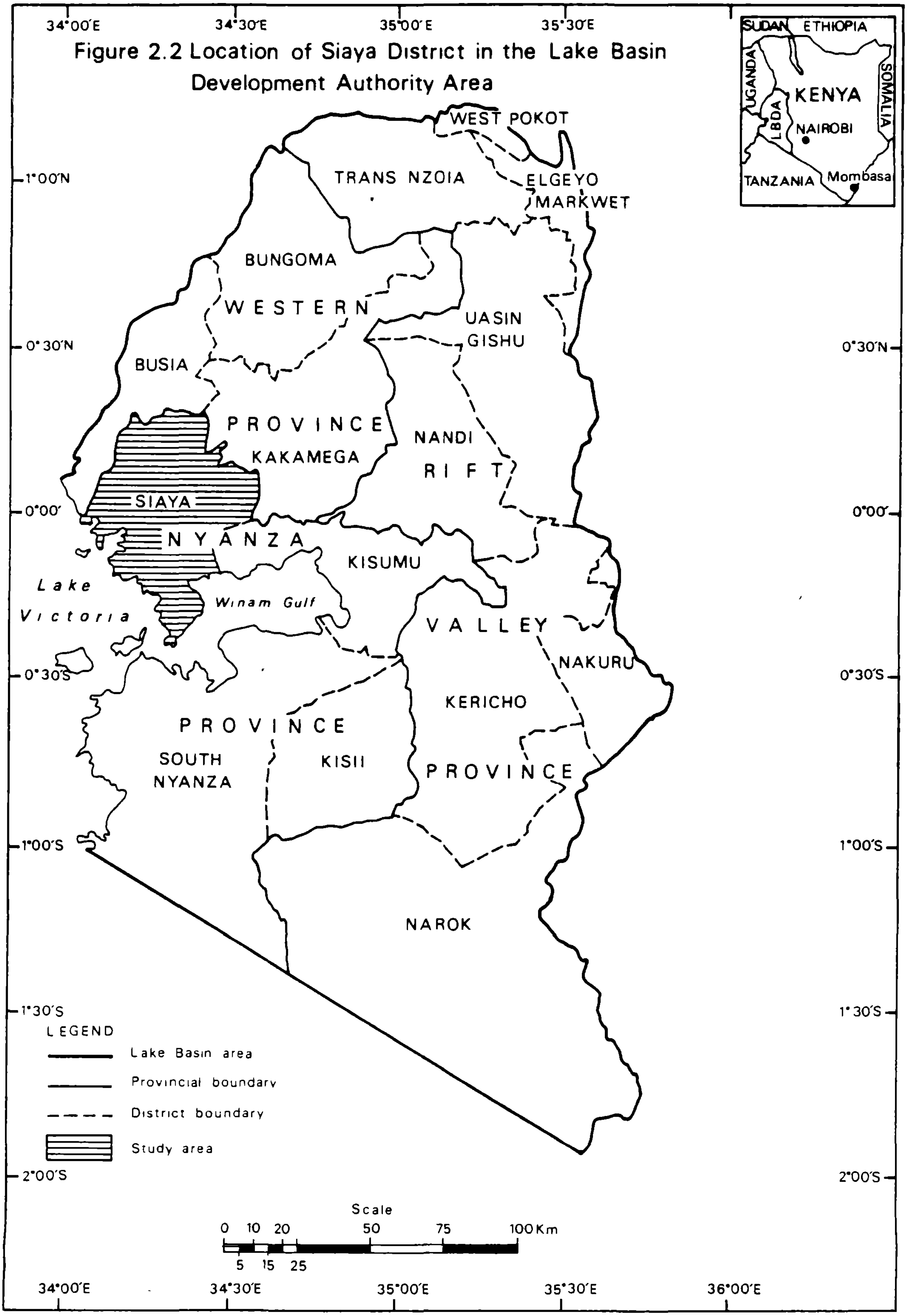


Figure 2.2 Location of Siaya District in the Lake Basin Development Authority Area

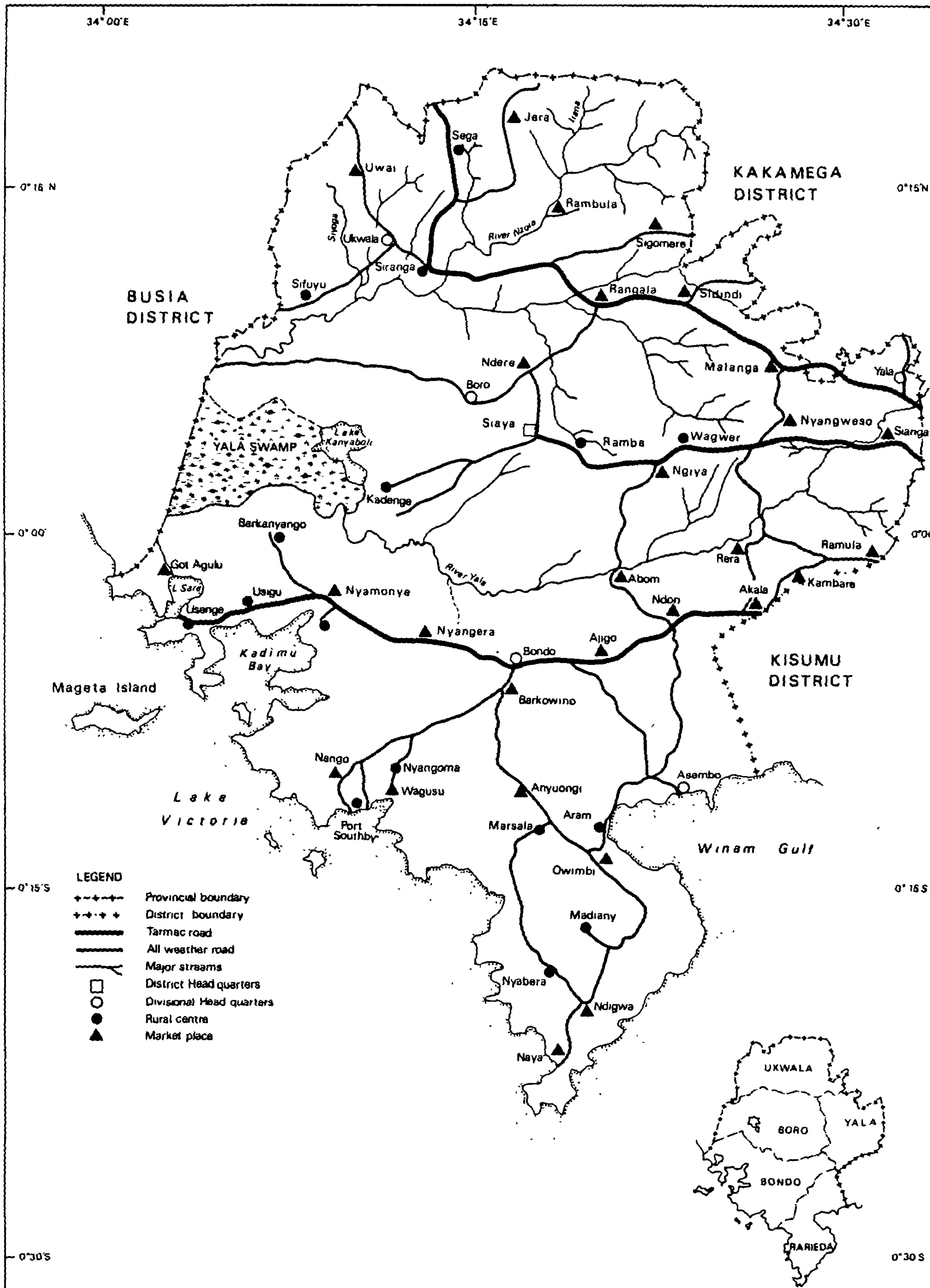


Figure 2.3 General map of Siaya District

2.1. LOCATION

Siaya District forms the northern part of Nyanza Province, located in the southwest corner of Kenya. It is bordered by Busia District to the west and north, by Kakamega District to the northeast, Kisumu District to the east and Lake Victoria to the south.

The area is roughly situated between latitudes 00^{o} 25' South and 00^{o} 18' North (UTM-grid: 9955-0035) and longitudes 34^{o} 00' East and 34^{o} 35' East (UTM-grid: 0610-0675).
The total surface area is about 2,500 (km^2), which is 20 % of the total land surface of Nyanza Province (12,500 km^2).
The extent and location of Siaya District are shown in Fig. 2.1 and Fig. 2.2.

Most of the District area is rural, with only one urban centre (Siaya Town). Additionally there are four major rural centres (Yala, Bondo, Ukwala and Asembo) and a large number of market and trading places (See Fig. 2.3).

There are three tarmac roads traversing the District, Kisumu-Busia; Maseno-Siaya; and Akala-Bondo-Usenge. In addition there is a network of all weather murram roads, connecting the major rural centres. The railway connection Kisumu- Butere passes Yala Town in the extreme eastern part of the area.

2.2. MAPS

Siaya District is covered by a number of topographical maps on different scales, published by the Survey of Kenya (Fig. 2.4.).

The KENYA Y-731 series on scale 1:50.000

The maps are printed in five colours.
Generally they have 50 (ft) contour lines with some sheets contoured at 20 (m) intervals.
The maps are largely based on 1967 aerial photographs and show great detail in physical features but are outdated for such information as roads, population centres and vegetation.
Map sheet numbers are shown in Fig. 2.4.

The KENYA SK-61 series on scale 1:50.000

This series of maps basically is a violet overprint of the Y-731 series, showing Locational and Sub-Locational boundaries and names.
The maps were printed and published in 1979. The administrative boundaries and names have changed considerably since 1979, for whih reason they are therefore rather outdated.

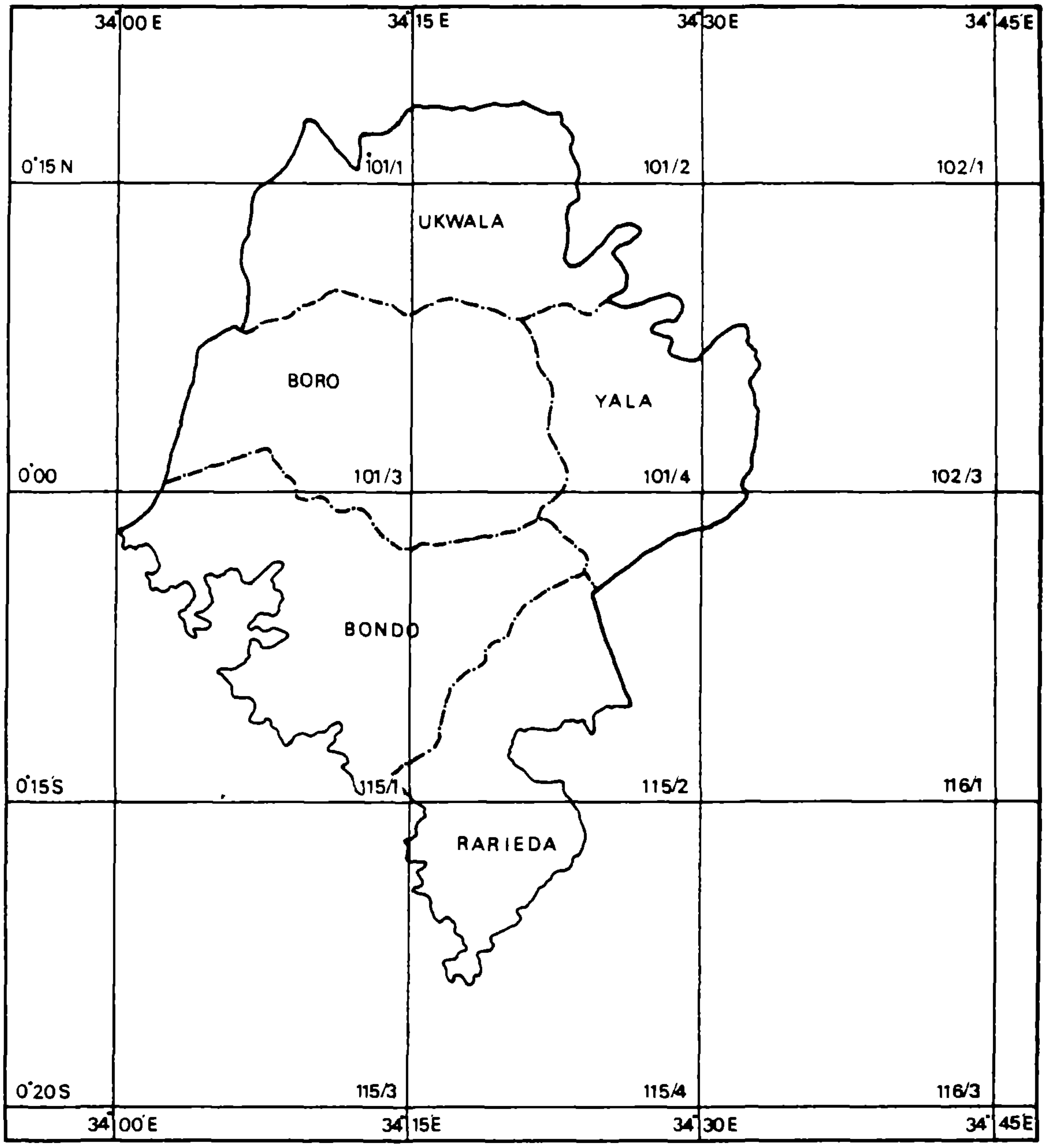


Figure 2.4 Topographical maps of the Survey of Kenya
(Scale 1:50000)

The EAST AFRICA Y-503 series on scale 1:250.00

These maps, printed in six colours with additional layer tints, show contour lines at either 200 (ft) or 60 (m.) intervals.
The last revision of this series is from 1973, but because the maps are based largely on 1957 and 1967 aerial photography, they are outdated as to infrastructural features and vegetation.

The LBDA series SK-104 on scale 1:250.00

In 1983, the Survey of Kenya published a special map for the LBDA. The series exists of two sheets.
The maps are printed in six different colours and show contour lines with 200 (ft) interval. Since this series basically is a direct extract from the EAST AFRICA Y-503 series, with no additional information, they show a rather outdated infrastructure.

The RDWSSP District Maps on scale 1:100.000

Annexed to this report are thematical maps of Siaya District on a scale 1:100.000.
For the preparation of the topographical base map, a contour lines interval of 50 (m)) and the grid system of Y-731 series were used. Other topographical features shown are roads, rivers, administrative centres ,major urban centres and market and trading places. This information was obtained from intensive field work, carried out as part of the RDWSSP

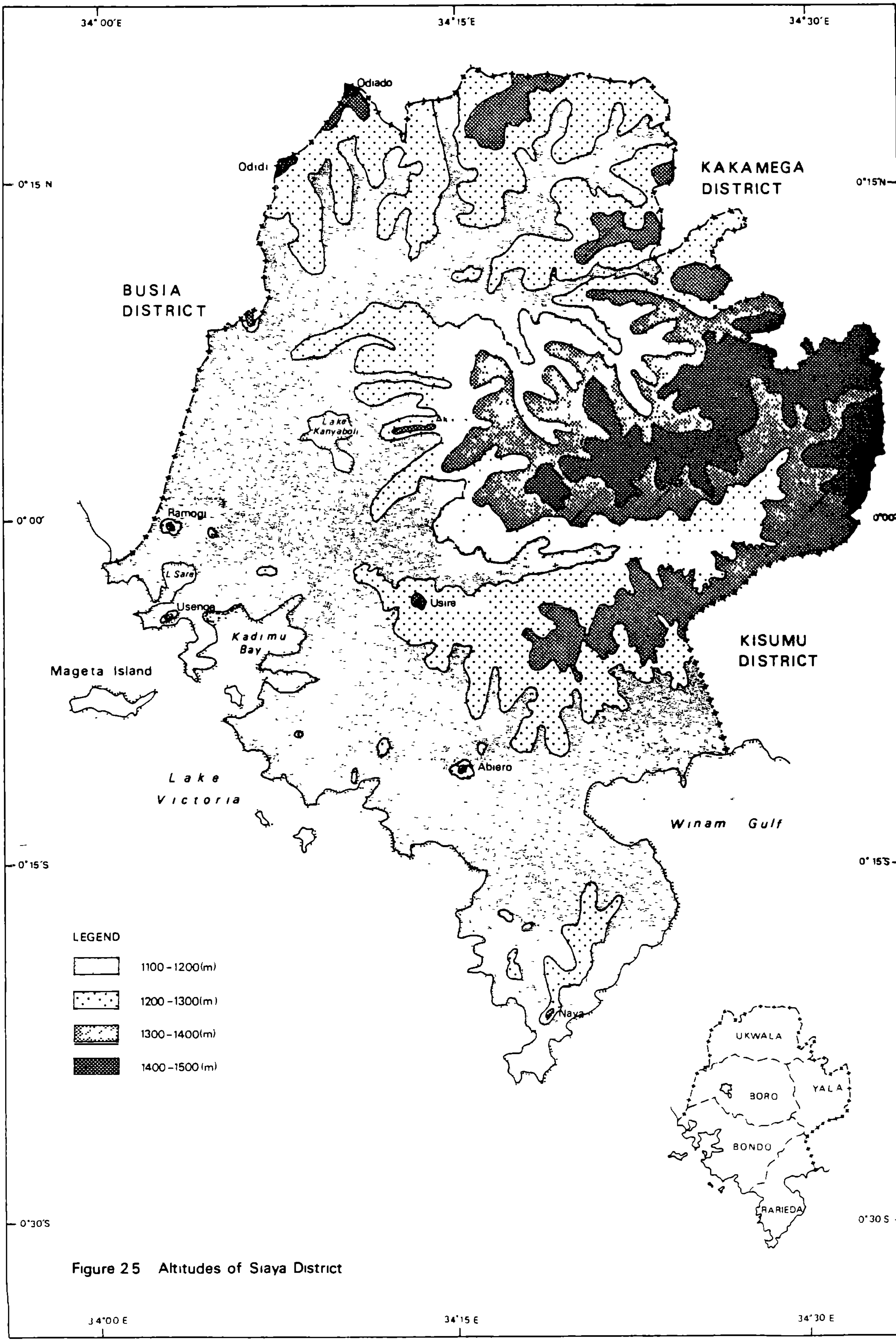


Figure 2.5 Altitudes of Siaya District

2.3. PHYSIOGRAPHIC FEATURES

Siaya District is characterized by a gently undulating landscape, consisting of broad, flat topped ridges and long and gentle valley slopes.
Altitudes range from about 1140 (m) along the Lake Victoria shores in the south to over 1400 (m) in the northeast of the District. Scattered hills, rising to about 1300 (m) occur mainly in the southern part of the District, from which the most prominent are: Got Ramogi (1318 m), Usenge Hill (1269 m), Got Abiero (1311 m), Usire (1301 m), and Naya (1271 m).
The generally flat landscape with the isolated hills and ridges are regarded as the remnants of an old peneplain.

The drainage system of Siaya District is dominated by two major rivers: Yala and Nzoia Rivers. Both rivers flow in a westward direction, through wide mature valleys, which both show signs of a later rejuvenation.

In the flat areas several swamps are found mainly along the Lake Victoria shore and along the Nzoia River. A vast swamp is found near the mouth of the Yala River (Yala Swamp), consisting of a large flooded area covered with a dense papyrus vegetation. A small section has been reclaimed and presently being cultivated by the LBDA.

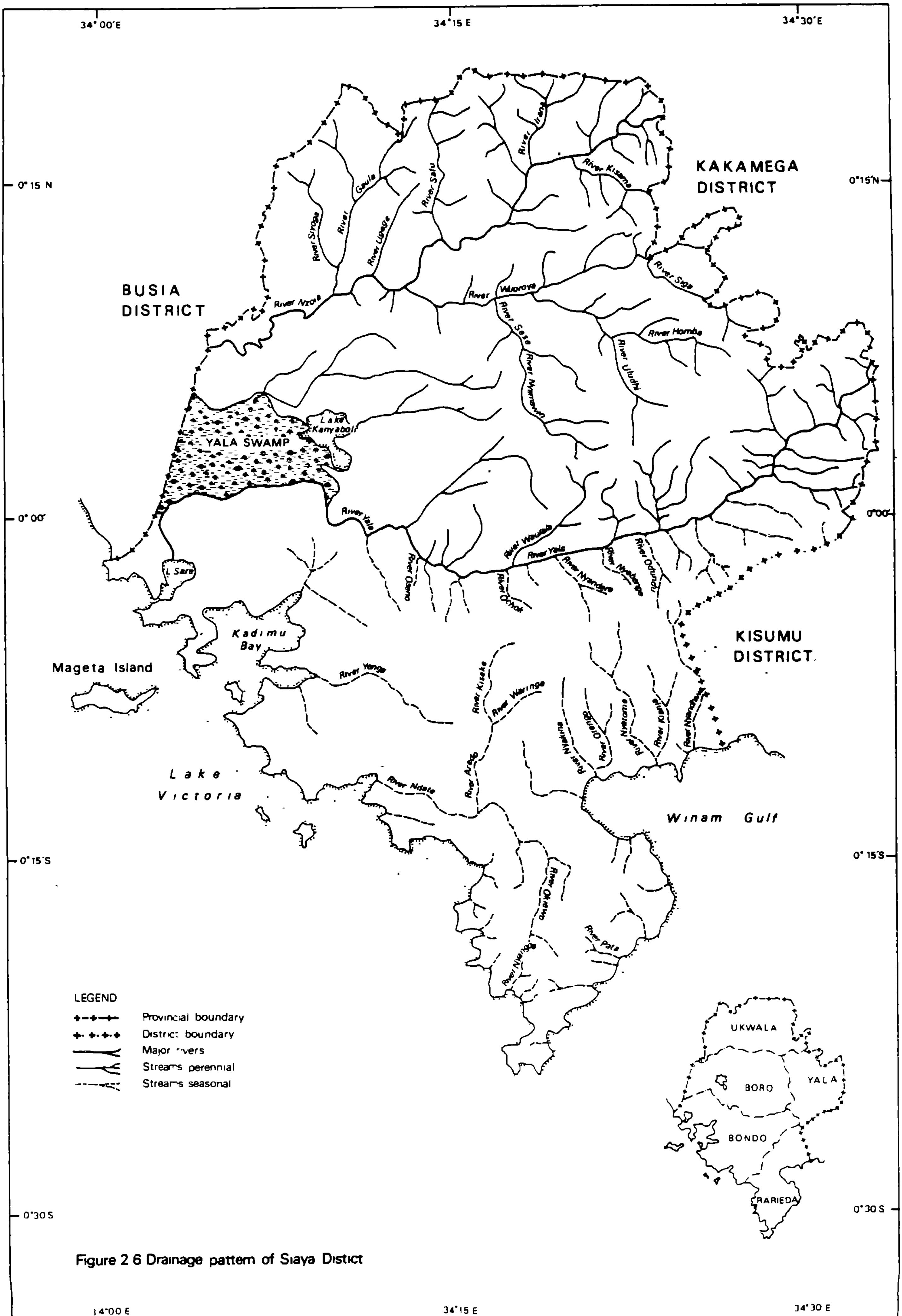


Figure 2 6 Drainage pattern of Siaya Distict

2.4. CLIMATE AND DRAINAGE

Climate

The climate of Siaya District is basically an inland equatorial type of climate, strongly influenced by the effects of topography and the Lake Victoria. The daily westerly winds which originate from Lake Victoria, converge with the prevailing easterly winds above the topographic higher parts of the District, causing a strong increase in rainfall. Hence rainfall is closely related to the altitude of the area. This is clearly illustrated in the mean annual rainfall pattern, which shows a steady increase from about 700 (mm) near the Lake Victoria shores in the southwest to about 2000 (mm) in the northeast near the border with Kakamega District.
The evaporation decreases with increasing altitude, resulting in an average evaporation of 1800-2000 (mm/year) in the south to about 1600-1800 (mm/year) in the northeastern part of the District.
Temperatures in the lower parts of the District vary from a mean minimum of 17^{o} C to a mean maximum of 30^{o} C, with a yearly average of 23^{o} C. In the topographical higher parts in the north-east part of the District the temperature is a few degrees lower resulting in a mean annual temperature of 21^{o} C.

For more detailed information about rainfall and evaporation is referred to part IV of this report.

Drainage

In Siaya District two different drainage zones can be distinguished:

--Zone 1, in the south covering large parts of Bondo and Rarieda Divisions, having exclusively seasonal rivers and streams.

--Zone 2, covering the rest of the District mainly containing perennial rivers.

Main perennial rivers in the District are Yala River originating from Nandi Hills and Nzoia River flowing from Mount Elgon. Both rivers flow in a west- southwest direction towards Lake Victoria. Most of the tributaries however, show a predominant north-south direction.

Streamflow data are discussed in detail in Part V, section 5.3. The drainage pattern of Siaya District is shown in Fig. 2.6. and catchment areas are shown in Fig. 4.11.

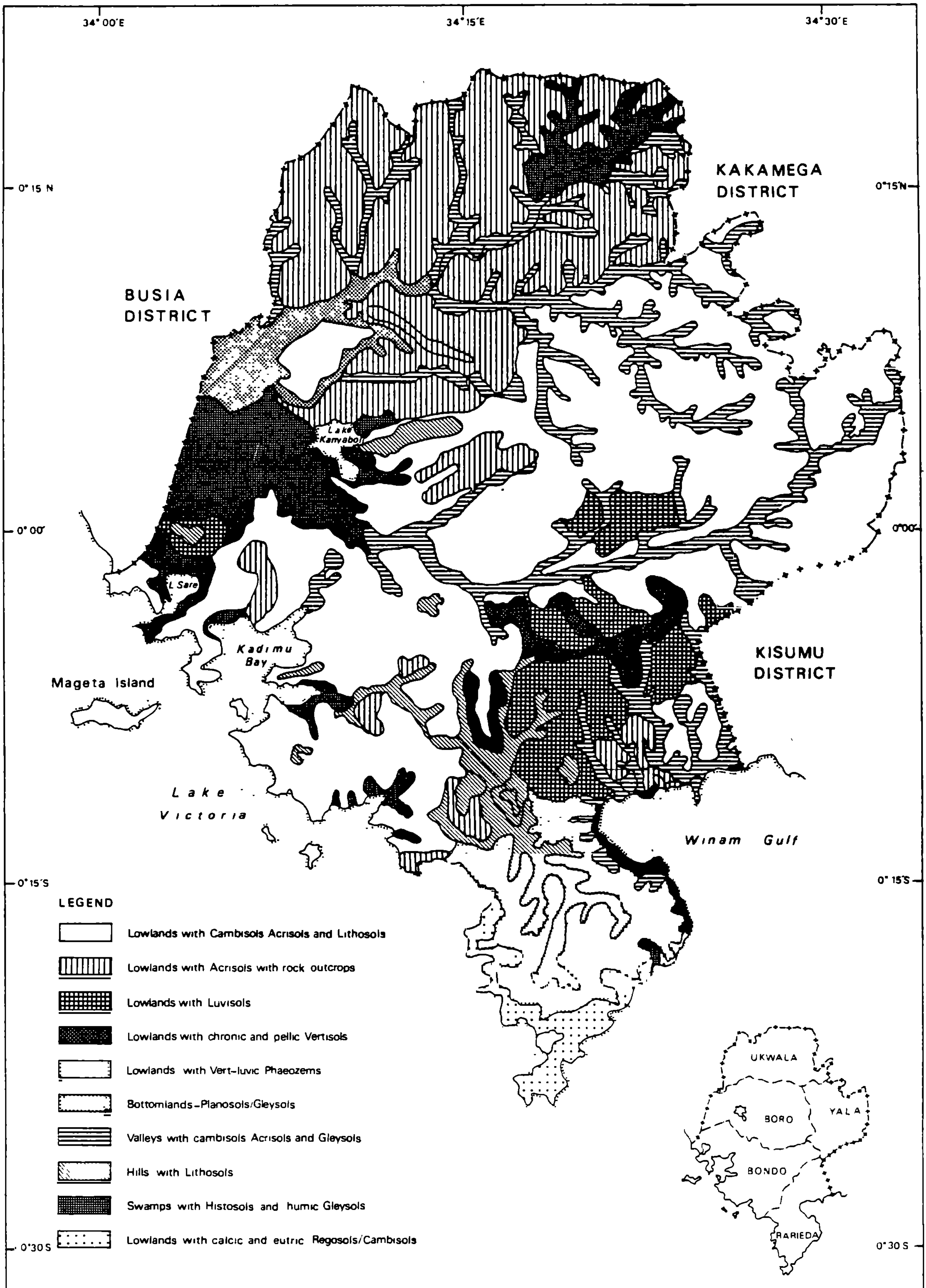


Figure 2 7 Soil map of Siaya District

2.5. SOILS AND LAND USE

Soils

Except for the fertile soils covering the volcanics in the southern part of Rarieda Division, all occurring soil types in Siaya District are of a moderate to poor fertility. The bottom-land soils (mainly consisting of Planosols and Gleysols) are generally poorly drained and mottled, resulting in frequent flooding. Soils in the lower upland areas (Cambisols and Lithosols) have a limited fertility and the water holding capacity is low.
The swamps (including Yala Swamp) have very poorly drained soils, consisting of deep clays and peat layers with commonly an acid humic top soil, having therefore limited agricultural possibilities.
Most prominent soil types are illustrated in Fig. 2.7.

Land use

The most recent and comprehensive study of the land use in the Lake Basin area was carried out by Ecosystems in 1983 (Ref.12). Results of this study for Siaya District were summarized, checked and supplemented by field checks by the Ministry of Planning and National Development (Ottichilo, 1986; Ref. 43).
A review of the most common land use types in Siaya District are given in Table 2.1.

TABLE 2.1. LAND USE TYPES COVERING SIAYA DISTRICT

NR.	LAND USE TYPE	PERCENT	COVER (KM2)
1	GRAZING	34.5	870
2	FALLOW	19.2	484
3	MAIZE	12.3	310
4	BUSHLAND	8.9	225
5	HEDGES	4.9	124
6	CASSAVA	4.7	118
7	BARE GROUND	2.2	56
8	STRUCTURES	1.6	40
9	COTTON	1.6	40
10	ROADS	1.5	38
11	SORGHUM	1.2	30
12	SUGAR CANE	0.9	23
13	WOODLOTS	0.3	8
14	OTHERS *	1.2	30

* FINGER MILLET, BANANAS, SWEET POTATOES, GROUNDNUTS, VEGETABLES AND MANGOES

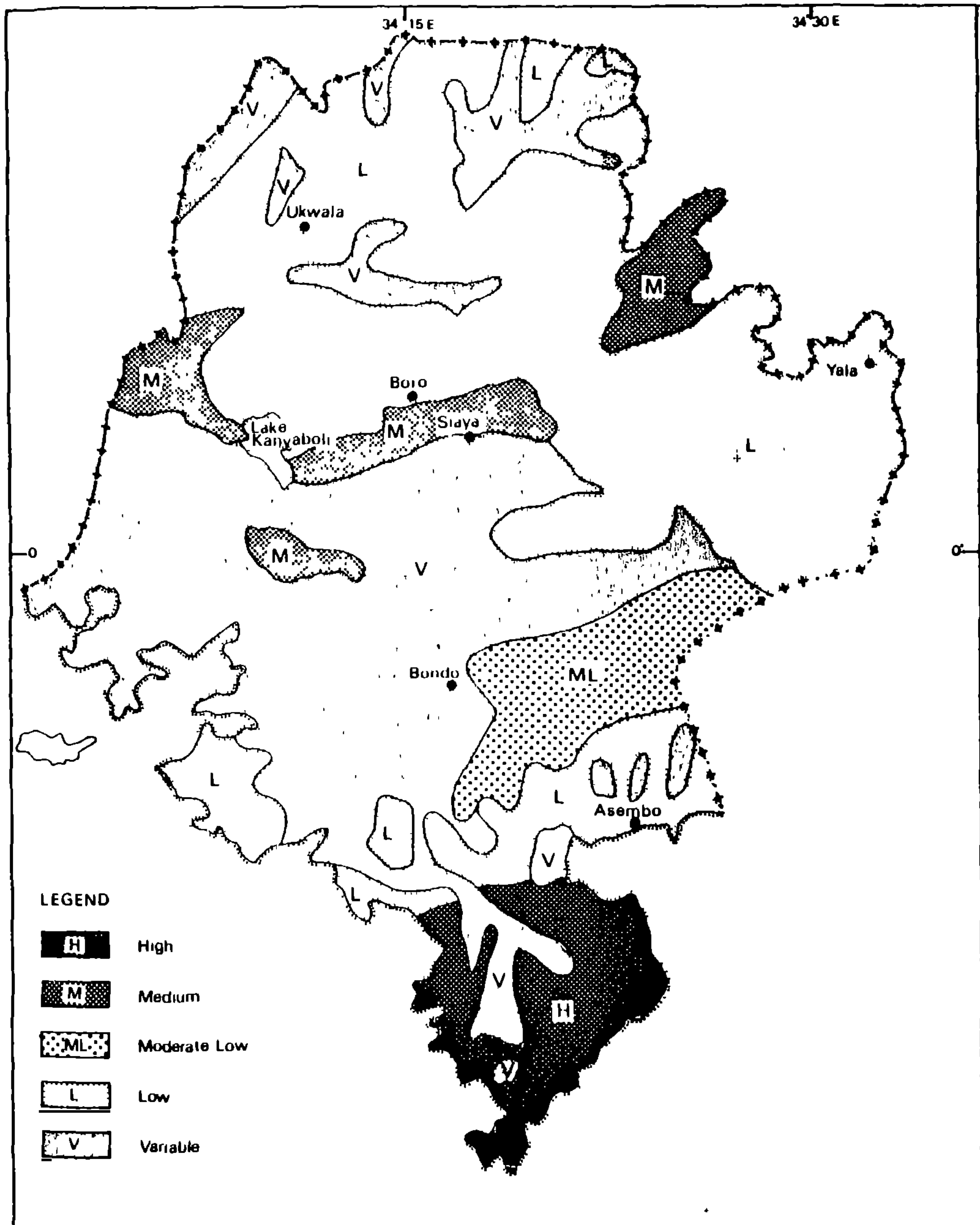


Figure 2.8A Generalized fertility map of Siaya District

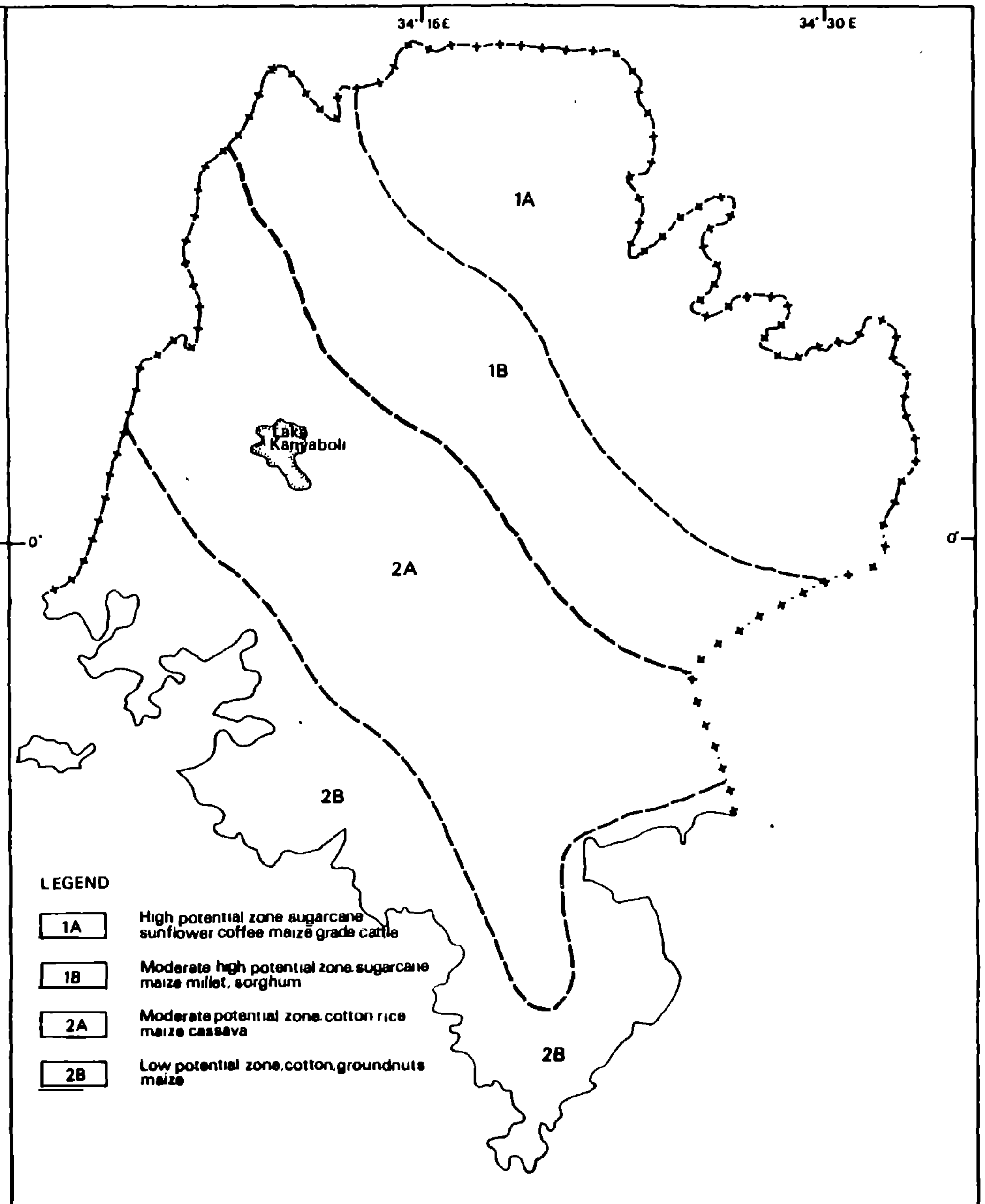


Figure 2.8B Generalized agro-economic zones in Siaya District

Siaya District has a total of agricultural land of 1642 (km^2) divided into four ago-economic zones (see Fig 2.8.).

1-High potential zone (52,000 ha), mainly found in Ukwala and Yala Divisions (zone 1A and 1B).
2-Medium potential zone (82,000 ha),which is widely distributed over the 5 Divisions (zone 2A).
3-Marginal zone (26,000 ha) is mainly found in parts of Bondo, Rarieda and south Yala Divisions (zone 2B).
4-Range and desert zone covering only a small area (4,000 ha) of Boro Division.

FOOD CROPS The most important food crops in Siaya District are maize, cassava and sorghum. Other food crops are finger millet, sweet potatoes, beans, groundnuts and vegetables. The District has the potential of growing rice, in particular in the Yala Swamp. At present the LBDA utilizes part of the reclaimed Swamp for rice seed bulking, which can be used for irrigated small holder rice schemes. Hence in the near future, rice can become an important food crop in the District.

CASH CROPS The main cash crops are sugar cane, cotton and coffee. Currently sugar cane is grown mainly in Ukwala and Yala Divisions. The area covered with sugar cane in eastern Ukwala and northern Yala division has substantially increased due to its close proximity of Mumias Sugar Factory. Due to the lack of other sugar factories in the District sugar cane growing has fallen dramatically in the remaining part of the District.
The southern part of Siaya District is suitable for growing cotton. However, low cotton prices, delayed payments to the farmers and the lack of credit facilities have led to a serious drop in cotton production.
Though the current coffee growing area in Siaya District is not more than about 100 (ha), there are good possibilities for expansion of this crop, mainly in Yala, Boro and Ukwala Divisions. The LBDA has planned to promote the growing of Robusta coffee in the District by producing seedlings in the Yala Swamp, which may make coffee in the near future an important cash crop.
The District has further a high potential for growing fruits and vegetables, however irrigation will be a necessity in most areas.

LIVESTOCK The keeping of livestock is an important activity, in particular in Boro, Bondo and Rarieda Divisions. Most livestock however, are of the local unimproved types and reared under traditional grazing systems. The estimated livestock population in 1986 amounted to about 123,500 cattle, 23,000 sheep and goats, and 900 donkeys (Ottichilo, 1986; Ref. 43).

FORESTRY Siaya District is one of the least forested Districts of the country, with only 0.3 % of the area forested. In 1982 a start has been made with afforestation programmes on the agri-culturally unproductive hill tops.

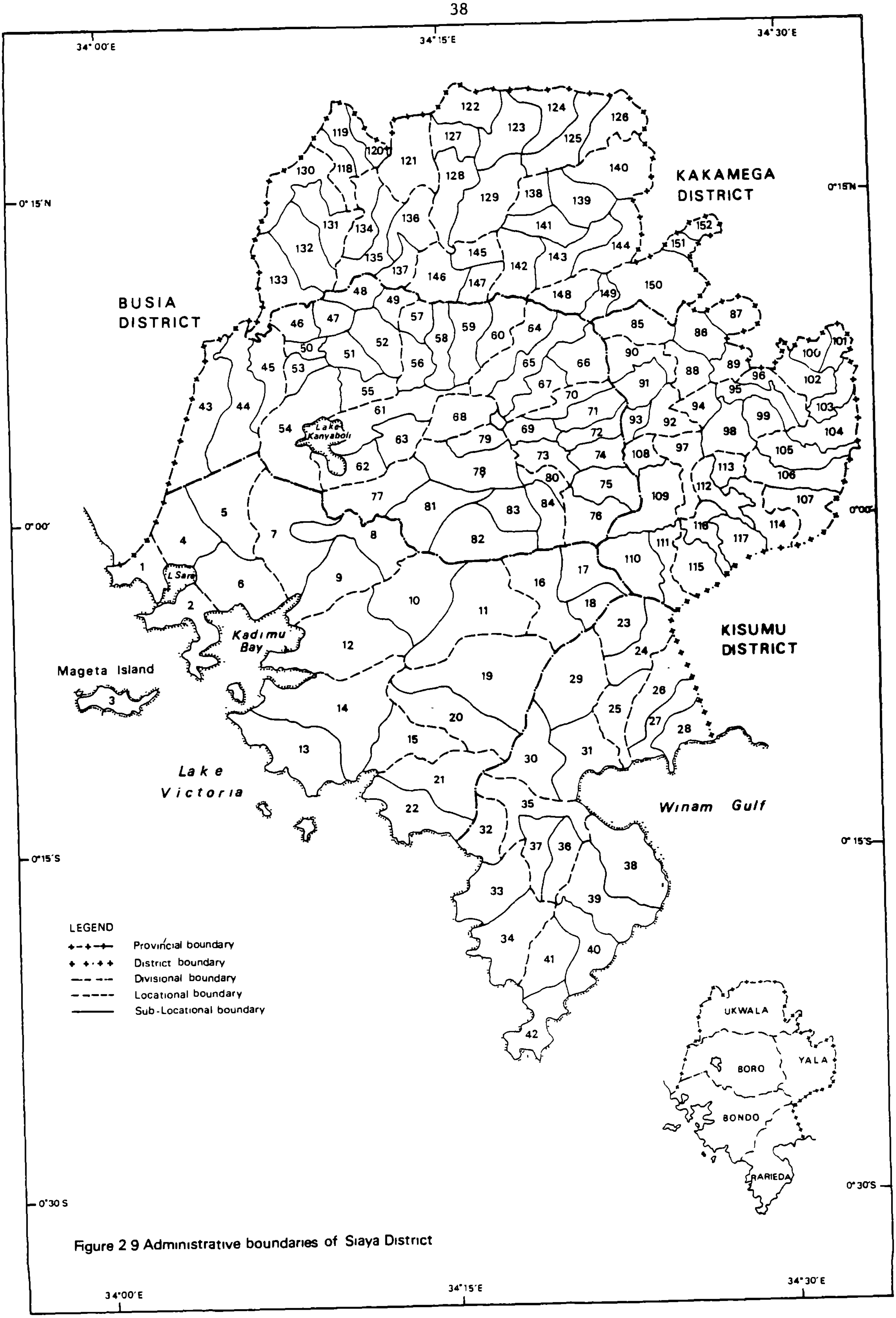


Figure 2 9 Administrative boundaries of Siaya District

BONDO DIVISION

WEST YIMBO
1. Got Agulu
2. Usenge
3. Mageta

CENTRAL YIMBO
4. Got Ramogi
5. Bar Kanyango
6. Usigu

EAST YIMBO
7. Nyamonye
8. Othach
9. Pala

WEST SAKWA
10. Maranda
11 Nyawita
12. Utonga

CENTRAL SAKWA
13. Uyawi
14. Nyangoma
15 W. Migwena

NORTH SAKWA
16. Ajigo
17. Abom
18 Bar-Chando

SOUTH SAKWA
19. Bar Kowino
20 Bar Migwena
21. Got Abiero
22. Nyaguda

RARIEDA DIVISION

CENTRAL ASEMBO
23. N. Ramba
24. S. Ramba
25. Memba

EAST ASEMBO
26. Omia Malo
27. Omia Diere
28. Omia Mwalo

WEST ASEMBO
29. Siger
30. Nyagoko
31. Mahaya

WEST UYOMA
32 Kagwa
33. Kokwiri
34. Nyabera

CENTRAL UYOMA
35. Masala
36. Kobong
37. Rachar

EAST UYOMA
38. Ragengni
39. Katwenga
40. Lieta
41. Ndigwa
42. Naya

BORO DIVISION

Usonga
43. Sumba
44. Nyadorera B
45. Nyadorera A

WEST ALEGO
46. Kabura Uhuyi
47. Kaikada Uradi
48. Komenya Kowala
49. Komenya Kalaka
50. Sigoma Uranga
51. Mahola Ulawe
52. Kodiere
53. Kaugagi Udenda
54. Kaugagi Hawinga
55 Gangu

CENTRAL ALEGO
56. Kochieng A
57. Kochieng B
58. Ojwando B
59. Koyeyo
60. Kakumu Kombewa
61. Ojwando A
62. Kadenge
63. Obambo

NORTH ALEGO
64. Komolo
65. Hono
66. Nyamila
67 Nyaigunga

EAST ALEGO
68. Mulaha
69. Karapul Ramba
70. Ulafu
71. Umala
72 Olwa
73. Bar Agulu
74. Mur Ngiya
75. Masumbi
76. Nyangoma

SOUTH ALEGO
77. Bar Olengo
78. Randago
79. Nyandiwa
80. Barding
81. Mur Malanga
82. Nyajuok
83. Bar Osimbo
84. Pap Oriang

YALA DIVISION

NORTH GEM
85. Ndere
86. Malanga
87. Got Regea
88. Lundha
89. Maliera

NORTH WEST GEM
90 Asayi
91. Sirembe
92. Malunga East
93. Malunga West

CENTRAL GEM
94 Siriwo
95. Nyandiwa
96. Nyawara
97. Wagai
98. Kagilo
99. Gongo

EAST GEM
100. Bar Sauri
101. Anyiko
102. Nyamninia
103. Jina
104. Marenyo
105. Lihanda
106. Uranga
107. Ramula

WEST GEM
108. Ulamba
109. Dienya
110. Kaudha
111. Kanyadet

SOUTH GEM
112 Onyinyore
113. Uriri
114. Gombe
115. Ndori
116. Rera
117. Kambare

UKWALA DIVISION

NORTH UGENYA
118. Uyundo
119. Nyalenya
120. Kagonya
121. Sega

EAST UGENYA
122. Jera
123. Ramunde
124. Kathieno A
125. Kathieno B
126. Murumba
127. Nyamsende
128. Ligala
129. Anyiko

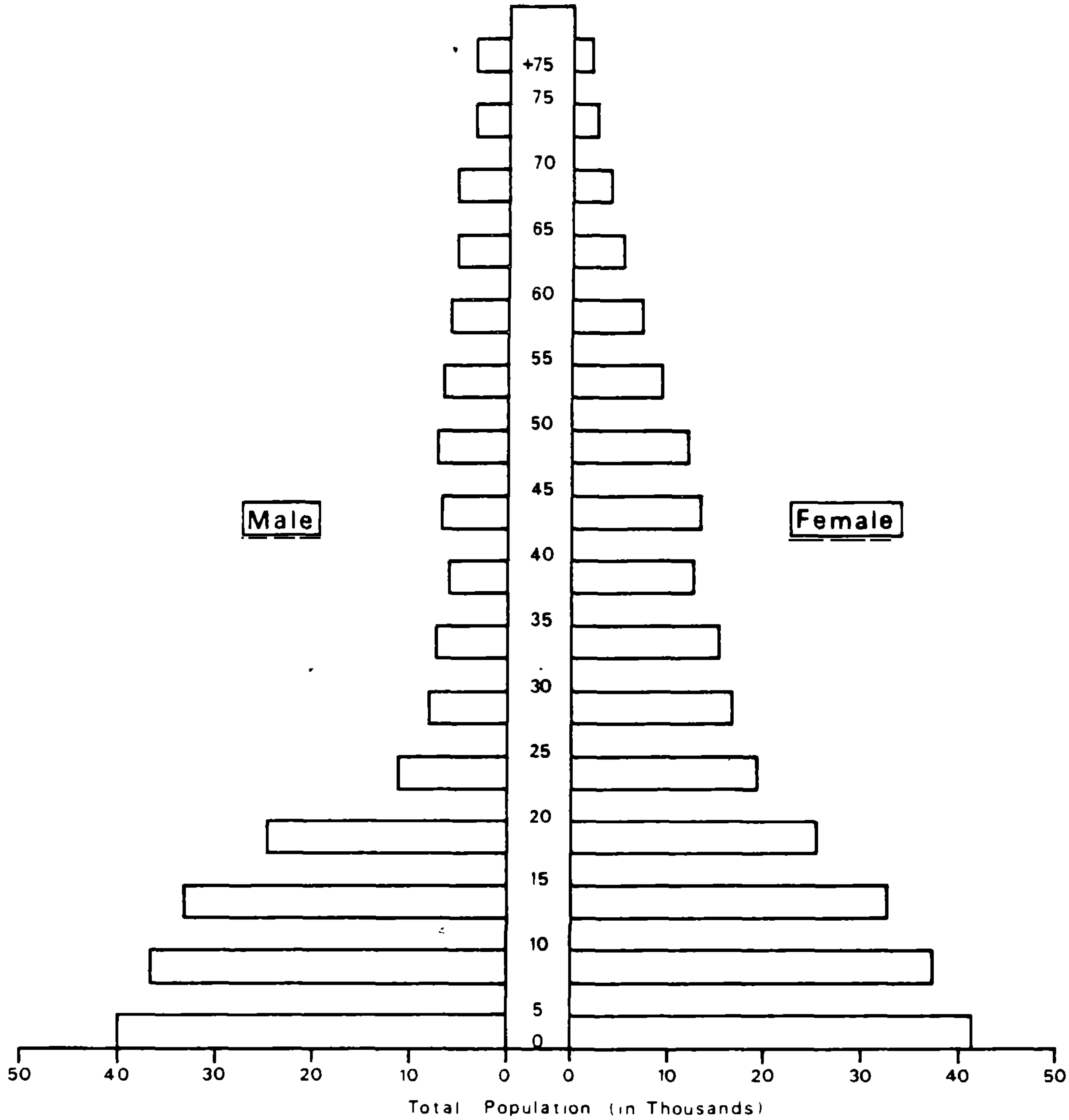
WEST UGENYA
130. Ndenga
131. Karadolo
132. Masat
133 Sifuyo

UKWALA
134. Doho
135. Simuru
136. Yenga
137. Siranga

UHOLO
138. Magoya
139. Asango
140. Tingare
141. Rambula
142. Ugunja
143. Sigomere
144. Madungu

SOUTH UGENYA
145. Ambira
146. Umala
147. Ngunya
148. Rangala
149. Simenya
150. Yiro
151. Ruwe
152. Uhuyi

Figure 2.10 Population Pyramid of Siaya District (1979)



Source CBS 1979

2.6. ADMINISTRATION

Figure 2.9 and MAP-2 (annexed to this report) show the sub-division of Siaya District into Divisions, Locations and Sub-Locations, as it was found during the RDWSSP surveys in 1987 and 1988.
The smallest administrative unit is a Sub-Location, which is administered by an Assistant Chief.
Several Sub-Locations (3-6) form together a Location headed by a Chief. A number of Locations in turn are grouped together and form a Division, which is administered by a District Officer (DO).

The Divisional, Locational and Sub-Locational boundaries largely are the agreed boundaries, used for the parliamentary and local government elections of 1988.

Basically the District is divided into 5 administrative Divisions, which are subdivided into 31 Locations and 152 Sub-Locations.

The administrative subdivision, is shown in Table 2.2.

TABLE 2.2. ADMINISTRATIVE SUBDIVISION (JANUARY 1988 SITUATION)

DIVISION NAME	SIZE (KM^2)	HEADQUARTERS NAME	NR OF LOCATIONS	NR OF SUB-LOCATIONS
BONDO	574	BONDO	7	22
RARIEDA	398	ASEMBO BAY	6	20
BORO	581	BORO	6	42
YALA	417	YALA	6	33
UKWALA	517	UKWALA	6	35
SIAYA DISTRICT	2483	SIAYA TOWN	31	152

Since the last census was held in 1979 a number of changes were made from which the most important was the split up of Bondo Division into two Divisions; Bondo and Rarieda Divisions.
Further a large number of Locations and Sub-Locations have been split up and/or renamed.

The present District headquarters is in Siaya Town. Chief's camps, Divisional and Locational headquarters and are indicated on Map I.

Politically Siaya District is divided in 5 constituencies each choosing its own Member of Parliament:

1 - Bondo
2 - Rarieda
3 - Alego-Usonga
4 - Gem
5 - Ugenya-Uholo

2.7. DEMOGRAPHIC CHARACTERISTICS

The population growth throughout Kenya is one of the highest recorded in the world. The present combination of high fertility, declining mortality and a relatively young population implies that this high rate of growth will most probably persist until well into the next century. West Kenya is one of the most densely populated areas of Kenya. A clear relationship between rainfall pattern and population density can be observed. Low rainfall areas in the southern part of Siaya District have relatively low densities about (200 and 250), while Yala and Ukwala Divisions, being the areas with the highest rainfall have estimated 1988 population densities of 350-400 people per (km^2).

Up to the present, in Kenya four nation wide population censuses have been carried out respectively in 1948, 1962, 1969 and 1979. The results of these censuses are published by the Kenyan Central Bureau of Statistics (CBS, Ref. 4 and 5) (see Table 2.3).

TABLE 2.3. POPULATION DATA ACCORDING TO THE POPULATION CENSUSES OF 1962, 1969 AND 1979.

	TOTAL POPULATION			GROWTH RATE	
	1962	1969	1979	'62-'69	69-'79
KENYA	8,636,000	10,942,000	15,327,000	3.4%	3.4%
NYANZA PROV.	1,564,000	2,122,000	2,644,000	3.7%	2.2%
SIAYA DISTR.	354,000	383,000	475,000	1.6%	2.2%

The relatively low population growth in Siaya District as well as in the whole of Nyanza Province between 1969 and 1979 was caused by a considerable under-counting of the population in this part of Kenya during the 1979 census. Revised growth rates for this period were published by the CBS in 1983 (Ref.5.). A more realistic figure of 3.5 % was calculated based on fertility and mortality data. Hence the 1979 total population of Siaya District was corrected to be about 540,000.
During the inventory survey carried out under the RDWSSP in 1987-1988 a population estimate per Division was made based on the number of water consumers (Table 2.4.). Comparing this 1987 population estimate with the corrected 1979 census figure the average growth rate for the entire Siaya District has been 3.1 %. on an average.
Using annual population growth rates of 3%, Table 2.5 presents the 1995 and 2005 population projections.

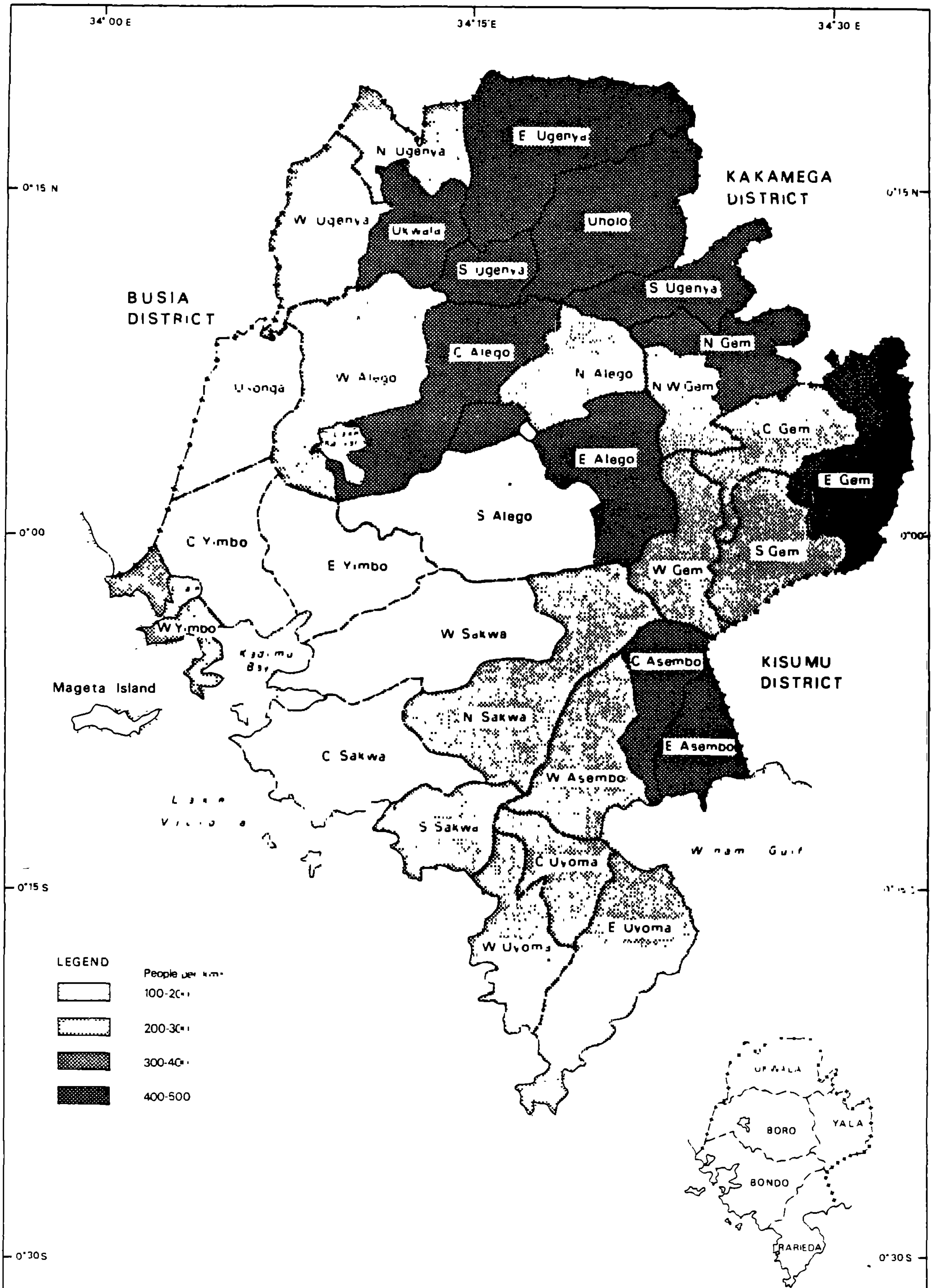


Figure 2 11 Population density of Siaya District (1988)

TABLE 2.4. PRESENT POPULATION OF SIAYA DISTRICT AS COMPARED WITH THE POPULATION OF 1979

	1979 CENSUS 2.2%	1979 * CORRECTED 3.5%	1987 ** 3.2%	1987 ***
BONDO	65,335	75,174	97,000	109,000
RARIEDA	74,918	86,199	110,000	109,000
BORO	117,816	129,634	172,000	157,000
YALA	94,030	108,193	138,000	139,000
UKWALA	122,417	140,778	179,000	176,000
SIAYA DISTRICT	474,516	539,977	696,000	690,000

* Adjusted population based on census (1979) results,CBS-Population Projections for Kenya 1980-2000, 1983).
** Integrated Regional Development Master Plan, JICA, 1987.
*** Population estimates based on consumers counting during the inventory survey (RDWSSP, 1987-1988).

An decrease in growth rate from 3.5 to 3.0 % is expected because of the increasing out migration from over-populated areas. Further it is anticipated that the present efforts of the family planning programme of the Kenyan Government will have a reducing effect on the population growth in the future.

The present average population density of about 276, with continued growth of 3.2 % per year, will increase to about 400 in 1995 and about 500 in 2005. It is however expected that this increasing pressure on the land resources will result in a decrease in growth rate, and increased out migration.
Present population density of Siaya District per Location is illustrated in Fig. 2.11.

TABLE 2.5. POPULATION PROJECTIONS OF SIAYA DISTRICT

DIVISION NAME	POPULATION 1987	1995 3%	2005 3%
BONDO	109,000	138,000	186,000
RARIEDA	109.000	138,000	186,000
BORO	157,000	199,000	267,000
YALA	139,000	176,000	237,000
UKWALA	176,000	223,000	300,000
SIAYA DISTRICT	690,000	874,000	1,176,000

Remarks; 3% growth rate is taken from the JICA study; "Integrated Regional Development Master Plan", 1987

FIG. 2.12 LIFE EXPECTANCY (1979 SITUATION)

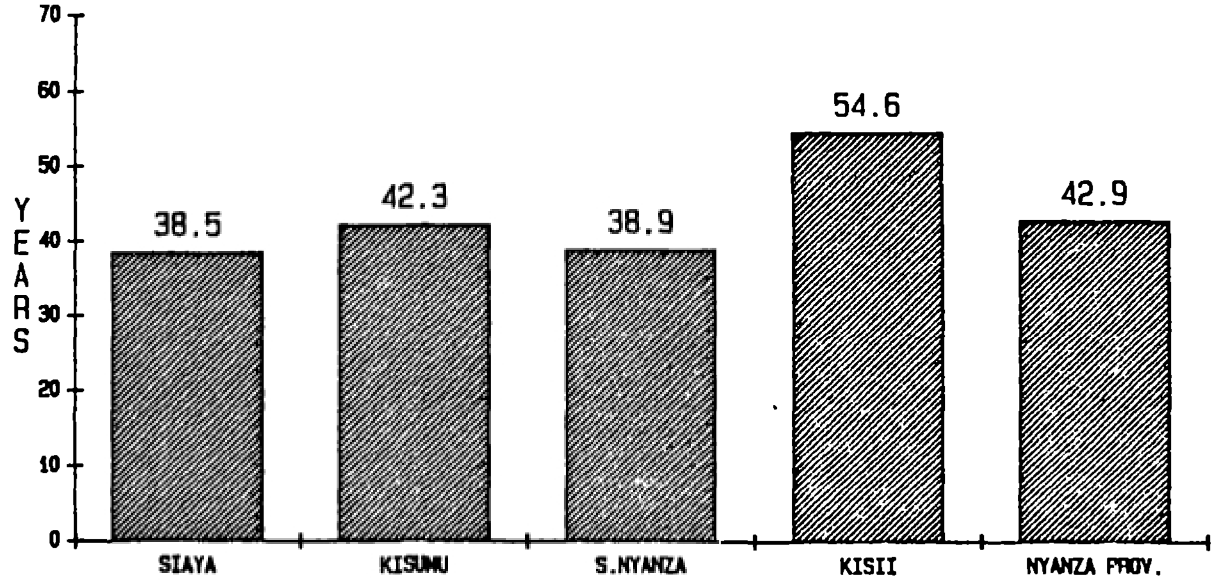
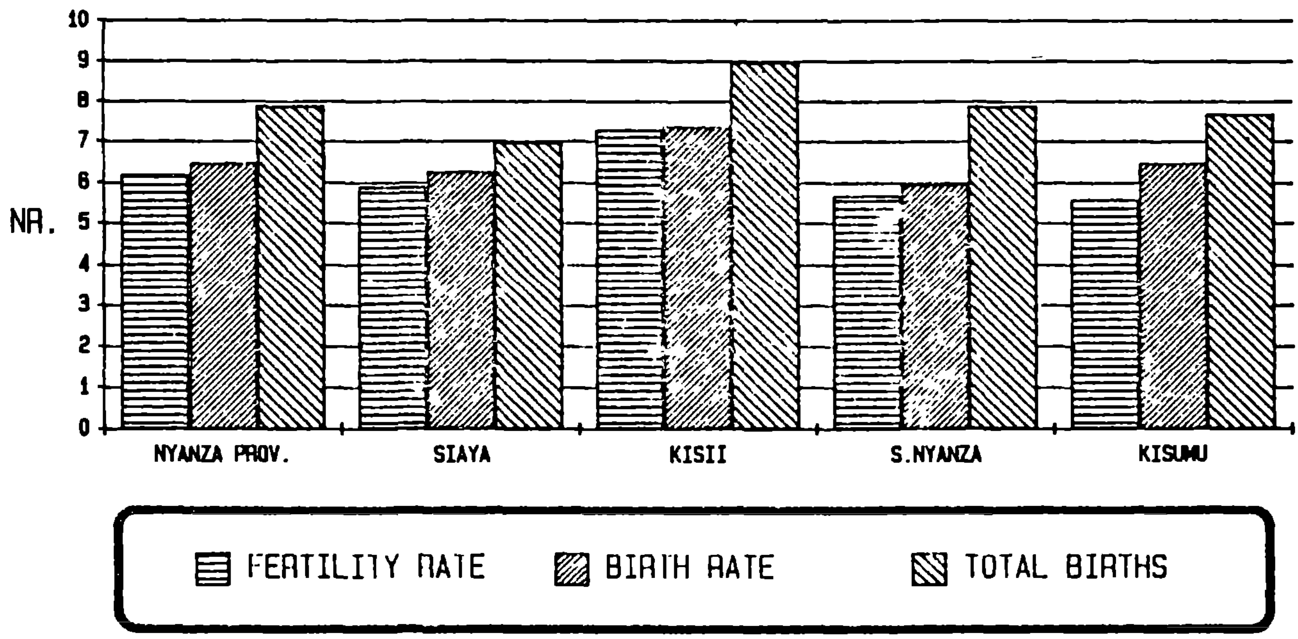


FIG. 2.13 BIRTH RATES IN SIAYA DISTRICT AS COMPARED WITH THE OTHER DISTRICTS IN NYANZA PROVINCE

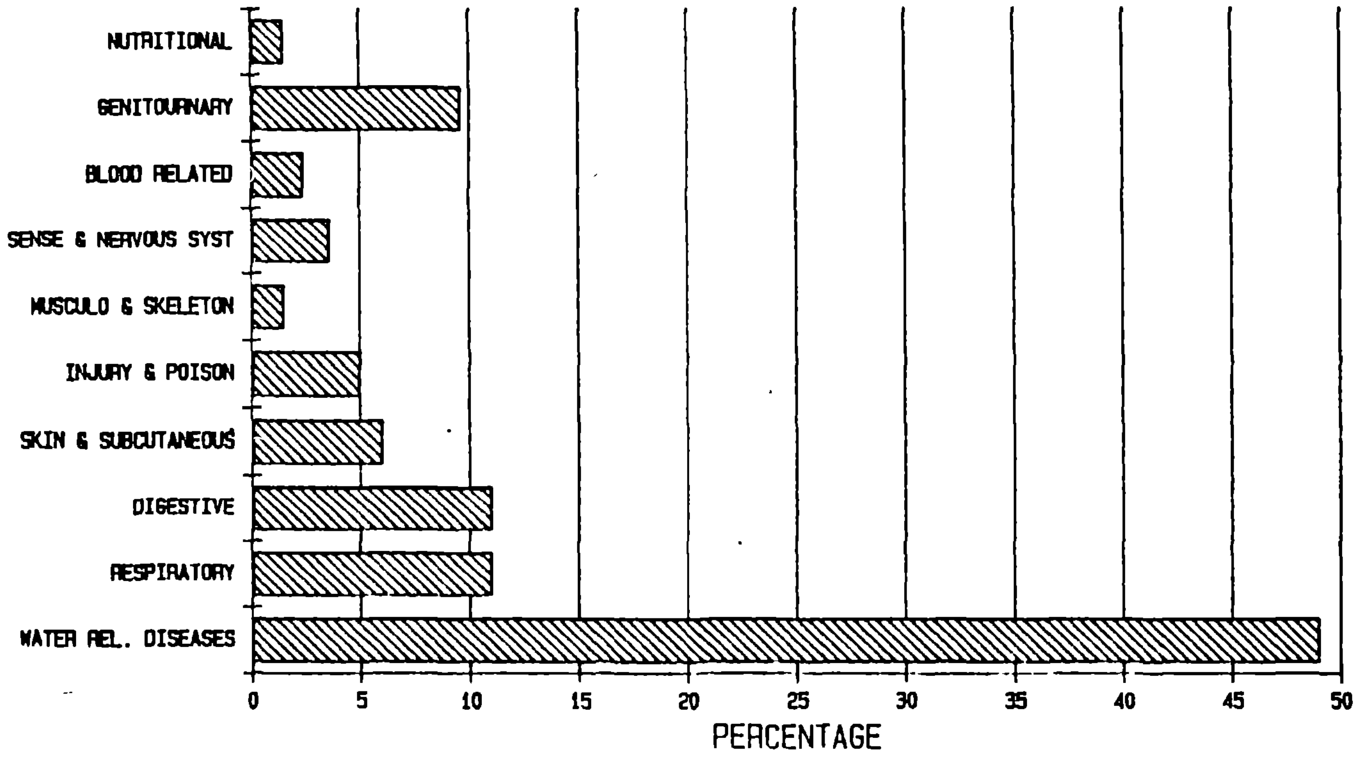


2.8. HEALTH ASPECTS

Present situation

A socio-economic survey carried out in Siaya District in 1987 revealed the most common diseases in the region, which are illustrated in Fig. 2.14. From this Figure it is evident that water related diseases are the most frequently occurring (48 %) followed by respiratory (13 %) and digestive (12 %) diseases.

FIGURE. 2.14 DISEASE RATES IN SIAYA DISTRICT.



Water related diseases include malaria, schistosomiasis, typhoid fever, gastro-entritis and dysentry.
Infant mortality as well as the child mortality rates in Siaya District are among the highest in Kenya (212 and 247 resp.) (See Fig. 2.16).
The general health situation in Siaya District is together with South Nyanza the worst of Nyanza Province. This is illustrated in the average life expectancy figure of 38.5 years in the District which is the lowest of the entire Nyanza Province.

Hence in Siaya District the need for clean drinking water is evident when considering that more than 60 % of the infant mortality is caused by diarrhoea.

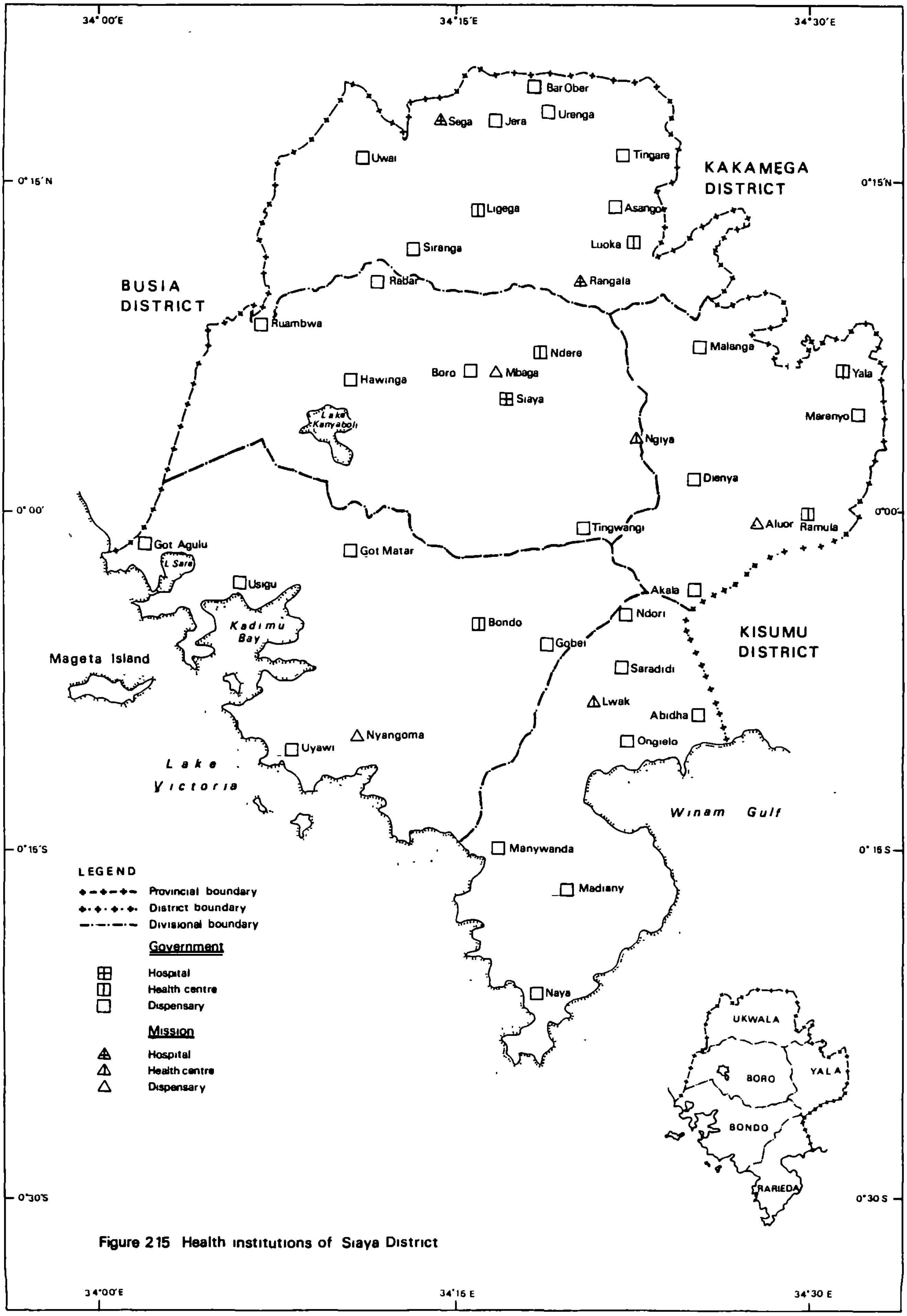


Figure 2.15 Health institutions of Siaya District

Health institutions

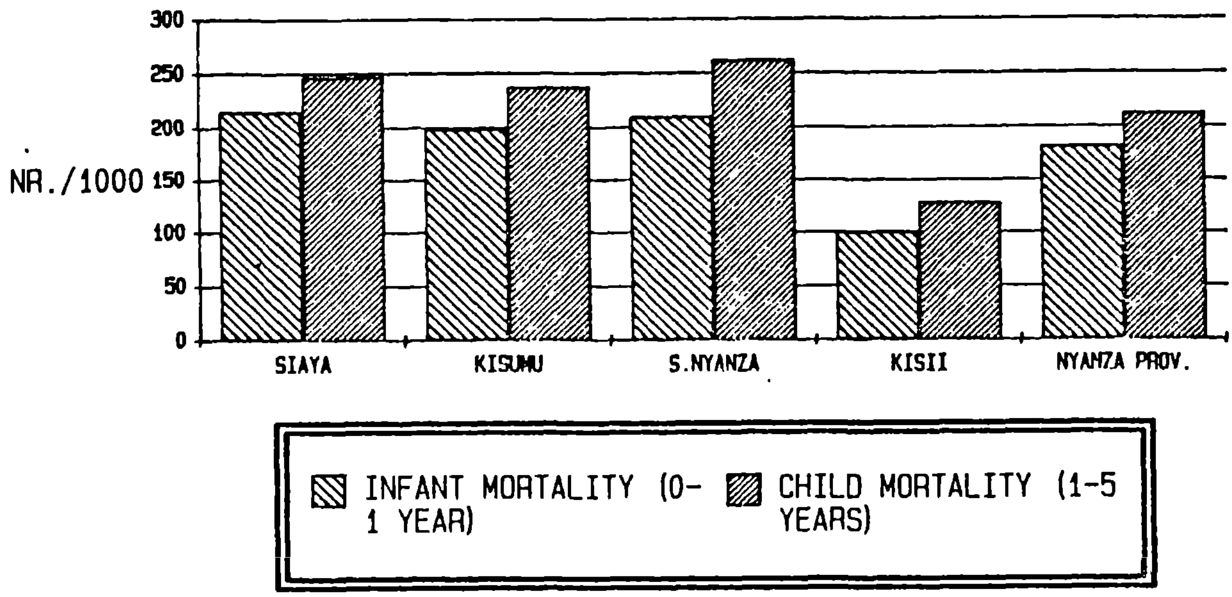
In Siaya District a number of health institutions are found (Fig.15). In total 45 health institutions are found from which 38 are managed by the government and 7 by missionary operated institutions.
There are 3 Hospitals located, one in Siaya Town, in Rangala and in Sega.
Further 14 Health Centres and 28 Dispensaries are present in the District (see Table 2.6).

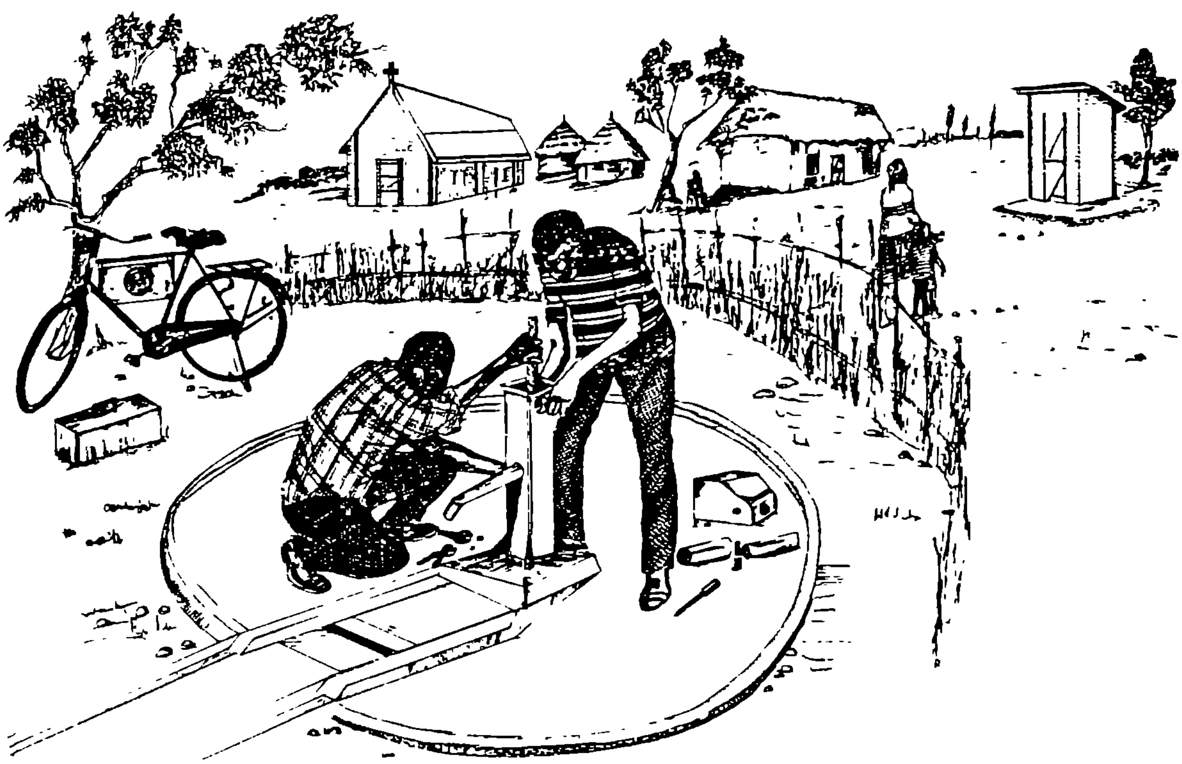
TABLE 2.6. HEALTH INSTITUTIONS IN SIAYA DISTRICT

TYPE OF HEALTH INSTITUTION	GOVERNMENT MANAGED	MISSIONARY MANAGED	TOTAL NR.
HOSPITAL	1	2	3
HEALTH CENTRE	11	3	14
DISPENSARIES	26	2	28
TOTAL	38	7	45

Generally the Health Centres offer more comprehensive services than Dispensaries, including beds for patients, maternity services, mother and child health care and family planning.
Location of all health institutions is shown in Fig. 2.15.

FIG. 2.16 MORTALITY RATES OF SIAYA DISTRICT AS COMPARED WITH THE OTHER DISTRICTS IN NYANZA PROVINCE





2.9. SUMMARY OF SOCIO-ECONOMIC DATA (1987)

General

Population	: 690,000	Size	: 2483 (km^2)
Population density	: 276	Altitude	: 1135-1500 (m)
Population growth	: (1979-1987) 3.2%	Tribe	: Luo

Administration

District Headquarters	: Siaya
Number of Divisions	: 5
Number of Locations	: 31
Number of Sub-Locations	: 152
Number of constituencies	: 5

Education

Number of primary schools	: 512
Number of secondary schools	: 53

Educational level*

None	: 21 %
Primary	: 39 %
Intermediate	: 29 %
Secondary	: 8 %
Teacher Training	:2.2 %
University	:0.1 %

Health Institutions

Hospitals	: 3
Health Centres	: 14
Dispensaries	: 28

Village Organizations

Women groups*	: 748
Farmers association*	: 17
Self help groups*	: 26
Market places	: 173

Major occupations* :

Farmer	: 88 %
Teacher	: 3 %
Self employed	: 3 %
Civil servant	: 3 %
Fisherman	:1.5 %

Average income* :

Kshs 0 - 500	: 33 %
Kshs 500 - 1000	: 29 %
Kshs 1000 - 2000	: 25 %
Kshs 2000 - 3000	: 8 %
Kshs >3000	: 5 %

Livestock

: Grade cattle	: 900
: Local cattle	: 123,500
: Sheep & goats	: 23,300
: Donkeys	: 900

* No data available from Ukwala Division.

PART III

EXISTING RURAL WATER SUPPLIES

Natural spring in Ukwala Division.

Borehole constructed by KEFINCO in Ukwala Division.

3.1. INVENTORY SURVEY

3.1.1. Objective

All existing water supply sources in Siaya District have been inventarized in order to assess the water supply situation in the District and to establish a plan of improvement (Water Supply Plan; Part VI).

3.1.2. Method

The water supply sources have been grouped into 2 different categories:

- Point sources
- Piped water supplies.

All natural and constructed point sources have been traced, mapped, described and evaluated by a group of 15 field surveyors. Each surveyor visited a well defined part of Siaya District in order to register all point sources where people fetch or use water in order:

- to record the geographical position of these point sources;
- to record their condition and functioning;
- to record their number of consumers;
- to examine whether the point source could be recommended for rehabilitation.

6th Edition May 1987

INVENTORY OF EXISTING AND CONSTRUCTED WATER COLLECTION POINTS

NUMBER
Name of site
Village
Sub-Location
Location
Division
District
Map sheet
Grid ref
Date of visit

NATURAL			CONSTRUCT						
Water Hole	Spring	River	Hand dug well	Hand drilled well	Roof catch ment	Bore hole	Ground catch ment	Dam	Spring improve ment
(WH)	(S)	(R)	(W)	(W)	(RC)	(BH)	(GC)	(D)	(S)

TECHNICAL INFORMATION

width / diameter (m)
depth (m)
water level (m-g)
discharge (estimate) (l/min)
type of material (lining or tank)
(handpump present (yes/no)
type of handpump (brand)
slab present (yes/no)
constructed by
year of construction

WELLS/ROOF CATCHMENT

condition lining (good/fair/poor)
if lining necessary
top lining (how many m)
full lining (m)
bottom lining (m)

condition of slab (good/fair/poor)
pump working (yes/no)
condition of reservoir (good/fair/poor)
condition of gutters (good/fair/poor)

GROUND CATCH./DAMS

erosion (yes/no)
spillway (silted/eroded/good/no)
reeds (yes/no
dam silted (yes/no)
leakage down (yes/no)
outlet pipe (yes/no)
tap (yes/no)
cattle trough (yes/no)
fenced (yes/no)

SPRINGS

leakage sides/underneath (yes/no)
condition of slab (good/fair/poor)
undermined (yes/no)
protect against surf water (yes/no)
presence of fence upstream (yes/no)
possib. of groundwater poll. (yes/no)
proper drainage downst (yes/no)
presence of overflow pipe (yes/no)
height of draw off pipe (m above gl)
handpump working (yes/no)

APPRAISAL OF FACILITY

general condition (good/fair/poor)
rehabilitation recommended (yes/no)
accessibility (foot/car)
type of protection (grav./shallow well)

rehabilitation works: new well ☐ deepen ☐ lining ☐ pump ☐ drain upstr ☐ spillway ☐ cattle tr ☐ connection to storage tank ☐ drain downstr ☐ fence ☐ cover ☐ overflowpipe ☐

water quality: milky ☐ muddy ☐ smelling ☐ salty ☐ clear ☐ colour ☐

WATER USE PATTERN

number of families served
total population served

use	yes	no
drinking		
cooking		
washing		
bathing		
cattle		
shamba irrigation		
brick making		
others		

if not used for drinking
number of alternative source

settlement pattern around point

scattered S
concentrated C

villages from which people originate

WATER QUALITY FROM LABORATORY

temperature		°C
conductivity		μ mho/cm
pH		
faecal coliforms		/100ml
turbidity		ntu
alkalinity		mg/l ($CaCO_3$)
hardness		mg/l ($CaCO_3$)
calcium		mg/l
magnesium		mg/l
chloride		mg/l
fluoride		mg/l
manganese		mg/l
iron		mg/l
sulphate		mg/l
phosphate		mg/l
ammonia		mg/l (as N)
nitrate		mg/l (as N)

WATER QUALITY OPINIONS

what does the community think of the water quality

	good	fair	poor
drinking			
cooking			
washing			

CONSTRAINTS OF WATER SUPPLY

	yes	no
is the source drying up		
during how many months no water		

if the source is drying
what action is taken.

	yes	no
- deepening		
- longer waiting periods		
- reduced water consumption		
- dependent on more remote sources		
- number of alternative source		

OWNERSHIP

	public	private
is the waterpoint public or private		

who owns the water point
who owns the land on which the water point is located
who can use the source

MAINTENANCE

	yes	no
is maintenance carried out		
	re	irr
if yes is it carried out regularly (re) or irregularly (irr)		

with what frequency is the maintenance carried out

daily	weekly	monthly	6monthly	yearly	other

who carries out the maintenance

REMARKS

All data were gathered using forms as shown in Fig. 3.1.
The position of the point sources was plotted on 1:50,000 scale topographical maps.
Data presented on the inventory forms have been stored in a (dBase III+) data base system for elaboration and presentation purposes.

All piped water supplies were visited by a water technician who described the water supply systems and indicated the required rehabilitation works. Key figures, like the number of consumers, number of taps etc. have been joined with the point sources data.

3.1.3. Implementation

The inventory survey started in February 1987 and ended in February 1988. Table 3.1 shows in which period each Division was surveyed.

Table 3.1. Time schedule inventory field survey

Division		Survey Period
Bondo	:	February 1987
Rarieda	:	March 1987
Boro	:	April 1987-May 1987
Yala	:	June 1987-July 1987
Ukwala	:	July 1987 (south of River Viratsi)
	:	December 1987-February 1988

3.1.4. Presentation

The results of the inventory survey are presented in Chapter 2 of the Divisional Reports (Ref.11.).
In this Siaya District Report, a summary of the main results of the survey is given.
Section 3.2. gives a description of the point sources.
Section 3.3. presents a detailed review of the piped water supplies in Siaya District.
Section 3.4. describes the use of domestic water supply sources.
Section 3.5. presents a general evaluation of rural water supply in Siaya District.

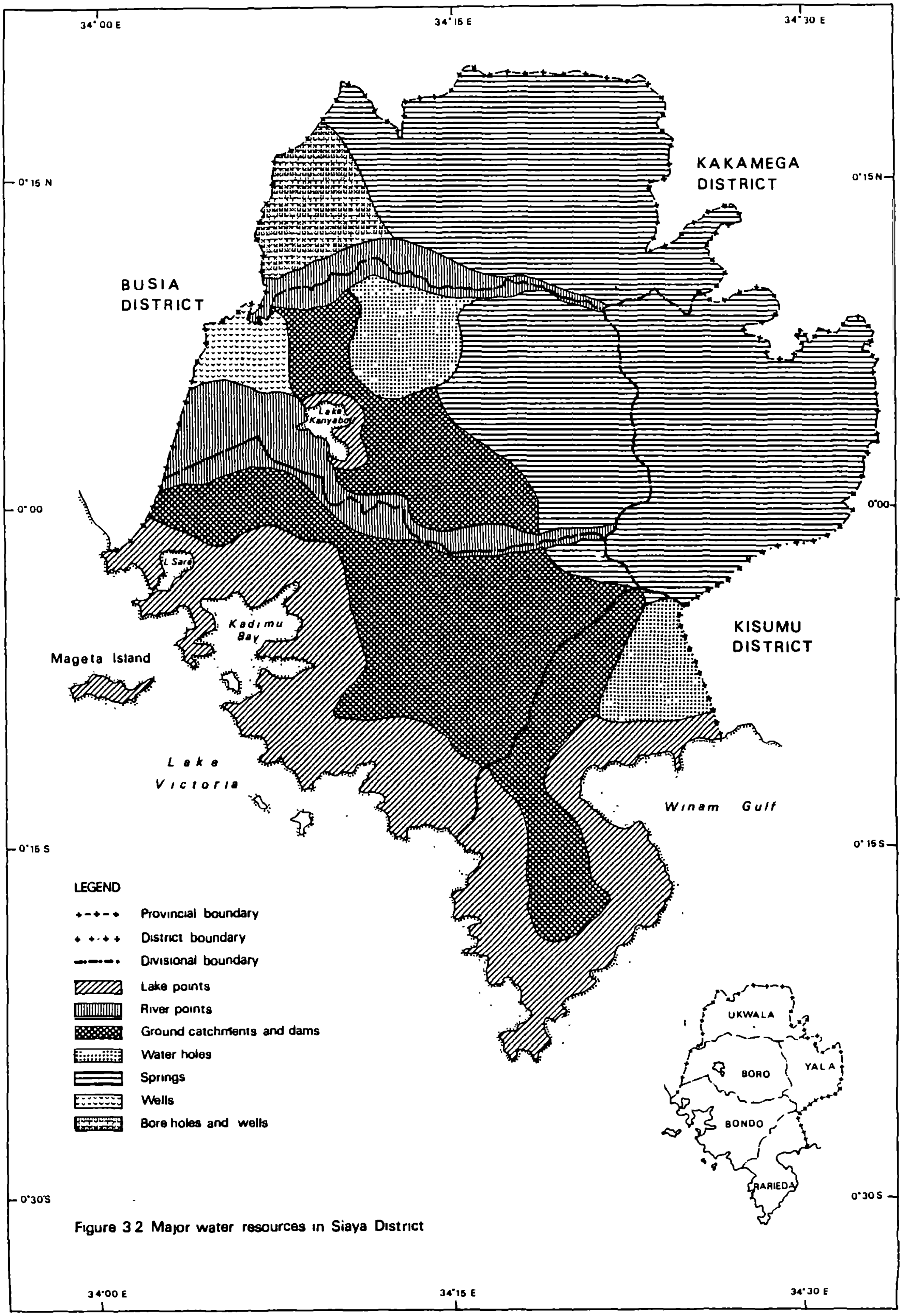


Figure 3 2 Major water resources in Siaya District

3.2. POINT SOURCES

3.2.1. Introduction

Most people living in Siaya District use point sources for domestic water supply. Water is used at or collected from a point where the source of water is found (water points).
Such a water point can be natural e.g. a spring or it can be constructed e.g. a well.
Section 3.2.2. describes the natural and constructed water points in Siaya district.

3.2.2. Type of point sources

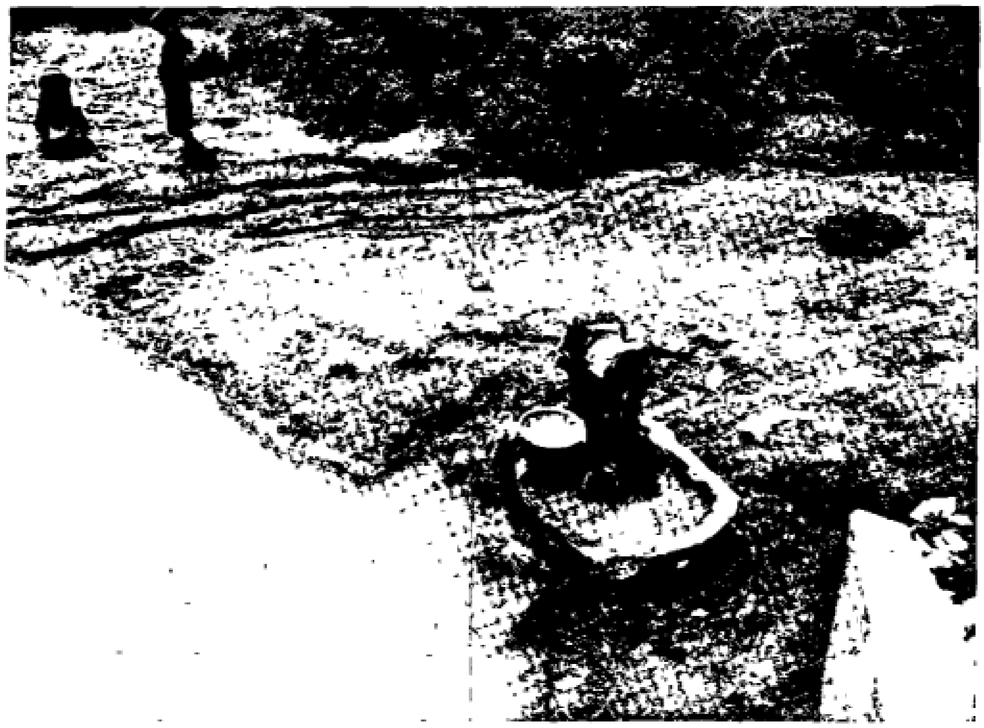
Point sources used for domestic water supply in Siaya District include:

- Water points along Lake Victoria, Lake Sare and Lake Kanyaboli (lake points)
- Water points along seasonal or perennial rivers (river points)
- Springs
- Water holes
- Hand dug, hand drilled or machine drilled wells (boreholes)
- Ground catchments
- Dams
- Roof catchments

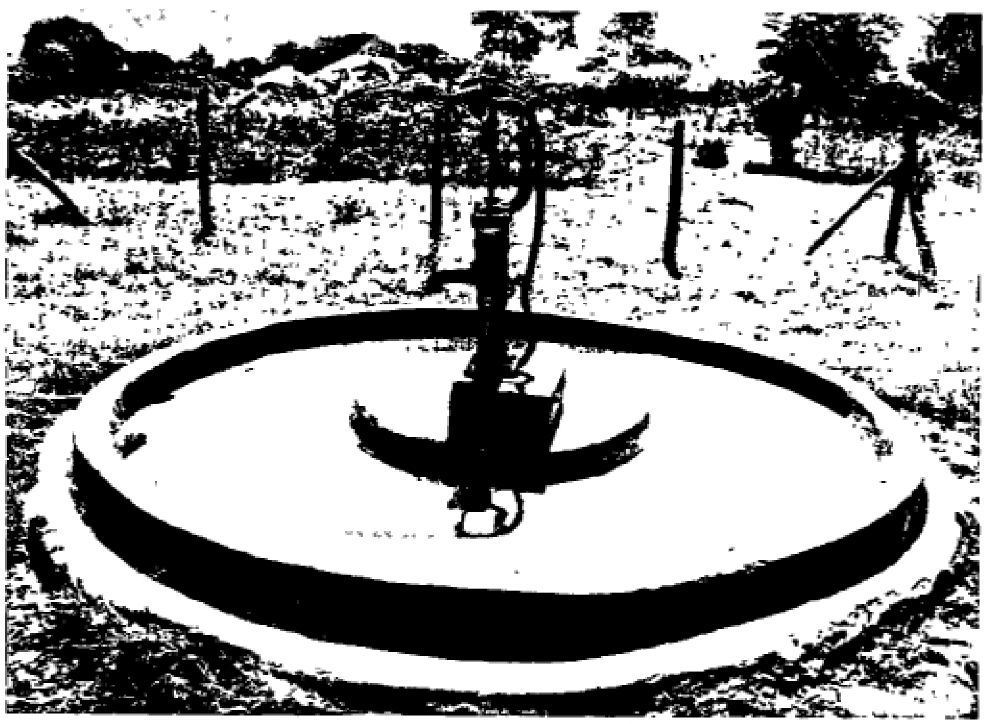
Fig. 3.2 shows the most frequently found and used types of point sources in each part of the District.
From southwest to northeast following the pattern of increasing annual rainfall, there are 3 different zones.

- In a 5-6 km wide zone along Lake Victoria hardly any water points are found. People walk to the Lake to fetch their water used for cooking and drinking.

- In the central zone, which covers most of Bondo Division and large parts of Boro and Rarieda Divisions, ground catchments and dams are used for domestic water supply. This central zone is intersected by the major rivers Yala and Nzoia which are frequently used in Bondo, Boro and Ukwala Divisions.
  In the north-eastern part of the central zone (Usonga Location in Boro Division and West Ugenya Location in Ukwala Division) many wells and boreholes are found which are the most frequently used point sources in these areas.
  At the eastern side of the central zone, there are two transition areas where many water holes are found. These transition areas are located in the northern part of Rarieda Division (East Asembo Location) and the northern part of Boro Division (Central and North Alego Locations).



"Improved" spring along River Sese; Boro Division.



Well near Bar Olengo school made with Belgian aid; Boro Division.

- In the eastern zone, which covers Yala Division, most of Ukwala and the eastern part of Boro Division, springs are the major water sources.

From the consumer's point of view each water point has the following characteristic features:

- The walking distance to reach the water point
- The water quality
- The amount of water which is available
- The way of use (private or communal ; free of charge or payment for abstracting water).

The walking distance depends on the ***density of communal water points.***
The water quality depends on the ***quality of the water source*** and ***the conditions under which the water is collected.***(risk of on the spot pollution)
The amount of water which is available depends on ***the yield*** of the source or ***the amount of water stored*** and the number of consumers using the water point. This number of consumers mainly depends on the ***water point density***
Most of the natural water points are used as ***communal*** facilities. Use of man-made facilities is often restricted or the consumer has to pay for it.

At the following pages detailed descriptions are given of each type of water point. The water point characteristics as waterpoint density , water quality etc. are given special emphasis

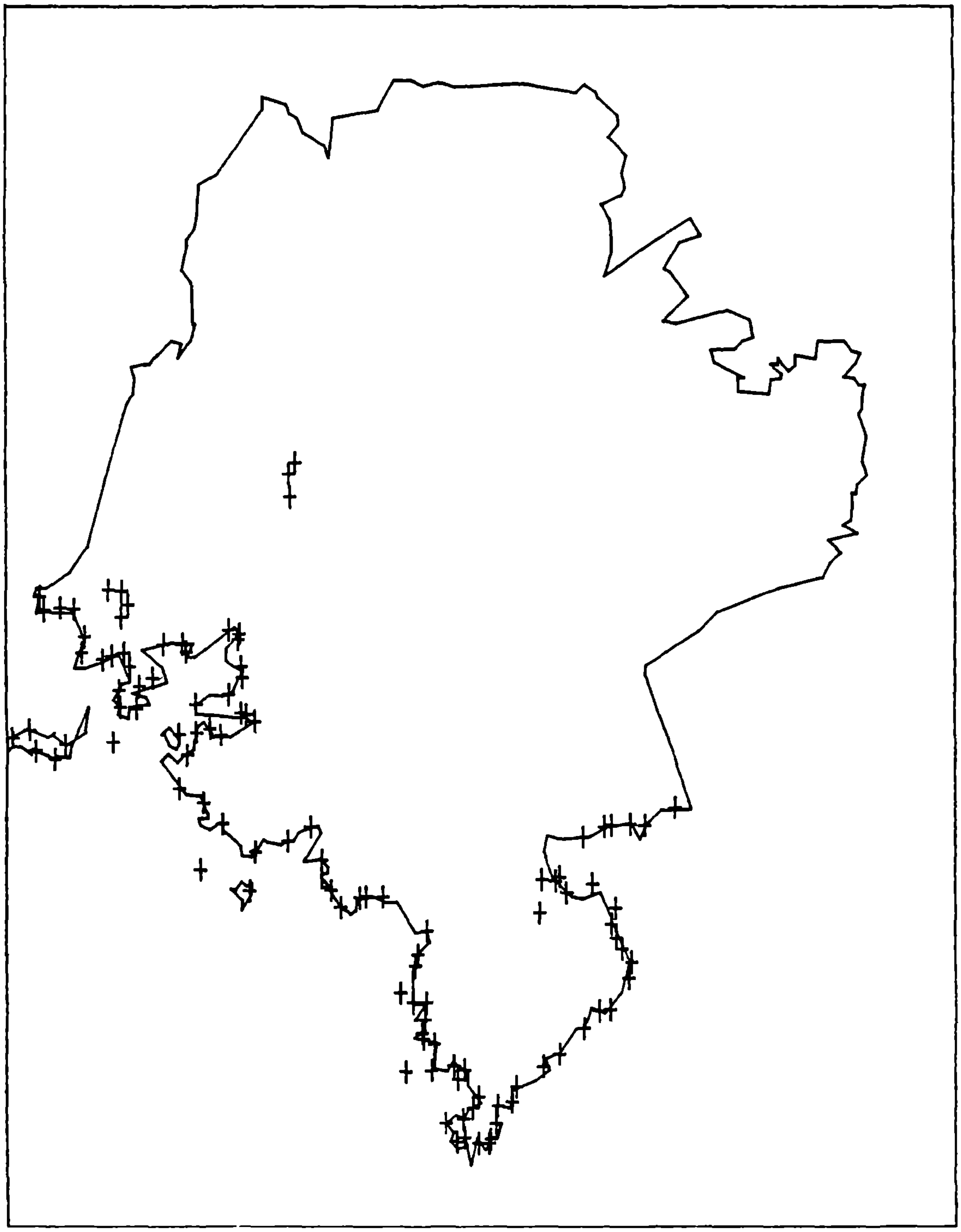


Fig. 3.3. Location of lake points in Siaya District.

Lake points

Lake points are beaches along Lake Victoria, Lake Sare and Lake Kanyaboli where people come to collect water.

Lake points are in particular important for domestic water supply in Bondo and Rarieda Divisions.
Fig 3.3 shows a computer plot of all lake points
A total number of 112 lake points have been recorded.

Lake points are used in areas where hardly no other water points are found. People often have to walk far to reach a lake point. In Bondo an Rarieda Divisions walking distances of up to 5-6 (km) have been recorded.
At many beaches , water vendors come to the lake to fill small containers or jerry cans which are brought to remote areas by donkey cars.

The quality of the water fetched is limited to poor. Water is abstracted from shallow waters which are also used by cattle and used for washing. There are hardly any currents or flows causing recirculation of the water. Lake Kanyaboli is steadily becoming brackish.

One of the main advantages of using lake points is their reliability in a quantitative sense. None of the lake points dries up. Using beaches which are well accessible, there is no queuing.

Lake point along Lake Kanyaboli; Boro Division.

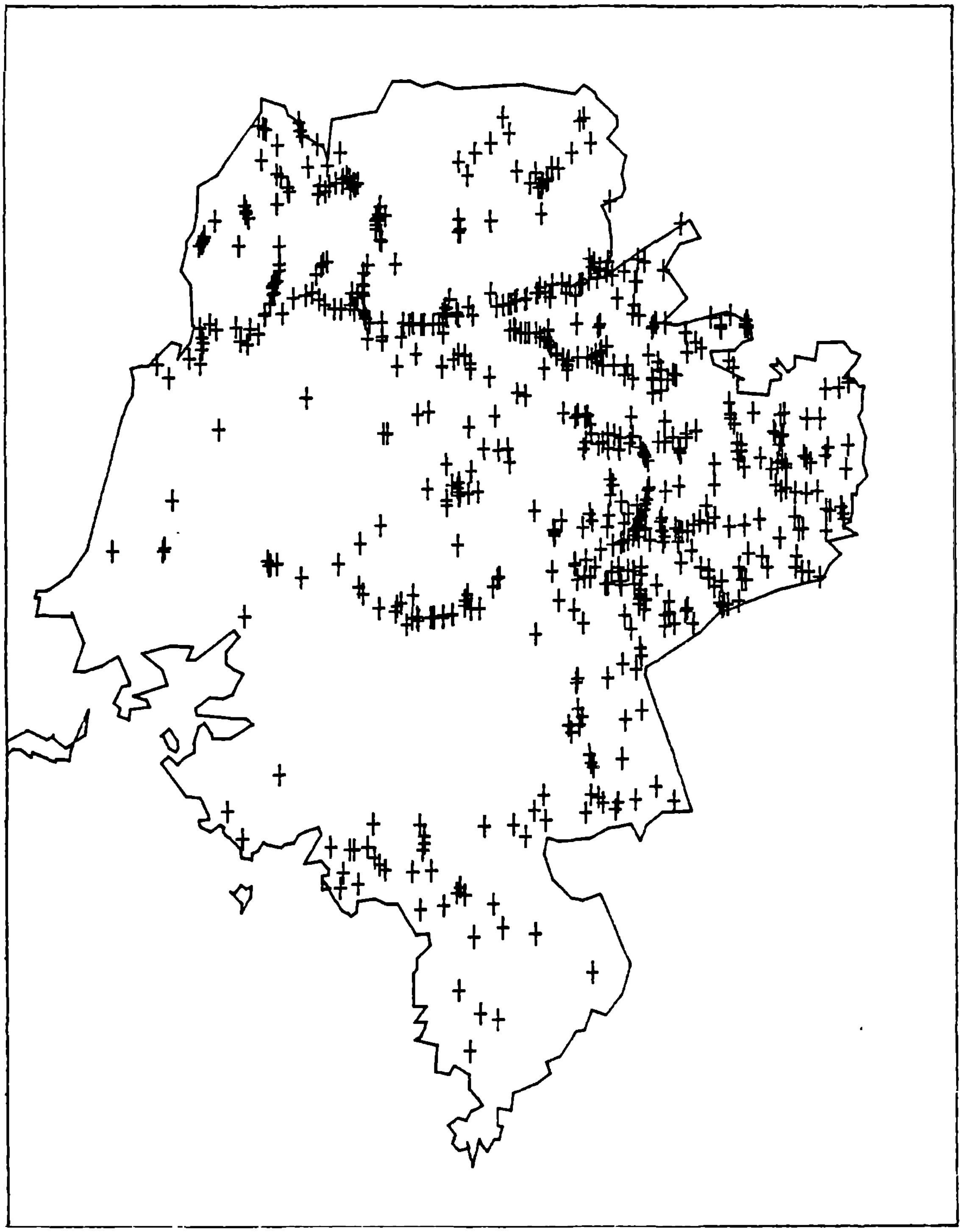


Fig. 3.4. Location of river points in Siaya District.

River points

River points are natural spots along seasonal or perennial rivers where people usually fetch their drinking and cooking water or where they bath and wash their clothes.

River points are found in dry areas like Bondo and Rarieda Divisions but also in wet areas like Yala and Ukwala Divisions. Fig 3.4 shows a computer plot of all river points.
A total number of 622 river points have been recorded.

In Rarieda, people often have to walk up to 2-3 (km) to reach a river point. In Yala and Ukwala Divisions walking distances are short. Only people living close to the rivers, use them for domestic water supply.

The quality of the water fetched from most rivers is poor. All rivers are contaminated due to cattle or human activities. River Nzoia is polluted due to industrial activities.

About 20 % of the river points dry up regularly. Most of these seasonal river points are found in Rarieda Division.

River point along River Yala; Yala Division.

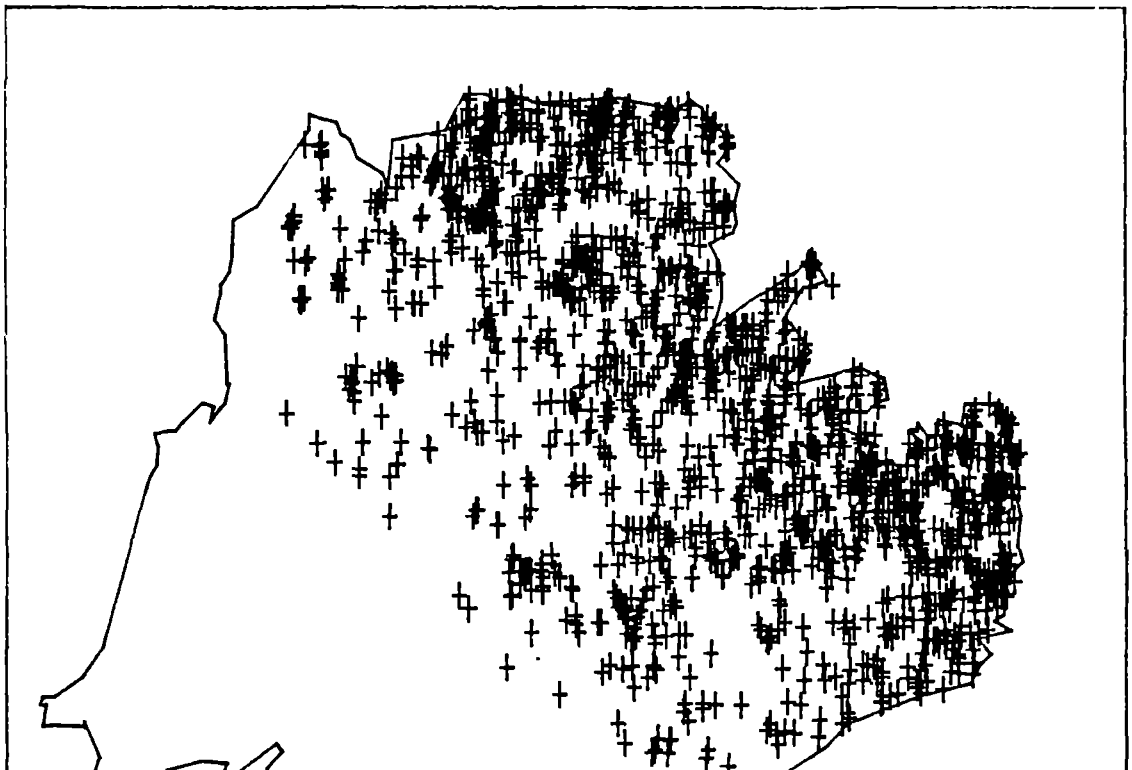


Fig. 3.5. Location of springs in Siaya District.

Springs

Springs are natural water points where ground water flows from the subsoil. Springs are often improved by building a retaining wall with an outflow pipe (improved springs).

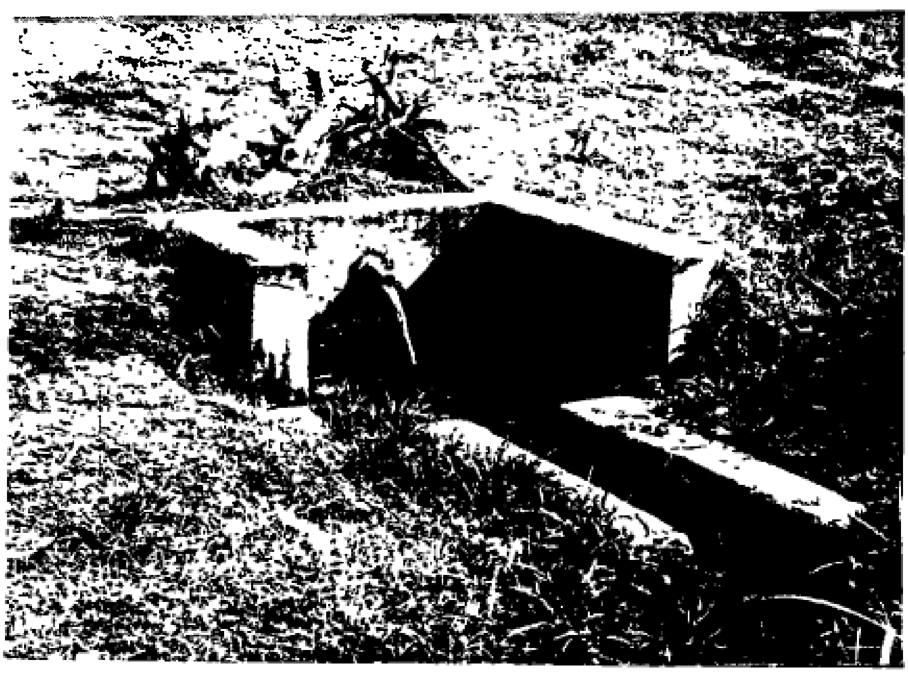
All springs in Siaya District are phreatic. There are no artesian springs.

Springs are the most frequently found type of water points in the District. A total number of 1601 springs was recorded during the inventory survey. Springs are in particular found in Boro, Yala and Ukwala Divisions. The average density of springs in these areas is about 1-2 springs per (km^2) limiting the average walking distance to 0.5-1.0 (km).
Fig 3.5 shows a computer plot of all springs found in the District

The spring water is seldom contaminated. The chemical and physical characteristics of the water make it suitable for human consumption. A substantial number of springs however is surrounded by pools of almost stagnant water. People have to fetch their drinking water from these pools which are contaminated by cattle or washing.

A total number of 216 springs have been improved which means that the water flows from an outflow pipe.

Most springs can be used all around the year. The average spring yield is about 20 (l/min).



Protected spring; Ukwala Division.

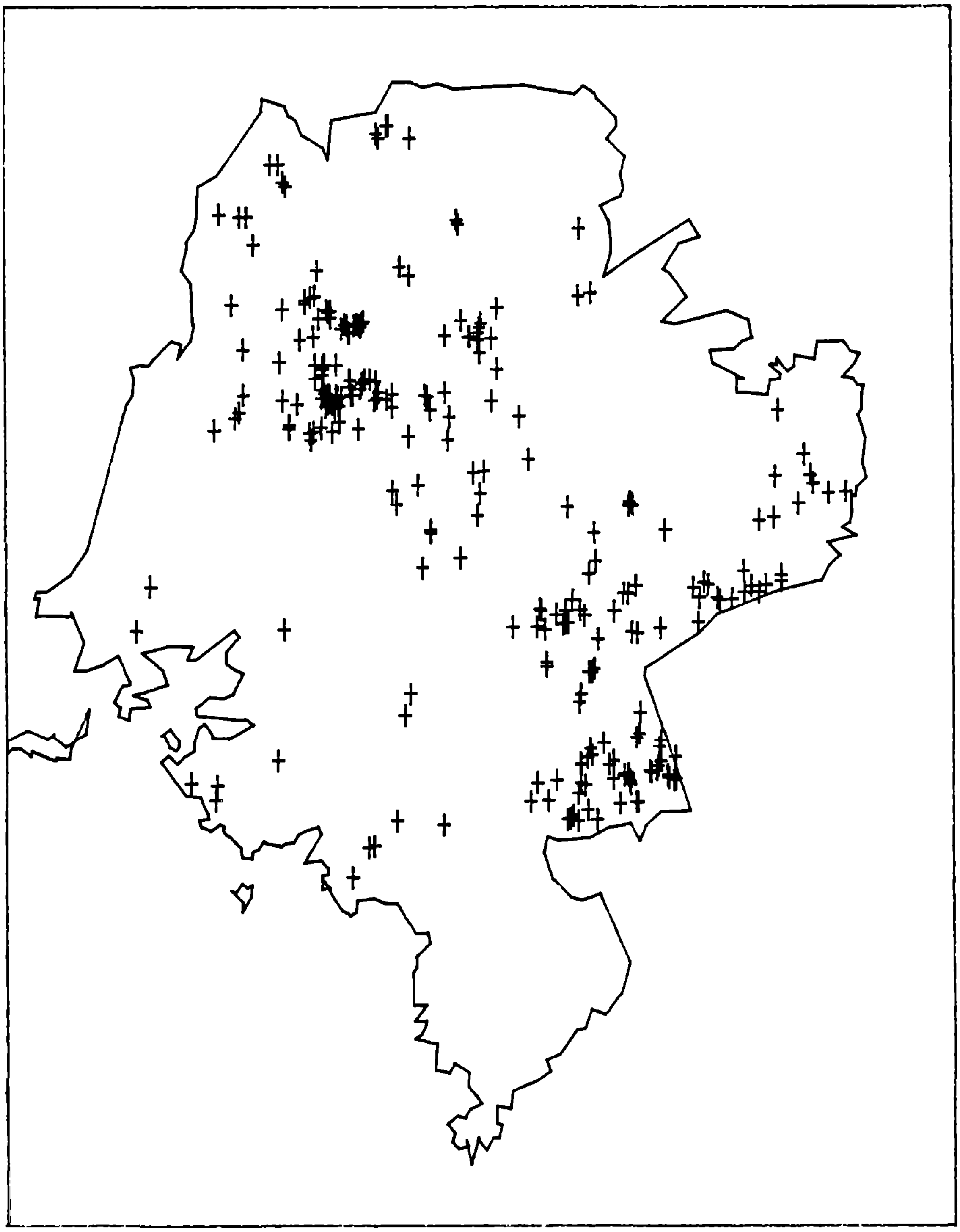


Fig. 3.6. Location of water holes in Siaya District.

Water holes

Water holes are natural water points found at terrain depressions frequently or permanently filled with stagnant ground or surface water.

The quality of the water collected at water holes is often poor. The stagnant open water is polluted due to washing, bathing and cattle.

A total number of 259 water holes were found during the inventory survey. Most of these water holes are located in Boro and Rarieda Divisions. Fig 3.6 shows a computer plot of all water holes found.
The water point densities in those parts of Boro and Rarieda Divisions where water holes are found are relatively high (about 1-2 water points per km^2), limiting the average walking distance to 0.5-1.0 (km).

A considerable number of water holes dries up regularly (about 45 %). This applies in particular for the water holes found in Bondo and Rarieda Divisions.

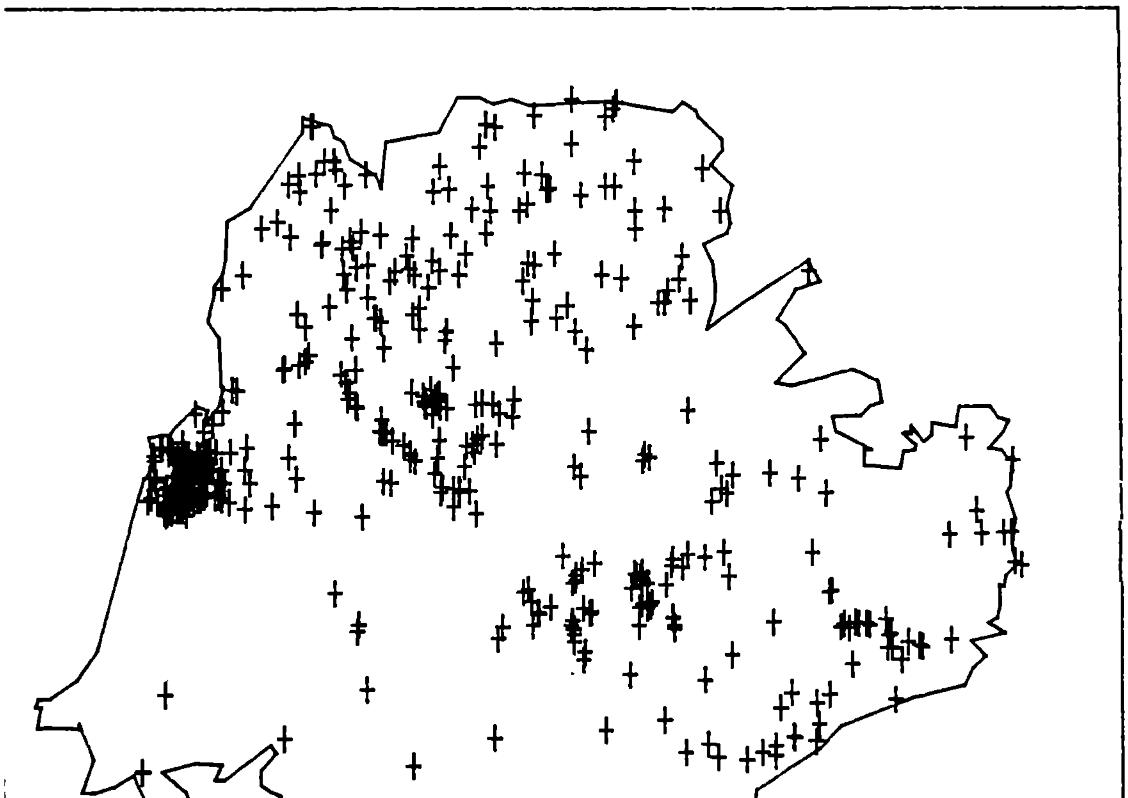


Fig. 3.7. Location of wells in Siaya District.

Wells

Both hand dug as well as hand drilled wells are found in Siaya District.
Hand dug wells are vertical holes made into the ground by digging, to exploit the ground water.
Hand drilled wells are made by using a hand auger to drill a small diameter vertical hole.

All over the District 492 wells have been found. Most of the wells are hand dug only 3 are hand drilled wells (all located in Usonga Location). Fig 3.7 shows a computer plot of all wells found in the District.
Hand dug wells have a diameter of 1.0 (m) and a depth ranging from less than 5 up to 30 (m). The hand drilled wells have a depth of less than 10 (m) and a diameter of 0.180-0.230 (m).

About 40 % of the wells are private facilities made at the owners compound. The walking distance to such a well is only a few metres.
Most public wells are found in Boro and Ukwala Divisions in areas having high water point densities. As a result also for these public water points walking distances are relatively short (<1 km). This however does not apply for the public wells found in Bondo and Rarieda Divisions.

The quality of the water collected from a well strongly differs from one well to another. The quality is good if the well is properly covered and equipped with a properly functioning hand pump. This applies to 112 wells. The water quality of the other wells is fair to poor. Many are contaminated by

- the use of buckets,
- inflow of polluted surface runoff,
- seepage water from pit latrines.

Most wells have a limited water supply capacity because digging was stopped after reaching the ground water table.

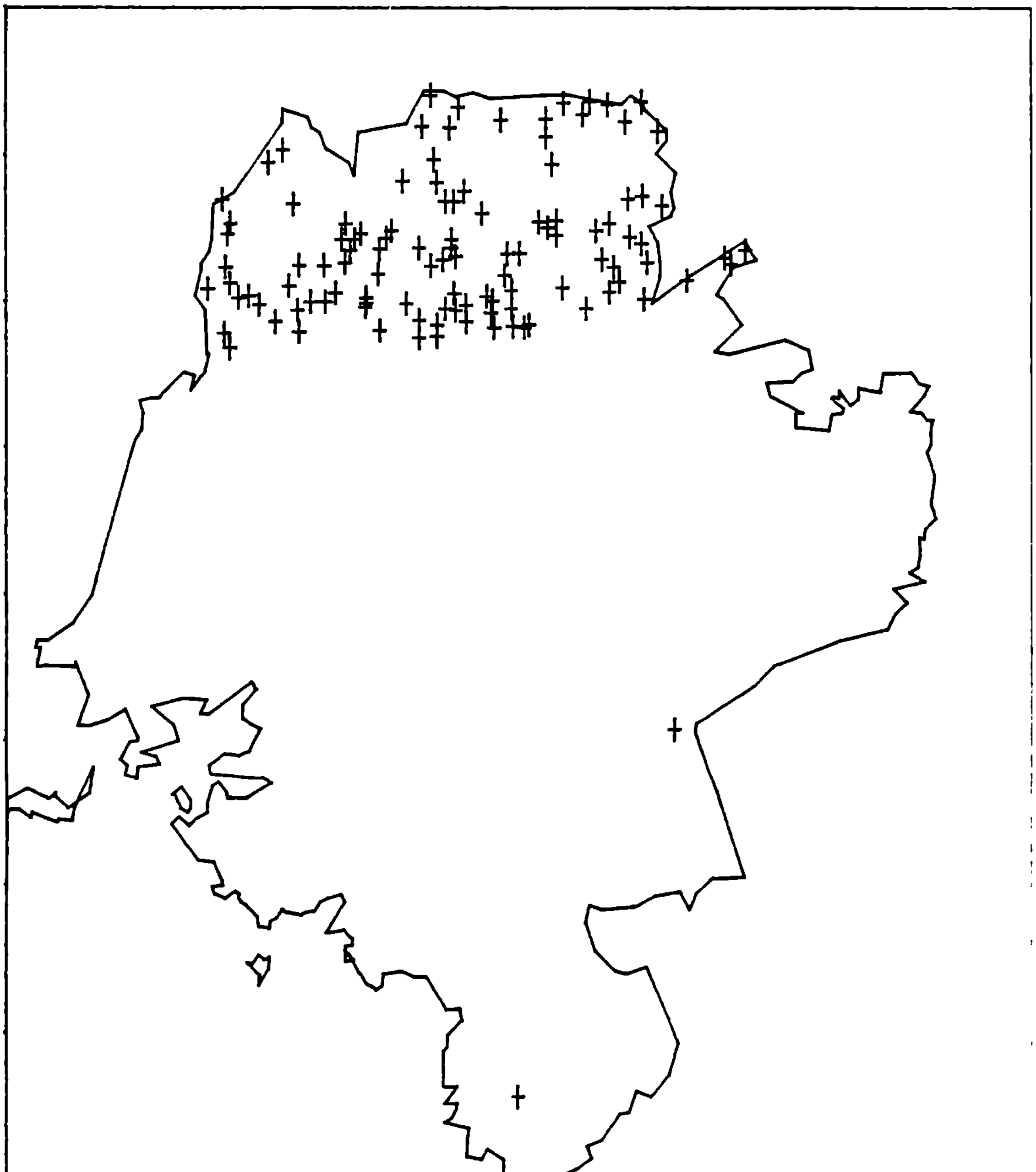


Fig. 3.8. Location of boreholes in Siaya District.

Boreholes

Boreholes are machine drilled wells used to exploit the deeper ground water.

Boreholes are used in Siaya District for both piped water supply as well as point sources. Used as point sources, the boreholes are equipped with hand pumps. The diameter of a borehole is 0.150-0.200 (m).
There are 112 boreholes in Siaya District which are used as point sources. Fig 3.8 shows that almost all boreholes are found in Ukwala Division.

All boreholes are used as public water points. Walking distances are small (<0.5 km). This is mainly due to the high water point densities found in Ukwala Division.

The water abstracted from boreholes is good. Most of the boreholes were checked on the presence of fecal coliforms. None of them appeared to be contaminated. Also the chemical constituents are all within Kenyan standards.
Incidentally there are complains about the hardness or the iron and manganese contents of the water.

Only 2 boreholes were found to dry up regularly.

Borehole made by KEFINCO in Ukwala Division.

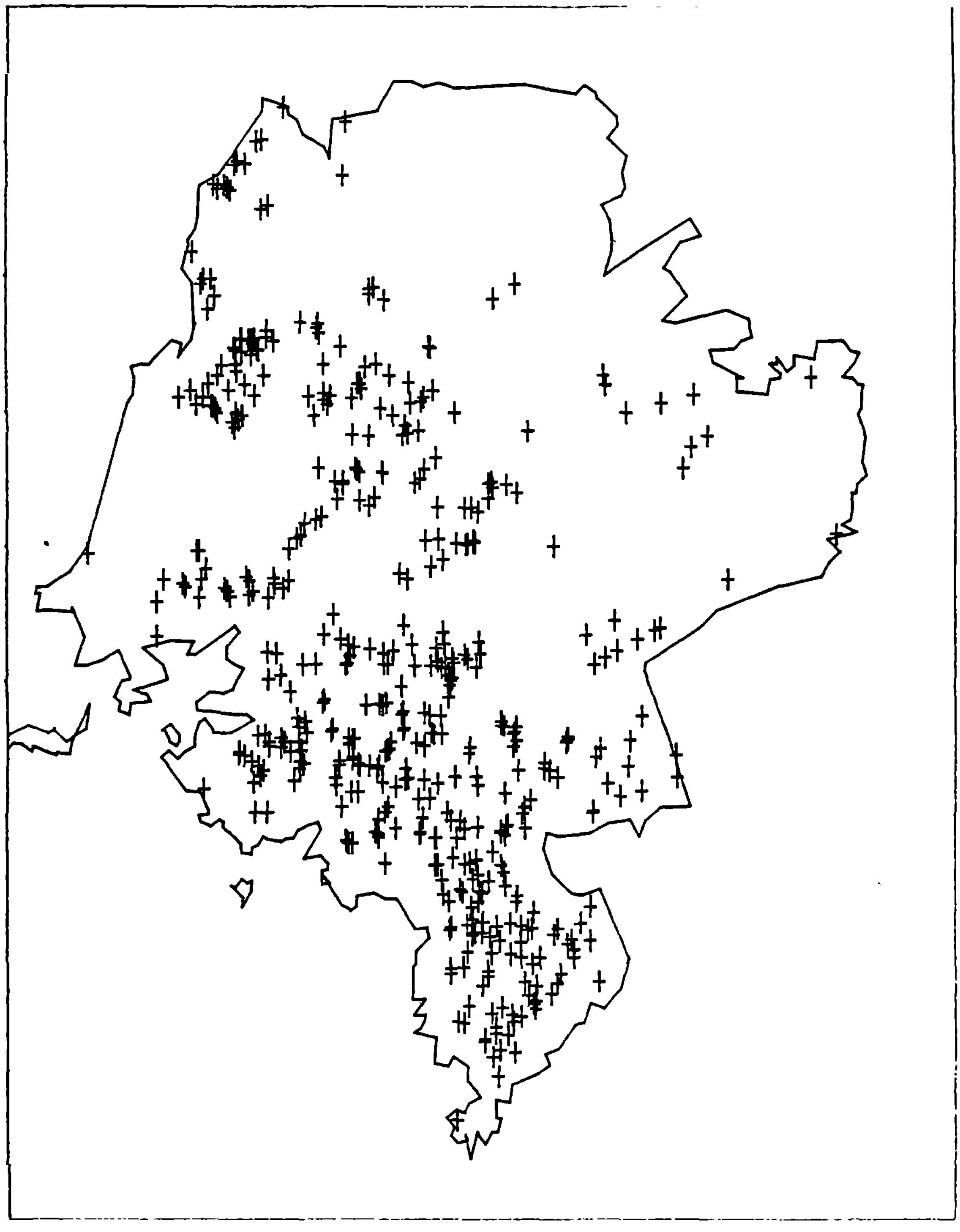


Fig. 3.9. Location of ground catchments in Siaya District.

Ground catchments

Ground catchments are man-made half circular shaped earthen dykes which are thrown up to capture and store surface runoff.

Ground catchments are important sources of domestic water supply in Siaya District. A total number of 476 ground catchments were found during the inventory survey. Most of these ground catchments are located in Boro, Bondo and Rarieda Divisions. In Bondo and Rarieda Divisions ground catchments are the most frequently found type of water points.

Ground catchments are public water points made in areas where no other water sources are available. Walking distances are up to 5 (km) to reach a ground catchment.

The quality of the water collected from a ground catchment is very poor. Polluted surface runoff is stored in an open reservoir used by cattle.

More than 80 % of all ground catchments (394) were reported to dry up regularly. On an average the period of being dry equals about 3 months. Figures of 9 months however have also been registered.

Ground catchment in Rarieda Division.

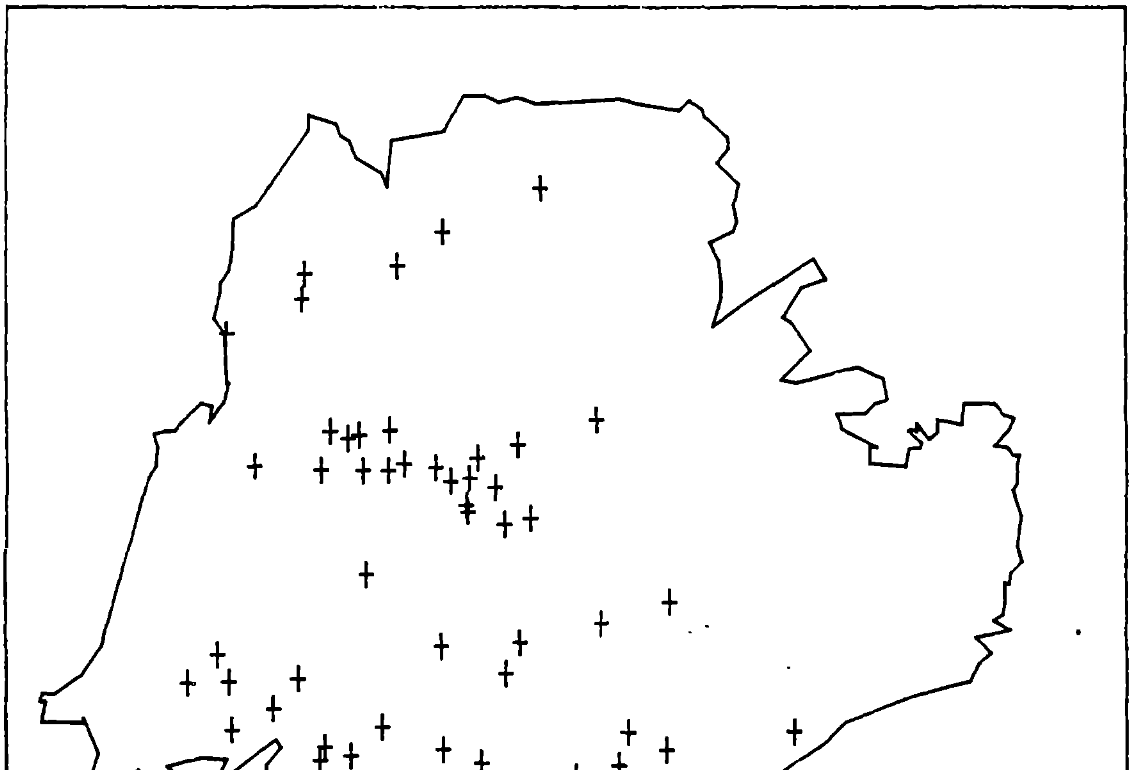


Fig. 3.10. Location of dams in Siaya District.

Dams

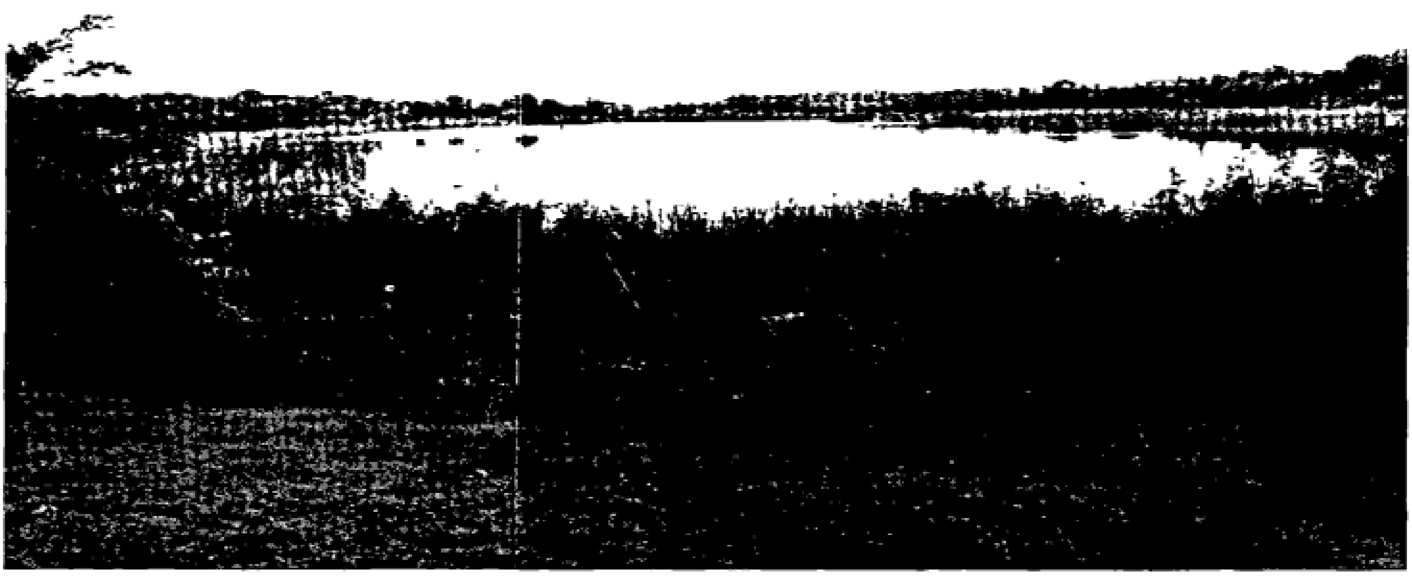
Dams are open water reservoirs, created by damming a seasonal or perennial river. Excess water evacuates via a spillway (which is often a lower part of the dam).

One hundred and nine (109) dams were found to be used for domestic water supply. Some dams in Boro and Ukwala Divisions are used for piped water supply.
Most dams are located in the same areas where ground catchments are found, (the western and central parts of Boro Division, Bondo Division and the northern part of Rarieda Division).
Fig 3.10 shows a computer plot of all dams found in Siaya District

All dams are public water supply facilities made in areas where no other water points are found. Walking distances in Bondo and Rarieda Divisions are up to 5 (km) to reach a dam.

The quality of the stored water is poor. The stored surface water is in particular polluted by the use of cattle.

About 40 % of the dams (44) dry up regularly. On an average the period of being dry equals about 3 months. Figures of up to 5-6 months however have also been recorded.



Mahola Dam used for both point source as well piped water supply; Boro Division.

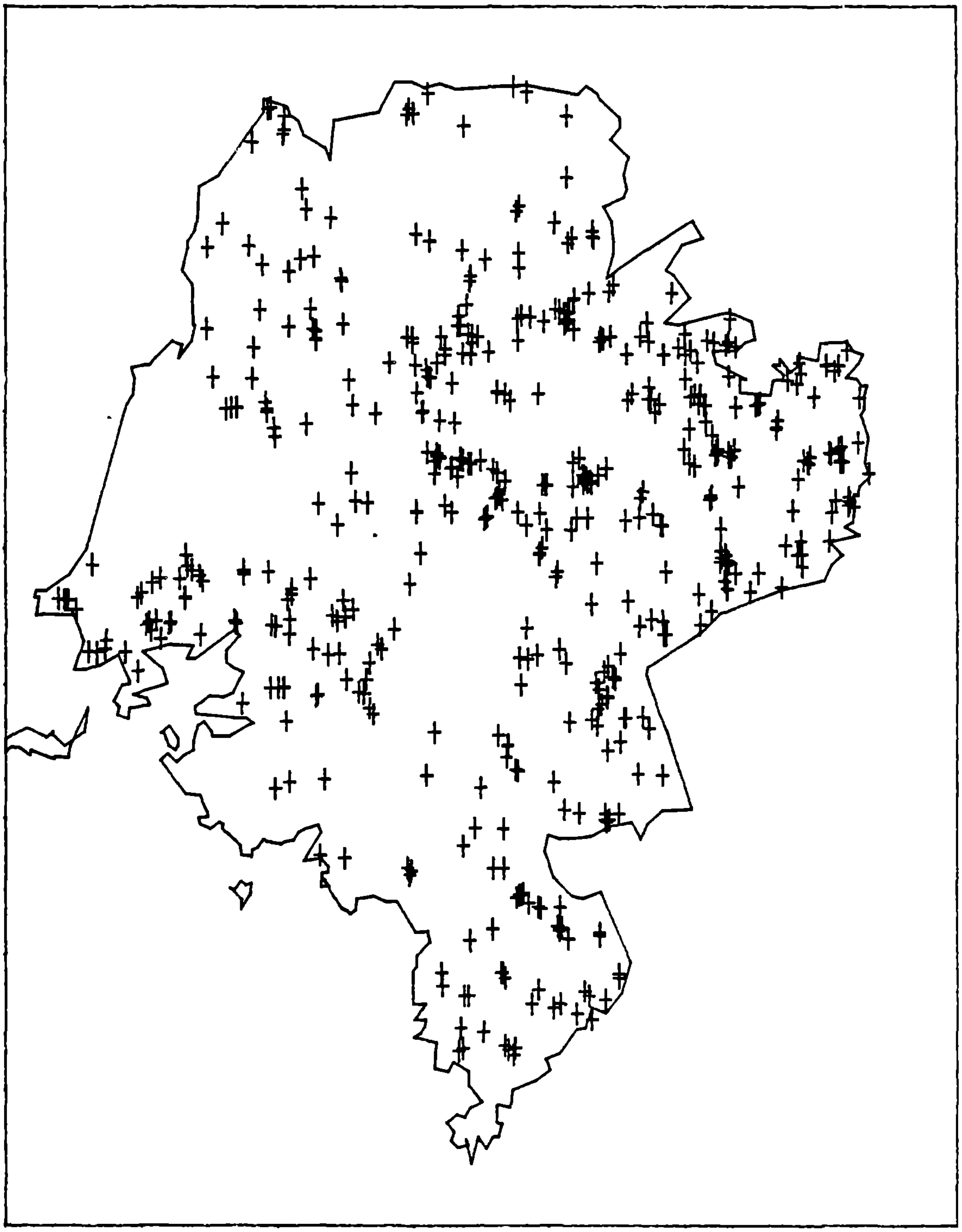


Fig. 3.11. Location of roof catchments in Siaya District.

Roof catchments

A roof catchment system consists of a hard cover sloping roof, gutters to collect the water from the roof and a pipe between the gutters and a storage tank in which the rain water is stored and from which the water is abstracted.

Most roof catchment systems in Siaya District are small and only used by one family. Such a system consist of a small roof gutter made at one side of the house connected with an empty drum or a small tank.
Larger systems are found at schools and health centres.

A total number of 525 roof catchment systems were recorded during the inventory survey. Roof catchments are found all over the District as shown in Fig. 3.11.

The far majority of all roof catchment systems are used as private facilities. As a result, people do not have to walk far to reach a roof catchment system.

The water quality is good. The risk of contamination is limited. The water sometimes tends to be slightly alkaline due to long retention periods in which lime is solved from the blockwork walls of the storage tanks.

The water supply capacity of a roof catchment system is small, which is mainly due to the limited roof size and the limited size of the gutters and pipe connection to the tank.

About 85 % of all roof catchment systems (443) were reported to dry up regularly. The average period of non-use due to drying up is recorded to be 3 months. Maximum periods of up to 9 months, however have also been recorded.

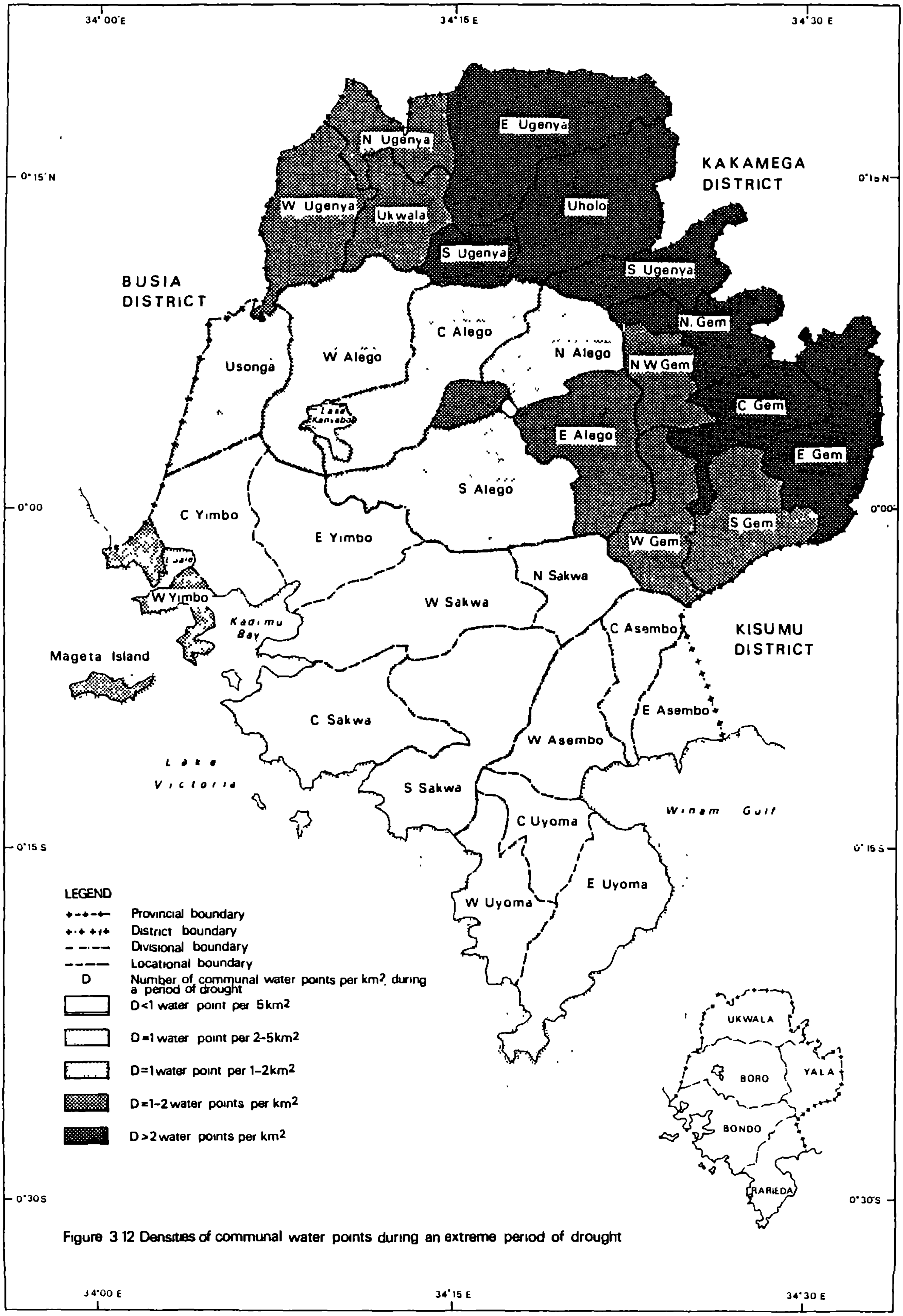


Figure 3 12 Densities of communal water points during an extreme period of drought

3.2.3. Water point density

A total number of 4,308 point sources have been found in Siaya District. On an average there are about 2 water points per (km^2).

Map III, "1987 Existing Water Supplies' shows the large differences with respect to the water point densities in the different areas.
In Bondo and Rarieda Divisions there is about 1 water point per (km^2). In Yala Division there are more than 3 water points per (km^2).

Many ground catchments, dams, roof catchments and wells dry up regularly. This has a large and negative impact on the water point densities.
Figure 3.12 shows the situation during a period of extreme drought; all water points recorded to dry up regularly are considered to be dry and therefore out of use.
The number of communal water points in East Yimbo and Central Uyoma Locations will reduce to less than 1 water point per 5 (km^2) while in the eastern parts of Ukwala and Yala Divisions there will still be more than 2 water points per (km^2).

3.2.4. Water quality

Water is used for different purposes. Washing and bathing is done near the water point.
Water used for drinking and cooking is hauled with buckets to the homes.

The quality of the water, fetched for drinking and cooking purposes, depends on the quality of the water source and the risk of contamination or pollution at the point where the water is abstracted.
The quality of ground and surface water resources in Siaya District is discussed in Parts IV and V of this report.
Summarized, the findings of the water quality analyses are:

- Ground water can be used all over the District without any treatment. Kenyan standards for Drinking Water Supply are met almost everywhere.
  Water from wells sometimes contains iron or manganese concentrations which are slightly too high causing stains in the laundry or a bitter taste of the water.
  A large number of springs and wells appeared to be contaminated. In most cases however, this is probably due to an "on the spot" pollution.

- Surface water always appears to be contaminated. The chemical constituents are all within Kenyan Standards. Turbidity of most surface waters is too high to exclude pretreatment of the water (coagulation/sedimentation).

On the spot pollution is the major problem at most water points.
Natural springs, water holes, ground catchments, dams, lake points and river points are all open.
Contamination or pollution can only be excluded by sealing the water source, controlled abstraction of water to be used and controlled evacuation of spilled water.

Springs

Most springs lack a proper drainage of the water.
Pools of almost stagnant water are often found around the springs.
These pools are used by cattle or for washing, but they are also used to collect water for drinking and cooking purposes.

Boreholes

All boreholes were found to deliver a good quality drinking water. More attention should be given to proper drainage and evacuation of spilled water and water used for washing.

Wells

Wells should have a cover, a proper lining and a pump. Many wells were found to be contaminated. Polluted surface runoff, ground water pollution due to the presence of a latrine and the use of buckets are the main causes of contamination.

Roof catchments

The rain water is polluted on the roof, but in particular in the roof gutters which are seldom cleaned. Most of the storage tanks are well covered apart from holes around the inlet pipe.
Controlled abstraction and evacuation of spilled water is guaranteed because of the limited water supply capacity (most consumers are very keen not to spill water) and the fact that most roof catchment systems are used as private facilities.
On the spot pollution should be excluded by regular cleaning of the gutters.

Water holes, lake points, river points, ground catchments and dams

On the spot pollution is always manifest. All measures aimed to exclude pollution of the water are doomed to fail.

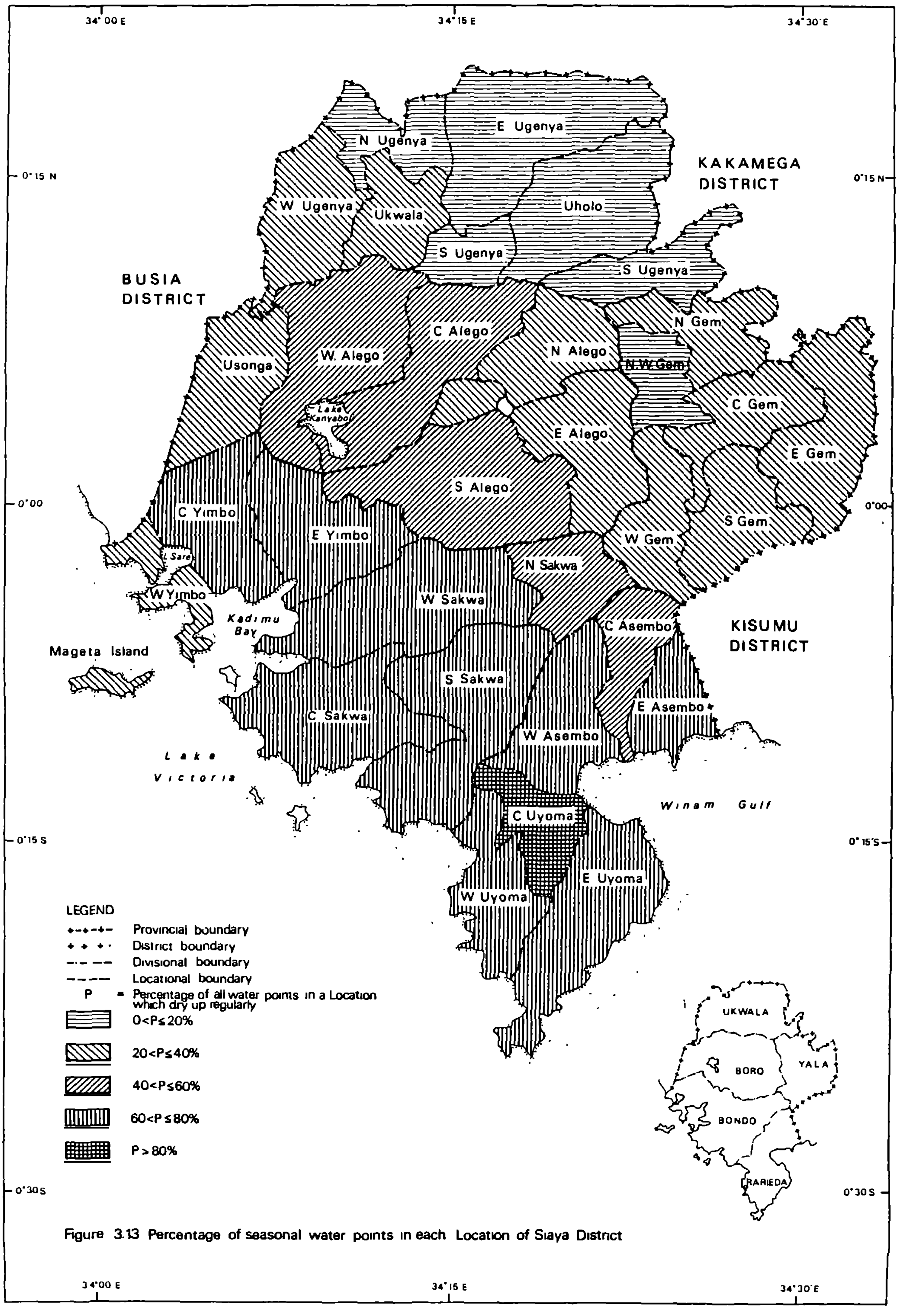


Figure 3.13 Percentage of seasonal water points in each Location of Siaya District

3.2.5. Perennial and seasonal water points

There are 2801 perennial water points in Siaya District. About 1500 water points (35 %), dry up regularly (seasonal water points).

Fig. 3.13 shows the percentage of seasonal water points in each Location.
Seasonal water points are in particular found in Bondo and Rarieda Divisions. In Central Uyoma Location almost 90 % of all water points was recorded to dry up regularly.

Fig. 3.14 shows the percentage of perennial water points per type of water point.
Most reliable in a quantitative sense are the lake points, boreholes, springs and river points. More than 80 % of these water sources are perennial. Seventy-seven (77) % of the wells and 60 % of the dams are used all around the year.
Most of the water holes, ground catchments and roof catchments dry up regularly. Only 1 out of 5 ground catchments or roof catchments is used all around the year.

FIG. 3.14 PERCENTAGES OF PERENNIAL WATER POINTS PER TYPE

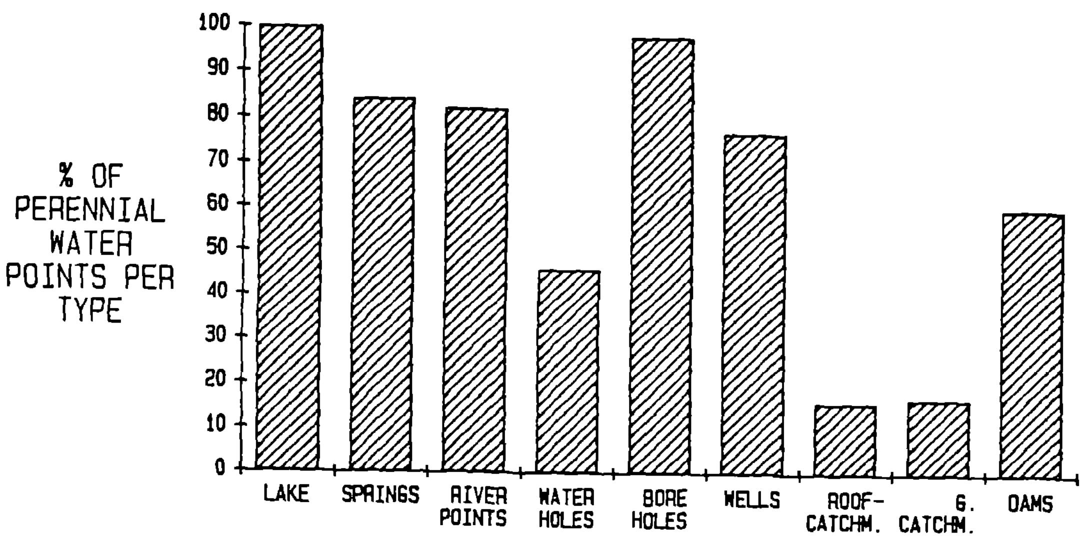
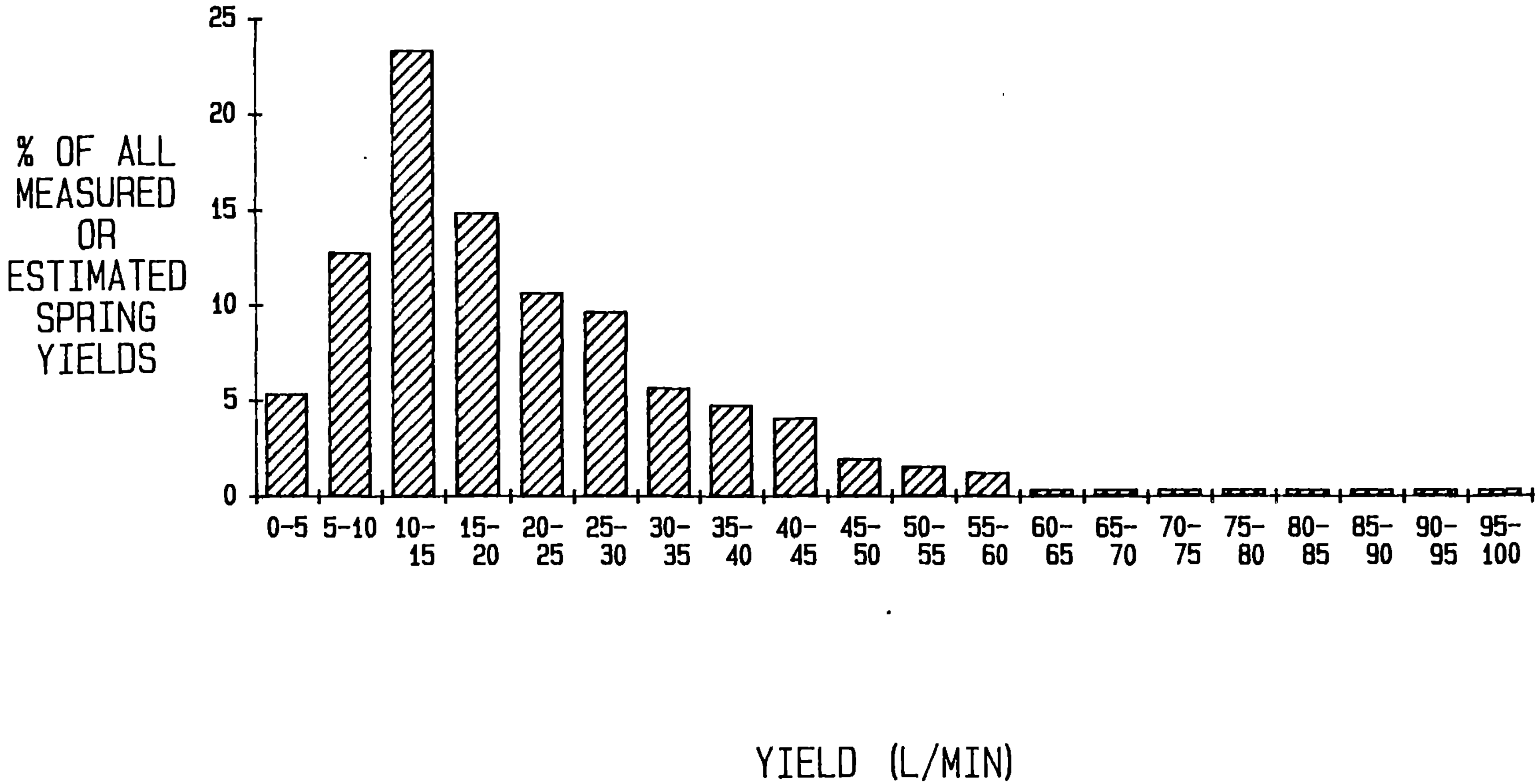


FIG. 3.15 SPRING YIELDS



3.2.6. Yield

The yield of most springs is sufficient for local use. The water supply capacity of water holes, wells, roof catchments and ground catchments is often insufficient. Restricted use of these types of water points (private facilities or controlled hours of opening) are often observed phenomena.

Fig. 3.15 shows a quantitative breakdown of the estimated and measured spring yields.
During the inventory survey , the spring yield was measured or estimated for about 67 % of all springs (1070).
The average yield of the springs was found to be about 23 (l/min). Only 5 % of the springs have yield of less than 5 (l/min).

Measuring of the spring yield using a sharp crested V-notch.

FIG. 3.16a GOOD WATER POINTS; A BREAKDOWN PER TYPE AND NUMBER

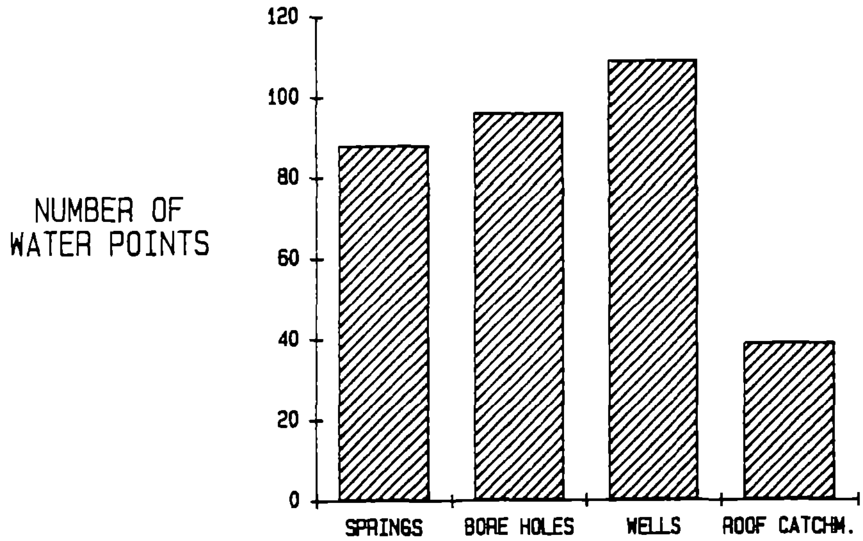
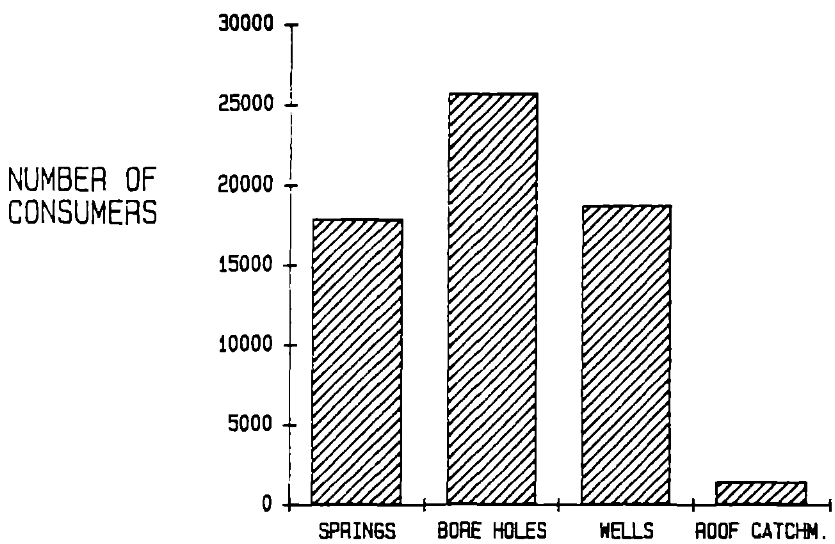


FIG. 3.16b GOOD WATER POINTS; A BREAKDOWN PER TYPE AND NUMBER OF CONSUMERS



3.2.7. Good water points

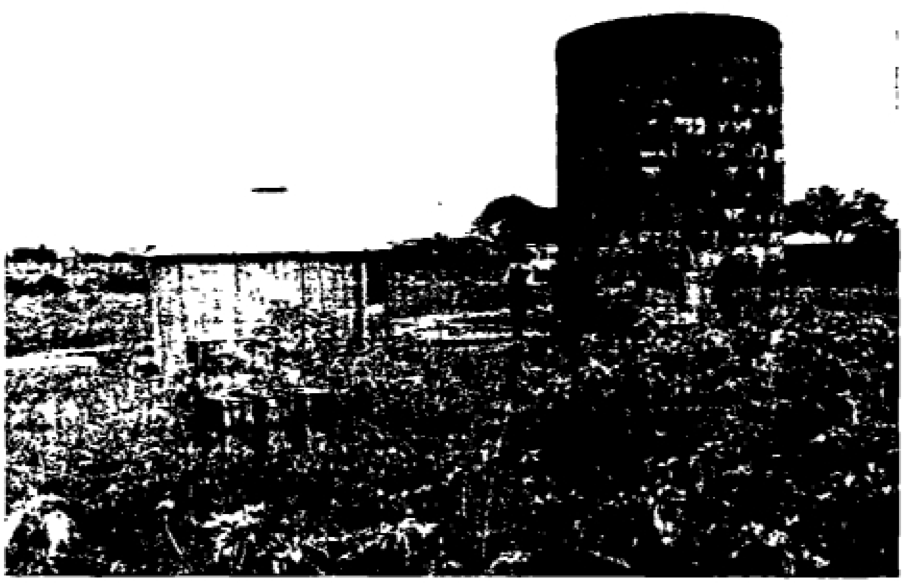
The inventory survey data have been screened to find "good" water points.
Good water points are either hand dug, hand drilled or machine drilled wells, improved springs or roof catchment systems, which fulfill the following requirements:

- Used for drinking water supply.
- Having a general condition which was marked in the field as "good".
- The water source or the stored water do not dry up
- If the water quality was checked, no bacteriological contamination was found while the chemical constituents are within the Kenyan Standards.
- Wells and boreholes with a slab, marked to be in a good condition and a hand pump which is properly working.
- Springs with a cover, marked to be in a good condition, a proper drainage of spilled water and no possibility of upstream pollution of the spring water.
- Roof catchments of which the gutters and storage tanks were marked to be in a good condition.

A total number of 333 good water points have been found. The good water points are used by about 64,000 people representing about 9 % of all registered consumers.
Most good water points are found in Yala and Ukwala Divisions.

Fig. 3.16 shows a breakdown related to the type of water points found to be good and their number of consumers. Wells are the most frequently found and boreholes are the most frequently used types of good water points.

Water kiosk, Aram Water Supply; Rarieda Division.



Communal water point, Uyoma Water Supply; Rarieda Division.

Table 3.2 Review of piped water supplies in Siaya District

Number	Name	Number of consumers	Status	Source	Operated by	Energy Source	Treatment
PS1	Osieko	0	Out of order	Lake	MoWD	Diesel driven pump	NO
PS2	Usenge	210	Regular Supply	Lake	Private	Diesel driven pump	NO
PS3	Usenge High School	650	Regular Supply	Lake	School	Diesel driven pump	NO
PS4	Ramogi Forest Research Station	260	Regular Supply	Lake + well	MoNR	Diesel driven pump	NO
PS5	Usigu	295	Regular Supply	Lake	School	Diesel driven pump	NO
PS6	Kapiyo	470	Regular Supply	Lake	Private	Diesel driven pump	NO
PS7	South Sakwa	0	Under construction	Lake	Community	Diesel driven pump	YES
PS8	Nyangoma Mission	1200	Regular Supply	BHs & Goldmine	Mission	Diesel & Electrical driven pumps	NO
PS9	Bondo	2000	Regular Supply	River	MoWD	Diesel driven pump	YES
PS10	Ramba-Ndori	900	Regular Supply	Stream	County Council	Diesel driven pump	NO
PS11	North Sakwa	0	Under construction	River	Community	Diesel driven pump	YES
PS12	Otere	375	Irregular Supply	Lake	MoWD	Diesel driven pump	NO
PS13	Asembo	0	Out of order	Lake	MoWD *	Diesel driven pump	NO
PS14	Lwak/Asembo	790	Regular Supply	Lake	MoH/School	Diesel driven pump	NO
PS15	Aram	1400	Irregular Supply	Lake	KFFH ##	Diesel driven pump	NO
PS16	Uyoma	6000	Irregular supply	Lake	MoWD	Diesel driven pump	YES
PS17	Uranga	300	Regular Supply	Borehole	MoWD	Diesel driven pump	NO
PS18	Mwer	920	Regular Supply	Dam	School	Diesel driven pump	NO
PS19	Siaya	7000	Regular Supply	Dam	MoWD	Electrical driven pump	YES
PS20	Kadenge	450	Regular Supply	Well	MoH	Electrical driven pump	NO
PS21	Ngiya Girls High School	560	Regular Supply	Stream	School	Diesel driven pump	NO
PS22	Ngiya Primary School	1000	Regular Supply	Spring	School	Diesel driven pump	NO
PS23	Aluor	1500	Regular Supply	Stream	MoWD	Diesel driven pump	NO
PS24	Marenyo	0	Out of use	Spring	Community & MoWD	Diesel driven pump	NO
PS25	Yala	0	Out of use	River	MoWD	Diesel & electrical driven pumps	YES
PS26	Sidindi-Malanga	9200	Regular Supply	River	MoWD	Hydro power generated-electrical driven pumps	YES
PS27	Sinaga	0	Out of order	River	MoWD	Diesel driven pump	YES
PS28	Nyawara	1000	Regular Supply	Spring	County Council	Diesel driven pump	NO
PS29	Sawagongo	0	Out of use	Stream	School	Diesel driven pump	NO
PS30	Mauna Dam	400	Irregular Supply	Dam	MoWD	Diesel driven pump	NO
PS31	Ukwala	1200	Regular Supply	Borehole	MoWD	Diesel driven pump	YES
PS32	Yenga	400	Irregular Supply	Dam	Community	Diesel driven pump	NO
PS33	Sega	1000	Regular Supply	Borehole	MoWD	Electrical driven pump	NO
PS34	Bar Ober	400	Irregular Supply	Spring	Community	Diesel driven pump	NO
PS35	Ugunja	800	Irregular Supply	River	Community	Diesel driven pump	NO
PS36	Sigomere-Uholo	0	Under construction	Spring	Community	Diesel driven pump	NO
PS37	Ambira High School	550	Regular Supply	Bore-hole	School	Electrical driven pump	NO
PS38	Peter Mugenya	0	Out of order	Spring	Private	Diesel driven pump	NO
	Total number of consumers	41230					

* A proposal

Kenya Freedom From Hunger

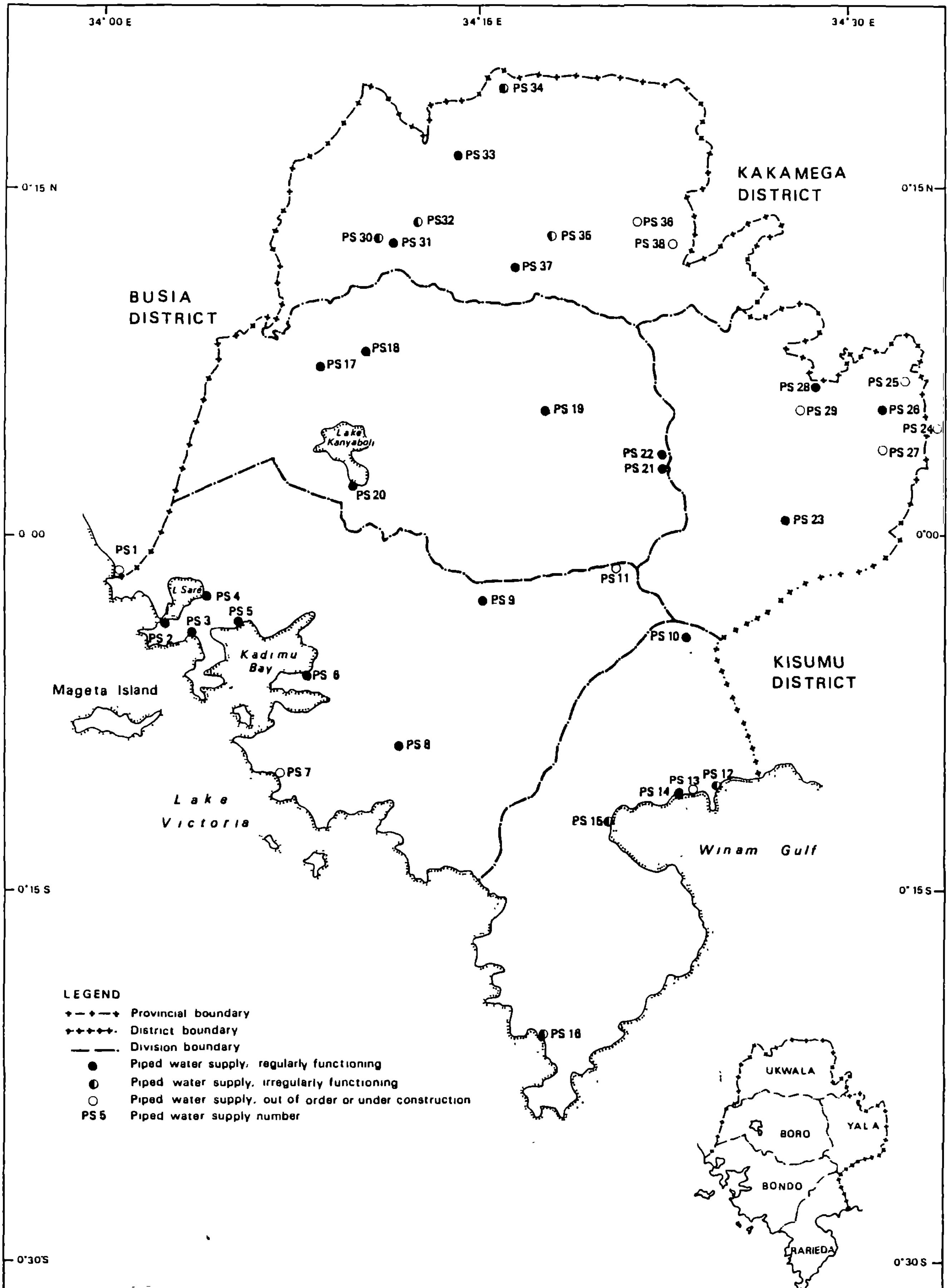


Figure 3.17 Piped water supplies in Siaya District

3.3. PIPED WATER SUPPLIES

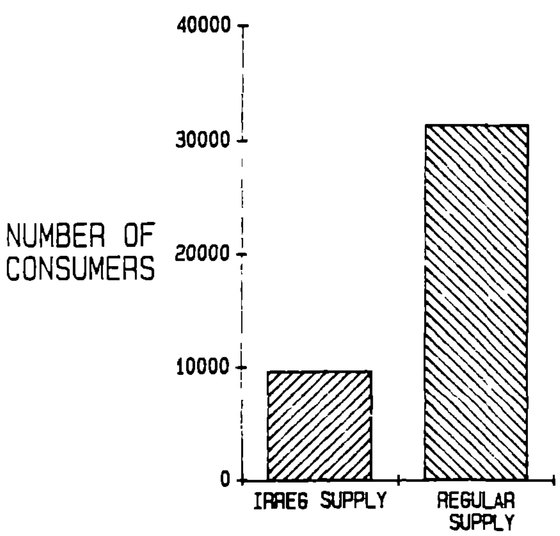
3.3.1. Introduction

There are 38 piped water supplies in Siaya District.
Table 3.2 contains a list of all piped schemes together with their main characteristics.
Fig. 3.17. shows where piped water supplies have been found.
The 1987 status of each water supply (under construction , regular or irregular supply of water , out of order) are indicated.
More detailed information concerning each piped water supply system is presented on Map III "1987 Existing water supplies".

In this section 3.3. some general aspects of piped water supply in Siaya District are discussed.
Section 3.3.2. gives a review of the operational status of the piped water supplies.
Section 3.3.3. describes the water sources and section 3.3.4. the energy resources used.
Section 3.3.5. discusses the reasons for having 14 piped water supplies out of order or irregularly functioning.
Section 3.3.6 discusses the problems of the 3 schemes which are under construction.
Section 3.3.7 discusses the three large rural piped water supplies found in the District, Uyoma Water Supply, Sidindi-Malanga Water Supply and Mauna Dam Water Supply.
Section 3.3.8 contains an evaluation of piped water supply in Siaya District.

FIG. 3.18a STATUS AND RELIABILITY OF PIPED WATER SUPPLIES; A BREAKDOWN PER NUMBER

FIG. 3.18b STATUS AND RELIABILITY OF PIPED WATER SUPPLIES; A BREAKDOWN PER NUMBER OF CONSUMERS



3.3.2. Operational status

Fig 3.18 gives a breakdown related to the status and reliability of the piped water supplies in Siaya District.
Fig. 3.18-a shows that:

- 21 schemes regularly supply water;
- 7 schemes are irregularly functioning;
- 7 schemes are out of order;
- 3 schemes are under construction

Out of 21 schemes , which regularly supply water, there are 7 of which only part of the distribution system is operational.
As a result there are only 14 schemes (37 %) which are effectively used.

Fig. 3.18-b shows that about 10,000 people or 24 % of all recorded piped water supply users ,irregularly receive water. Supply interruptions vary between 1 day and several months.

Abandoned communal water point, Uyoma Water Supply; Rarieda Division.

FIG. 3.19a WATER SOURCES OF PIPED WATER SUPPLY; A BREAKDOWN PER NUMBER

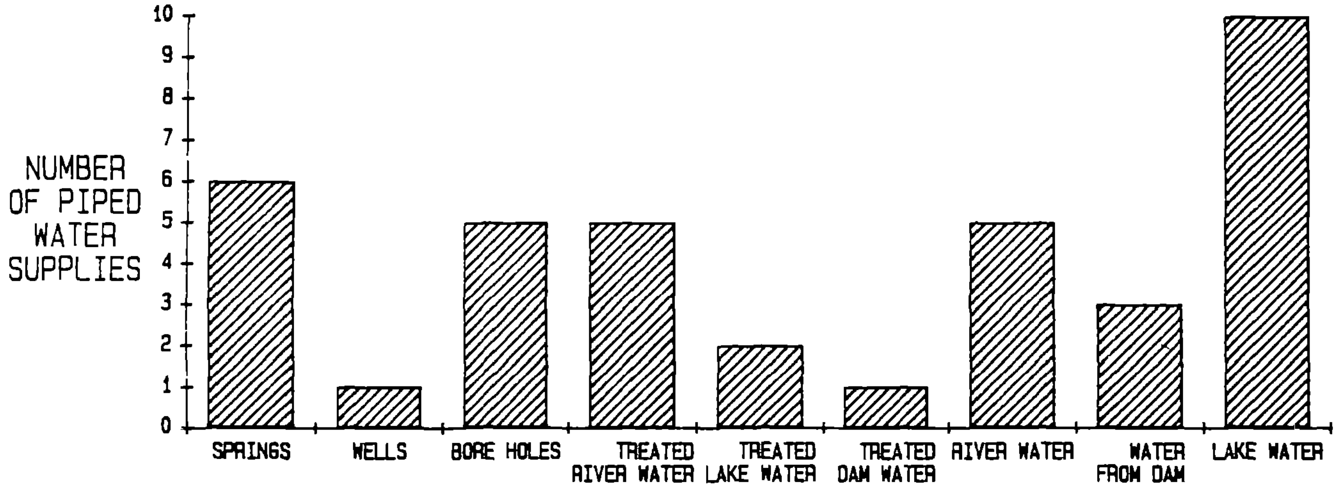
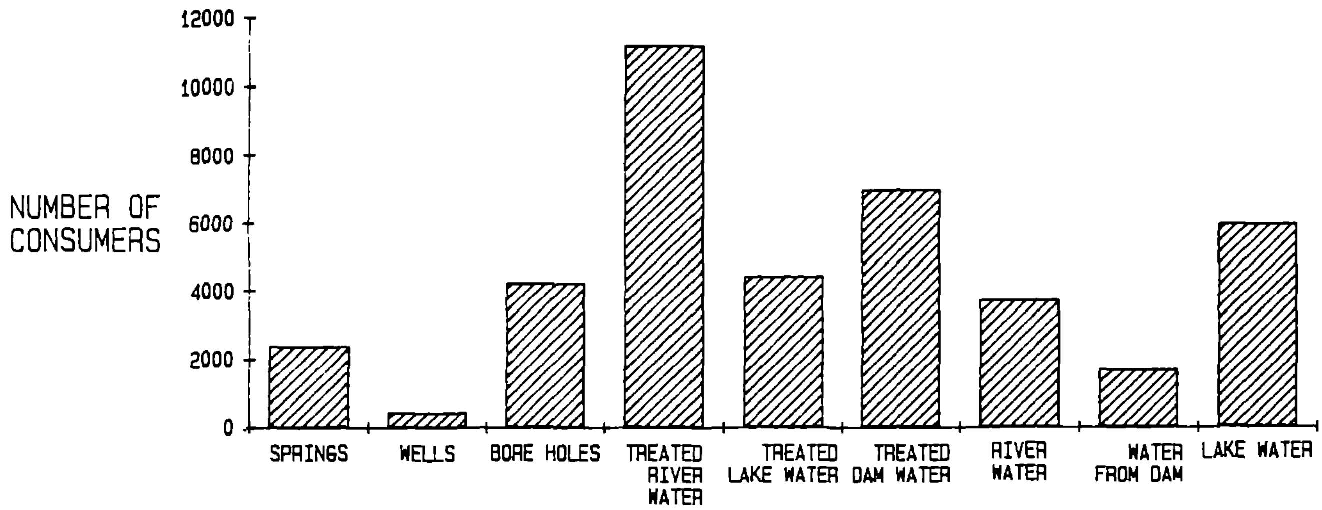


FIG. 3.19b WATER SOURCES OF PIPED WATER SUPPLY; A BREAKDOWN PER NUMBER OF CONSUMERS



3.3.3. Water sources used

Fig 3.19.a. shows which water sources are used for piped water supply.
Surface water is most frequently used. (Lake Victoria 12 schemes, rivers 9 schemes, dams 5 schemes). There are only 12 schemes using ground water sources (springs, boreholes and wells).
Most of the "Lake Victoria" water supplies have no water treatment (10 out of 12). About 40 % of all supplies using rivers or dams have a water treatment system.

Fig. 3.19.b. gives a breakdown per number of consumers.
Most people use treated surface water. There are 2 relatively large schemes pumping water from River Yala (Bondo Water Supply and Sidindi-Malanga Water Supply).
Siaya Water Supply uses a dam source and Uyoma Water Supply uses Lake Victoria. All of these 4 schemes have a water treatment system.
In total 24,200 consumers (60 %) use treated surface water.
Seven thousand one hundred (7100) consumers (about 15 %) use ground water.
If both categories are summed it appears that about 75 % of the piped water supply users have access to "safe" piped water.
Twenty-five (25) % use unreliable sources as Lake Victoria, rivers and dams without any water treatment.

Intake Usenge Water Supply; Bondo Division.

FIG. 3.20a ENERGY RESOURCES FOR PIPED WATER SUPPLIES; A BREAKDOWN PER NUMBER

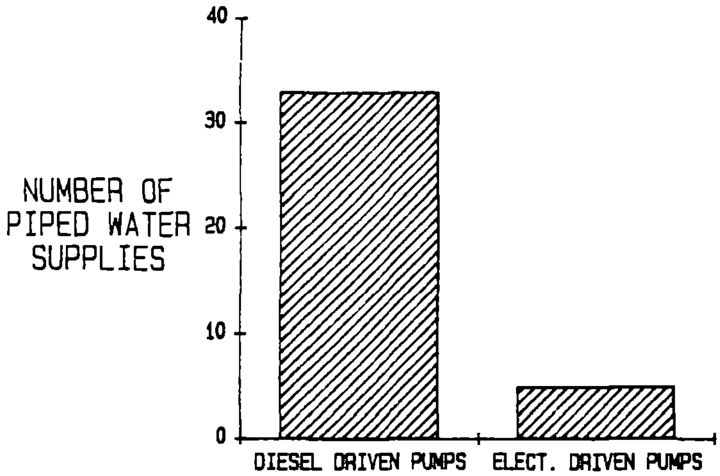
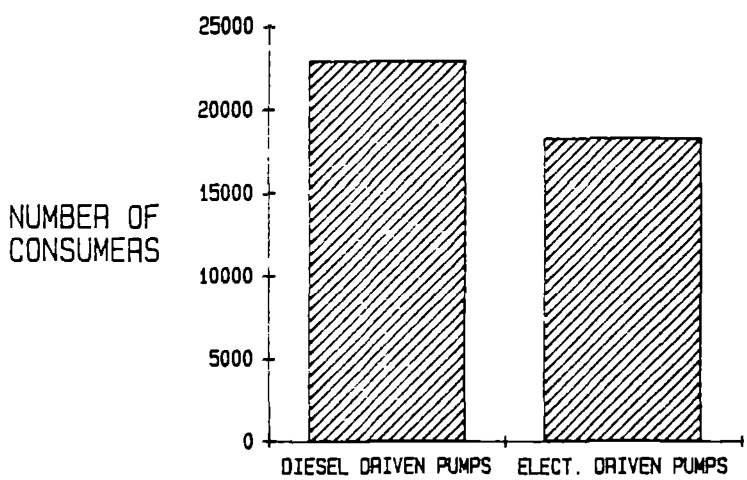
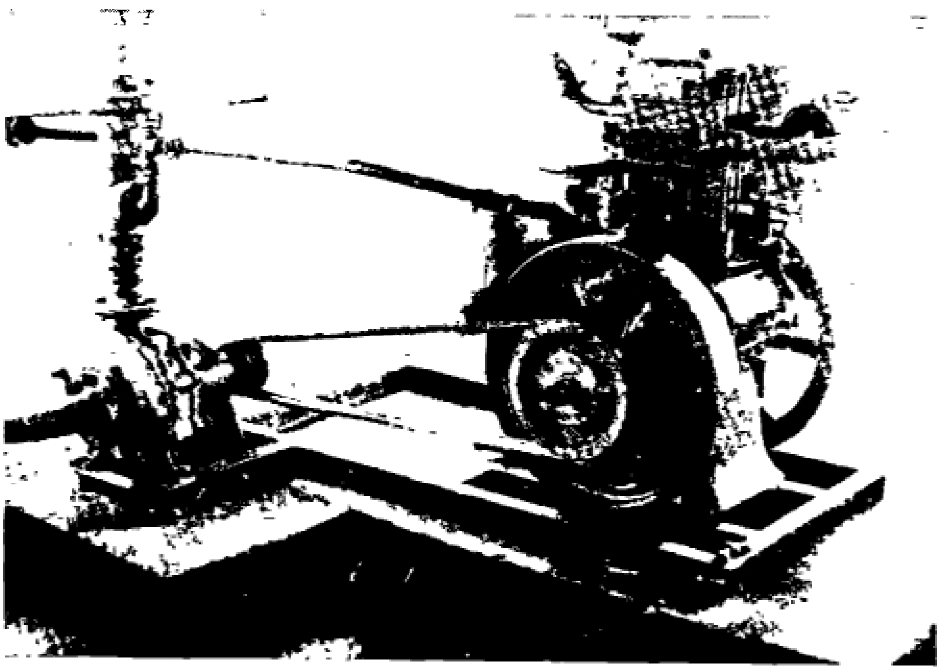


FIG. 3.20b ENERGY RESOURCES FOR PIPED WATER SUPPLIES; A BREAKDOWN PER NUMBER OF CONSUMERS



3.3.4. Energy resources used

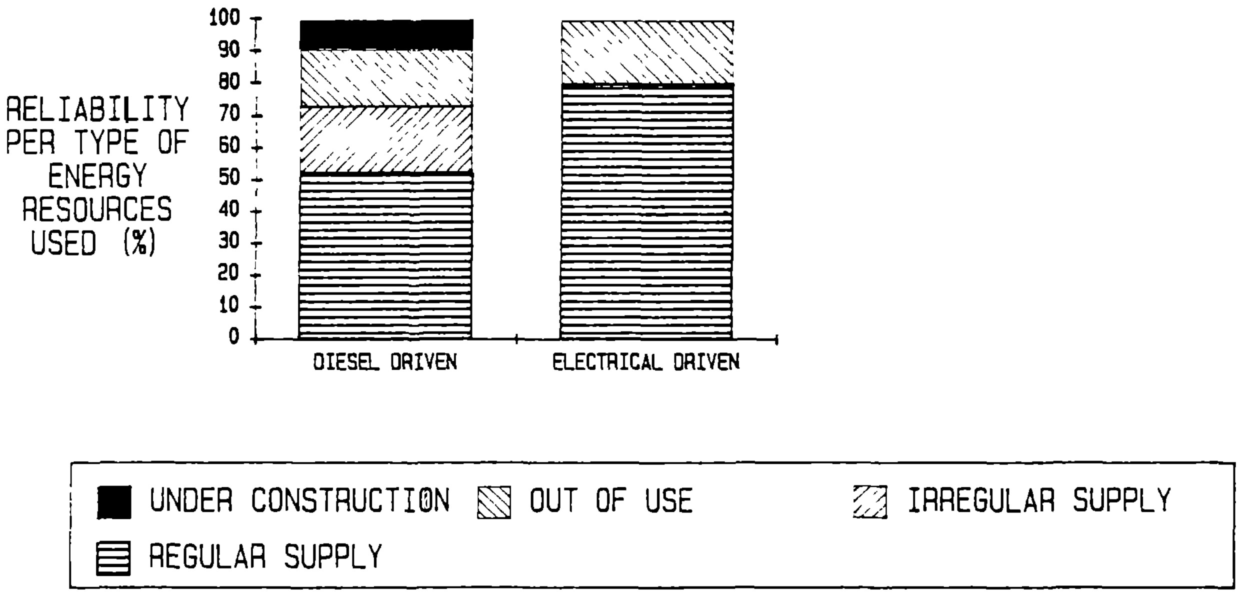
Fig 3.20 shows the energy resources used for piped water supply. There are no gravity water supplies in Siaya District.
Most piped water supplies use diesel driven pumps (33 schemes). Only the large schemes use electrical driven pumps.
About 23,000 people or 55 % depend on diesel supplies; 45 % on electrical driven pumps (electricity supply via power lines).



Diesel driven pump, Bondo Water Supply.

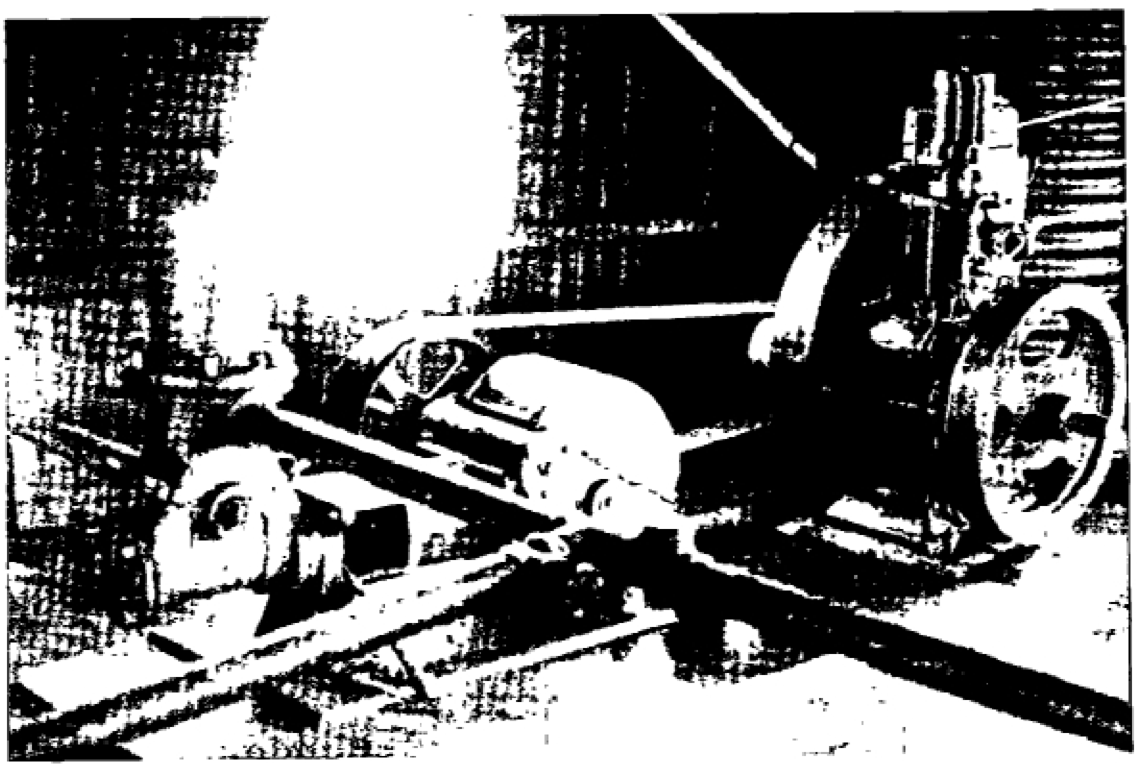
Electrical and turbine driven pumps, Sidindi-Malanga Water Supply.

FIG. 3.21 RELIABILITY OF PIPED WATER SUPPLIES AS RELATED TO THE ENERGY RESOURCES USED



3.3.5. Reasons for irregular supply of water or non functioning

There are 14 schemes out of order or irregularly supplying water. Fig. 3.21 shows that there is a clear relation between the non-functioning or irregularly functioning of piped water supplies and the energy resources used. Eighty (80) % of all schemes with electrical driven pumps regularly supply water. Only one scheme (Yala Water Supply) was found to be out of use. (Yala Water Supply has been replaced by Sidindi-Malanga Water Supply). Out of 30 schemes having diesel driven pumps, 7 are out of order and another 6 are only irregularly in operation.
The main reasons for being out of order are diesel engines which have broken down or have been removed.
The main reason for irregular supply of water is an insufficient supply of diesel. Large schemes like Uyoma Water Supply and Mauna Dam Water Supply are getting just enough diesel, to run the pumps for about 1 week in a month.



Diesel driven plunger pump

3.3.6. Piped water supplies under construction

There are 3 piped water supplies under construction:

- South Sakwa Water Supply
- North Sakwa Water Supply
- Sigomere-Uhole Water Supply

South and North Sakwa Water Supplies are both under construction for about 10-15 years allready and have not been completed yet. Sigomere-Uhole Water Supply is an existing scheme which is complete renewed. The rehabilitation works are almost finished.

South Sakwa Water Supply comprises an intake of water from Lake Victoria, a water treatment including coagulation, sedimentation, filtration and chlorination, a transmission main to Serawongo hill and distribution of water for Central and South Sakwa Locations. (Bondo Division).
Only the treatment works , the transmission main and part of the distribution system have been made.
The intake and one of the distribution mains are under construction.
It is a self help project. Implementation is done by the communities, supported by the Diocese of Kisumu and Nyangoma Mission. Completion of the construction works is hampered by a lack of the required management skills to complete such a large project.

North Sakwa Water Supply comprises an intake of water from River Yala, a water treatment including coagulation, sedimentation, filtration and chlorination, a transmission main to a storage tank near Majiwa School and a distribution of water for East Yimbo and West and North Sakwa Locations (Bondo Division).
Like South Sakwa Water Supply, also the North Sakwa Water Supply project is far from being completed.
The water treatment system is still under construction. The transmission main and main storage tank have been built.
There is no distribution system.
North Sakwa Water Supply is also a self-help project, of which the completion is hampered by absence of the management skills.

Sigomere-Uhole Water Supply is a relatively small scheme (<5000 consumers) which is rehabilitated by MoWD.
Water is abstracted from a spring and pumped to an elevated steel storage tank from where it is distributed to the Sigomere-Uhole community (Ukwala Division).
Rehabilitation works are nearing completion. A new pump house, transmission main and storage tank have been built.

It is the projects opinion that a professional organization is needed to complete the construction works of both Sakwa Water Supplies.
Completion of South Sakwa Water Supply is urgently needed. Central and South Sakwa Locations are among the worst supplied areas of Siaya District.
For North Sakwa Water Supply it is advised to redesign the water treatment system in order to limit its capacity and to also limit the distribution system.

For both schemes expertise is needed to design a long time sustainable operation and maintenance system .

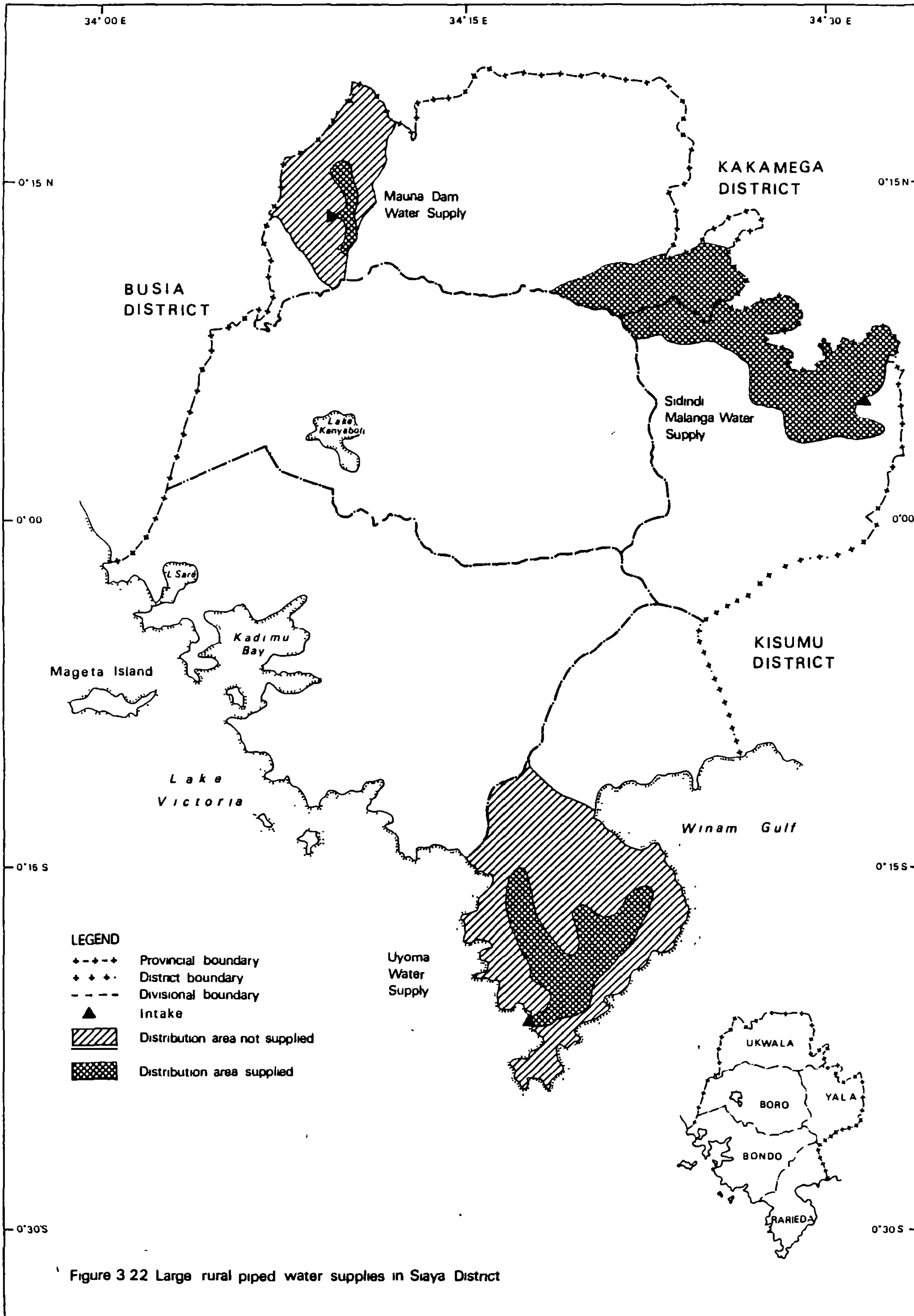


Figure 3 22 Large rural piped water supplies in Siaya District

3.3.7. Large rural piped water supplies

There are 3 piped water suppy systems in Siaya District which have extensive distribution systems.

- Uyoma Water Supply
- Mauna Dam Water Supply
- Sidindi-Malanga Water Supply.

Fig. 3.22 shows the distribution areas of each scheme including those parts which are out of use and those parts which are still (irregularly) supplied.

Uyoma Water Supply should cover the whole of the Uyoma peninsula reaching from Luanda Kotieno in the extreme southern point up to Anyuongi and Aram in the north.
The distribution system was designed to have 182 communal water points. Records kept at the pumping station, show that there are 99 communal water points and 83 private connections supplied. A field survey revealed that only the distribution mains from Naya hill storage tank to Manywanda and from Naya hill to Ragengni are supplied. Water does not reach further north , nor south from Naya hill.
Some of the problems encountered are:

- Revenues of water supply are insufficient. People collecting water at the communal water points pay 5 shilling cents for one bucket of water. People having a private connection only pay a flat rate of Kshs 15/= per month. Large consumers like schools and health centres pay an amount of Kshs 75/= per month.

- The plant operator can not control the revenues collected, nor buy the required diesel and chlorine. Diesel is supplied from Siaya DWE's office.

- The supply of diesel is by far insufficient. About 15 % of the monthly required amount of diesel (6000 l) is delivered. As a result water is only pumped for about 5 days in a month.

- Two pumps were found to be out of order when visiting the scheme (one pump of the low lift pumping station and one pump of the high lift pumping station).

- Distribution lines which have broken are never repaired.

- The water is unequally distributed. Water does not reach the northern part of the distribution system due to a massive abstraction of water in the southern part and a limited pump capacity.

- There are no means of transport to maintain or repair the distribution system.

Mauna Dam Water Supply which should cover the western part of Ukwala Division has similar problems.
Water is pumped to a big storage tank located at the boundary with Western Province.
One out of two pumps which are available is out of order. Moreover, also for Mauna Dam the diesel supply is insufficient. Water is pumped for about 80 (h) a month. Water does not reach the main storage tank. All gravity lines are therefore not supplied.
Only 24 private connections which are directly connected to the transmission main are irregularly getting water (total number of consumers about 400).
The history of Mauna Dam Water Supply is a long series of failed efforts to use communal water points. The original scheme built in 1972 had 44 communal water points; all have been abandoned.
Ten (10) water kiosks were made by CIDA when the scheme was rehabilitated in 1982. The only 2 water kiosks, which were still operational have been disconnected because people did not pay for the water.

Sidindi-Malanga Water Supply is in a far better condition than the other two schemes. Electrical and turbine driven pumps are used in the Sidindi-Malanga scheme.
Pump failure due to a lack of diesel is therefore excluded.
All distribution lines are supplied. The main problem however is that only part of the water kiosks is effectively used. A kiosk lease holder must have a license of the D.O office to vend water. A lot of kiosks have no lease holder. Some kiosks are only used by a limited number of consumers. Presence of other sources nearby and massive communal use of flat rate charged private connections are the most important reasons for this limited use.

Other problems observed are similar to those mentioned for Uyoma Water Supply.

- No means of transport to maintain or repair the distribution system.
- An unequal distribution of water with massive spillage at some points.
- Broken pipes causing supply interruptions.

Characteristic for all 3 schemes are the big problems encountered in distributing the water.

3.3.8. Evaluation

The need for piped water supply systems

There are infact only two situations which require construction of a piped water supply system.

- A piped system, is the best and cheapest solution to supply a densely populated area like an important administrative centre or a town.

- Piped water supply is needed if there are no point sources available and it has proved to be very difficult to make point sources like wells.

Using these two criteria it appears that some piped water supplies in Siaya District are useful and some are not.
Bondo, Yala, Siaya and Ukwala Town should all be supplied via a piped system (densely populated areas).
Central and South Sakwa should be supplied via a piped system because there are no point sources around. Construction of wells and boreholes has proved to be very difficult.
Contrary however, construction of Mauna Dam Water Supply and North Sakwa Water Supply is disfavoured. Both areas are sparsely populated and there are good opportunities for constructing wells or boreholes.

The need for water treatment

Most of the piped water supplies in Siaya District (26 out of 38) use surface water sources. This is partly due to the need for large capacity systems (major administrative centres and towns with private connections). Partly however it is also due to the absence of suitable ground water sources.
Apart from Lake Victoria, a few major rivers and some dams there are no water sources of sufficient capacity to be used for piped distribution.
Use of piped water supply in Siaya District therefore often means water treatment.

The need to pump water using electrical driven pumps

Large capacity water sources like Lake Victoria, the major perennial rivers and large dams are all located at low altitudes , far away from the people to be supplied.
As a result all water has to be pumped ; there are no gravity supplies.
The number of suitable intake sites is limited. Pumping stations are often far away from the distribution area. The absence of power lines necessitates to use diesel engines.
Figure 3.21 shows however that piped water supply using diesel driven pumps should be disfavoured.
Half of all diesel driven pumps are out of order or irregularly in operation.

The only reliable alternative is to use electrical driven pumps, which necessitates to build a power line or to locate the pump house near an existing power line.

The need to decentralize the management of piped water supply

Effective operation and maintenance of a piped water supply is only feasible if full responsibility is given to the piped supply staff to:

- collect water supply revenues
- to use these revenues directly to purchase spare parts, chlorine, diesel etc.
- to disconnect people who do not pay for their water, etc.

The piped supply staff should be headed by a project director who is controlled by local authorities.

The DWE's office of the MoWD should be responsible for major repairs, rehabilitation works or construction of new facilities which are beyond the capacity of the piped water supply staff. These works should be done at "real cost" basis and paid for by the project director of the piped water supply.

Training of piped water supply staff should be done at District, Provincial or National level.

The need for adequate staff and means of transport

The number of staff, and their skills and level should be related to the size of the piped water supply.
Without having proper means of transport it is impossible to collect revenues and to monitor, maintain and repair a large distribution network.

The need to be self supporting

Running a piped water supply system involves a lot of money.
Money is needed to pay for the diesel or electricity, for the chemicals (chlorine, alum, soda ash), for buying spare parts, for paying salaries etc.
A long time sustainable piped water supply system is only feasible if the system is running on a cost-effective basis.
The user should pay for his water.
Private and communal water points should all be metered.
Flat rate charging does not bring the consciousness that piped water is a scarce commodity. Unlimited private use of water often leads to no supply of water to the communal taps located at the outskirts of the distribution system.
People living in areas like Bondo and Rarieda Divisions are well prepared to pay for their water.

Design modifications

Standard designs are used for both the water treatment as well as the transmission mains and distribution lines.
The following design modifications should be taken into consideration.

Raw water storage and sedimentation basins

Raw water storage is never practised, but could be very useful during periods when the quality of the water is worse.
The turbidity of most river waters strongly fluctuates. Often high quantities of alum and soda ash have to be used to reduce the turbidity to an acceptable low level which enables to filtrate the water. Raw water storage and inlet of water only during periods when the water quality is good will strongly reduce chemical expenses.

Rapid sand filtration plus chlorination

It is common practice to use rapid sand filtration and post chlorination to treat the water. Slow sand filtration is never practised. Slow sand filtration is a labour intensive way of water treatment. The main advantages however are that :

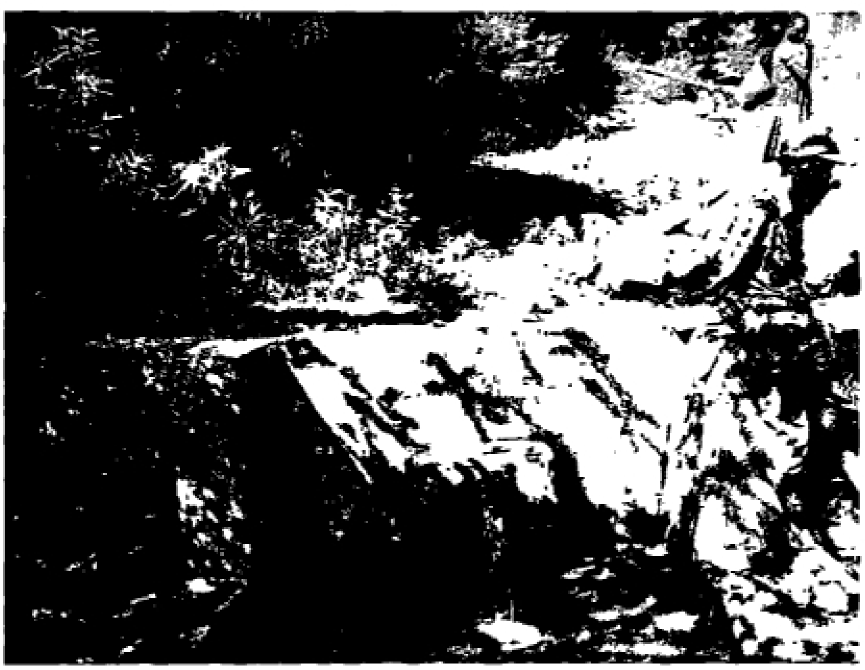
- no water is spilled with back washing of filters
- less supervision and pumping costs
- no use of chlorine which is a scarce commodity.

Distribution

It is advised to exclude the common practice of making distribution points which are directly connected to the transmission mains. A considerable number of distribution systems are ineffectively used due to massive water abstraction from the transmission mains.
Most parts of Mauna Dam Water Supply are not used because the water does not reach the main storage tank. The limited supply of water is completely consumed by private connections to the transmission main.

Float valves should not be used.
Large amounts of water are spilled because of float valves which are not working. Distribution of water should not be based on a consecutive filling of storage tanks. All tanks should be filled at the same moment.

Protected springs in Ukwala Division.



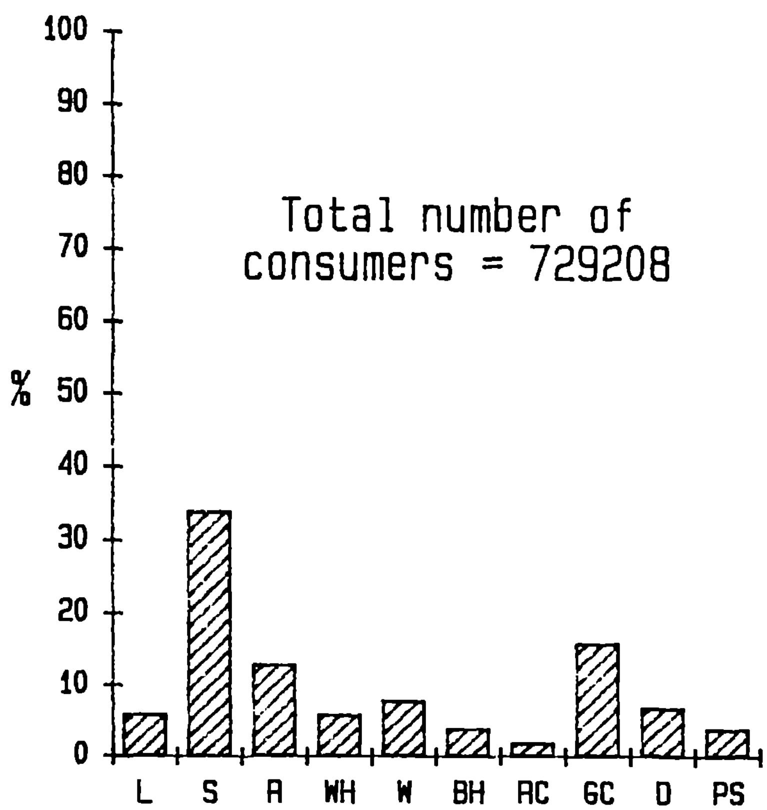
3.4. DOMESTIC USE OF RURAL WATER SUPPLIES

3.4.1. Use of the different water sources

Most people in Siaya District depend on point sources. About 4,000 point sources are used by about 690,000 people.
Piped water supplies (38 schemes) are used by 40,000 people only.

Fig 3.23 shows a further breakdown related to the type of water sources used.
Springs, used by 35 % of all consumers are the most important water resources, followed by ground catchments (16 %) and rivers (13 %).
Wells, dams, Lake Victoria and water holes are all used by about 6-7 % of the consumers.
The use of boreholes, piped water supplies and roof catchments is limited to less than 5 %.

FIG. 3.23 USE OF WATER SUPPLY SOURCES IN SIAYA DISTRICT.



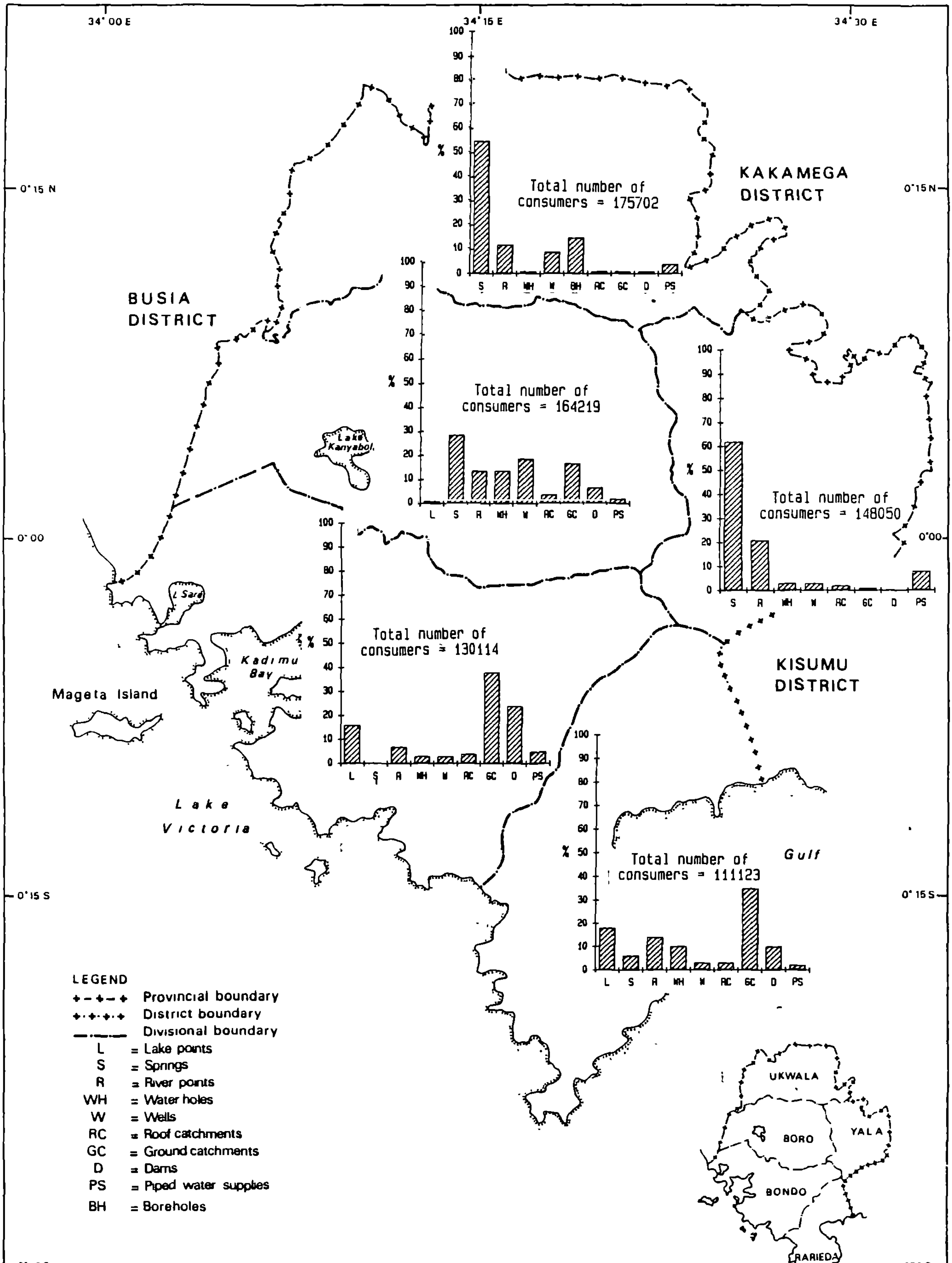
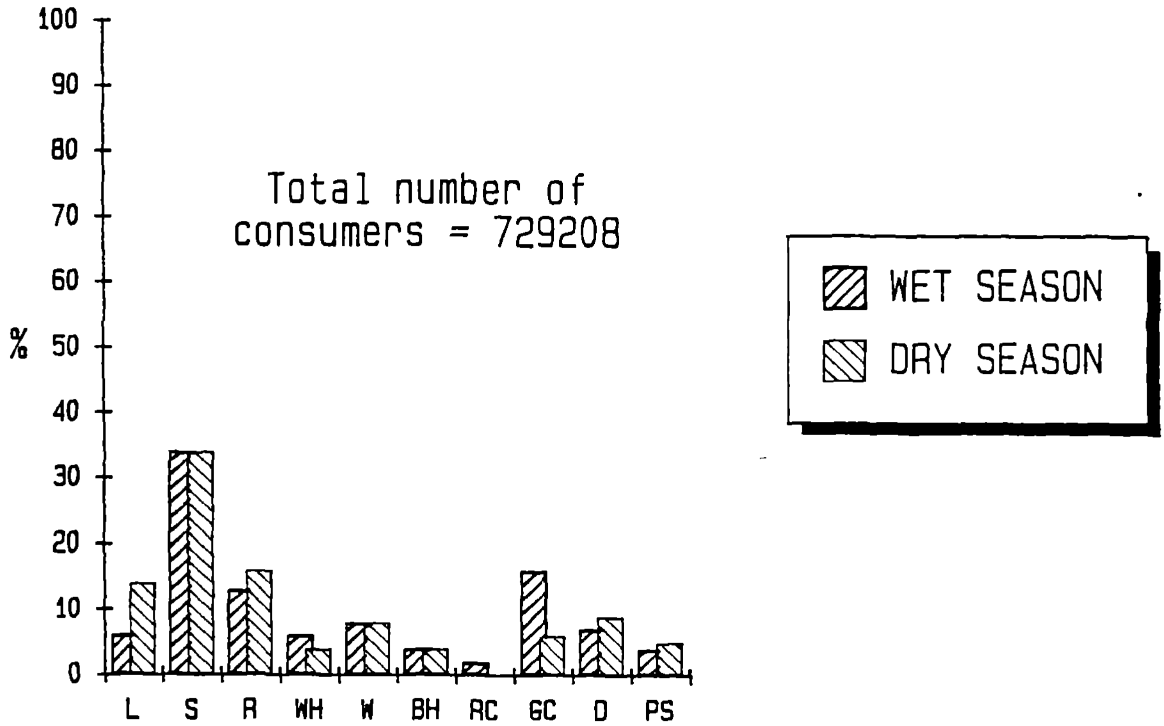


Figure 3 24 Use of water supply sources per Division in Siaya District

Fig. 3.24 shows the differences of use of water supply sources per Division.
In Bondo and Rarieda Divisions most people use ground catchments, dams or Lake Victoria.
Boro Division is a transition zone where springs, wells, water holes, ground catchments, dams and rivers are all important water sources.
Springs are the most frequently used water sources in both Ukwala and Yala Divisions.
In Yala Division many people use rivers or piped water supply taps. In Ukwala Division there is a significant use of boreholes, rivers and wells.

FIG. 3.25 USE OF WATER SUPPLY SOURCES DURING WET AND DRY SEASON IN SIAYA DISTRICT.



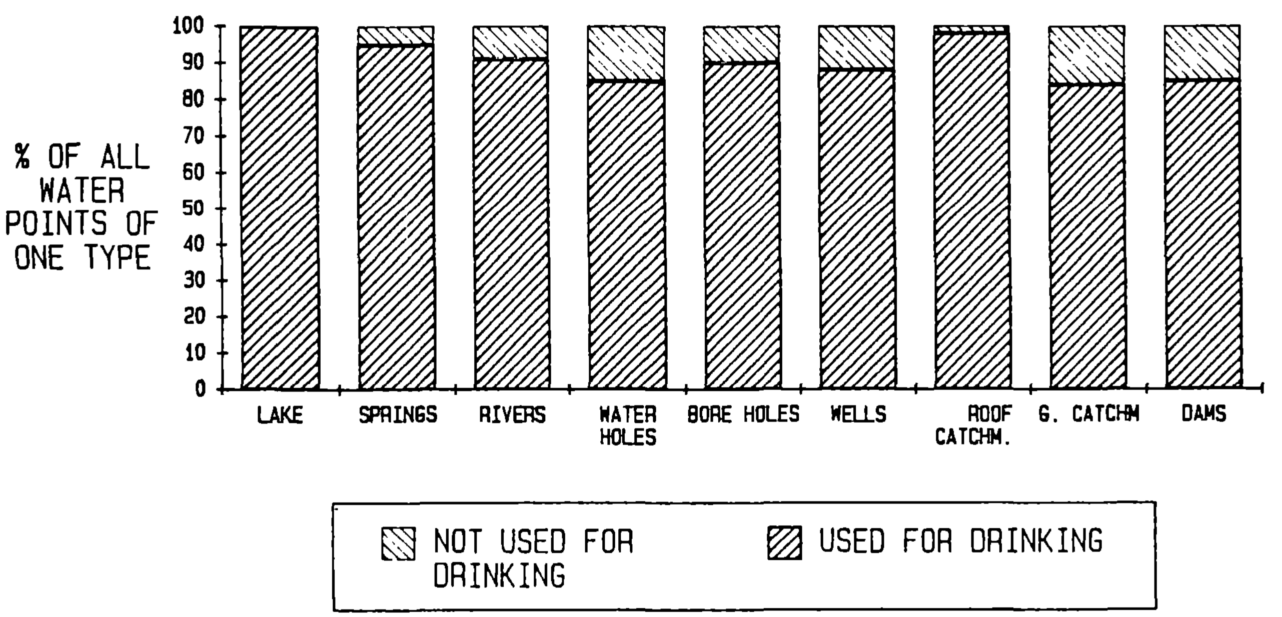
3.4.2. Seasonal differences

Fig. 3.25 shows the differences between the wet and the dry season.Use of ground catchments, water holes and roof catchments sharply reduces during periods of drought. The use of roof catchments during the dry season is almost neglectable.
Use of lake and river points, dams and piped water supplies goes up during periods of drought.

3.4.3. Water points used for drinking purposes

Fig. 3.26 shows, for each type of water point the percentage which are used for drinking purposes. It shows that almost all water points are used for drinking. Even bad quality sources as dams, ground catchments and water holes are used for more than 80 % to get drinking water.
The percentage of wells and boreholes used for drinking is relatively low (88-90%). This is due to complains about the taste of the water (Hardness, iron, manganese content etc.).
Springs and roof catchments are considered to be good sources of drinking water.
Lake water is used everywhere for drinking because there are no suitable alternatives around.

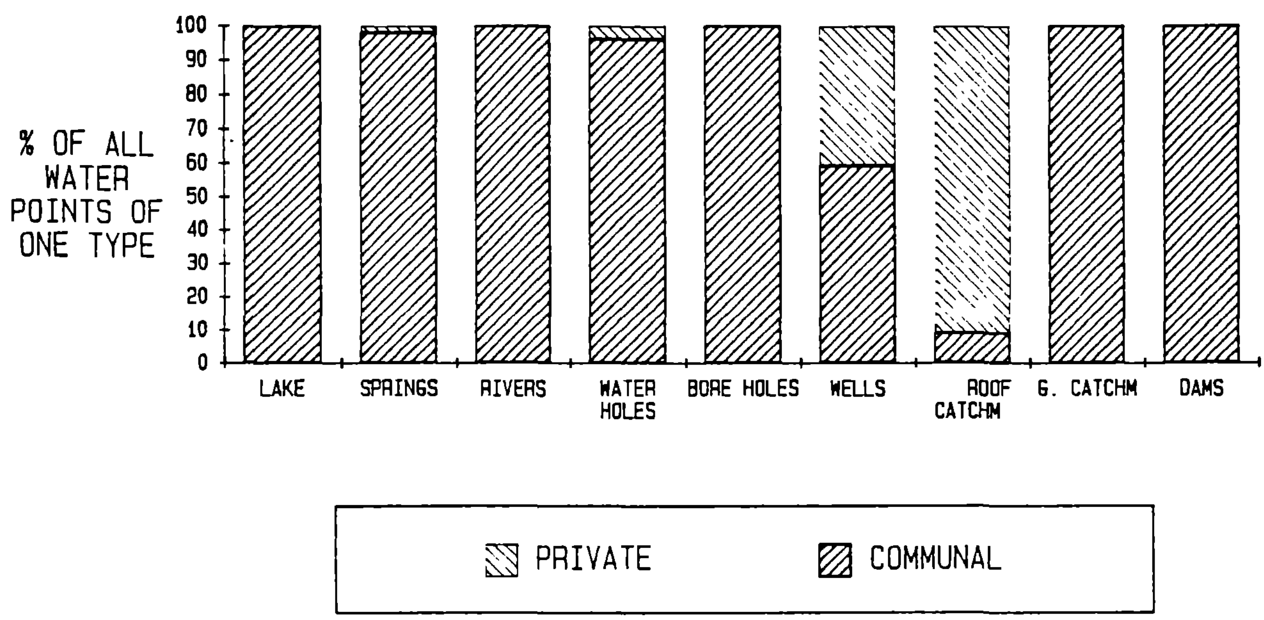
FIG. 3.26 WATER POINTS USED FOR DRINKING AND WATER POINTS WHICH ARE NOT USED FOR DRINKING



3.4.4. Private and communal water points

Fig 3.27 shows the way water points are used, as private or as communal facilities.
Dams, ground catchments, rivers, lake points and all boreholes are public facilities.
A few springs and water holes are private. About 60 % of all wells are public water points.
Less than 10 % of the roof catchments are communal water points.

FIG. 3.27 PRIVATE AND PUBLIC USE OF WATER POINTS



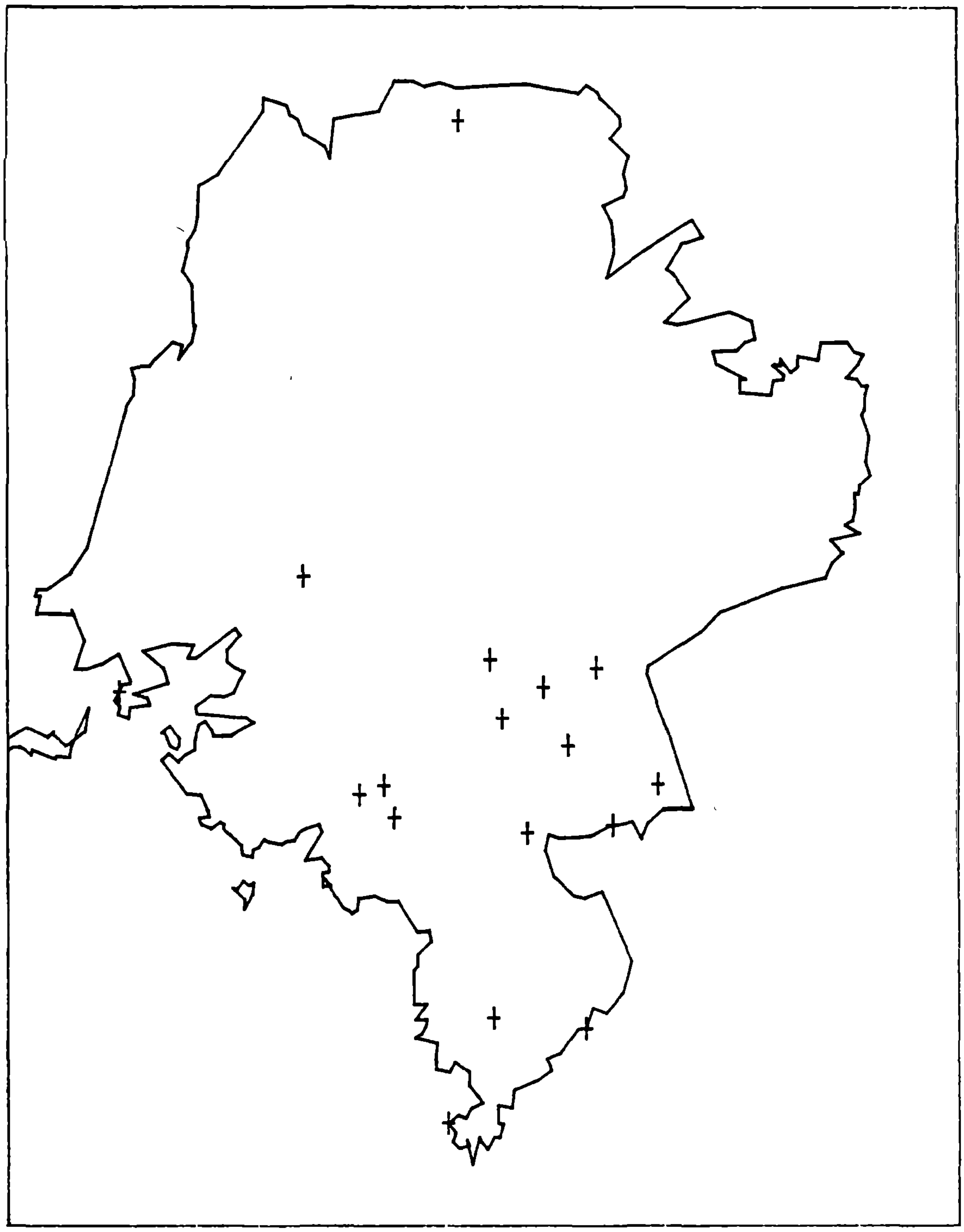


Fig. 3.28. Location of water points serving more than 1000 consumers.

3.4.5. Number of consumers per water point

The average number of consumers per water point (including piped water supply taps) is 142.
This figure is above the Kisii average of 135 but under the South Nyanza figure of 177.
There are large differences between the average number of consumers per Division as shown in Table 3.3.

Table 3.3. Average number of consumers per water point per Division

Division	Average number of consumers
Bondo	178
Rarieda	237
Boro	154
Yala	112
Ukwala	115
Siaya District	142

Despite of its low population density the average figure for Rarieda Division appears to be twice as high as those found for Yala and Ukwala Divisions.
Table 3.4. shows the differences per type of water point used.

Table 3.4. Average number of consumers per type of water point (wet season situation)

Type of water point	Average number of consumers
Lake points	337
River points	156
Springs	154
Water holes	166
Wells	115
Boreholes	234
Ground catchment	244
Dams	409
Roof catchments	31

The average number of consumers of the communal type of water points is all over 150.
Wells and roof catchments of which 40% resp. 90% are privately used have less than 150 consumers per water point.
Fig. 3.28 shows a computer plot of the water points which were found to have more than 1000 consumers. Finding such a high number of consumers often reflects local water supply problems due to an absence of sufficient water points.
Most of these "1000 consumer points" are located in Bondo, and Rarieda Divisions.

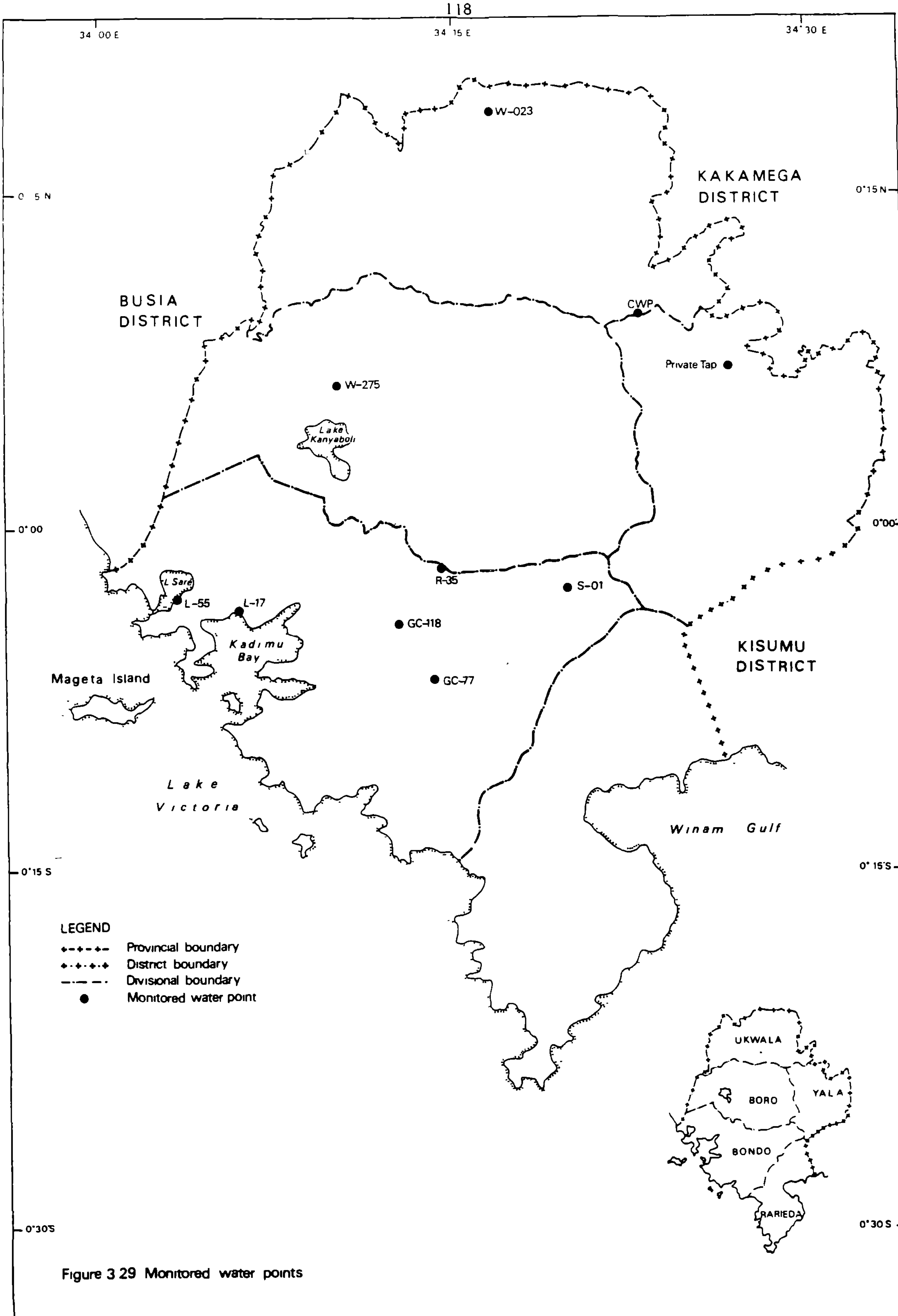


Figure 3.29 Monitored water points

3.4.6. Water demand

Ten (10) different water points, located in Bondo, Boro, Yala and Ukwala Divisions, were monitored during one day starting at 6.00 a.m. and lasting till 7.00 p.m. in order to measure how much water was collected and by how many people. From these data the per capita water consumption has been calculated. Fig. 3.29 shows which water points have been monitored.

- S-01, a protected spring in Bondo Division.
- GC-77 and GC-118, two ground catchments in Bondo Division.
- L-55 and L-17, two water points along Lake Sare and Lake Victoria.
- R-35, a river point along River Yala.
- W-275 and W-023, two wells both equipped with hand pumps located in Boro and Ukwala Divisions.
- One communal water point (C.W.P) of Sidindi-Malanga Water Supply , located at the boundary between Yala and Ukwala Divisions.
- One private tap connected to Sidindi-Malanga Water Supply located in Yala Division.

People visiting these water points were asked to give their names, the name of the head of their family and the number of people for whom they were fetching water. Time of arrival and the amount of water collected were recorded. Table 3.5 shows the results of this survey.

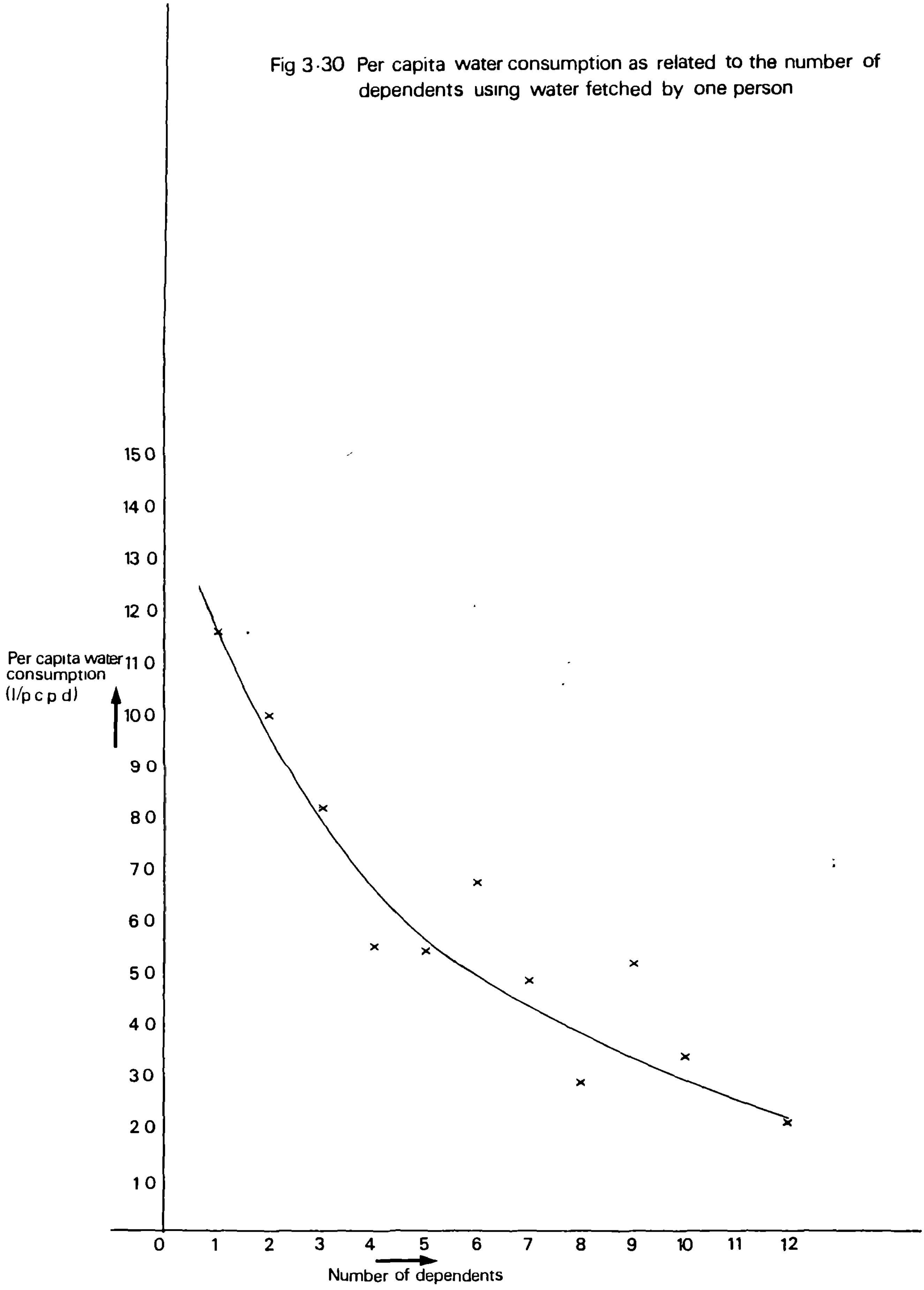
Number of different people visiting a water point

The number of people visiting a water point depends on the local water point density , the population density and whether the water point is used as a private or as a communal facility.
The private tap of Sidindi-Malanga Water Supply was used by 6 women (owner of the tap + close relatives).
In areas having many water points, like Yala and Ukwala Divisions, even good water points are only visited by 30-40 women.
In areas where only a few water points are found like Bondo Division, some water points are visited by more than 100 different women.

Number of visits per day to a water point

The average number of visits per day to a water point mainly depends on the average walking distance and varies from 1.2 up to 2.3 visits per person per day.

Fig 3·30 Per capita water consumption as related to the number of dependents using water fetched by one person



In the dry areas along Lake Victoria where people have to walk far to reach a water point, most people only fetch water once a day.
In Yala Division where most water points are found nearby, most people make at least 2 trips per day to fetch water.

Amount of water fetched per visit

The average amount of water collected and brought home per trip varies from 14 up to 22 litres per person per trip.
People who have to walk far tend to take more water with them than people living closer to a water point.
Extreme figures are found for lake point L-17 (22 l/per person per trip) and het communal tap of Sidindi-Malanga Water Supply (14 l/per person per trip).
Use of wheel barrows and donkeys , as frequently observed along the Lake, considerably increases the amount of water transported per person per day.

Water supply capacity of a water point

The amount of water collected from one water point varies from 155 (l) for the private tap up to 4000 (l) for spring S-01.
The amount of water fetched during one day depends on the number of different people visiting the water point, the average number of visits per day and the amount of water transported per trip.
The maximum water supply capacity of a water point in Siaya District is estimated at 7.5 (m^3/day) (150 visitors, 2.5 trips, 20 l/trip).

Number of dependents per water point

The number of people who depend on one water point varies from 20 to 580. Subdividing the number of dependents by the number of people visiting a water point, it appears that on an average 1 woman brings water to her home for about 4-6 dependents.

Per capita water consumption

The per capita water consumption strongly depends on the number of people who will use the water brought by one person to a home. Fig.3.30 shows this.
If the water is only used by one person the average per capita consumption will often be more than 10 (l/p.c.p.d) If the water is used by 10 people, the per capita consumption will often be less than 2 (l/p.c.p.d).

Taking all dependents of one water point into account the average per capita water consumption varies from 5.3 (l/p.c.p.d) to 14.8 (l/p.c.p.d).

Table 3.5 Water consumption

Water point	Division	Population Density	Area covered	Average walking distance	Maximum walking distance	No of people fetching water	No of visits per person per day	Amount of water transported per trip	Total amount of water fetched	Number of dependants	Per capita water consumption
		(inh/km2)	(km2)	(km)	(km)			(l)	(l)		(l/c/day)
S-01	Bondo	151	3.3	1.0	2.2	118	1.79	18.4	4064	498	8.2
GC-77	Bondo	56	7.2	1.5	3.0	99	1.75	21.1	3653	401	9.1
GC-118	Bondo	38	9.8	1.5	3.0	77	1.94	21.6	3326	372	8.9
L-55	Bondo	132	1.3	1.0	2.0	46	1.46	17.1	1140	171	6.7
L-17	Bondo	78	7.5	2.0	4.5	111	1.19	22.7	3123	587	5.3
R-35	Bondo	104	3.3	2.0	4.0	59	1.49	20.8	1912	344	5.6
W-275	Boro	61	2.2	0.6	1.5	39	1.54	16.2	991	134	7.4
W-023	Ukwala	162	0.6	0.5	0.6	39	1.54	13.6	806	97	8.3
Communal water point	Yala	113	0.6	0.3	0.6	27	2.30	14.8	1005	68	14.8
Private tap	Yala	53	0.3	0	0	4	2.00	15.6	125	16	7.8
Water point average		95	3.6	1.0	2.1	62	1.70	18.2	2015	269	8.2

3.5. EVALUATION OF THE SIAYA RURAL WATER SUPPLY SITUATION

Most characteristic of the rural water supply situation in Siaya District are the extreme differences between the very difficult water supply situation in the southern part (Bondo and Rarieda Divisions) and the good situation in the northern part (Yala and Ukwala Divisions).
The situation in Bondo and Rarieda is among the worst found in Nyanza Province, comparable with areas like Macalder and Mbita Divisions (South Nyanza District).
On the other hand, there are hardly no areas which have better rural water supply facilities than Ukwala Division.
Boro Division is in fact a transition zone between the dry areas of Bondo and Rarieda and the wet areas of Yala and Ukwala Divisions.
The differences between Bondo and Rarieda on the one hand and Yala and Ukwala on other hand are best illustrated by the water point densities and type of water points used in both areas.
In most parts of Bondo and Rarieda there is only 1 communal water point per 5 (km^2) which does not dry up. In Yala and Ukwala Divisions, this figure is about 10 times as high (2 communal water points per km^2).
In Bondo and Rarieda Divisions the most frequently found and used type of water points are dams and ground catchments supplying a bad quality of drinking water. In Yala and Ukwala most people use springs which supply an excellent quality of drinking water.

Next to the differences between the southern and the northern parts, a characteristic aspect of the Siaya rural water supplies is the wide variety of different water resources used.
Springs are the most frequently found and used type of water points. Apart from springs, however also Lake Victoria, many seasonal and perennial rivers, dams, ground catchments, water holes, boreholes, wells, roof catchments, and piped water supplies are intensively used. This is completely different from the situation found in e.g. Kisii District where almost exclusively springs are used.

Contrary to what might have been expected , most efforts aimed at improvement of the water supply situation have been made in areas which from an objective point of view should have gotten the lowest priority.
Most boreholes, wells and spring protections are found in Yala and Ukwala Divisions. The largest piped water supply system found in the District, Sidindi-Malanga Water Supply, covers parts of Yala and Ukwala Divisions. This is a violent contrast to the situation in Bondo and Rarieda Divisions where no boreholes are found and hardly any properly working piped water supply system.

Rural water supply in Bondo and Rarieda Divisions;
donkey cars and dried up dams.

The water supply situation in Bondo and Rarieda Divisions is unacceptable.
Development of these areas is impossible if people have to walk up to 5-6 (km) to find water for drinking or cooking, water which is contaminated and hardly enough for washing and bathing.
Such a situation not only blocks development but it also constitutes a permanent danger to human health.

All existing types of water supply facilities have to be taken into accounting in preparing a water supply plan.
Although dams and ground catchments have intrinsic disadvantages (contamination of the retained water can not be excluded), both facilities have proved to be best adopted to the difficult situation found in Bondo and Rarieda Divisions.
As indicated above, emphasis must be given to improvement of the water supplies in Bondo, Rarieda and Boro Divisions.
The situation in these areas is much worse than the situation in Yala and Ukwala.

PART IV

EXPLORATION OF GROUND WATER RESOURCES

4.1. GEOLOGY

4.1.1. Introduction

Ground water presence and consequently the exploration techniques depend to a large extend on the geology of the area. Other factors which influence the ground water occurrence as morphology, topography and pedology are strongly related with the geological setting of the region as well.
Without a proper understanding of the geological framework of a ground water system, it is impossible to quantify the resource. The initial stage of the assessment must therefore be the study of the geology

For this purpose a study has been made of the existing geological maps and reports, supplemented with geological field investigations and remote sensing studies.

4.1.2. Previous investigations

The geology of Siaya District has been surveyed between 1934 and 1954 by geologists of the Survey of Kenya, who published a number of comprehensive reports and maps on a scale 1:125,000.
Siaya District is covered by the following reports and maps:

- Report No.4
  "Geological Survey of No.2 Mining Area, Kavirondo, North-West Quadrant".
  by C.S. Hitchen (1936)

- Report No. 5
  "Preliminary Report on the Geology of the No.1 Mining Area, North and Central Kavirondo".
  by W. Pulfrey (1936)

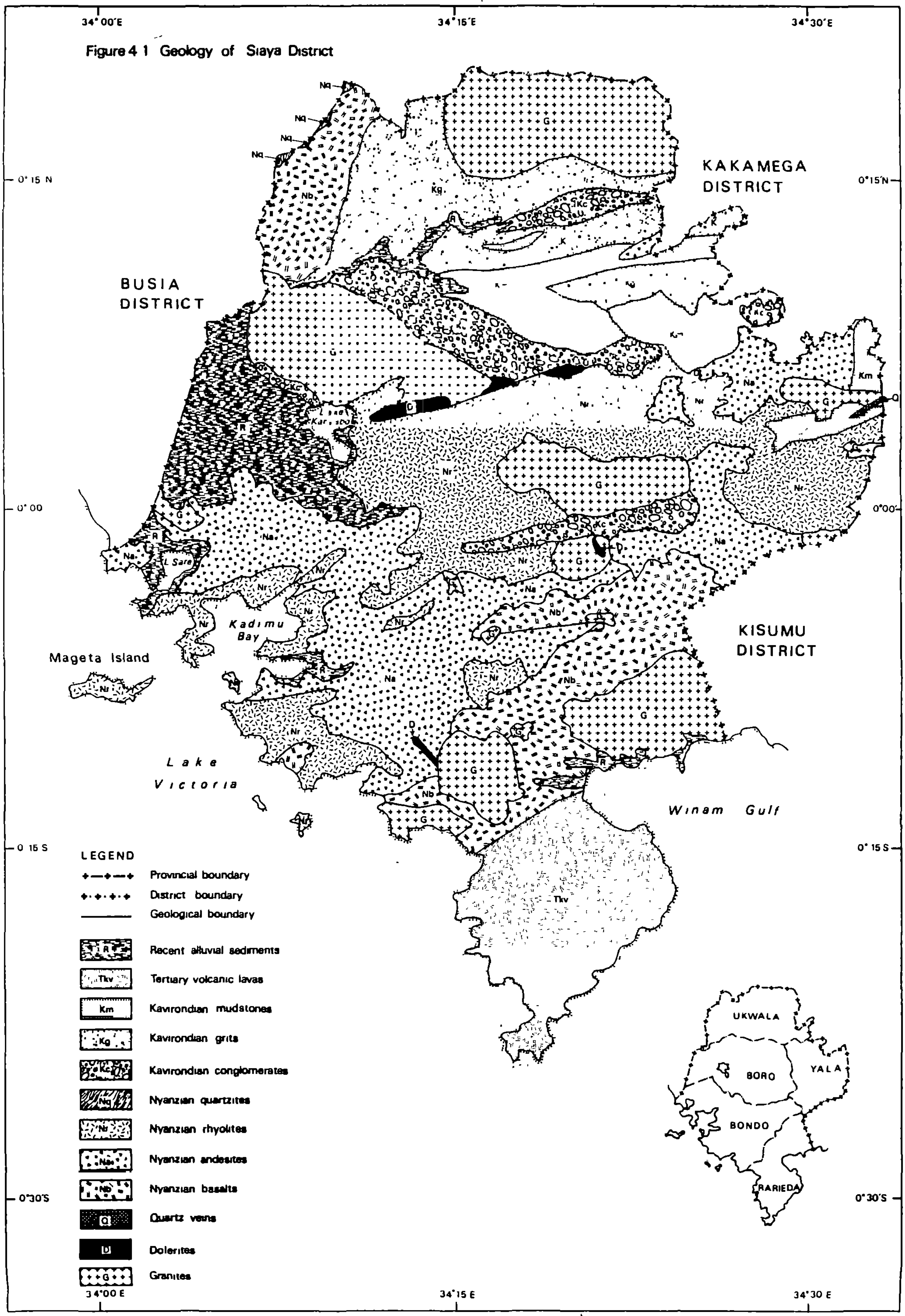
- Report No. 6
  "Geological Survey of No. 2 Mining Area, Kavirondo, North-East Quadrant".
  by C.S. Hitchen (1937)

- Report No. 7
  "Geological Survey of No.2 Mining Area, Kavirondo, South-West Quadrant."
  by W. Pulfrey (1938)

- Report No. 21
  "Geology of the Kisumu District".
  by E.R. Saggerson (1952)

- Report No. 28
  "Geology of the Kakamega Area"
  by A. Huddleston (1954).

Although 30 to 40 years old, the geological maps and descriptions of the stratigraphy and lithology are detailed and of a good standard.


34° 00'E
34° 15'E
34° 30'E
Figure 4 1 Geology of Siaya District
KAKAMEGA
DISTRICT
BUSIA
DISTRICT
KISUMU
DISTRICT
Mageta Island
Kadimu
Bay
Lake
Victoria
Winam Gulf
L Sare
0° 15 N
0° 00
0 15 S
0°30'S
LEGEND
Provincial boundary
District boundary
Geological boundary
Recent alluvial sediments
Tertiary volcanic lavas
Kavirondian mudstones
Kavirondian grits
Kavirondian conglomerates
Nyanzian quartzites
Nyanzian rhyolites
Nyanzian andesites
Nyanzian basalts
Quartz veins
Dolerites
Granites
UKWALA
BORO
YALA
BONDO
RARIEDA

However, there are a few shortcomings. For the preparation of the geological maps, topographical maps were used which were on a scale of 1:250,000 and not very detailed. The topographic control of the geological maps therefore is generally not very accurate.

Because of the lack of good quality aerial photographs and satellite images, often geological structures as faults, and fracture patterns, which are quite relevant in ground water occurrence, do not appear on the existing geological maps.

4.1.3. Geological maps prepared by the RDWSSP

As part of the survey reports of the 5 Divisions of Siaya District geological maps were prepared (Scale 1:50,000) for each Division. As a basis the (1:50,000) topographical map sheets were used of the Survey of Kenya (Y-731 series). The existing geological information (scale 1:125,000) was transformed to this scale maps and supplemented with information from field investigations and remote sensing interpretations.

A geological map (Map-4) is annexed to this report covering Siaya District on a scale of 1:100,000. The map is generally a compilation of the above mentioned Divisional maps with some minor simplifications and elimination of irrelevant details.

4.1.4. Regional geology

Siaya District forms part of the old African Craton, built up out of Precambrian rocks. Since the time these rocks were formed and the area emerged above sea level (about 2000 million years ago), for a very long period no major geological activities took place. Until the Miocene (about 10 million years ago), when major tectonic activities started to affect the area. The same tectonic forces which initiated the formation of the East African Rift Valley in Kenya had only minor influence in this part of the country.
The Kavirondo Rift which branches from the main Rift Valley intersects the southern part of Siaya Division (Uyoma Peninsula) and simultaneous volcanic eruptions from Kisingiri volcano covered the peninsula (Fig. 4.3a.).
However a large number of faults developed throughout the whole area during this period and some older faults were rejuvenated It is in particular this relatively young system of faults and fractures which plays an important role in the ground water potential of the area, as will be discussed later in this chapter.

FIG 4.2a. ROCK SYSTEMS OF SIAYA DISTRICT

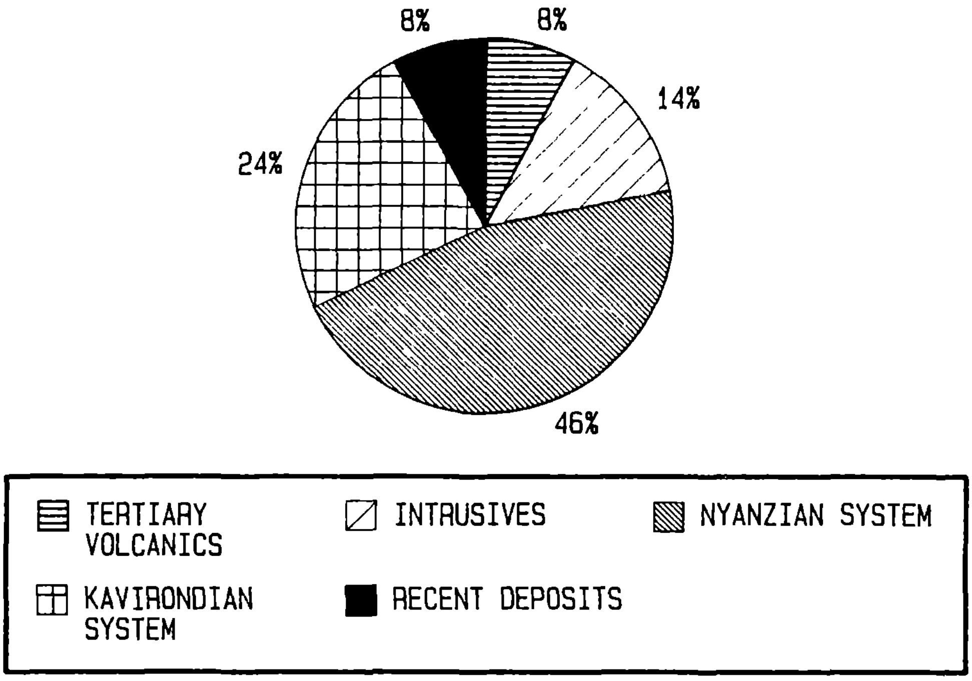
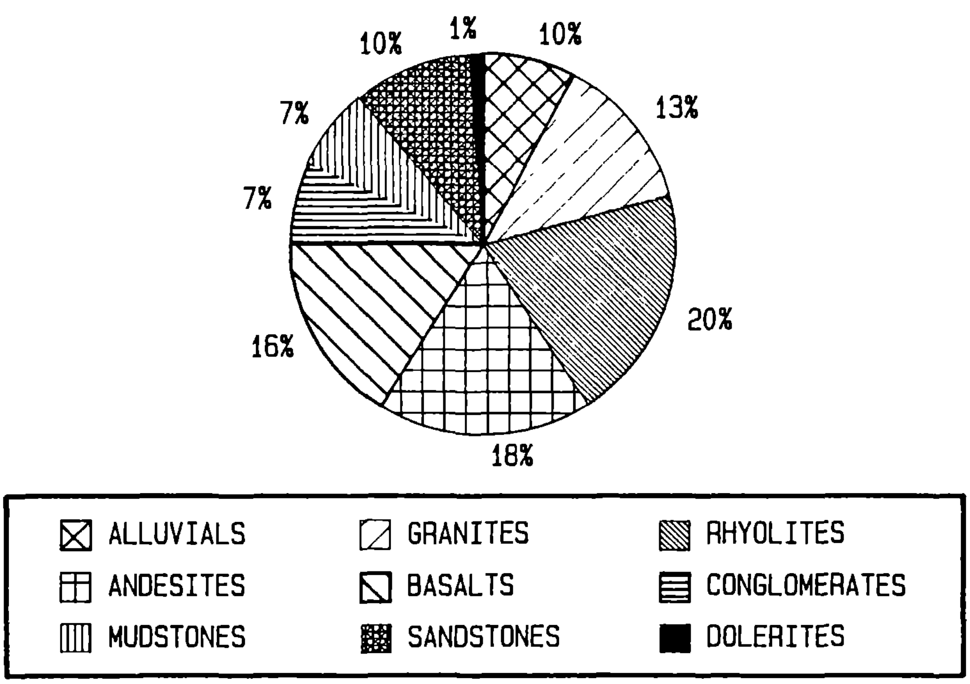


FIG 4.2b. ROCK TYPES OF SIAYA DISTRICT



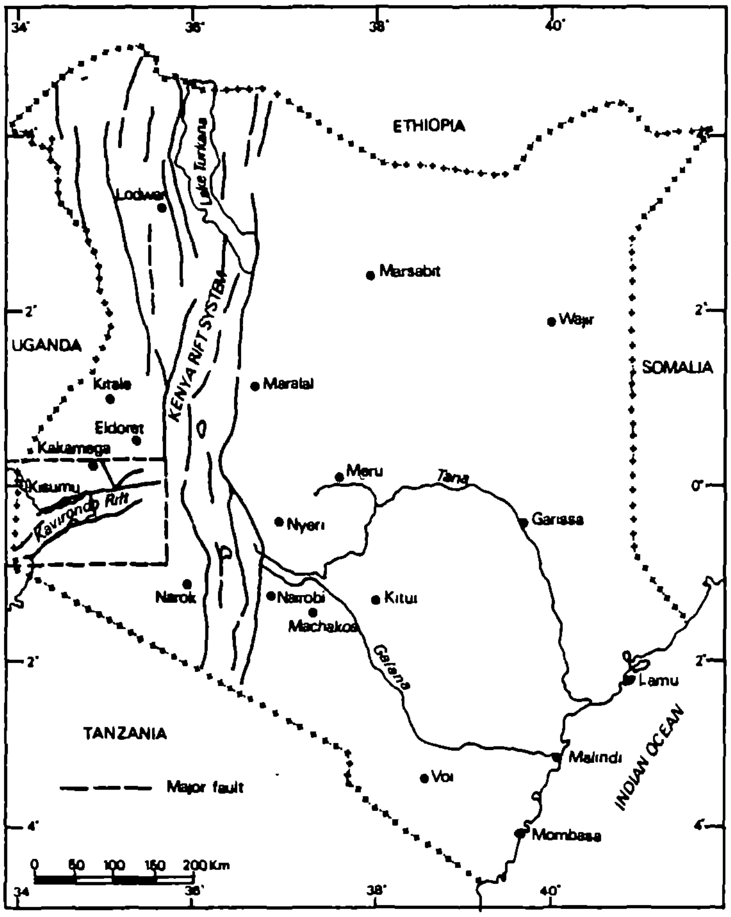


Figure 4 3a Rift valleys of Kenya

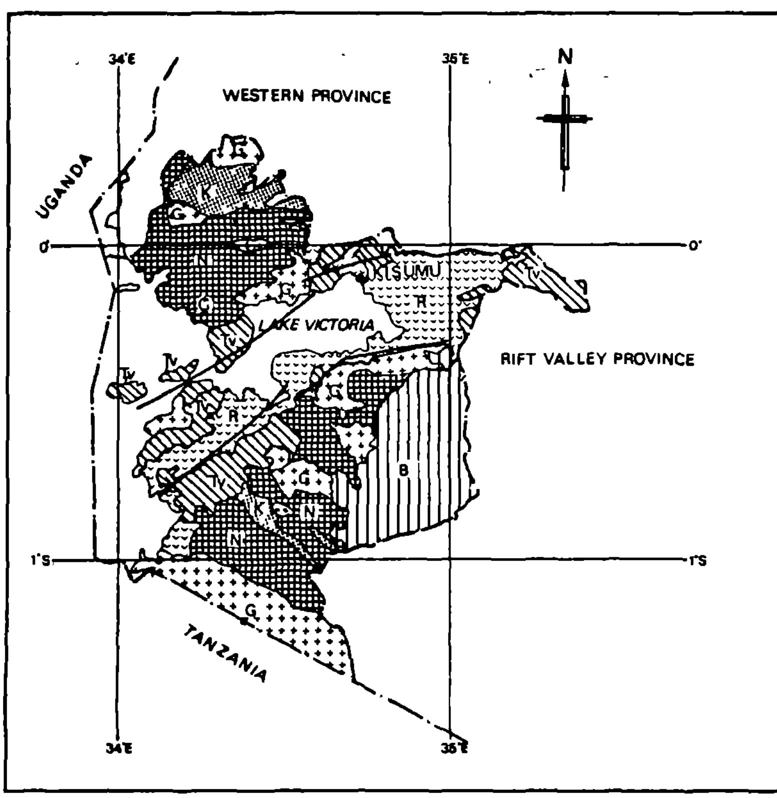


Figure 4.3b Simplified Geological Map of Nyanza Province

Table 4.1 Geological History of Siaya District

Time Period	Rock System	Geological Symbol	Unit Lithology	Description of geological events
QUATERNARY	RECENT	R	Alluvium Superficial deposits. Lake deposits	Sedimentation of erosion products Yala Swamp Sedimentation
TERTIARY	MIOCENE	TKV	Nevetinitic lavas, tuffs and agglomerates	Development of Kavirondo Rift Valley and associated basic volcanic eruptions
PRECAMBRIAN	KAVIRONDIAN	Km Kg Kc	Mudstones Arkosic sandstones Conglomerates	Increased erosion and deposition of continental sediments
	INTRUSIVES	D G	Dolerites Granites	Basic dyke intrusions Intrusion of acid batholiths
	NYANZIAN	Nq Nr Na Nb	Quartzites Rhyolites, tuff and agglomerates Andesites Basaltic lavas	Formation of the African craton

4.1.5. Brief description of the rock formations

Nyanzian System

Rocks of the Nyanzian System are the oldest exposed in the area (2200 million year), covering large areas of southern Siaya District. The rocks of the system mainly consist of volcanics as basalts, andesites and rhyolites. They are folded along northwest-southeast striking axes and underwent low grade metamorphism.

Intrusives

Two major phases of intrusions have been identified in Siaya District: one of post-Nyanzian/pre-Kavirondian age and one of post-kavirondian pre-Bukoban age. These intrusives are mainly granitic rocks, locally sheared and well jointed.

The intrusives, due to typical granite weathering, now form erosional remnants rising above the general ground level (ridges, tors, bare-rock surfaces and inselbergs).
At some locations doleritic dyke intrusions are found, generally parallel to major fracture trends.

Kavirondian System

Rocks of this system are sedimentary derivates of the Nyanzian System and post-Nyanzian intrusives.
The rocks consist of conglomerates, grits and mudstones and occur as inliers within the rocks of the Nyanzian System. The Kavirondian sedimentary rocks mainly are exposed in the northern part of the District covering large areas of Ukwala and Yala Divisions.

They are believed to be deposited under continental torrential conditions, after the Nyanzian deposits had emerged above sea level.

Tertiary volcanics

Rocks of Tertiary age have been found only in the southern part of the area on the Uyoma peninsula. The rocks consist of nepheline lavas, agglomerates and tuffs, originated from the Kisingiri volcano in South Nyanza.

Recent

Recent sedimentary deposits occur in the western part of the area and along the main rivers Yala and Nzoia. The sediments are rather fine grained alluvials and lake deposits consisting of clays and silty sands.

The distribution of rock types in Siaya District is illustrated in the Figures 4.1. and 4.2.

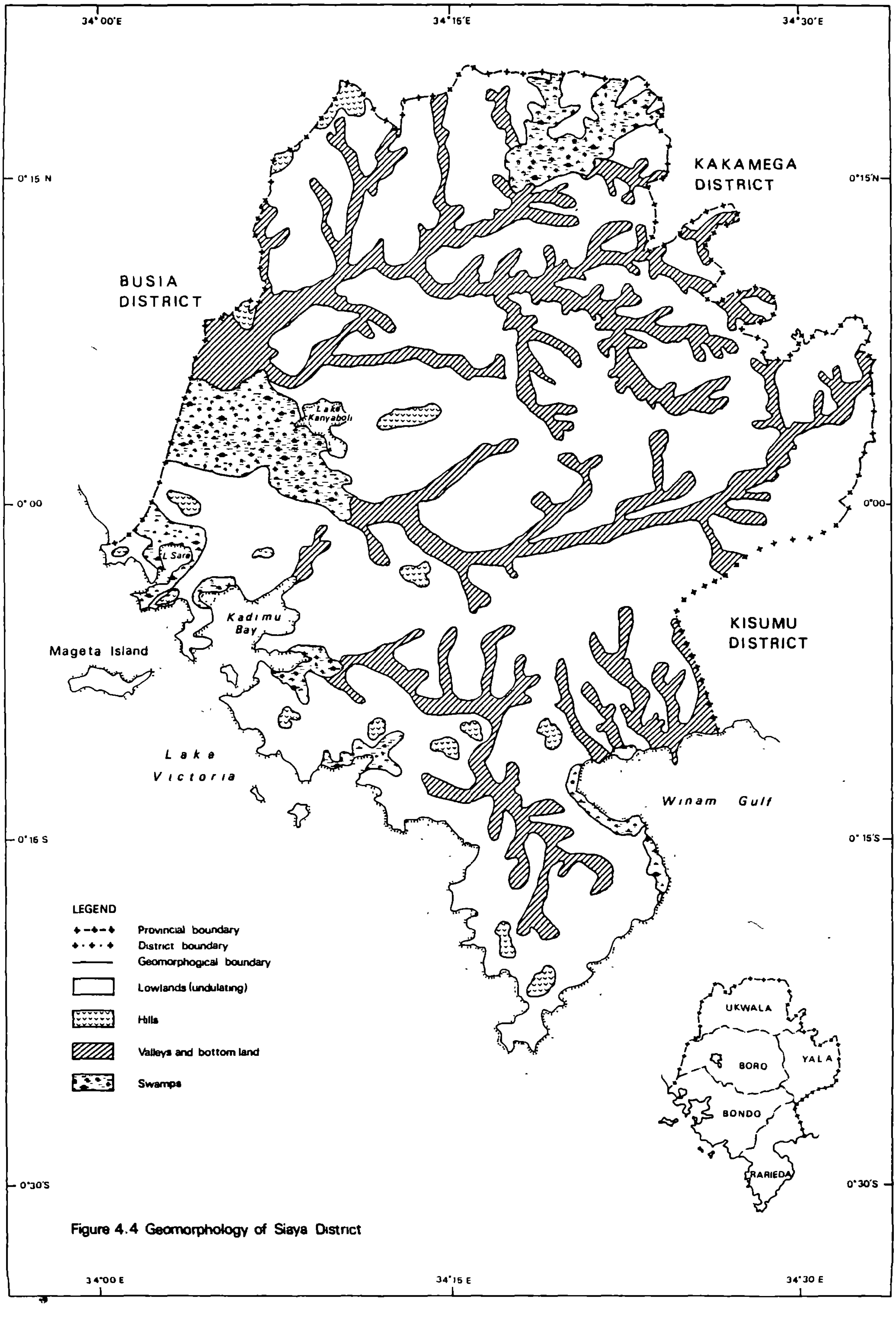


Figure 4.4 Geomorphology of Siaya District

4.2. GEOMOPHOLOGY

Geomorphologically several units can be distinguished in Siaya District.

- lowlands
- valleys and bottomlands
- swamps
- hills

The distribution of the geomorphological units is presented in Figure 4.4.

Lowlands. The bulk of the Siaya District area consists of a gently undulating lowland landscape shaped by (intensely eroded) Nyanzian and Kavirondian rock formations.
Altitudes range from 1140 (m) which is just above the Lake Victoria level to about 1400 (m) in the more hilly northeastern part of the District.

Valleys and bottomlands. Flat-bottomed valleys and bottomlands are mainly found along the main streams as Nzoia and Yala Rivers and their tributaries. Both rivers have incised their own beddings during recent times, therefore eroding most of their previous deposits and terraces.
The bottomlands are filled up with fine clays and sands, which are generally of a limited thickness of not more than 5-10 (m).

Swamps. Along the Lake Victoria shore and in particular near the mouth of Yala and Nzoia Rivers, extreme flat areas are found. Due to the frequent flooding of these areas large swamps have developed from which Yala Swamp is the most predominant in the area.
The swamps are underlain with fine alluvial sedimentary deposits of variable thickness. Relatively thick deposits (30-40) m.) of very clayey material are found in the Yala Swamp area alternated with layers of peat and fine silty sand.

Hills. In particular in the southern part of the District numerous hills are found. Most of them consist of granitic rocks which are more resistant to weathering than the Nyanzian volcanics, thus resulting in a number of inselbergs.

In the northwest corner along the border with Busia District a few steep hills are found consisting of sheared Nyanzian quartzite rocks.

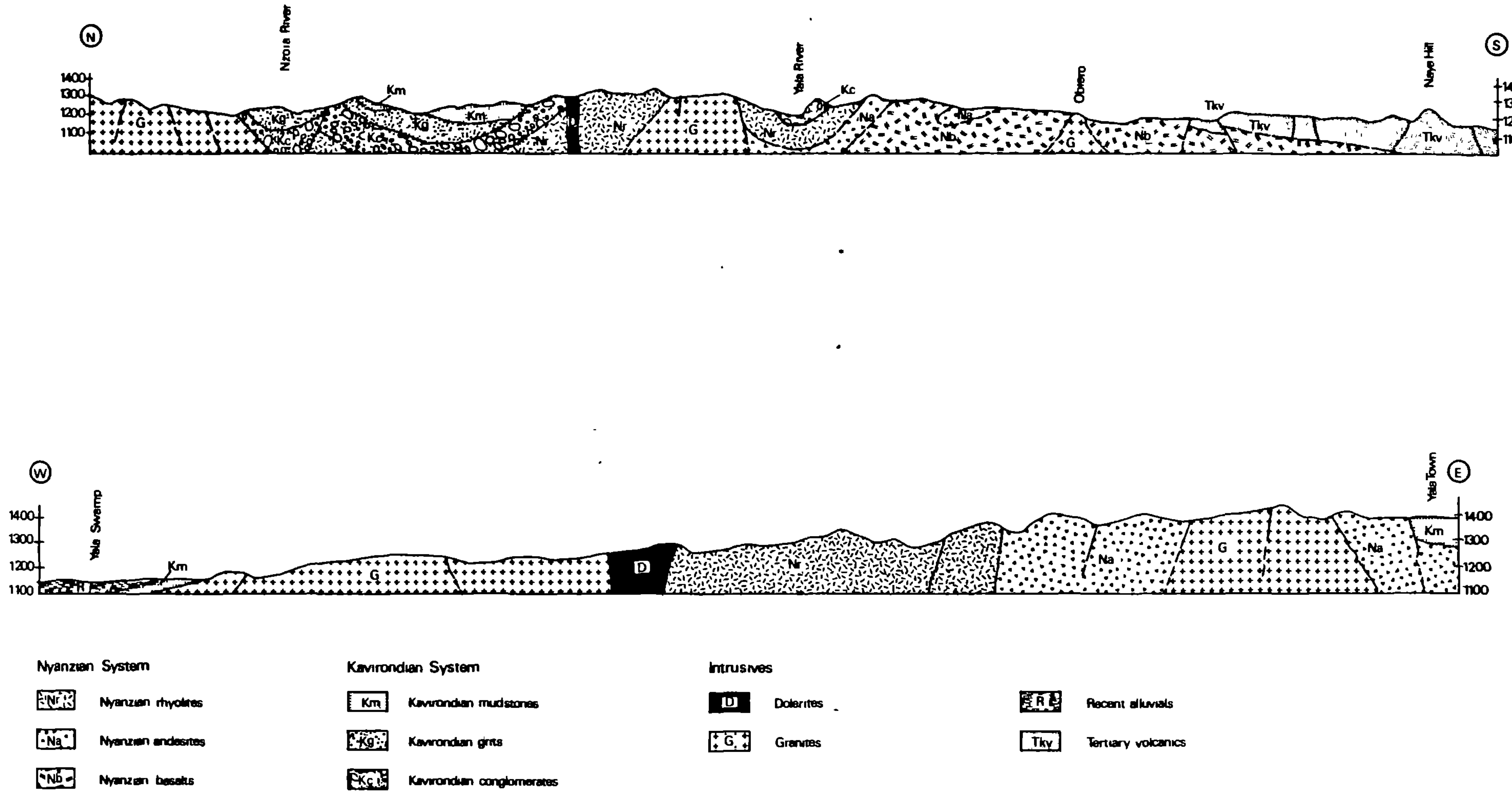


Figure 4.5 Geological cross sections of Siaya District

4.3. PREVIOUS GROUND WATER RESOURCES ASSESSMENT STUDIES

The first comprehensive investigation into the ground water potential of western Kenya (Nyanza and Western provinces) was carried out in 1980 by Ker, Priestman and Ass. (Ref.24).
The main purpose of this hydrogeological study was to determine the availability of ground water and its potential as a water source for the rural population.

The assessment of the ground water resources by Ker, Priestman and Ass. essentially has been a desk study, in which available information was analysed, and supplemented with a few field checks.
Information collected and presented in the report include rainfall, evaporation and streamflow as well as geological data. Extensive use was made of borehole completion records, on file with the MoWD.

From these investigations it was concluded that ground water potential of the Granites and Nyanzian volcanics in Siaya District is generally very poor. With the exception of the Kavirondian conglomerates and grits all other rock types had very poor hydraulic parameters. Due to the generally clayey soils overlying the volcanic rocks it was found that infiltration from rain in these areas was rather low.

Recommendations given by Ker, Priestman and Ass., for the Siaya area was to develop the ground water resources, which were thought to be abundantly present within the Kavirondian rocks.

Most of the later studies (mainly feasibility studies for water supply systems) have used the results and conclusions of above named Consultants.

4.4. THE RDWSSP APPROACH TO GROUND WATER EXPLORATION IN SIAYA DISTRICT

During the systematic ground water resources survey carried out between 1987 and 1988 the following ground water characteristics were investigated.

- types of aquifers
- exploration techniques for different types of aquifers
- quantities of ground water available for abstraction for domestic use
- ground water quality.

As shown in Fig. 4.2, 90% of the area of Siaya District is underlain by hard rocks and the remaining part is covered with alluvial sedimentary rocks.
Ground water occurrence and consequently the exploration techniques are closely related to this geological distinction.

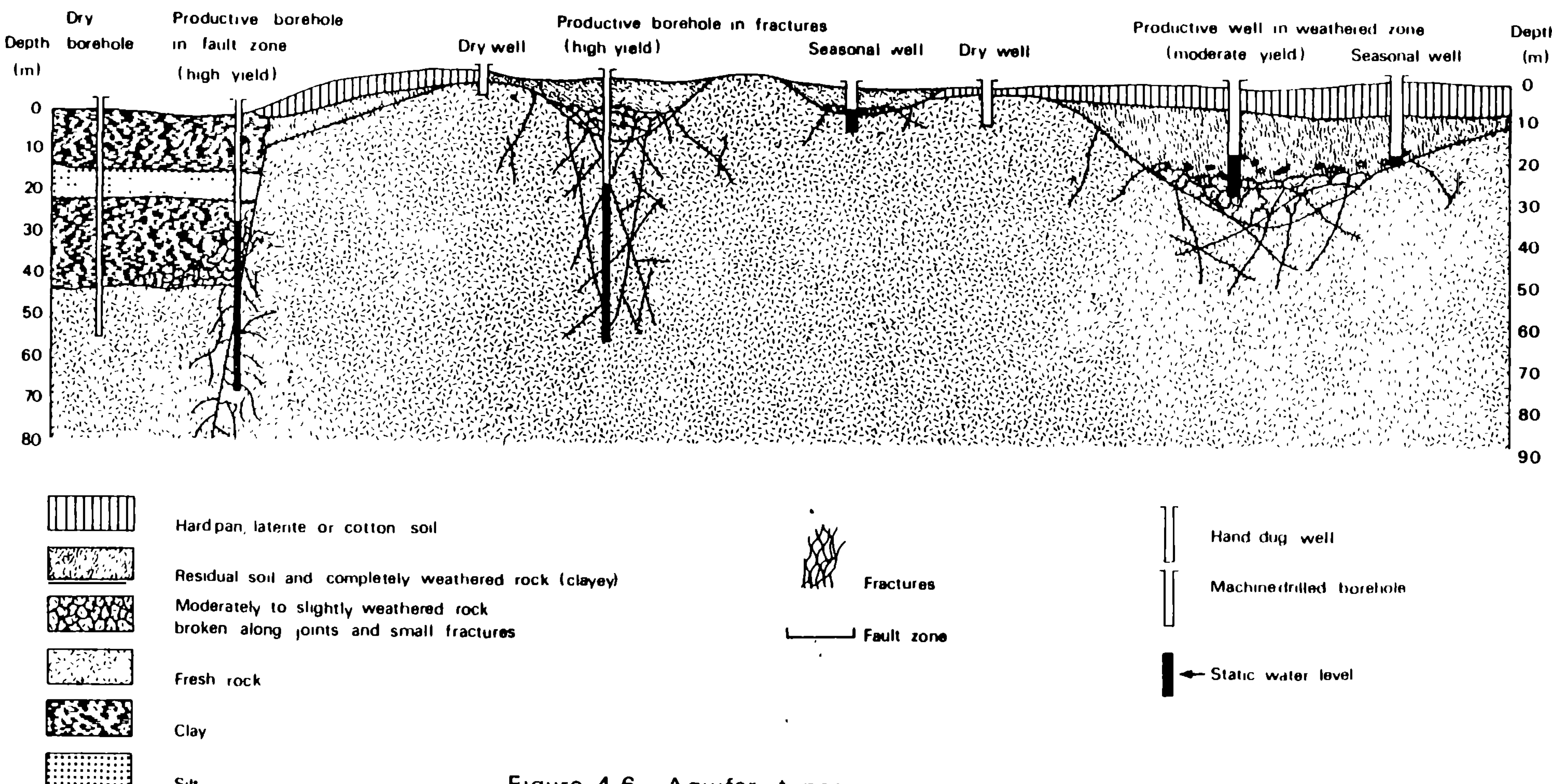


Figure 4.6 Aquifer types

Hence the ground water assessment will be discussed for both geological regimes separately.

- ground water resources in the areas underlain with hard rock

- ground water resources in the sedimentary areas.

4.5. GROUND WATER ASSESSMENT IN HARD ROCK AREAS

Fresh hard rocks like granite or lavas have a very low primary porosity and can therefore not contain any significant amounts of ground water.
In areas underlain by hard rocks ground water can only be found in two types of aquifers:

- Within the weathered layer on top of the hard rocks.

- In cracks and fissures in the rocks (joints, fractures and faults).

4.5.1. Ground water occurrence in the weathered layer

The chemical and mechanical disintegration of the hard rocks has resulted in a cover of weathered rock material overlaying the fresh parent rock. The higher horizons of the weathered layer are usually very clayey, consisting of completely weathered and highly altered rock, in which no original rock structures can be found anymore. Feldspar minerals are commonly completely altered to clay minerals, creating high porosities, but extremely low permeabilities. The thickness of this decomposed layer may range from 5-25 (m) and is 10 (m) on an average.
Between the decomposed layer and the fresh bedrock the weathered layer consists of less weathered, partly altered rock material, which usually has a higher permeability. The average thickness of this part of the weathered layer is 10-20 (m) in the topographically lower areas, but may be totally absent on steep slopes and hill tops.

Ground water, is usually found within this less weathered zone with relatively higher permeabilities, of depths between 10 and 60 (m). Where the depth to the ground water is less than 30 (m) below ground level, and when seasonal ground water level fluctuations are not excessive, this type of aquifers can be exploited by means of hand dug wells.

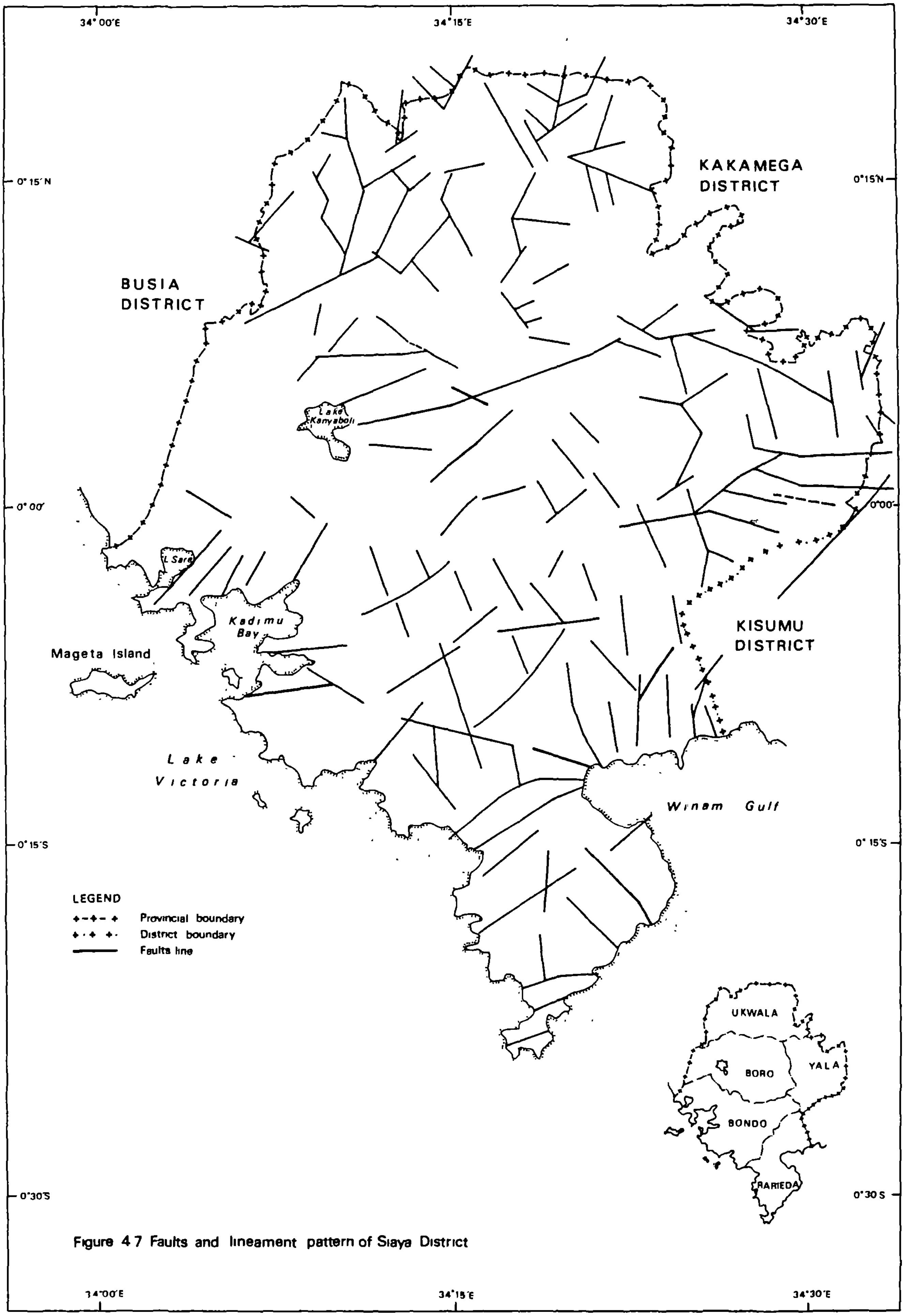


Figure 4 7 Faults and lineament pattern of Siaya District

4.5.2. Ground water occurrence in faults and fracture zones

Although ground water usually is present within the weathered layer, frequently this type of aquifer does not produce sufficient yield.
Recent investigations carried out in areas with a similar geological environment revealed that high yield wells can be located in major fault and fracture zones (UNESCO, Ref.52).

The Precambrian rock formations in Siaya District underwent a long history of rock deformations which resulted in a large number of joints, fractures and faults.

From the results of the on-going borehole drilling programme in Nyanza Province it appears that frequently high yield wells (10-50 m^3/hr.) can be constructed in major fault zones while the surrounding areas have only a moderate to low ground water potential.
This can be explained as follows:

- Along fault or fracture zones weathering can penetrate much deeper, thus creating sub-vertical zones filled up, with coarse weathered rock material having generally much higher transmissivity values than the surrounding areas.

- Ground water accumulates from large areas to these faults or fracture zones producing therefore a steady recharge.

Exploration methods

The exploration method for this type of aquifers developed by the programme is aimed at accurately detecting such fault or fracture zones in the field.

For this purpose the following survey components can be distinguished.

- mapping of the most important fault and fracture lineations by means of remote sensing and aerial photo interpretations;

- geophysical field surveys along profiles across these inferred fracture or fault lineations.

Remote sensing and aerial photo interpretations

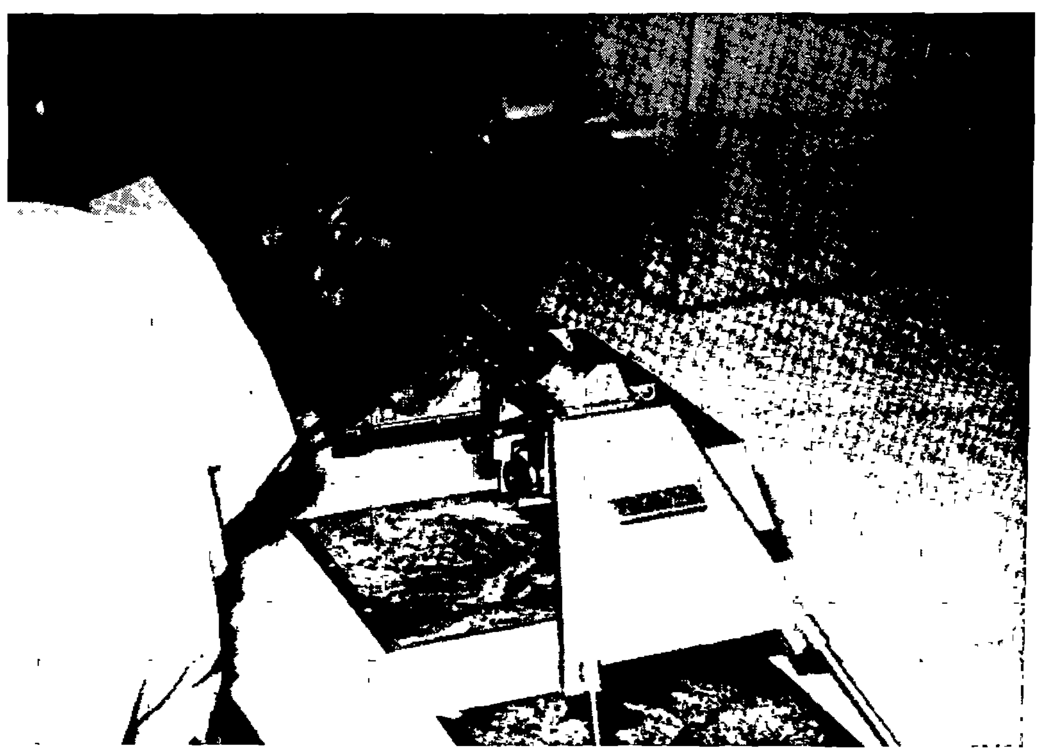
Aerial photographs were used of the V-13-B series taken in 1967 with an approximate scale of 1:50,000.
For the interpretation of satellite images use was made of the Landsat MSS false colour composite exposures, numbers 181/60 and 181/61 (January 1979) on a scale of 1:250,000.

Faults and fractures generally appear clearly on aerial photographs as linear features. Steep to sub-vertical faults form straight lines, while low angle faults appear as curved lines. Indications for the presence of faults or fractures are frequently found as elongated valleys or linear vegetation patterns. Satellite images reveal the major fault structures, as well as regional scale geological features such as fault escarpments, volcanic complexes and differences in major rock types.

From existing data and experience gained during the Programme, it became evident that wells were most successful when located on fault structures and that sometimes a location error of 10 (m) can make the difference between a high yield well and a unproductive well.

It is therefore necessary to precisely locate the faults in the field, wich is done by detailed on-site geophysical survey.

Fig. 4.7. shows the fault and fracture pattern found through aerial photograph and remote sensing interpretation.



Aerial photograph interpretation.

Geophysical survey method.

After experimenting and comparing several geophysical survey methods, a combination of geo-electrical (GE) and electro-magnetic (EM) measurements was chosen, which appeared to produce the best results.
A standard survey set up was designed, which can simply and quickly be applied.
The standard field survey comprises:

- horizontal loop EM conductivity profiling
- horizontal GE profiling
- vertical electrical soundings.

For the geo-electrical measurements, use is made of the SAS-300 Terrameter from ABEM. The electro-magnetic survey is done with an EM-34 conductivity meter from GEONICS.
Fig. 4.8. shows the locations of geophysically investigated sites in Siaya District.

Electro-magnetic profiling

The geophysical field survey commonly starts with electro-magnetic profiling, perpendicular to an inferred fault or fracture zone. Generally the vertical dipole mode is used (coils aligned in parallel horizontal position.
First a coil spacing of 40 (m) is used after which the same profile is measured again with a coil spacing of 20 (m).
Using a configuration with a coil spacing of 20 (m) a maximum exploration depth of about 15-20 (m) is obtained, while with a coil spacing of 40 (m) the maximum exploration depth is increased to approximately 30-40 (m).
The intervals between each consecutive measuring point along the profile normally is 10 (m). The length of the profiles varies from 400 to 600 (m).

Electro-magnetic profiling.

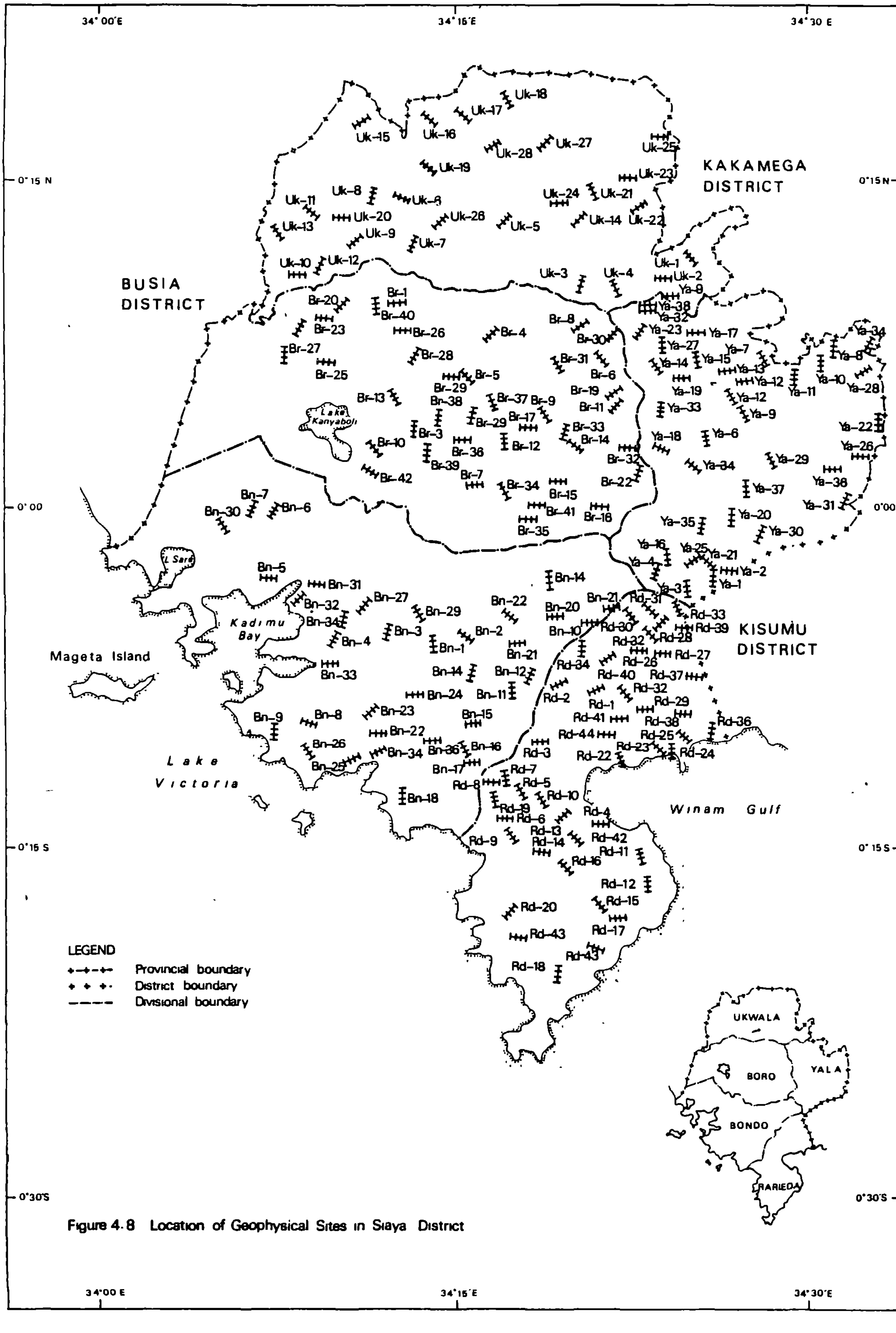


Figure 4.8 Location of Geophysical Sites in Siaya District

Horizontal electrical profiling

After completion of the EM profiles a horizontal electrical profile is measured along the same line.
For this type of survey the Wenner configuration is used, with the distance between the current electrodes AB fixed at 60 (m) and the distance between the potential electrodes MN at 20 (m). Like the EM profiles, the interval spacing between the measurements normally is 10 (m).

Horizontal electrical profiling.

Qualitative evaluation of profiling data in the field

Both the EM and GE profile data reflect lateral changes in electrical resistivity, corresponding with variations in lithology, weathering, fracturing, thickness of layers, water content or salinity up to a depth of 20-40 (m).

Although generally the EM profiles reflect the same lateral changes as the GE profiles, the EM profiles, in particular, proved to be very sensitive to fault and fracture zones which can be traced by this method with an accuracy of a few meters.

The recorded data of EM and GE profiles is plotted and interpreted in the field and where a fracture or fault is inferred, a number of vertical electrical soundings (VES) are measured along the profile line.
If no clear anomaly on the profiles is recognized additional profile lines are measured, commonly running parallel to the first line.

Vertical electrical sounding

After completion of the profiles, along the most promising profile line 4-6 vertical electrical soundings are executed. The soundings are performed according to the Schlumberger configuration with a maximum current electrode spacing of 200 (m). The spacing between the soundings is variable, ranging from 70-170 (m).

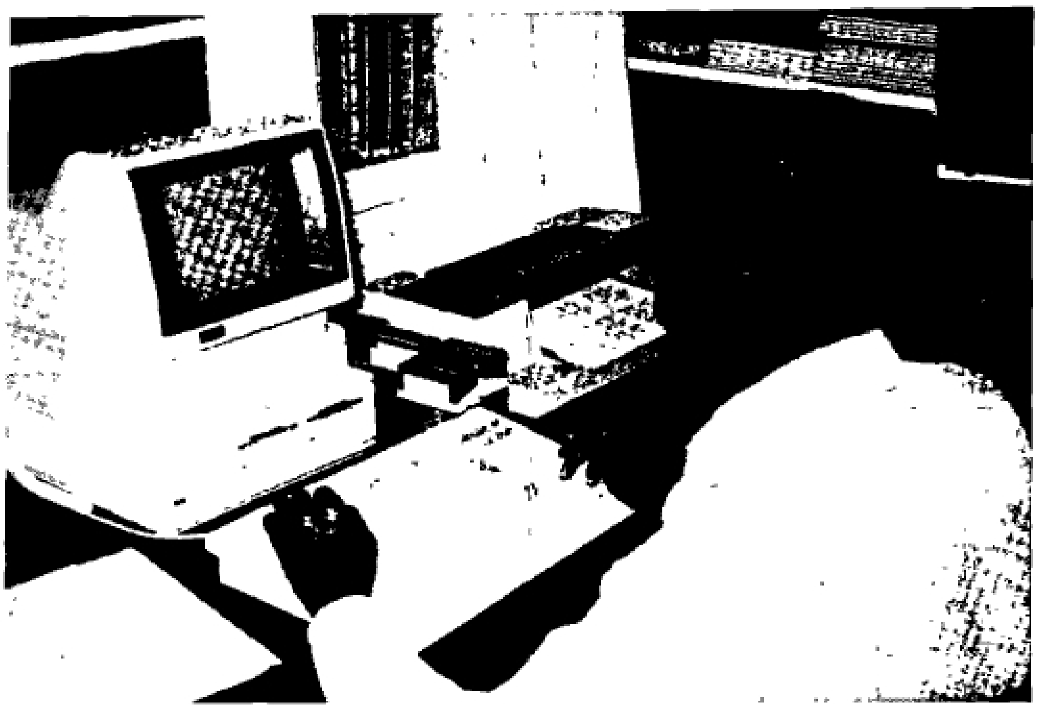
From the vertical electrical soundings carried out this way, the resistivity and thickness of (sub) horizontal layers is interpreted to locate the depth of potential aquifer zones.

Field geophysical survey - vertical electrical sounding.

Interpretation of the combined results of the GE and EM surveys

The geophysical data are interpreted and elaborated by means of a micro computer, and results are plotted in schematic cross-sections. From the elaborated geophysical data, for each surveyed site, conclusions are drawn regarding:

- presence and depth of different zones of weathering;
- depth to the unweathered bed rock;
- presence and depth of ground water table;
- thickness of aquifers;
- presence and accurate location of (sub) vertical discontinuities as faults, intrusive dykes and lithological boundaries etc;
- salinity of ground water.



Interpretation of geophysical data by microcomputer.

Based on these conclusions, the best well site, the depth and type of well, (a hand dug well or machine drilled borehole), can be selected.

With this standard procedure of geophysical survey a certain routine is achieved by the field surveyors, which results in a high accuracy of measurements and a minimum of errors. In 90 % of the initial surveys, sufficient information is gathered to fully interpret the data in terms of ground water potential and to indicate the most promising well locations.

Applicability of the ground water survey methods

The ground water survey method adopted and developed by the RDWSSP is applicable almost everywhere in rural areas and can be executed in a quick and effective manner in the field.
With the method, it is possible to study large areas in a relatively short period.
Both (sub-)horizontal as well as (sub-)vertical water bearing zones can be detected up to a depth of 75 (m), which proved to be sufficiently deep in hard rock areas.
Advantages which the survey method offers compared to other geophysical methods are:

- the geophysical instruments used by the Programme are easy to operate and need little maintenance;

- some of the instruments (ABEM-Terrameter) are available and servicable in Kenya and are already used by the MoWD and ground water exploration companies in the country;

- in contrast to most other geophysical exploration methods, both the GE and EM survey results give an indication of the ground water salinity;

- without the use of high voltages, explosives or radioactive sources, the method is completely safe and without risks for the surveyors and the public.

Based on the geophysical survey results, recommendations can be made which may considerably reduce the costs of an implementation programme.

- By accurately establishing the most suitable well location, the percentage of productive wells is increased whereby the expenses for dry holes are reduced.

- By reducing the depth of boreholes on interpreted hydrogeological grounds, considerable costs can be saved.

Limitations of the method.

- The geophysical methods can not be applied in areas with intense shrub vegetation or a dense pattern of fences, without cutting and clearing them first.

- The survey results become disturbed and unreliable in areas close to power lines, metal fences, under ground pipe systems and telephone cables.

- Mineralized zones influence and may disturb the interpretations of the geophysical data.

When to apply geophysics in ground water surveys.

From the ground water investigations in all parts of Nyanza Province during the past 4 years, the following conclusions about the necessity of geophysical field survey can be made:

- In areas with a mean annual rainfall of less than 1200 (mm/year) always a geophysical survey is recommended. Exploitable amounts of ground water are generally exclusively found in faults or fracture zones.

- Areas with a mean annual rainfall between 1200-1600 (mm/year), generally a geophysical survey is recommended. It is strongly cost reducing in any well construction programme.

- Areas with a mean annual rainfall of more than 1600 (mm/year), usually no geophysical survey is necessary for the siting of hand dug wells. However for medium to high yield boreholes a detailed geophysical survey is recommended.

It should be stressed, however, that the above stated is a strong generalization and that other factors than rainfall as topography geomophology and geology will influence the decision whether to apply geophysical survey methods or not.

4.6. GROUND WATER ASSESSMENT IN SEDIMENTARY AREAS

About 10% of Siaya District is covered by sediments.
The sediments are Pleistocene to Recent in age and include mainly lacustrine and fluviatile deposits.
The investigations carried out subsequently by Ker Priestman and Ass. (Ref. 24) and the RDWSSP pointed out and confirmed the importance of these sediments as aquifers.
The ground water exploration of the sedimentary deposits is discussed separately because the approach differs from the survey methods used to detect ground water in hard rock areas as described in the section above.
Thick deposits of sediments are found near the mouth of both Yala and Nzoia Rivers. A vast area of this sedimentary basin, however is permanently flooded (Yala Swamp). Investigations carried out in the reclaimed part of the Yala Swamp showed that:

- the sedimentary deposits in this particular area had an average thickness of about 50-60 (m)

- the thickness of the deposits increases towards the west

- the sediments consist of rather clayey deposits alternated with more sandy and silty clay layers, which are frequently water bearing

- due to intense evaporation of the shallow ground water locally the ground water can be rather saline (EC>2500 uS/cm).

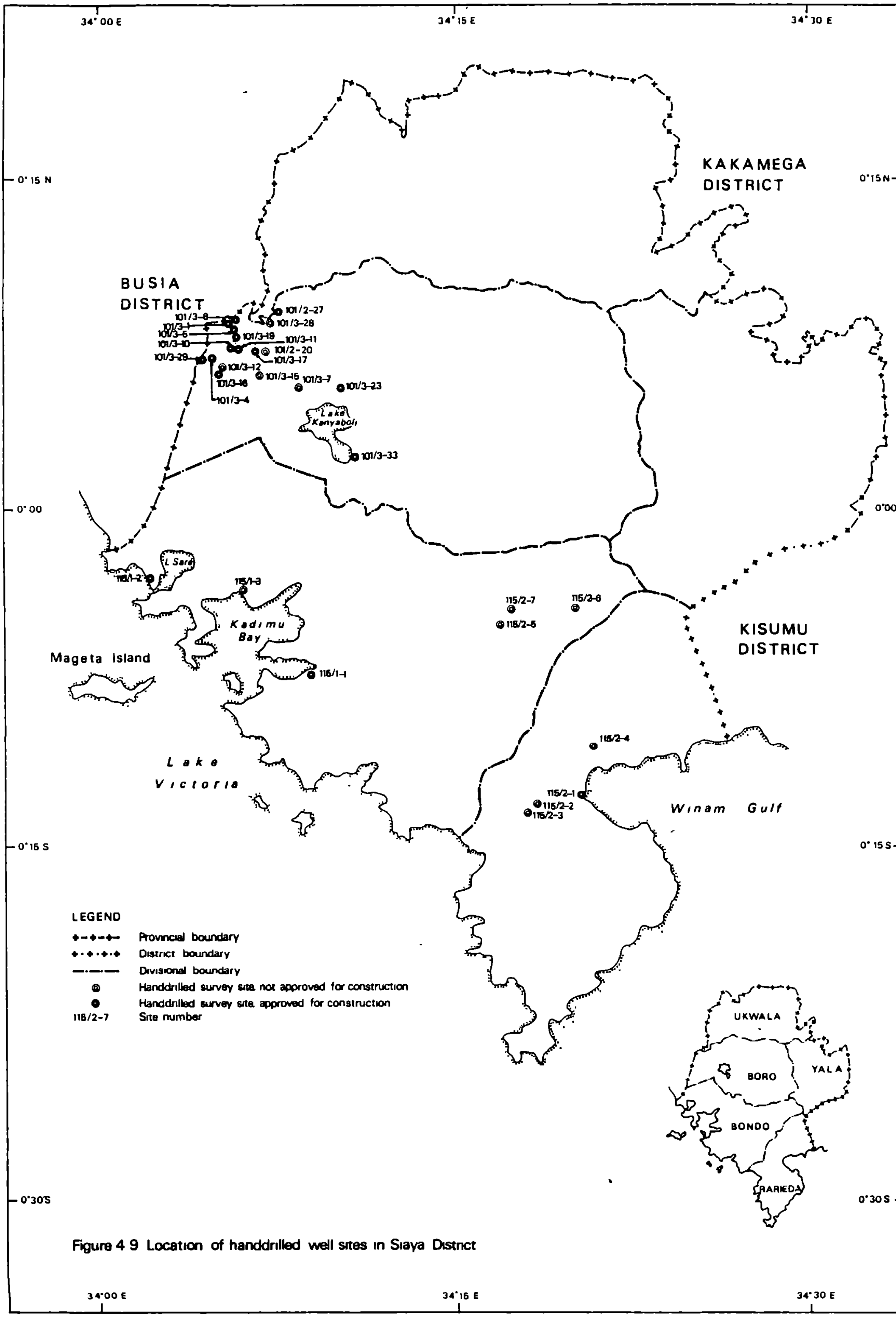


Figure 4 9 Location of handdrilled well sites in Siaya District

Exploration methods

Generally thick accumulations of sediments are explored by means of vertical electrical soundings.
The detection of individual aquifers however depends entirely on the depth of occurrence, thickness an formation resistivity contrast with the other sediments.
When the sedimentary deposits are not very thick (<30 m), the RDWSSP has developed a direct method of ground water exploration.

The method involves the drilling by hand of small diameter (7-10 cm) test holes.
In case that ground water is found, temporary casing and screen is installed in the holes, after which they are test pumped.
In view of the water quality problems, this direct method offers the advantage that water samples can be taken and analyzed.

For an extensive and detailed description of ground water survey by means of the hand drilling method, the method's applicability and its limitations as well as a review of the tools and equipment used, one is referred to the Main Report of the RDWSSP (Ref.10) and the Final Report of the Lake Basin Shallow Wells Pilot Project (Ref.9).

Applicability of hand drilling method in Siaya District

The method of hand drilling has the advantage that it is a fast and low-cost method with direct results about the shallow aquifer properties and ground water quality.
However the method has several limitations.

- drilling can only be carried out upto a limited depth (maximum 20-25 m).
- drilling can not penetrate through a sub-surface duricust or stone layers.

There are in Siaya District two aspects which further limit the possibilities of exploration of ground water from shallow aquifers in sedimentary deposits.

- In particular along the lake shore, the salinity of the ground water in alluvial sediments may be high and exceeding the standard for drinking water (EC 2,500 uS/cm).
- In densely populated areas the shallow aquifers often are bacteriologically polluted.

As a result of the above mentioned limitations the hand drilling method of ground water exploration can be applied only in a relatively small area in the western part of the District.

- Usonga Location (Boro Division)
- West Yimbo Location (Bondo Division)

Fig. 4.9 shows the hand drilling survey sites in Siaya District.

Construction of a hand drilled well.

4.7. ASSESSMENT OF THE GROUND WATER POTENTIAL

4.7.1. Introduction

A common way of estimating the ground water potential is to calculate that part of rainfall that recharges yearly to the permanent ground water. The total amount of recharged ground water can be used for abstraction without seriously affecting the ground water situation. For an accurate estimate of the ground water recharge a proper evaluation has to be made of the factors which determine it, like:

- rainfall
- runoff
- evaporation
- soil moisture conditions

Rainfall, runoff and evaporation data have been studied from various sources and compared with recharge calculations from the existing literature.
Based on data of existing ground water sources (as wells, springs and boreholes), combined with the results of the ground water survey carried out in the 5 Divisions the ground water potential of Siaya District is discussed.

4.7.2. Rainfall

Rainfall records from a total of 26 stations have been analysed. Some of these stations have been in existence for more than twenty years. However many stations have incomplete records, and on an average only about 8 years of complete records per station is available. All rainfall data have been screened and elaborated by a recently developed computer programme called HYMOS (implemented for the LBDA by Delft Hydraulic Laboratory (Ref.8.).

The mean annual rainfall figures of each station have been calculated and are shown in Table 4.2. The mean annual rainfall data have been used to draw the mean annual rainfall map of Siaya District (Fig. 4.10.).

The mean annual rainfall varies from about 700 (mm/year) in the southwestern part along the Lake Victoria shore upto over 2000 (mm/year) in the northeastern part of the District. In general an increase in mean annual rainfall can be observed from the southwest towards the northeast of Siaya District.

Rainfall per catchment area

In Siaya District 6 catchment areas are distinguished.

- Siyoga catchment - (1EF)
- Nzoia catchment - (1EE)
- Wuoroya catchment - (1EG)
- Yala catchment - (1FG)
- Lake Victoria - West catchment - (1HC)
- Lake Victoria - East catchment - (1HB)

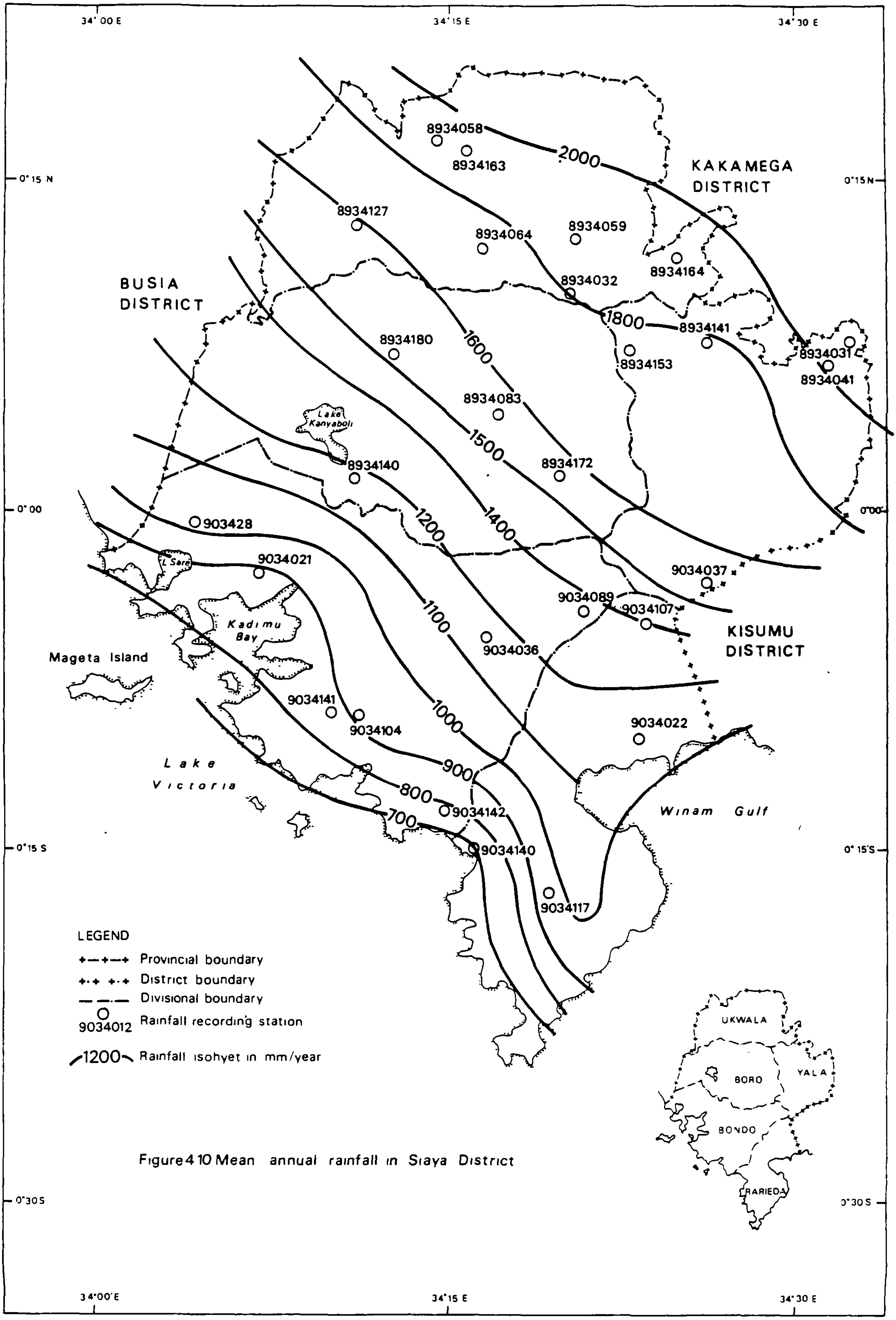


Figure 4.10 Mean annual rainfall in Siaya District

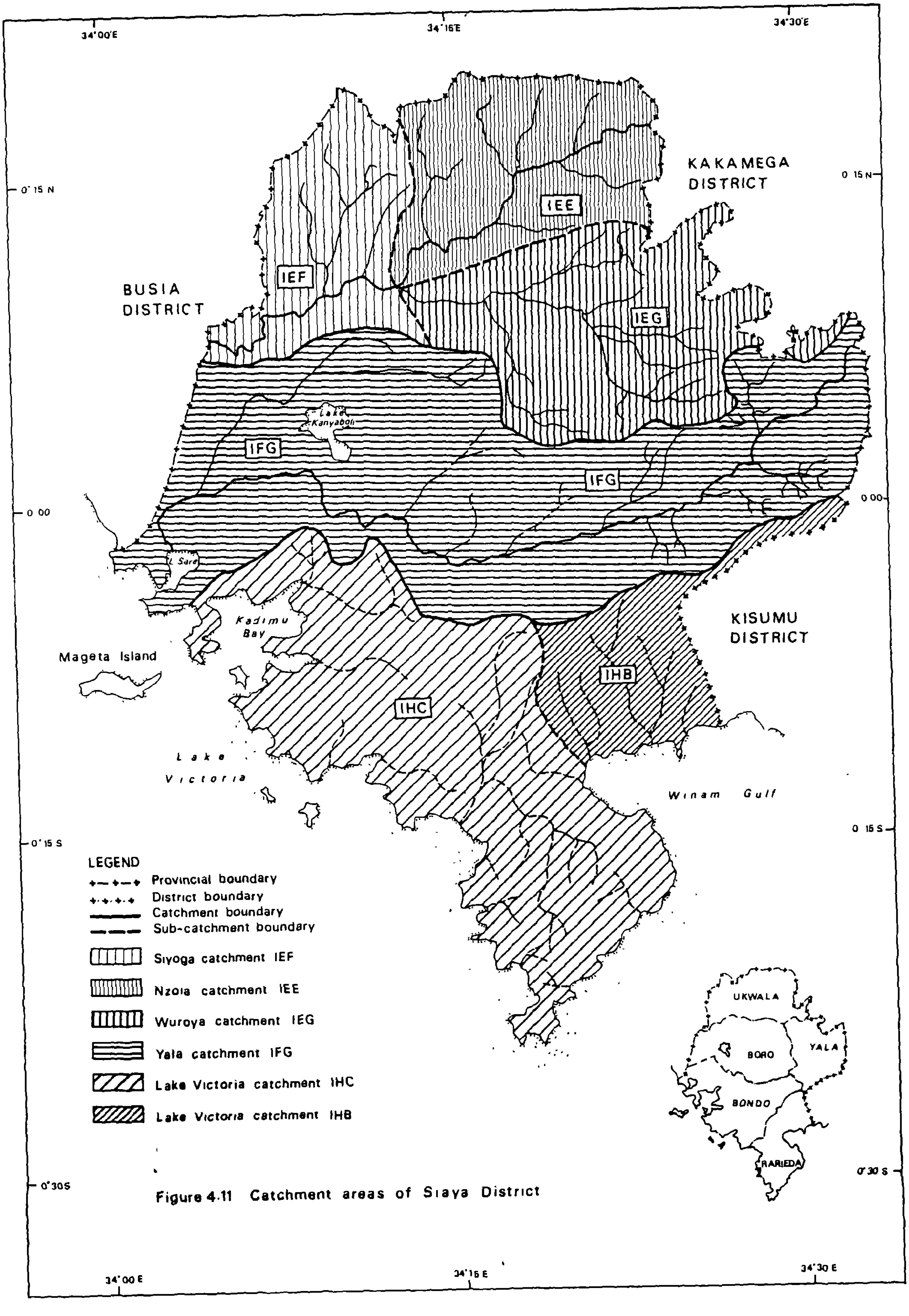
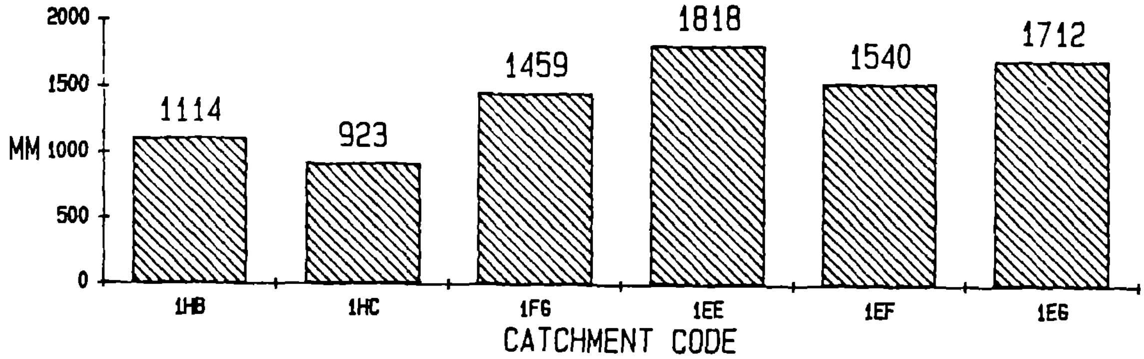


Figure 4.11 Catchment areas of Siaya District

Table 4.2. Rainfall figures for various stations in Siaya District

Station No.	Station Name	Altitude (m) above sea level	Latitude	Longitude	Years of Recording	Years of complete records	Mean Annual Rainfall (mm/year)	Remarks
08934031	St. Mary's Yala	1464	00 06' N	34 32' E	23	13	1950	
08934032	Rangala Sch.	1385	00 10' N	34 21' E	23	5	1846	
08934041	Yala Mwihila Sch.	1464	00 11' N	34 32' E	23	14	2102	
08934058	Sega Pri. Sch.	1230	00 16' N	34 14' E	23	10	2258	
08934059	Buholo Chief's Camp	1230	00 11' N	34 20' E	23	15	1828	
08934064	Ambira Chief's Camp	1260	00 11' N	34 17' E	23	4	1680	
08934083	Siaya	1342	00 04' N	34 18' E	6	0	-	No data
08934127	Ukwala D.O. Office	1256	00 12' N	34 12' E	20	12	1507	
08934140	Kadenge Swamp	1167	00 02' N	34 11' E	16	10	1155	
08934141	Malanga Chief's Cmp.	1524	00 08' N	34 26' E	14	11	1717	
08934153	Ujimbe Farm	1524	00 07' S	34 22' E	12	10	1643	
08934163	Sihay Chief's Camp	1250	00 15' N	34 15' E	8	3	1637	
08934164	Yiro Baraza Hall	1300	00 10' N	34 24' E	8	3	1767	
08934172	Board Harambee Sch.	1300	00 10' N	34 19' E	8	0	1490	
08934180	Muweri Chief's Camp	1260	00 07' N	34 12' E	6	2	-	Data unreliable
09034021	Bondo Usigu H. Centre	1235	00 07' S	34 06' E	23	14	-	Data unreliable
09034036	Bondo Water Supply	1220	00 03' S	34 17' E	19	13	1182	
09034022	Ongielo Asembo Disp.	1137	00 11' S	34 23' E	23	12	1113	
09034037	Akala Dispensary	1220	00 05' S	34 26' E	23	17	1540	
09034104	Nyangoma Mission	1220	00 09' S	34 11' E	15	11	1045	
09034083	Sakwa Ralingo	1310	00 05' S	34 20' E	23	2	1650	
09034117	Madiany Chief's Camp	1140	00 17' S	34 19' E	12	0	-	No data
09034128	Ramogi Forest Stat.	1137	00 03' S	34 02' E	10	7	1075	
09034140	Manyuanda Chief's Cmp.	1220	00 15' S	34 16' E	7	2	670	
09034141	Mahaya Chief's Camp	1220	00 09' S	34 10' E	7	1	846	
09034142	Lela Nyikeye C. Camp.	1220	00 13' S	34 15' E	5	1	746	

FIG. 4.12 MEAN ANNUAL RAINFALL PER CATCHMENT IN SIAYA DISTRICT



The seasonal distribution of rainfall is illustrated in Figure 4.13 where the mean monthly rainfall per catchment are plotted. The seasonal distribution generally is as follows.

Major rainy period	:	From March-May, with April usually being the month with the highest rainfall (150-250 mm/month).
Minor rainy period	:	During October-November. The mean rainfall during this period is 100-180 (mm/month).
Major dry period	:	From December-February, with December being the driest month with an average rainfal of 80-110 (mm/month).
Minor dry period	:	From June-September with July being the driest month of this period with a mean rainfall of 90-130 (mm/month).

FIG.4.13a MEAN MONTHLY RAINFALL IN SIAYA DISTRICT

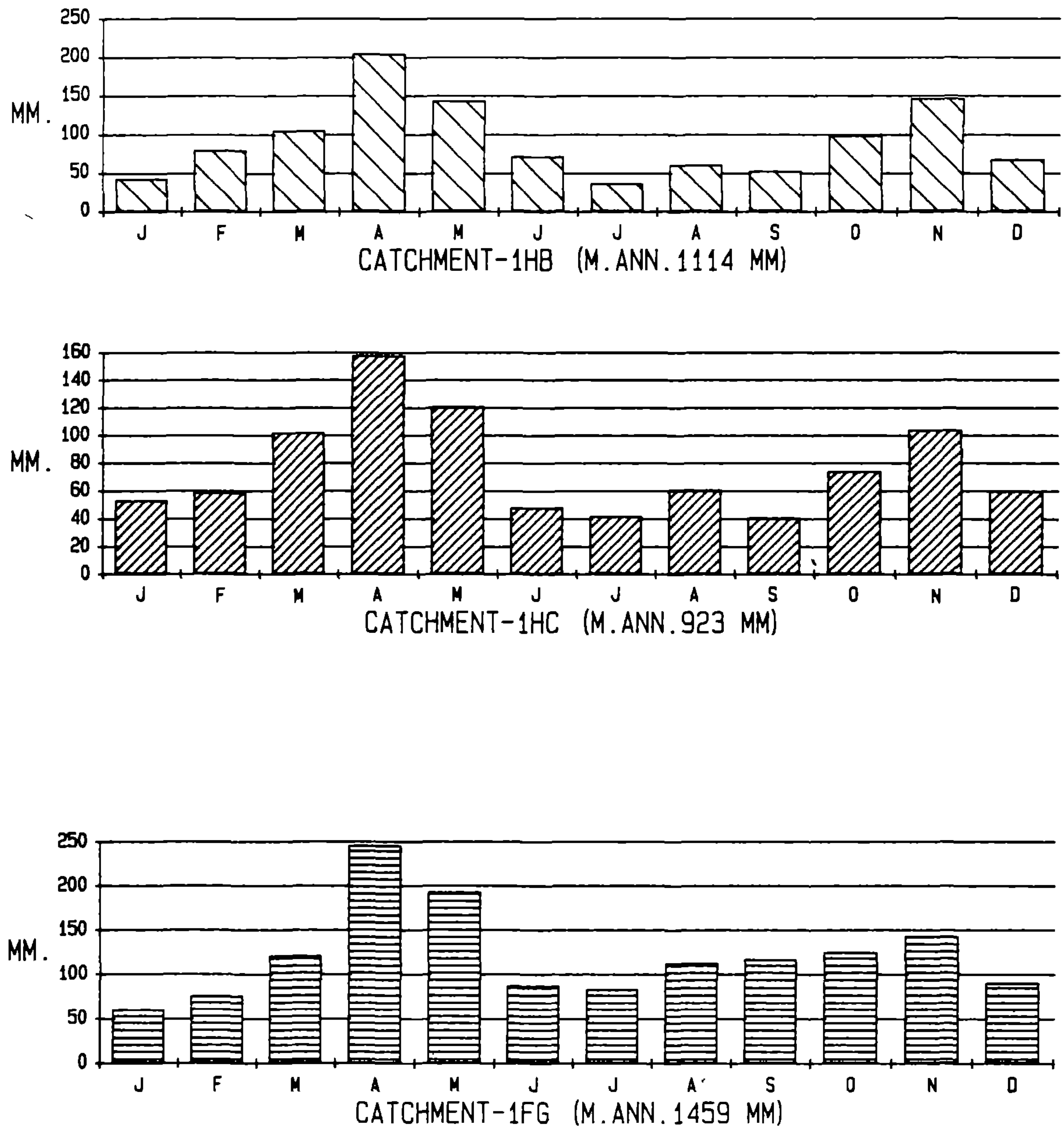
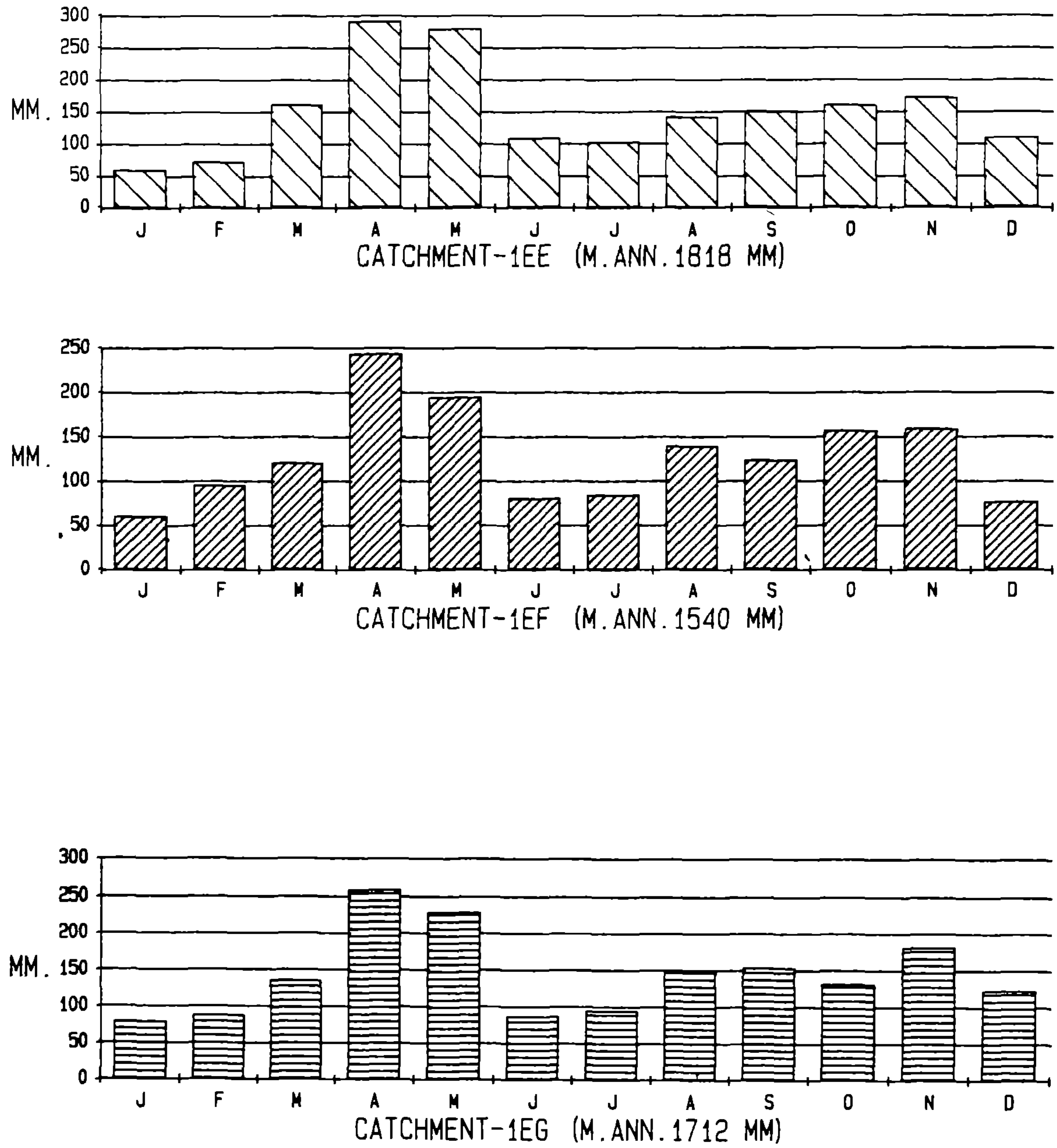


FIG 4 13b MEAN MONTHLY RAINFALL IN SIAYA DISTRICT



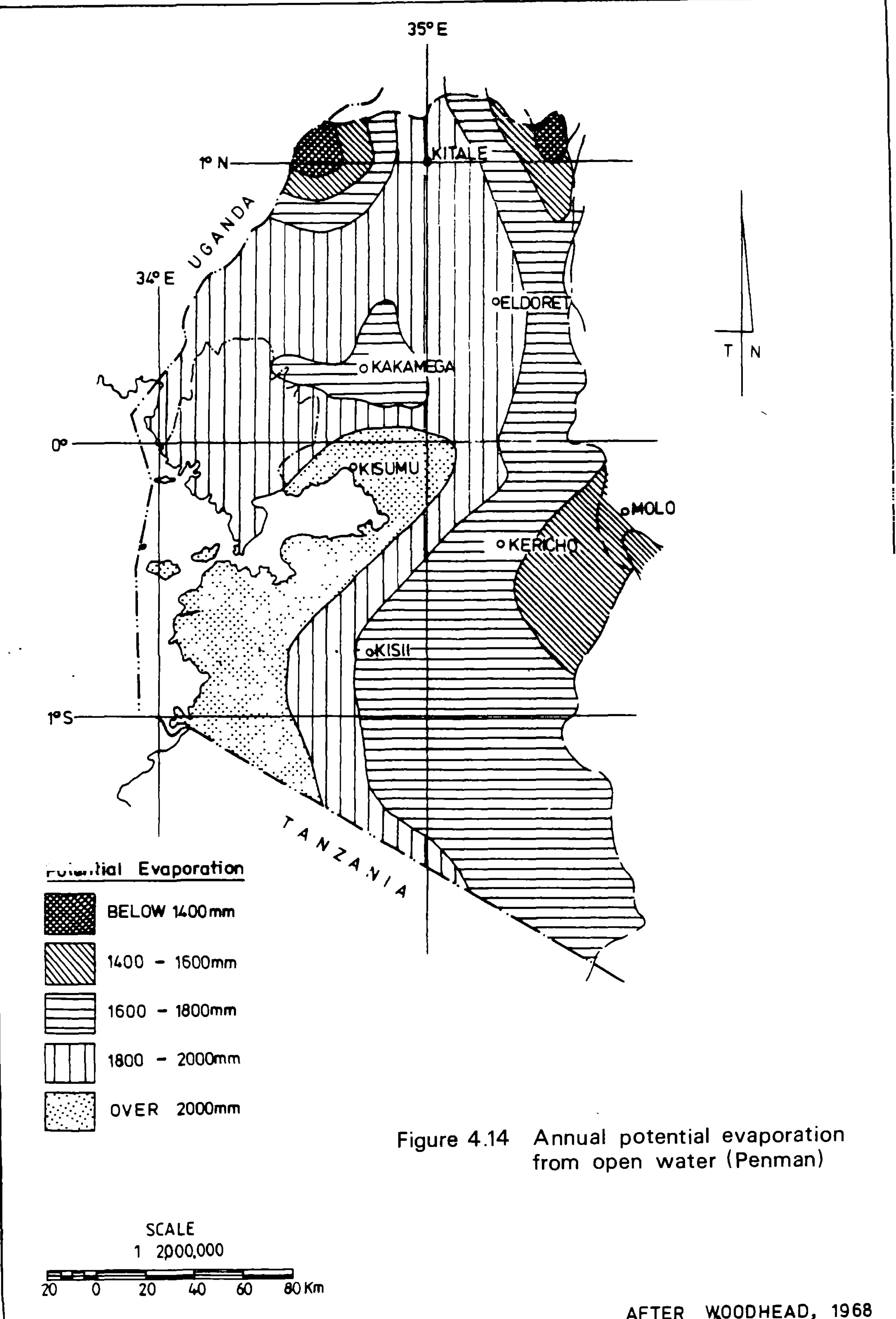


Figure 4.14 Annual potential evaporation from open water (Penman)

AFTER WOODHEAD, 1968

4.7.3. Surface runoff

Surface runoff is that part of precipitation which travels overland and through channels. After overland flow enters a stream channel, it becomes streamflow. However runoff is directly related with streamflow and is further discussed in Chapter 5 under "Surface water resources".
In this report runoff data from various sources have been used.

- Calculated runoff figures as presented by the Kenyan National Master Water Plan (TAMS, Ref.48.).
- Streamflow data calculated from discharge measurements elaborated and presented by the LBDA DATA CENTRE (HYMOS Ref.8.).

The mean annual runoff per catchment is as follows:

- catchment - 1EF: 418 (mm/year)
- catchment - 1EE: 611 (mm/year)
- catchment - 1EG: 529 (mm/year)
- catchment - 1FG: 401 (mm/year)
- catchment - 1HC: 150 (mm/year)
- catchment - 1HB: 306 (mm/year)

4.7.4. Evaporation

Annual and monthly potential evaporation from open water have been calculated for Kenya by Woodhead (Ref.56). Woodhead used "Penmans formula" and included corrections for altitude and latitude. Evaporation data have been used of a period from 1936 up till 1962. Based on these evaporation figures the Survey of Kenya has published a map showing "Annual Potential Evaporation from open water", for the whole of Western Kenya (Fig.4.14.).
According to this map an annual potential evaporation of about 1800-2000 (mm/year) is given for almost the entire area of Siaya District.

In addition daily evaporation data of two recording stations within the area have been analysed (Bondo Water Supply Met. Station and Kadenge Met. Station).
Both stations are operating for more than 10 years and have a rather complete series of records.
The mean monthly potential evaporation data of both stations are presented in Table 4.3

TABLE 4.3. EVAPORATION DATA MEASURED IN SIAYA DISTRICT

STATION	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	YEAR
KADENGE MET.ST.	153	142	152	119	116	109	119	128	138	142	125	137	1580
BONDO WAT. SUPPLY	175	172	184	151	148	139	137	158	162	154	145	155	1880
SIAYA DISTRICT	164	157	168	135	132	124	128	143	150	148	135	146	1730

For water balance calculations the average values of the two recording stations have been used as mean monthly and annual evaporation for all 6 catchment areas.

4.7.5. Soil moisture storage

When rainfall runoff and evaporation data are known for a particular catchment the amount of infiltrated water can be calculated as follows.

$$INF = P - Q - Ac \qquad (4.1)$$

INF = amount of infiltrated water (mm/year)
P = mean annual rainfall (mm/year)
Q = mean annual runoff (mm/year)
Ac = mean annual evapotranspiration (mm/year)

However not all infiltrated water will percolate to the permanent ground water. Part of it will remain in the sub-surface as soil moisture which may be evaporated in a later stage. After the soil moisture content reaches a saturation level, the excess water will percolate to the deeper ground water.

In the literature several values are given for the maximum soil moisture storage, ranging from 100-200 (mm) depending on the soil conditions (Woodhead, Ref 56; and Ker Priestman & Ass, Ref 24). Considering the grade and depth of weathering and soil types of Siaya District an average value of 120 (mm) is used for the catchments 1HB and 1HC, and 150 (mm) for the remaining four catchments.

4.7.6. Evapotranspiration

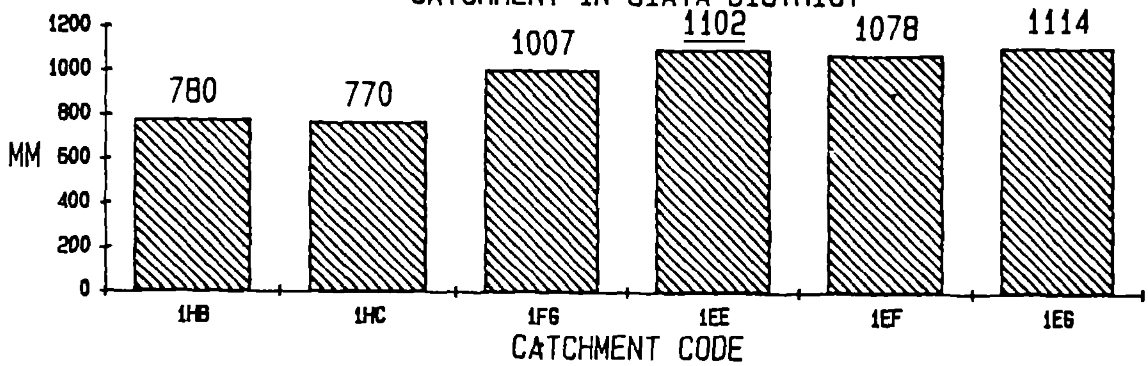
The potential evapotranspiration of a vegetated area is defined as the evapotranspiration that would occur if the soil moisture content would not be limited. According to the National Master Water Plan (Tams, Ref.48), it is usually expressed as a ratio of the open water evaporation, and amounts generally around 75 % of the open water evaporation in areas with permanent crops and about 80 % or more in hot and dry lowland areas (Siaya District).

Based on the potential monthly evapotranspiration (80%) as defined above, combined with the mean monthly rainfall and runoff data, the actual monthly evapotranspiration is calculated. All rainfall recording stations show that during most part of the year, the monthly potential evapotranspiration exceeds the mean monthly rainfall minus runoff except during the months April, May and occasionally October and November.

Taking into consideration that the actual monthly evapotranspiration can not exceed the monthly amount of rainfall plus the amount of excess soil moisture minus the amount of surface runoff the mean monthly actual evapotranspiration per catchment is as follows:

Catchment 1HB	:	780 (mm/year)
Catchment 1HC	:	770 (mm/year)
Catchment 1FG	:	1007 (mm/year)
Catchment 1EE	:	1102 (mm/year)
Catchment 1EF	:	1078 (mm/year)
Catchment 1EG	:	1114 (mm/year)

FIG.4.15. MEAN ANNUAL EVAPOTRANSPIRATION PER CATCHMENT IN SIAYA DISTRICT



4.7.7. Ground water recharge

When rainfall, runoff, soil moisture changes and evapotranspiration data are known, the amount of water which is yearly added to the permanent ground water can be estimated (recharge).
The recharge is calculated using a modification of formula 4.1:

$$R = P - Q - Ac + Sm \qquad (4.2)$$

R = yearly amount of recharge ground water
P = mean annual rainfall
Q = mean annual runoff
Ac = mean annual evapotranspiration
Sm = mean annual changes in soil moisture

or simplified:

$$R = P - Q - AE \qquad (4.3)$$

where AE = mean annual actual evaporation including changes in soil moisture.

With the calculation of recharge using the above formula some remarks have to be made:

- Inflow from adjacent areas and outflow of ground water are neglected. In case of Siaya District this is certainly incorrect. Generally some ground water will enter the District from the northeast and outflow will occur in the southern part of the area into Lake Victoria. However, the quantities are difficult to estimate.

- In the monthly recharge calculations, no considerations have been made about rainfall intensity and duration.

- For an accurate water balance calculation very precise and extensive hydrological data of the concerned area are required, which are rarely available. Consequently the present ground water balance study should be regarded as an estimation, which above all permits an understanding of the relations between the various factors that comprise it.

4.7.8. Recharge per catchment

Catchment 1HB

Mean annual rainfall in this catchment covering the southeastern part of Siaya District varies between 1000 and 1200 (mm/year) and is 1114 (mm/year) on an average. The total surface area of this catchment comprises about 177 (km^2). Mean annual runoff is 306 (mm/year) and the mean annual evapotranspiration is 780 (mm/year). The total amount of recharge is then calculated as follows:

R = P-Q-AE
= 1114-306-780
= 28 mm/year.

Total amount of recharge in the entire catchment is:

$$Rtot = A \times R \times 10^3 \quad (4.4)$$

Rtot = Total amount of annual recharge (m^3/year)
A = Total surface area (km^2)
R = Annual amount of recharged ground water (mm/year)

Rtot = $177 \times 28 \times 10^3$
= 4.9×10^6 (m^3/year)

Catchment 1HC

Total surface area = 615 (km^2)
Mean annual rainfall = 923 (mm/year)
Mean annual runoff = 150 (mm/year)
Mean annual evapotranspiration = 770 (mm/year)

R = P-Q-AE
= 923-150-770
= 3 (mm/year)

Rtot = $A \times R \times 10^3$
= $615 \times 3 \times 10^3$
= 1.8×10^6 (m^3/year)

Catchment 1FG

Total surface area = 887 (km^2)
Mean annual rainfall = 1459 (mm/year)
Mean annual runoff = 401 (mm/year)
Mean annual evapotranspiration = 1007 (mm/year)

R = P-Q-AE
= 1459-401-1007
= 51 (mm/year)

Rtot = $A \times R \times 10^3$
= $887 \times 51 \times 10^3$
= 45.2×10^6 (m^3/year)

Catchment 1EE

Total surface area = 233 (km^2)
Mean annual rainfall = 1818 (mm/year)
Mean annual runoff = 611 (mm/year)
Mean annual evapotranspiration = 1102 (mm/year)

R = P-Q-AE
= 1818-611-1102
= 105 (mm/year)

Water balance calculations for the catchments of Siaya District

WATER BALANCE OF SUB-CATCHMENT 1HC

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	YEAR
MEAN MONTHLY RAINFALL (P)	53	59	102	158	121	48	42	61	41	74	104	60	923
RUNOFF (Q)	7	8	14	35	24	7	7	9	6	10	15	8	150
INF=P-Q	46	51	88	123	97	41	35	52	35	64	89	52	773
PAN EVAPORATION (E0)	164	157	168	135	132	124	128	143	150	148	135	146	1,730
POT. EVAP. 80% (ETp)	131	126	134	108	106	99	102	114	120	118	108	117	1,384
ACT. EVAP. (ETa)	46	51	88	108	97	41	35	52	35	64	89	52	758
SOIL MOISTURE (MAX=120)													
SMi=SMf+INF	46	51	88	123	109	44	35	52	35	64	89	52	788
AE=ETpf	46	51	88	108	106	44	35	52	35	64	89	52	770
SMf=SMi-AE	0	0	0	12	3	0	0	0	0	0	0	0	15
RECHARGE (R)	0	0	0	3	0	0	0	0	0	0	0	0	3

WATER BALANCE OF SUB-CATCHMENT 1HB

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	YEAR
MEAN MONTHLY RAINFALL (P)	43	80	105	205	144	72	37	61	53	99	147	68	1,114
RUNOFF (Q)	15	18	32	57	45	25	18	19	11	16	27	23	306
INF=P-Q	28	62	73	148	99	47	19	42	42	83	120	45	808
PAN EVAPORATION (E0)	164	157	168	135	132	124	128	143	150	148	135	146	1,730
POT. EVAP. 80% (ETp)	131	126	134	108	106	99	102	114	120	118	108	117	1,384
ACT. EVAP. (ETa)	28	62	73	108	99	47	19	42	42	83	108	45	756
SOIL MOISTURE (MAX=120)													
SMi=SMf+INF	28	62	73	148	111	52	19	42	42	83	120	57	837
AE=ETpf	28	62	73	108	106	52	19	42	42	83	108	57	780
SMf=SMi-AE	0	0	0	12	5	0	0	0	0	0	12	0	29
RECHARGE (R)	0	0	0	28	0	0	0	0	0	0	0	0	28

WATER BALANCE OF SUB-CATCHMENT 1FG

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	YEAR
MEAN MONTHLY RAINFALL (P)	61	77	121	246	193	88	84	113	117	125	143	91	1,459
RUNOFF (Q)	13	18	27	61	69	41	21	27	25	31	46	22	401
INF=P-Q	48	59	94	185	124	47	63	86	92	94	97	69	1,058
PAN EVAPORATION (E0)	164	157	168	135	132	124	128	143	150	148	135	146	1,730
POT. EVAP. 80% (ETp)	131	126	134	108	106	99	102	114	120	118	108	117	1,384
ACT. EVAP. (ETa)	48	59	94	108	106	47	63	86	92	94	97	69	963
SOIL MOISTURE (MAX=150)													
SMi=SMf+INF	48	59	94	185	166	91	63	86	92	94	97	69	1,144
AE=ETpf	48	59	94	108	106	91	63	86	92	94	97	69	1,007
SMf=SMi-AE	0	0	0	42	44	0	0	0	0	0	0	0	86
RECHARGE (R)	0	0	0	35	16	0	0	0	0	0	0	0	51

Rtot = A x R x 10^3
= 233 x 105 x 10^3
= 24.5 x 10^6 (m^3/year)

Catchment 1EF

Total surface area = 238 (km^2)
Mean annual rainfall = 1540 (mm/year)
Mean annual runoff = 418 (mm/year)
Mean annual evapotranspiration = 1078 (mm/year)

R = P-Q-AE
= 1540-418-1078
= 44 (mm/year)

Rtot = A X R x 10^3
= 238 x 44 x 10^3
= 10.5 x 10^6 (m^3/year)

Catchment 1EG

Total surface area = 337 (km^2)
Mean annual rainfall = 1712 (mm/year)
Mean annual runoff = 529 (mm/year)
Mean annual evapotranspiration = 1114 (mm/year)

R = P-Q-AE
= 1712-529-1114
= 69 (mm/year)

Rtot = A x R x 10^3
= 337 x 69 x 10^3
= 23.3 x 10^6 (m^3/year)

Water balance calculations for the catchments of Siaya District

WATER BALANCE OF SUB-CATCHMENT 1EE

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	YEAR
MEAN MONTHLY RAINFALL (P)	60	73	162	292	280	109	103	143	152	161	173	110	1,818
RUNOFF (Q)	14	18	59	101	108	53	23	38	47	51	62	37	611
INF=P-Q	46	55	103	191	172	56	80	105	105	110	111	73	1,207
PAN EVAPORATION (EO)	164	157	168	135	132	124	128	143	150	148	135	146	1,730
POT. EVAP. 80% (ETp)	131	126	134	108	106	99	102	114	120	118	108	117	1,384
ACT. EVAP. (ETa)	46	55	103	108	106	56	80	105	105	110	108	73	1,055
SOIL MOISTURE (MAX=150)													
SMi=SMf+INF	46	55	103	191	214	100	81	105	105	110	111	76	1,298
AE=ETpf	46	55	103	108	106	99	81	105	105	110	108	76	1,102
SMf=SMi-AE	0	0	0	42	44	1	0	0	0	0	3	0	91
RECHARGE (R)	0	0	0	41	64	0	0	0	0	0	0	0	105

WATER BALANCE OF SUB-CATCHMENT 1EF

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	YEAR
MEAN MONTHLY RAINFALL (P)	61	96	121	244	195	81	85	140	124	157	159	77	1,540
RUNOFF (Q)	14	23	26	71	66	25	19	36	33	41	45	19	418
INF=P-Q	47	73	95	173	129	56	66	104	91	116	114	58	1,122
PAN EVAPORATION (EO)	164	157	168	135	132	124	128	143	150	148	135	146	1,730
POT. EVAP. 80% (ETp)	131	126	134	108	106	99	102	114	120	118	108	117	1,384
ACT. EVAP. (ETa)	47	73	95	108	106	56	66	104	91	116	108	58	1,028
SOIL MOISTURE (MAX=150)													
SMi=SMf+INF	47	73	95	173	171	100	67	104	91	116	114	64	1,216
AE=ETpf	47	73	95	108	106	99	67	104	91	116	108	64	1,078
SMf=SMi-AE	0	0	0	42	44	1	0	0	0	0	6	0	94
RECHARGE (R)	0	0	0	23	21	0	0	0	0	0	0	0	44

WATER BALANCE OF SUB-CATCHMENT 1EG

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	YEAR
MEAN MONTHLY RAINFALL (P)	79	88	136	259	228	87	95	149	154	132	182	123	1,712
RUNOFF (Q)	16	23	56	79	81	39	21	32	34	39	68	41	529
INF=P-Q	63	65	80	180	147	48	74	117	120	93	114	82	1,183
PAN EVAPORATION (EO)	164	157	168	135	132	124	128	143	150	148	135	146	1,730
POT. EVAP. 80% (ETp)	131	126	134	108	106	99	102	114	120	118	108	117	1,384
ACT. EVAP. (ETa)	63	65	80	108	106	48	74	114	120	93	108	82	1,061
SOIL MOISTURE (MAX=150)													
SMi=SMf+INF	63	65	80	180	189	92	74	117	123	96	114	88	1,281
AE=ETpf	63	65	80	108	106	92	74	114	120	96	108	88	1,114
SMf=SMi-AE	0	0	0	42	44	0	0	3	3	0	6	0	98
RECHARGE (R)	0	0	0	30	39	0	0	0	0	0	0	0	69

4.8. AVAILABLE GROUND WATER RESOURCES

Based on the water balance calculations carried out per catchment the total ground water potential can be estimated (Table 4.4.).

TABLE 4.4. GROUND WATER POTENTIAL IN SIAYA DISTRICT

CATCHMENT NAME	CATCHMENT CODE	SURFACE AREA IN (KM^2)	TOTAL VOL. GROUND WATER 10^6 (M^3/YEAR)	TOTAL VOL. GROUND WATER PER WELL* (M^3/DAY)
LAKE VICTORIA E.	1HB	177	4.9	60
LAKE VICTORIA W.	1HC	615	1.8	6.3
YALA	1FG	887	45.2	110
NZOIA	1EE	233	24.5	226
SIYOGA	1EF	238	10.5	95
WUOROYA	1EG	337	23.3	150
SIAYA DISTRICT		2487	110.2	95

*Remark: The last column gives the theoretically available ground water per well per day, assuming one well covers an area with a radius of 500 (m) which means one well per 0.785 (km^2)

When comparing this total amount of available ground water (110 x 10^6 m^3/year) with the total population of Siaya District (690,000), then it results that on an average about 436, liters/capita/day is available.

However, as can be observed from Table 4.4. ground water resources are not homogeneously spread over the entire area. Relatively little ground water is available in the southern part of the District and abundant ground water seems to be present in the catchment areas covering the northern and northeastern part of the District.
Roughly 3 zones can be distinguished (Figure 4.16.).

- Zone 1, poor ground water potential.
- Zone 2, intermediate ground water potential.
- Zone 3, good ground water potential.

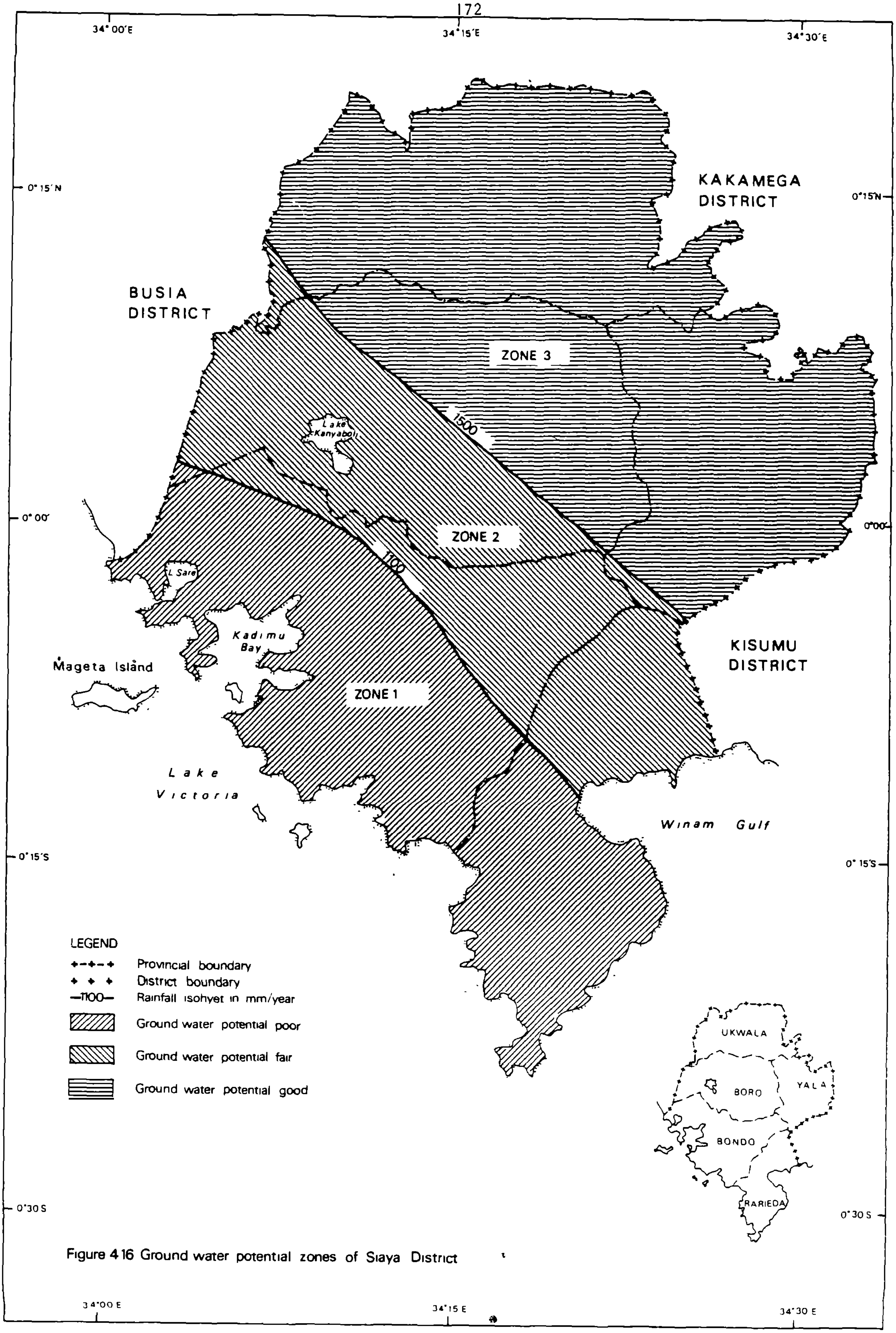


Figure 4.16 Ground water potential zones of Siaya District

4.8.1. Ground water resources in Zone 1

Location
The area of Zone 1 covers roughly the south and south western part of the District, including most part of Bondo Division and the Uyoma Peninsula of Rarieda Division. The area is defined by the 1100 (mm) mean annual rainfall isohyet and coincides with the catchment area - 1HC.

Hydrogeology
The entire area is underlain with hard rocks of mainly volcanic origin. The mean annual rainfall ranges between 700 (mm) near the Lake Victoria shore to 1100 (mm) at its northern boundary. Recharge calculations for this area resulted in a very low figure (3 (mm)) with a total yearly amount of about 1.8×10^6 (m^3/year). Assuming one well is constructed per area with a radius of 500 (m), which means one well per 0.785 (km^2), only 6.3 (m^3/day) or 262.5 (lts/hr) is available. This amount even if all can be used, is not sufficient to supply any type of well.

Existing ground water supplies
Very few wells and springs are found in this zone 1:

7 springs (from which 3 dry up)
11 wells (from which 3 dry up and 3 have high salinity)
14 boreholes (from which 8 are dry)

The above poor list of ground water resources confirms the absence of ground water in large parts of this area. A further complication is the ground water quality, which is very poor, due to salinity in vast areas along the Lake Victoria shore (see Fig. 4.18.).

Ground water development possibilities
The ground water potential in Zone 1 can be qualified as very poor.
Shallow ground water (5-15 m) is totally absent in Uyoma Peninsula and in large areas of Bondo Division. In the areas along the Lake Victory shore where usually shallow ground water occurs, it appears frequently to be unsuitable for consumption due to it's high salinity.
Deep ground water may be present in the major fault structures, however, from the 11 boreholes the RDWSSP drilled mostly in faults zones spread over the area, resulted that at 7 sites no or insufficient ground water was available.

Summarizing the ground water opportunities in Zone 1 it can be concluded that almost no prospects for ground water development in this area exist.

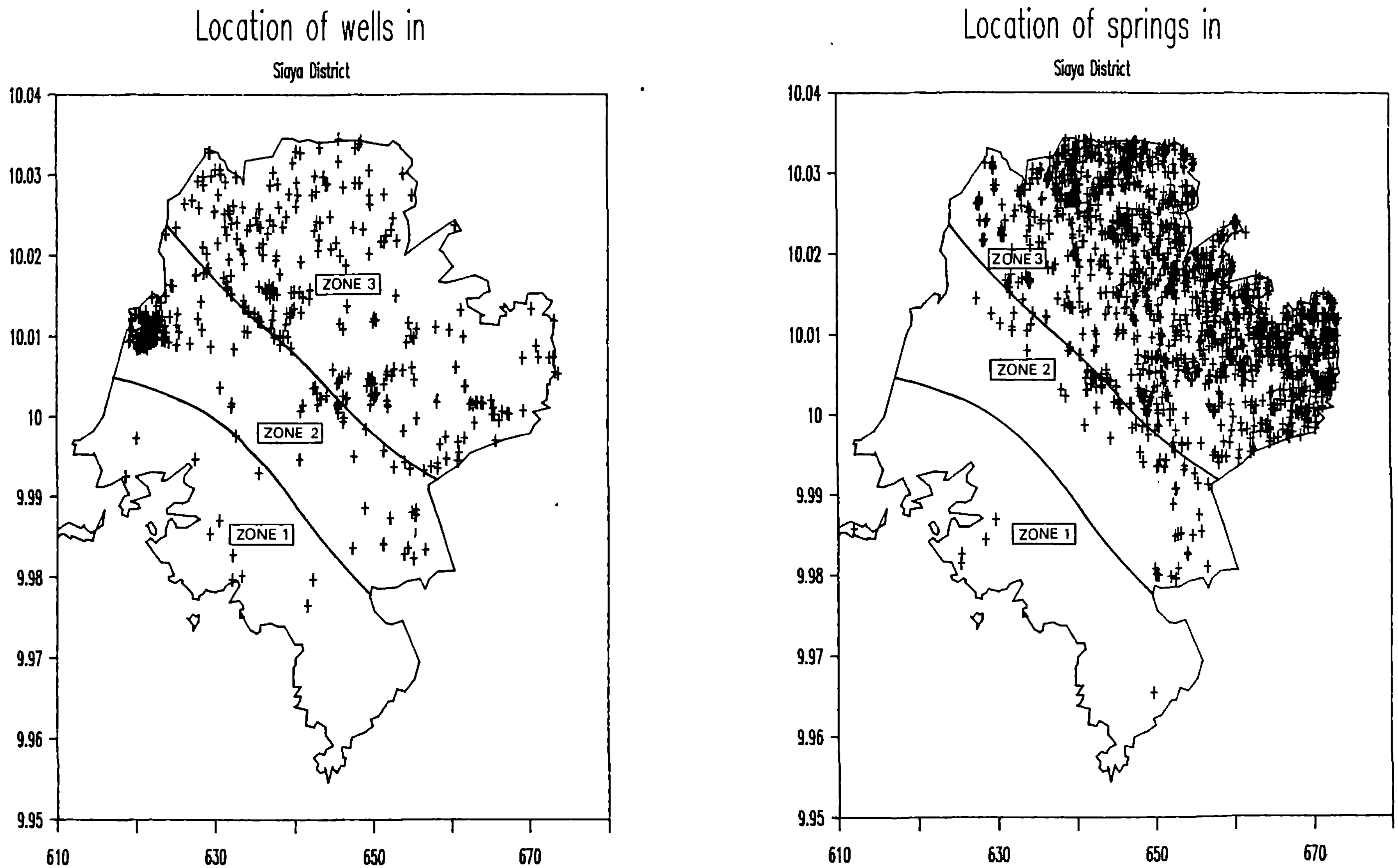


Figure 4 17 Distribution of existing wells and springs per ground water potential zone

4.8.2. Ground water resources in Zone 2

Location

The area of Zone 2 is defined by the rainfall isohyet of 1500 (mm) in the north and of 1100 (mm) in the south (Fig. 4.16). The zone covers western and southern Boro Division and Asembo of Rarieda Division, roughly coinciding with the catchment 1HB (Asembo) and the western part of catchment 1FG.

Hydrogeology

The western part of Zone II consist of a large swampy area (Yala Swamp) covered with alluvial sediments. The remaining part of the area is underlain by mainly volcanic hard rocks of Precambrian age. From the southwest there is a gradual increase of mean annual rainfall from 1100 to 1500 (mm) in a northeastward direction. A fair amount of annual recharge takes place resulting in about 40-60 (m^3/day) ground water available per theoretical well site (of 0.785 km^2).

On an average the potential available amount of ground water therefore generally will be sufficient for domestic water supply wells.
Shallow ground water (3-10 m) is present in the sedimentary deposits in the western part of the area. However due to intense evaporation and long retention time of the ground water the EC-values of the water are rather high and quite often the ground water is too saline for human consumption (EC>2500 u/cm).
In the remaining part of the area ground water is commonly present in hydrogeologically favourable areas (broad valleys and lower slopes) at relatively shallow depth.

Existing ground water supplies

Zone 2 forms a transition zone between zone 1 with virtually no ground water abstraction points and zone 3 were a great density of wells and springs occurs (Fig. 4.17).
Wells are found scattered over the entire area and in particular in the extreme western corner, covering Usonga Location with more than 140 wells.

Springs which indicate shallow ground water are mostly found in the northern and eastern part of this zone 2.
Ground water level as measured in the wells ranges from the 3-12 (m-gl) and is about 6 (m-gl) on an average.

Ground water development possibilities

The ground water potential in Zone 2 is fair to good. Generally an increase in ground water potential can be observed from the south towards the northeast part of the area.
Shallow ground water is present almost everywhere throughout the area at depths rarely exceeding 10 (m-gl).
In and around the Yala Swamp area ground water can be saline due to evaporation effects. In most parts of the area ground water can be abstracted through hand dug wells. At a number of locations ground water will be too deep for well digging and a machine drilled borehole is required.

4.8.3. Ground water resources in Zone 3

Location

Zone 3 covers the northern and northeastern part of Siaya District, including Ukwala and Yala Divisions and the northeast part of Boro Division. The area covers the catchments 1EE, 1EF, 1EG and part of 1FG.

Hydrogeology

The area is underlain mostly by Kavirondian Precambrian sedimentary rocks and minor volcanics and intrusives. The mean annual rainfall varies from 1500 (mm) in the south to about 2000 (mm) in the north and northeastern part of the area. In Table 4.4 it was shown that the catchments covering this area have a good amount of recharge, with generally more than 100 (m^3/day) of ground water available per theoretical well site of 0.785 (km^2).

Abundant ground water is therefore available for ground water abstraction wells and boreholes. Shallow ground water is abundantly available within the weathered layer and large quantities of deeper ground water is available in major faults and fracture zones.

Existing ground water supplies

As is shown in Fig. 4.17. abundant springs, wells, and boreholes can be found in this area:

- 1400 springs, of which more than 1000 perennial
- 250 wells, of which more than 200 perennial
- 125 boreholes, of which 110 are productive

Wells are spread equally over the area and commonly are rather shallow, about 7-8 (m-gl) on an average.
Springs are found in all parts of Zone 3 but tend to be more numerous towards the north and northeastern part of the area.
Ground water available from springs amounts to about 15.5 x 10^6 (m^3/year), which is about 10 times the total available ground water in Zone 1.
Boreholes have been constructed almost exclusively in Ukwala Division. In most of the boreholes which are spread over the entire area of Ukwala Division ground water was encountered at an average depth of 30 (m-gl) with an average static water level of about 15 (m-gl)

Ground water development possibilities

The ground water potential of Zone 3 can be qualified as excellent. Everywhere ground water is present and often at shallow depth (5-10 mg-l). Throughout the area hand dug wells can be constructed. No saline ground water has been found in this area. Large amounts of ground water are also present at the deeper fault and fracture aquifers which can be exploited through machine drilled boreholes. However generally already sufficient ground water is present within the weathered layer for a hand dug well. It is therefore only in rare occasions necessary to construct a machine drilled borehole as rural domestic water supply.

4.9 GROUND WATER QUALITY

4.9.1. Introduction

An appraisal of the physical quality (odour, colour) and the measurement of pH an EC was carried out for every water point recorded during the inventory surveys in the 5 Divisions.
In addition chemical analyses were carried out on 93 existing wells, 186 springs and 84 boreholes (Ukwala Division)

Tested parameters are:

- turbidity
- alkalinity
- hardness
- iron
- manganese
- chloride
- fluoride
- nitrate
- feacal coliforms

In this project the Kenyan Standards of Quality for Domestic Water have been used.
The parameters most relevant to the project have been summarized in Table 4.5.

4.9.2. Results and conclusions

Electrical conductivity (EC)

The electrical conductivity of water is the ability to conduct an electric current. Pure water has a very low electrical conductivity, but when charged ions are in solution the water becomes conductive. As ion concentrations increase, conductivity increases. A high ion concentration in water is commonly caused by a large amount of dissolved salts.

EC values have been measured for all water points recorded during the inventory survey.

From the distribution of the EC-values of all the ground water resources as springs, wells and boreholes, the following conclusions can be drawn:

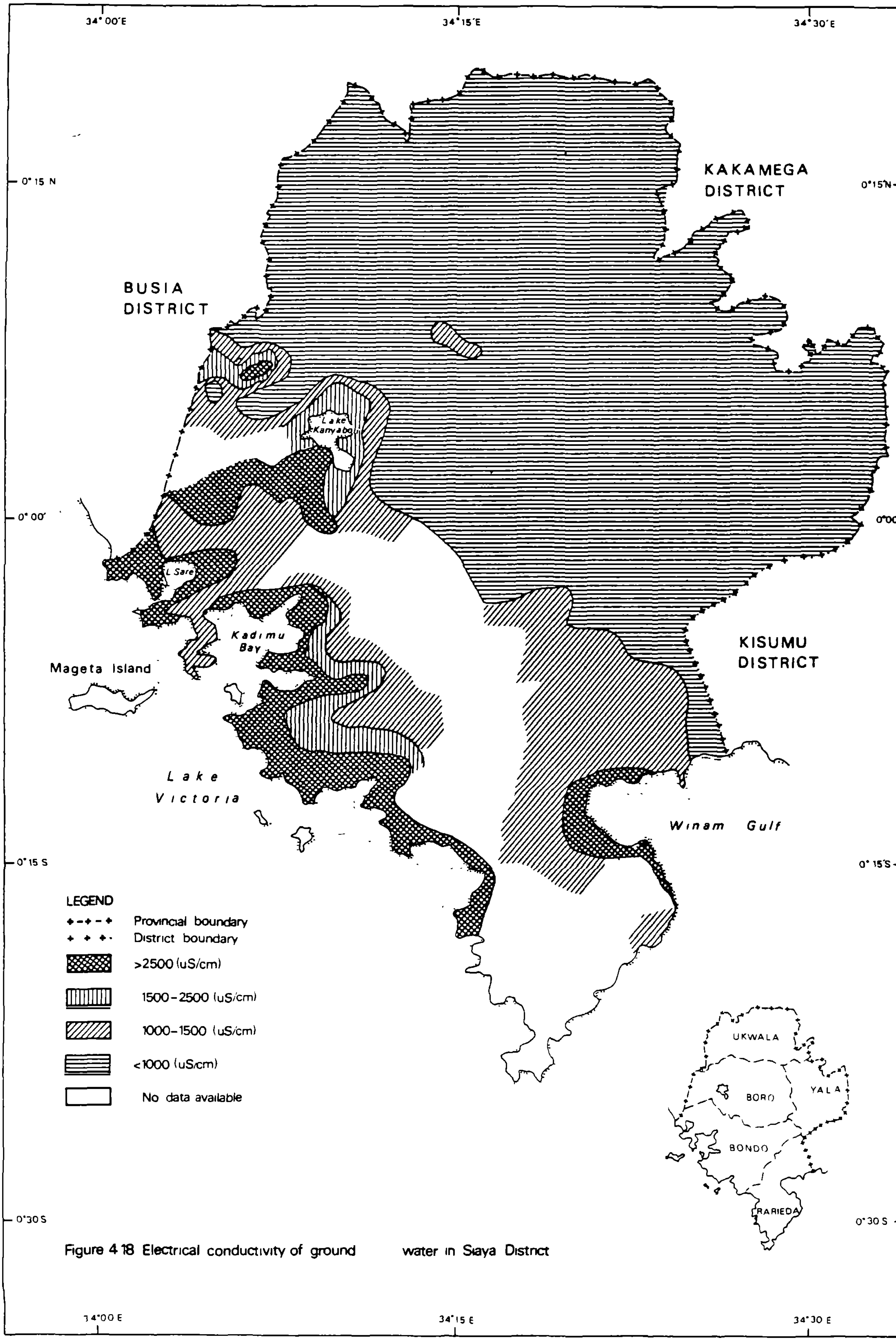


Figure 4 18 Electrical conductivity of ground water in Siaya District

Table 4.5. Summary of most relevant water quality standards for rural domestic water supply in Kenya

Quality parameter	Kenyan Standard
Physio-chemical parameters	
Electrical conductivity at 25 C (EC)	2500 (us/cm)
Total dissolved solids (TDS)	1500 (mg-1.)
pH	6.5-8.5
Colour	50 (mg pt/l)
Turbidity	25 (NTU)
Chemical parameters affecting human health	
Fluoride	1.5 (mg/l)
Nitrate	30 (mg/l)
Chemical parameters affecting salinity	
Total hardness	500 (mg/l)
Alkalinity	not mentioned
Calcium	200 (mg/l)
Magnesium	150 (mg/l)
Chloride	600 (mg/l)
Sulphate	600 (mg/l)
Phosphate	not mentioned
Non-toxic metals	
Iron	1.0 (mg/l)
Manganese	0.5 (mg/l)
Organic pollution	
Ammonia	not mentioned
Permanganate	10 (mg/l)
Bacteriological parameters	
E-coli	MPN/100 (ml)

- Ground water with high EC-values (>2500 uS/cm) is found in large areas along the Lake Victoria shore of Rarieda and Bondo Divisions. In western Boro Division locally high EC-values are recorded from shallow ground water present near Lake Kanyaboli and the Yala Swamp.

- Average EC-values decrease gradually in a north and northeastward direction.

- In Ukwala and Yala Divisions nowhere saline ground water is found.

The average EC-values per Division are illustrated in Table 4.6.A and B.

pH-values

From all existing water points pH values have been measured. The values range from 6.0 to 7.0 which is well within the recommended Kenyan Standard.

Other chemical parameters

In general it can be concluded that the ground water in Siaya District is chemically safe and fit for human consumption. The toxic chemical constituents Nitrate and Fluoride were nowhere measured in concentrations exceeding the Kenyan Standards. At a number of samples iron and manganese concentrations were found slightly higher than the recommended standards. However both iron and manganese are not harmful for human health and will only affect the taste of the drinking water or in higher concentrations may cause stains on laundry.

Feacal coliforms

Ground water samples tested for feacal coliforms from wells and boreholes with a proper slab and functioning hand pump was found not contaminated. The same applies for the proper protected springs which were found free of feacal coliforms.
However wells without a cover or slab and unprotected springs frequently have contaminated ground water due to contamination on the collection spot.

TABLE 4.6.A. SUMMARY OF CHEMICAL ANALYSES ON WELLS IN SIAYA DISTRICT

DIVISION	NR. OF WELLS	NR. OF CHEMIC. TESTS	AVERAGE EC (uS/CM)	NR. OF BACTER. TESTS	NR. OF BACTER. POLLUT.
BONDO	14	7	1230	7	6
RARIEDA	17	4	530	4	2
BORO	282	29	642	19	14
YALA	50	19	256	15	4
UKWALA	119	34	288	34	0
SIAYA DISTRICT	482	93	528	79	26

TABLE 4.6.B. SUMMARY OF CHEMICAL ANALYSES ON SPRINGS IN SIAYA DISTRICT

DIVISION	NR. OF SPRINGS	NR. OF CHEMIC. TESTS	AVERAGE EC (uS/CM)	NR. OF BACTER. TESTS	NR. OF BACTER. POLLUT.
BONDO	15	13	580	13	9
RARIEDA	23	9	307	9	8
BORO	202	19	257	14	10
YALA	671	133	136	68	16
UKWALA	691	12	131	9	2
SIAYA DISTRICT	1602	186	156	113	45

PART V

SURFACE WATER SURVEY

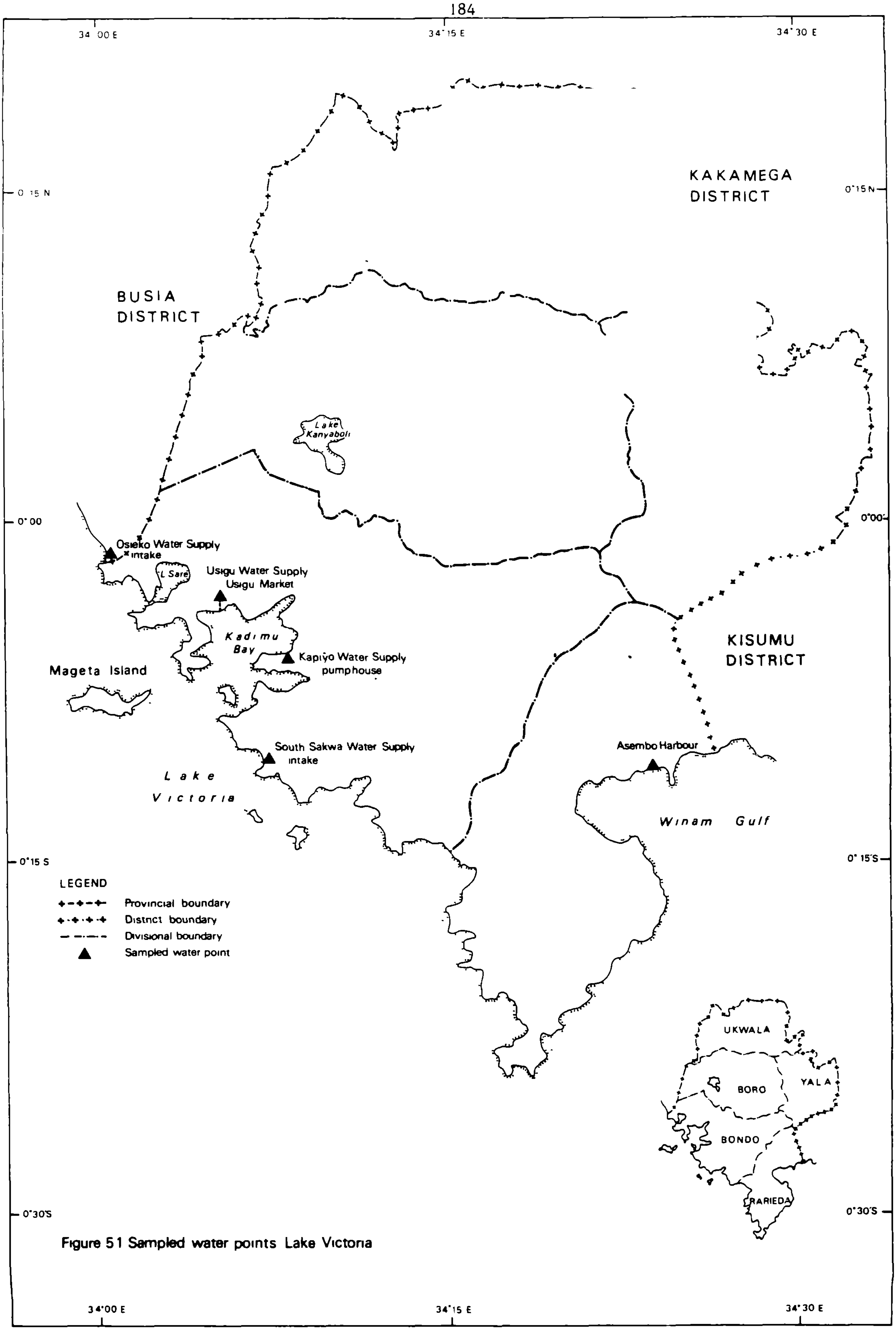


Figure 5.1 Sampled water points Lake Victoria

5.1. INTRODUCTION

Lake Victoria, Lake Kanyaboli and the major perennial rivers in Siaya District have been surveyed in order to assess the opportunities to use these surface water sources for piped water supply. The purposes of use of Lake Victoria , the water pollution and the water quality of the Lake are discussed in section 5.2.
Section 5.3 deals with the water quality of Lake Kanyaboli.
Section 5.4 gives a review of the minimum flows of the major rivers in Siaya District as well as a review of the results of water quality analyses as done for these rivers.
Section 5.5 gives a summary of the results of the surface water survey.

5.2. LAKE VICTORIA

5.2.1. Use of lake water

Lake Victoria water is used for domestic purposes, for cattle watering and for small scale irrigation. Apart from a gold processing plant at Asembo, there are no industries which pump water from the Lake or dispose waste water to it. Small fishing centres are found all along the Lake shore, in particular in West and Central Yimbo and the western shore of the Uyoma peninsula. Misori and Luanda Kotieno are major market centres where fish is sold.

5.2.2. Water pollution

Water pollution was monitored during a survey of the Lake Victoria shores done in November 1987. A boat with an outboard engine was used to follow the coast line from Osieko at the boundary with Western Province up to Kokise School near the District boundary with Kisumu. Locally the water along the shores is contaminated due to washing and cattle watering. Sincere surface water pollution was not found. There are no sewers or drainage channels through which waste water is flushed to the Lake.
The gold processing plant near Asembo, uses water to wash grinded rock. The effluent is flushed to sedimentation basins having an overflow to the Lake.

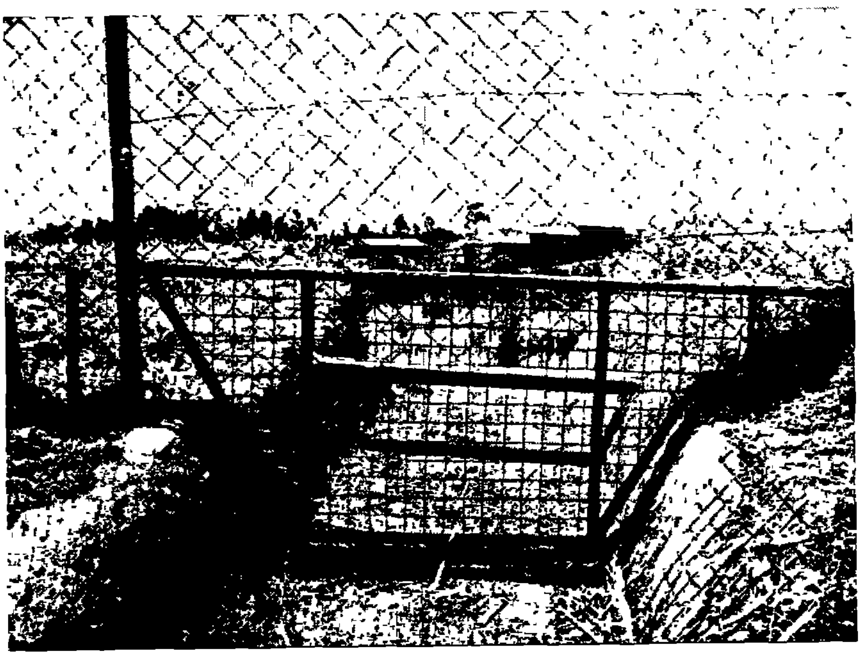
5.2.3. Water quality

In 1981-1982 water samples were taken at 4 different points along the Lake. (see Fig. 5.1.). Sampling was done as a part of the Sakwa Water Supply Project (Ref. 7.).
The samples were taken:

- near the intake of South Sakwa Water Supply,
- near the intake of Osieko Water Supply
- at Usigu Market (Usigu Water Supply),
- at the pump house of Kapiyo Water Supply.

Sedimentation basin.

Gold processing plant Asembo, Rarieda Division.



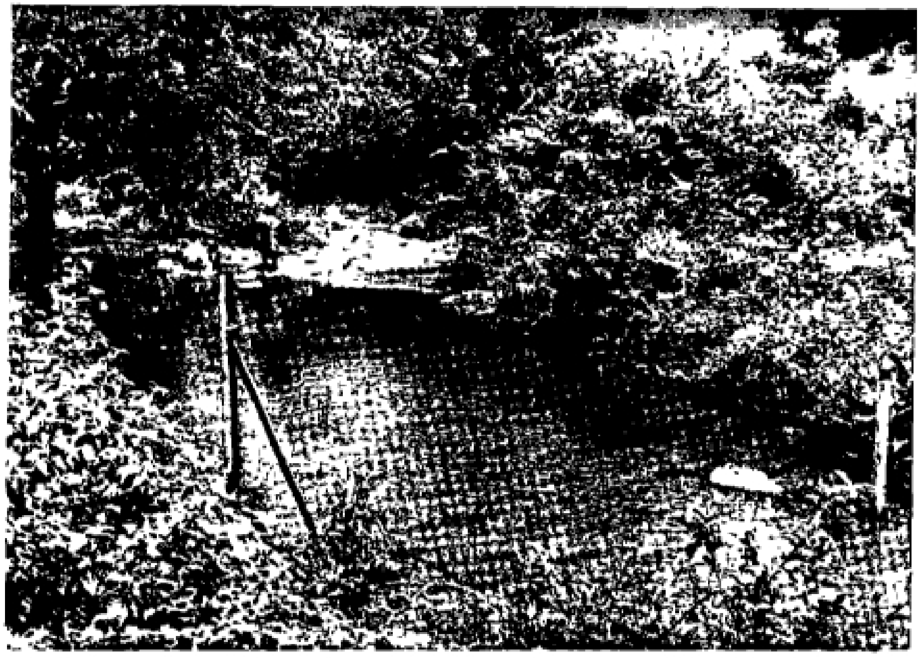
Spillway sedimentation basins.

The results of the water quality analyses are summarized in Annex 5.1.
The chemical constituents of the Lake water are within the Kenyan standards for drinking water supply. Only the iron and manganese concentrations were incidentally found to be too high.
The bacteriological quality of the water was not checked.

In 1975 samples were taken from Asembo Bay (Ref. 38). This was done at 3 different points along the shore and 13 different points offshore (up to 500 m from the Asembo harbour pier).
The results of the water quality analyses are also summarized in Annex 5.1.
The water was found to be slightly alkaline (pH ranging from 7.0-8.3), soft (total hardness ranging from 30-58 mg/l $CaCO_3$) and moderately mineralised (EC ranging from 90-180 uS/cm).
None of the chemical constituents were beyond Kenyan standards.
The colour and turbidity of the water were found to be low (colour = 30 Hazen units; turbidity 3 JTU). The water was found to be contaminated. Out of 13 water samples taken offshore 7 samples showed a bacteriological contamination ranging from 2-14 E-coli colonies/100 ml.

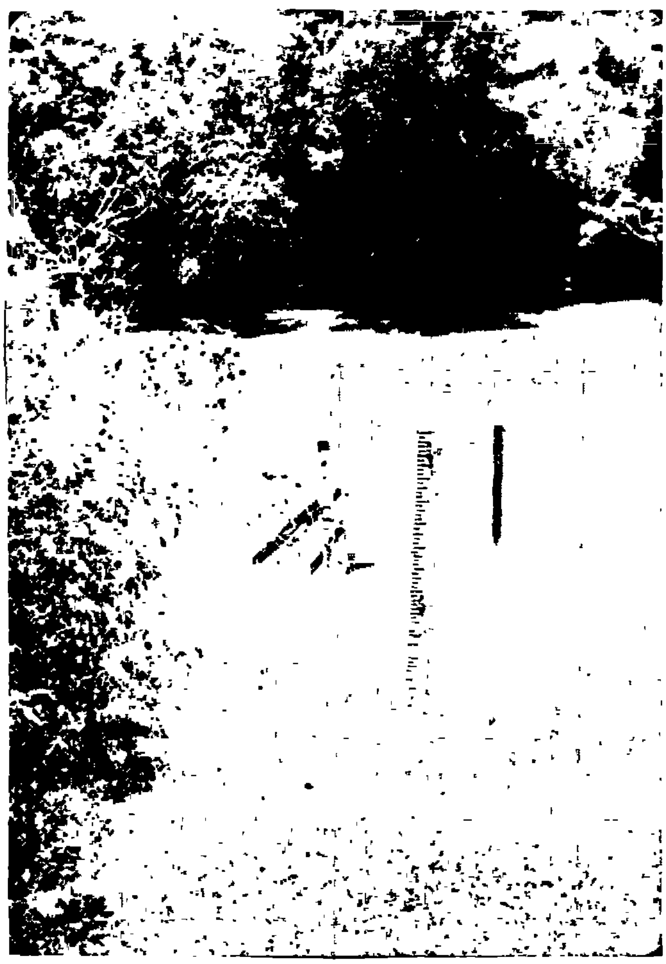
In 1984 and 1985 , both the Winam Gulf as well as the main Lake were surveyed to determine the environmental habitat conditions and the influence of river water induced pollution (Ref. 59).
During the first survey a clear difference was found between the Winam Gulf and the main Lake. The main Lake was found to have a better quality than the Winam Gulf. Only the shallow parts of the Winam Gulf (Kisumu Bay and the river mouths of Kibos,Nyando and Sondu/Miriu) are critical (mesotrophic with respect to Total N and Total P)
The second survey in 1985 revealed that in contrast to the situation observed one year before in the Winam Gulf , the waters of Nzoia and Yala rivers appeared to dilute the main Lake. A phenomena which however might be seasonal.
A problem observed all over the Lake , but in particular near the river mouths , are bloom causing blue-green algae (Microcystis Cyanophyta). These algae blooms might cause water treatment problems. Blue green algae are also known to produce toxins which are harmful to both the aquatic life as well as man.

Based on the results of the boat survey , the water quality analyses as done in the past and the more recent observations with respect to aquatic live conditions , it is concluded that Lake Victoria can be used as a source for piped water supply.
Raw water storage basins could be of great importance in order to bridge periods in which algae blooms impede the intake of water from the Lake. Moreover these basins could be used for plain sedimentation reducing the costs of pretreatment. Coagulation might be superfluous under normal conditions. Detailed investigations on the spot however are always needed.
Chlorination is a prerequisite. The water at most places along the shoreline is contaminated.



RGS 1-EE2, River Safu.

River Gauging Stations (R.G.S.)

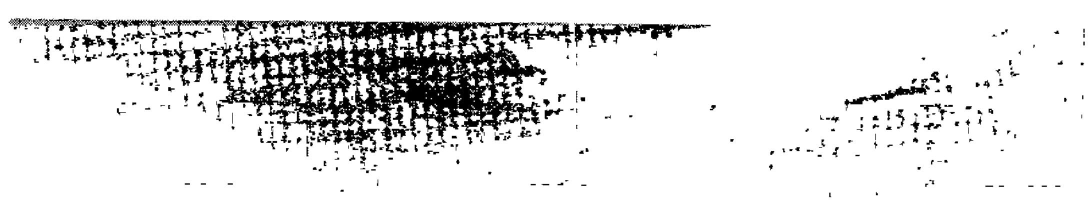


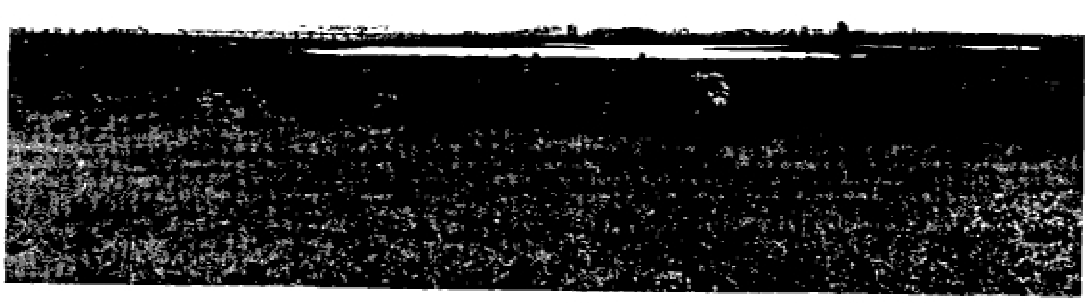
RGS 1-FG2 Bondo Water Supply, River Yala.

5.3. LAKE KANYABOLI

During the inventory survey water samples were taken from Lake Kanyaboli to measure the electrical conductivity (E.C) of the water.
Three samples were taken along the shoreline. The average EC value was found to be about 600 (uS/cm). Two samples were taken from wells made along the lake. The ground water along Lake Kanyaboli was found to be saline (EC=2000 uS/cm). This probably also applies to the deeper water layers of the lake itself. Shallow surface water layers are fresh to brackish.
Lake Kanyaboli is getting more and more salty because the lake water is not replenished anymore via River Yala.

Lake Kanyaboli is not suited for piped water supply. A lot of people living along the lake, use ground catchments, dams or wells because the water abstracted from these sources tastes better. The water is less salty. Making a piped water supply, the quality of the water can not be improved.





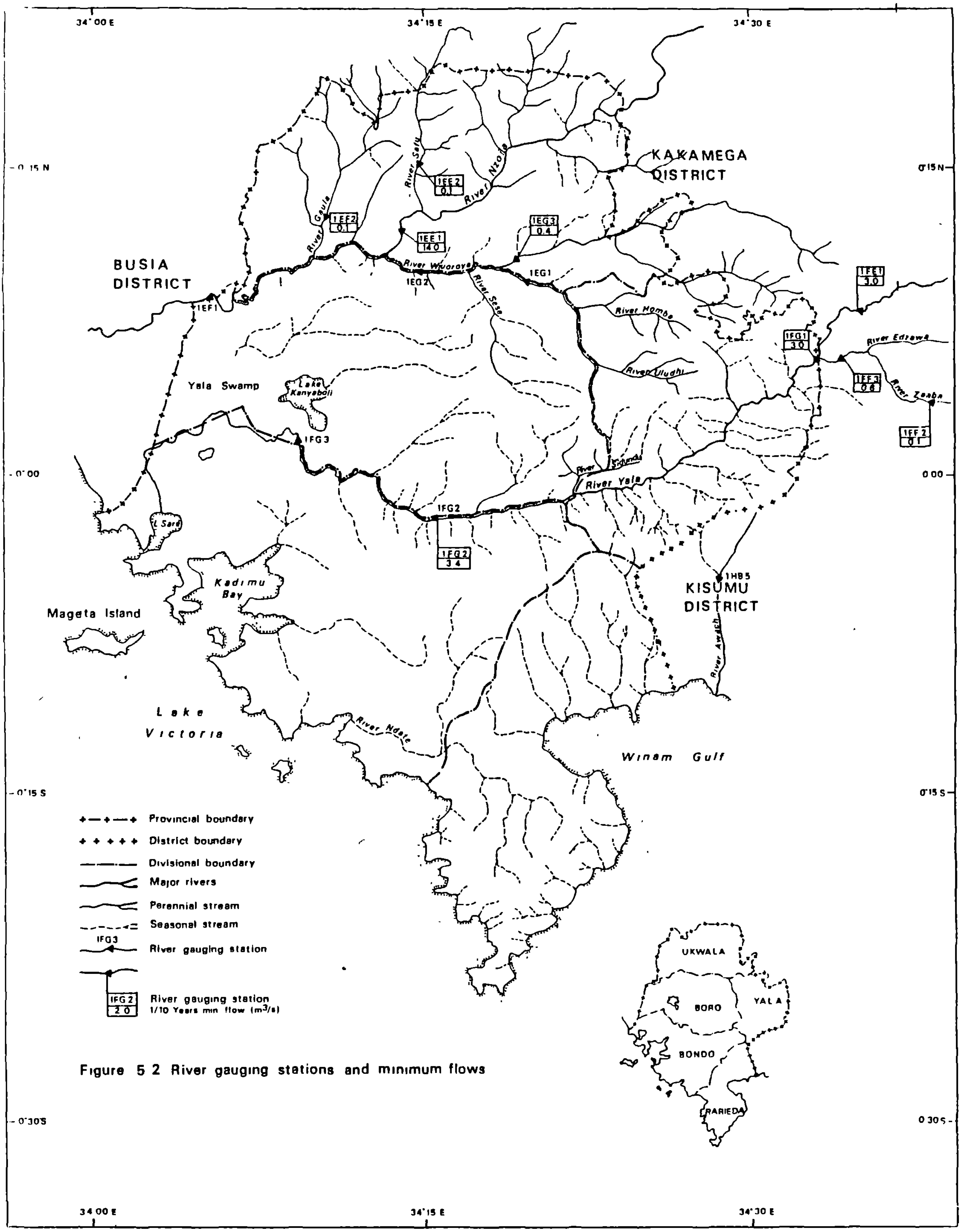


Figure 5.2 River gauging stations and minimum flows

5.4. MAJOR RIVERS

5.4.1. Perennial and seasonal rivers

Figure 5.2 shows that most rivers in Bondo, Rarieda and Boro Divisions are seasonal. Only the rivers Yala and Sese are perennial. Most of the small streams in Yala Division dry up regularly.
The rivers Homba, Uludhi and Sidundu are perennial and intensively used for domestic water supply in Yala Division.
Most rivers in Ukwala Division are perennial. The rivers Gaula, Safu and Wuoroya are intensively used for domestic water supply.

5.4.2. Flows

Fig. 5.2 shows the position of 12 different River Gauging Stations (R.G.S.) along the major perennial rivers of Siaya District.
River Gauging Stations are staff gauges installed to daily read the river levels. Using rating curves it is possible to calculate from these water level registrations the belonging river flows. Characteristics of the River Gauging Stations, indicated in Fig. 5.2, are presented in Annex 5.2.

The water levels, as recorded by the MoWD and the rating curves as submitted by the Ministry have been stored by LBDA in a computerized data base system called HYMOS.
Using HYMOS data, RDWSSP has calculated minimum flows at 9 different points. The once in 10 years occurring minimum flows at the stations 1EE1, 1EE2, 1EF2, 1EG3, 1FE1, 1FF2, 1FF3, 1FG1 and 1FG2 are indicated in Figure 5.2.

River Nzoia near Ukwala.

River Yala near Kudho.

Table 5.1. Water supply potential of the major rivers in Siaya District

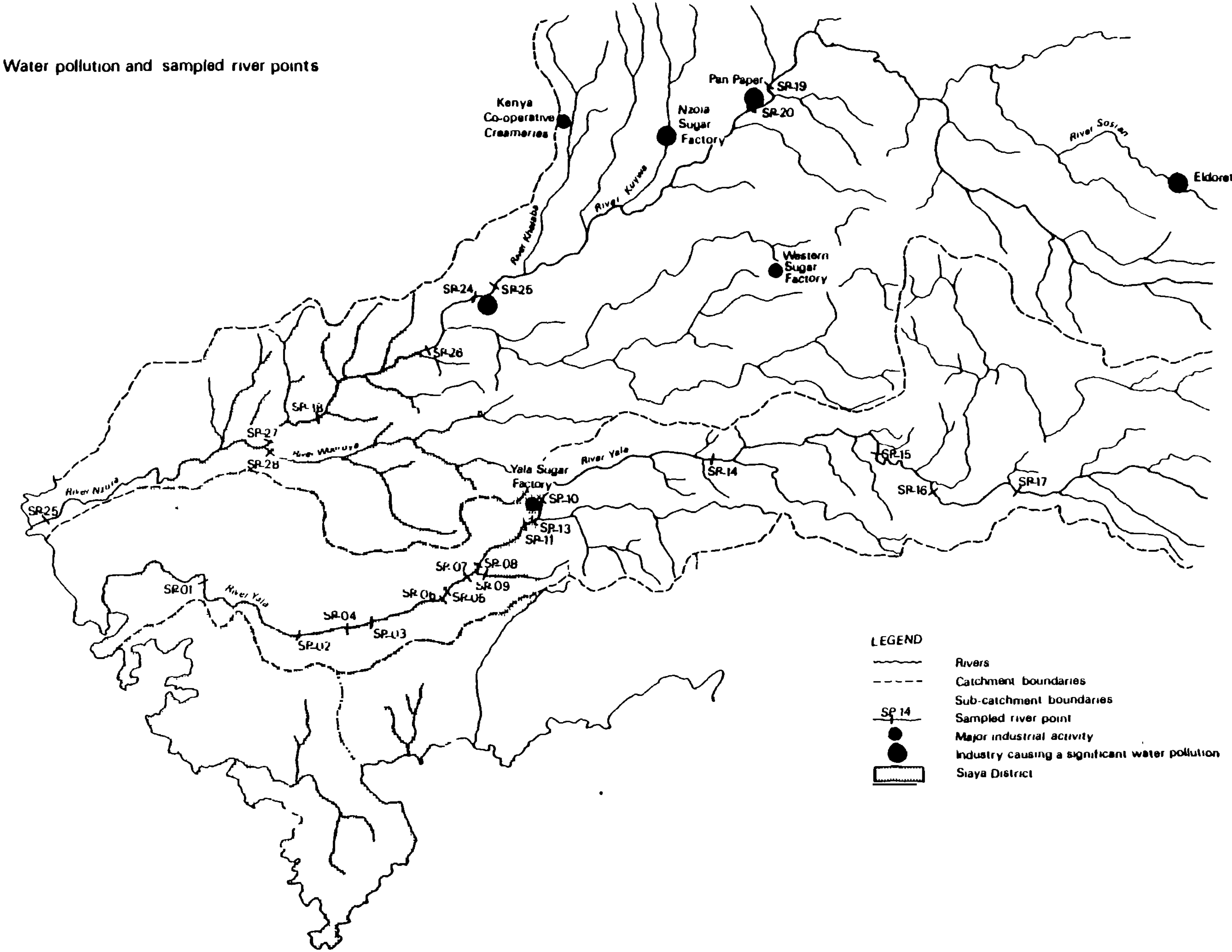
River	1/10 years min flow (m^3/s)	Potential number of supplied people: consumption 20(l/p.c.p.d)	Potential number of supplied people: consumption 100(l/p.c.p.d)
Nzoia	14.0	6,000,000	1,200,000
Safu	0.06	25,000	5,000
Gaula	0.07	30,000	6,000
Wuoroya	0.4	170,000	30,000
Homba	0.06*	25,000	5,000
Uludhi	0.09*	40,000	8,000
Sidundu	0.05*	22,000	4,000
Yala(Yala Town)	3.0	1,300,000	260,000
Yala(Bondo Div)	3.4	1,450,000	300,000

*Estimated min flow (based on flows calculated for station 1EG3).

Table 5.1 shows the water supply potential of the major rivers in Siaya District. In calculating the water supply potential it has been assumed that raw water storage reservoirs are not made. Water abstraction is moreover limited to only 10 % of the once in 10 years minimum flows. Such a low level has been chosen in order to exclude water supply problems downstream. Two different levels of water consumption are considered: public taps (consumption level 20 l/p.c.p.d) and house or yard taps (consumption level 100 l/p.c.p.d).

Both Yala and Nzoia Rivers have the potential to supply a few hundred thousand to over one million people. River Wuoroya could be used as a source for a medium scale piped water supply system, to be used by at least 30,000 people.
The other rivers, Safu, Gaula, Homba, Uludhi and Sidundu could be used for small scale piped water supply. (<10,000 consumers).

Figure 5 3 Water pollution and sampled river points



5.4.3. Water quality

Fig. 5.3 shows which rivers have been sampled. Regularly water samples are taken by LBDA laboratory at the points SP13, SP14, SP15 and SP16 (all located along River Yala) as well as the points SP18, SP19 and SP24 along River Nzoia.
The other points indicated in Fig. 5.3 are incidentally visited or have been sampled once as a part of the RDWSSP surface water survey.
The results of the water quality analyses are indicated in Annex 5.3.
The main conclusions of the analyses are as follows:

1 River Nzoia is more polluted than River Yala. This is best reflected by the lower dissolved oxygen (D.O.) concentrations which have been found. On an average, the River Nzoia D.O concentrations equal to 4.6 (mg O_2/l) while the River Yala samples show a much higher average of 8.2 (mg O_2/l).

2 All measured concentrations have been compared with the Kenyan Standards for rural domestic water supply.

- The colour of the water, expressed in Pt/Co units, of almost all samples is too high. The River Yala average is 81 Pt/Co units and the River Nzoia average is 125 Pt/Co units (standard 50 = Pt/Co).

- The turbidity of the water of most samples is too high. The River Yala average is 59 NTU and the Nzoia River average = 98 NTU (standard = 25 NTU).

- The pH is always between 6.5 and 8.5. The water of both rivers is slightly alkaline (pH=7.3-7.4).

- Conductivity figures are all low (between 50 and 150 uS/cm) and far under the Kenyan standard of 2500 (uS/cm).

- The alkalinity and hardness of the river waters are low. Maximum hardness figures are found to be about 100 (mg/l) $CaCO_3$, indicating soft water.

- The nitrate concentrations are all less than 10 (mg/l) (standard = 30 mg/l). Relatively high concentrations were only found for River Dhenena, a small tributary of River Yala.

- The concentrations of ammonia are all less than 2.0 (mg/l).

- The concentrations of chloride are all low (less than 7.2 mg/l, Kenyan Standard = 600 (mg/l)).

- The concentrations of fluoride are all less than 1 (mg/l). (Kenyan Standard = 1.5 mg/l).

- The manganese and iron concentrations are regularly found to be too high. The maximum manganese concentration is 0.7 (mg/l) (standard = 0.5 mg/l). The maximum iron concentration is 2.5 (mg/l) (standard = 1.0 mg/l).

- The phosphate and sulphate concentrations are low.

- Related to the turbidity of the water, dissolved oxygen concentrations are sometimes low 2-3 (mg O_2/l). A complete oxygen depletion has not been found.

- The B.O.D. concentrations at some points along the rivers are high. Just down stream of Mumias Sugar Factory a BOD concentration of 307 (mg O_2/l) was measured.

3 One sample taken at point SP-24 was analysed by the Kenyan Bureau of Standards on the presence of heavy metals and other toxic substances.
Only cadmium and phenols are found to be too high. Cadmium has a clear toxic effect. Phenols influence the aesthetic quality of the water.

Based on the results of the water quality analysis it is concluded that River Yala is suitable for piped water supply.
A full treatment of the water including coagulation, sedimentation, filtration and chlorination is a prerequisite.

River Nzoia is not suitable for drinking water supply. The risk of anaerobic conditions causing reductions from nitrate to nitrite and from sulphate to hydrogen sulphide, which are both toxic substances, is not excluded.
Moreover cadmium and phenols are found to be too high. The phenol concentration could be reduced by intensive chlorination. Coagulation and sedimentation might reduce the cadmium concentration of the water. Without using actived carbon filtration, there are however no guarantees to reach an acceptable level of cadmium concentrations. Actived carbon filtration is judged to be too complicated within the context of a rural water supply system.

5.5. CONCLUSIONS

1 Lake Victoria can be used for piped water supply. Severe contamination or pollution of the water has not been found.
The chemical constituents of the water are within Kenyan Standards for domestic water supply. The iron and manganese concentrations which are incidentally found to be too high can be reduced by sedimentation and filtration. It is advised to create raw water storage basins to bridge periods in which an intake of water is impossible due to for instance algae blooms. The colour and turbidity figures are rather low and do not fluctuate much. Pre-treatment of the water can be rather simple if a proper intake site is selected. The need for coagulation should be investigated on the spot.
Chlorination of the water is needed.

2 Lake Kanyaboli is not suitable for piped water supply. The lake water is getting brackish because there is no replenishment of the water via River Yala and a large evaporation surplus.
Desalination of the water is not feasible. Ground catchments, dams and water holes will continue to be used because their water tastes better.

3 Most rivers in Bondo, Rarieda and Boro Divisions are seasonal and therefore unsuited, for piped water supply.

4 The minimum flows of most perennial rivers in Yala and Ukwala enables to use them for small scale piped water supplies (<10,000 consumers).

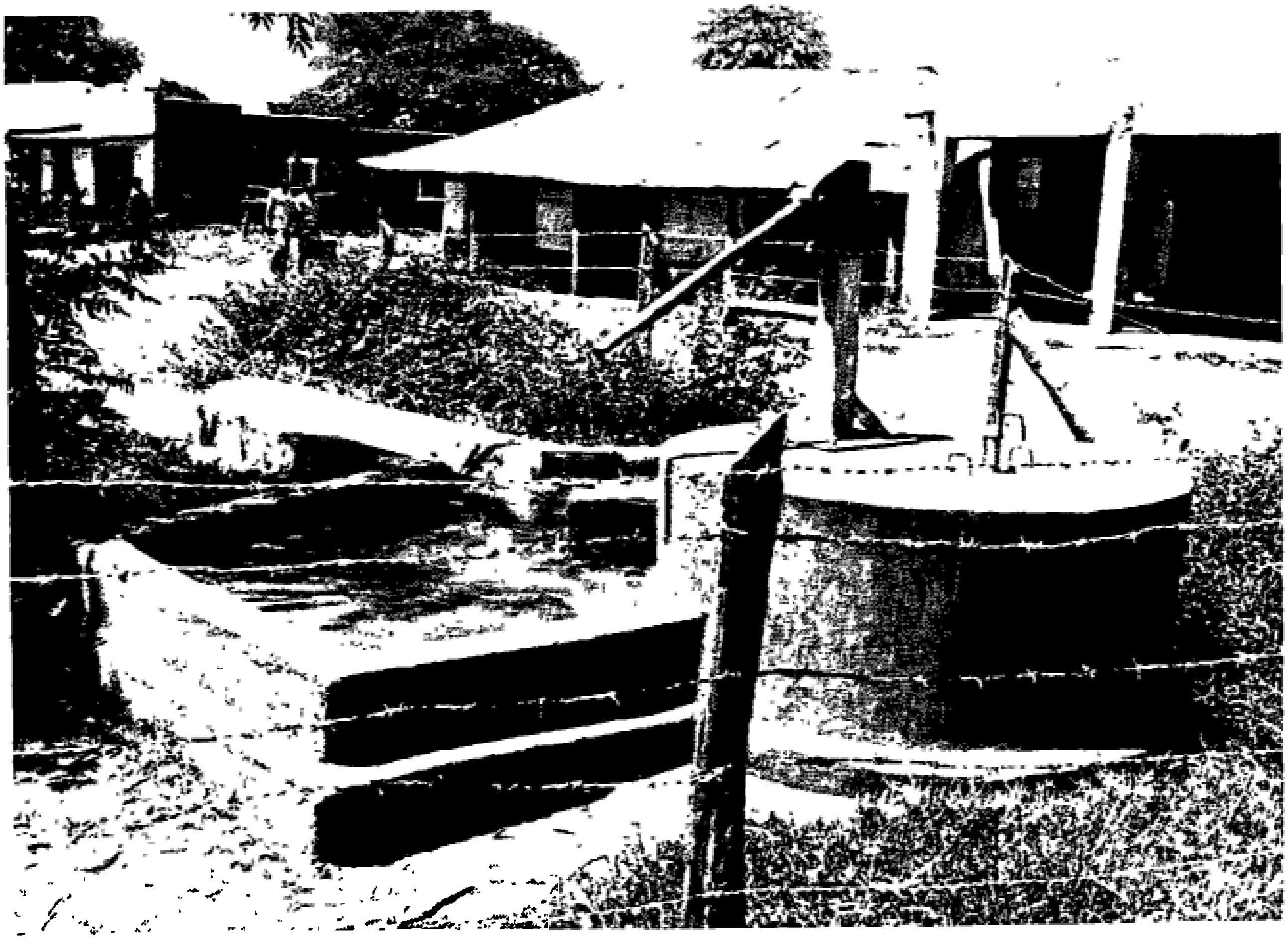
5 River Wuoroya could be used as a source for a medium scale piped water supply (up to 30,000 consumers).

6 River Yala is suitable for piped water supply. No severe pollution has been found. Using the river water requires a full treatment including coagulation, filtration and chlorination.

7 River Nzoia is unsuited for piped water supply.
The river is polluted, causing low oxygen levels. The risk of anaerobic conditions causing harmful reductions of nitrate and sulphate is manifest.
Cadmium and phenols were found to be too high. A long time sustainable treatment of the water to reduce these substances is not feasible.

P A R T V I

W A T E R S U P P L Y P L A N



Access to good quality drinking water.

6.1. OBJECTIVE

6.1.1. Improvement policy and targets

When the International Drinking Water & Sanitation Decade started, the Government of Kenya subscribed to the declaration of the Decade by stating that the water supply target for 1990 would be to cover 75% of the rural population.
Comparing this figure with the 9 % using safe and reliable point sources (see section 3.2.7) and an estimated 4 % using safe and reliable piped water supplies, it will be clear that the 75 % target will not be reached.
The prevailing policy to construct piped water supplies in rural areas has to be reviewed. There is need for an adjustment of the water supply policy and redefinition of the targets.

6.1.2. A two phases water supply improvement

The ultimate goal of all improvement efforts is to supply ***sufficient and good quality drinking water*** to the entire rural population of Siaya District.
The word "sufficient" needs further explanation.
For drinking and cooking purposes, 10 (l/p.c.p.d) are sufficient. (see section 3.4.6.). Such an amount of water is insufficient however, for substantial sanitary improvements as in house washing and cleaning, water closets etc.
Neither it is sufficient for productive use of water e.g. small scale irrigation.
Sufficient from these points of view means, a domestic water consumption of at least 100 (l/p.c.p.d).

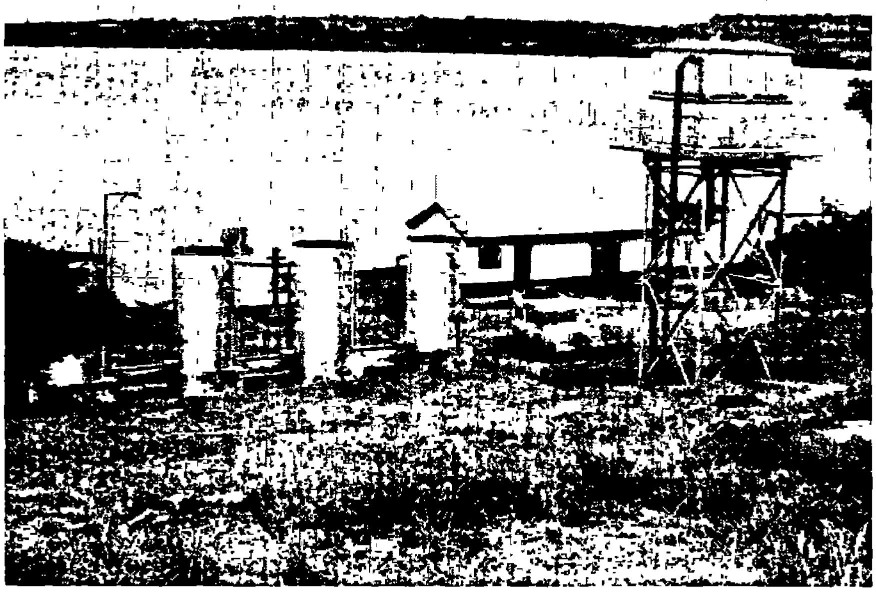
A consumption level of 10 (l/p.c.p.d) enables to use communal water points. Once or twice a day, one or two buckets of water are brought from the communal water point to the homes. Washing and bathing is done near the water point.
A consumption level of 100 (l/p.c.p.d) requires to have a private water point or to have a private connection to a piped water supply system.

The general objective, "sufficient and good quality drinking water" has been specified by indicating two water supply levels.

Level I : The entire rural population of Siaya District has ***access to good quality drinking water***. The amount of water available is sufficient for safe drinking and cooking.

Level II : The entire rural population of Siaya District is supplied with ***sufficient and good quality drinking water***, enough to use the water at home for all domestic purposes as e.g. washing and bathing.

Point source water supply.



Treatment works of a piped water supply system.

6.1.3. RDWSSP policy

The RDWSSP policy for improvement is to focuss upon Level I.
It is a short to medium term approach to first guarantee that the entire population at least has access to safe and reliable communal water points.

The Water Supply Plan, as described in the following paragraphs, aims at reaching Level I within 5-10 years.
A time schedule for reaching Level II can not be given.
Construction of long term sustainable piped water supplies will depend on the presence of organisations capable to properly operate and maintain these piped water supplies.

Mageta Island; the only water source available is Lake Victoria.

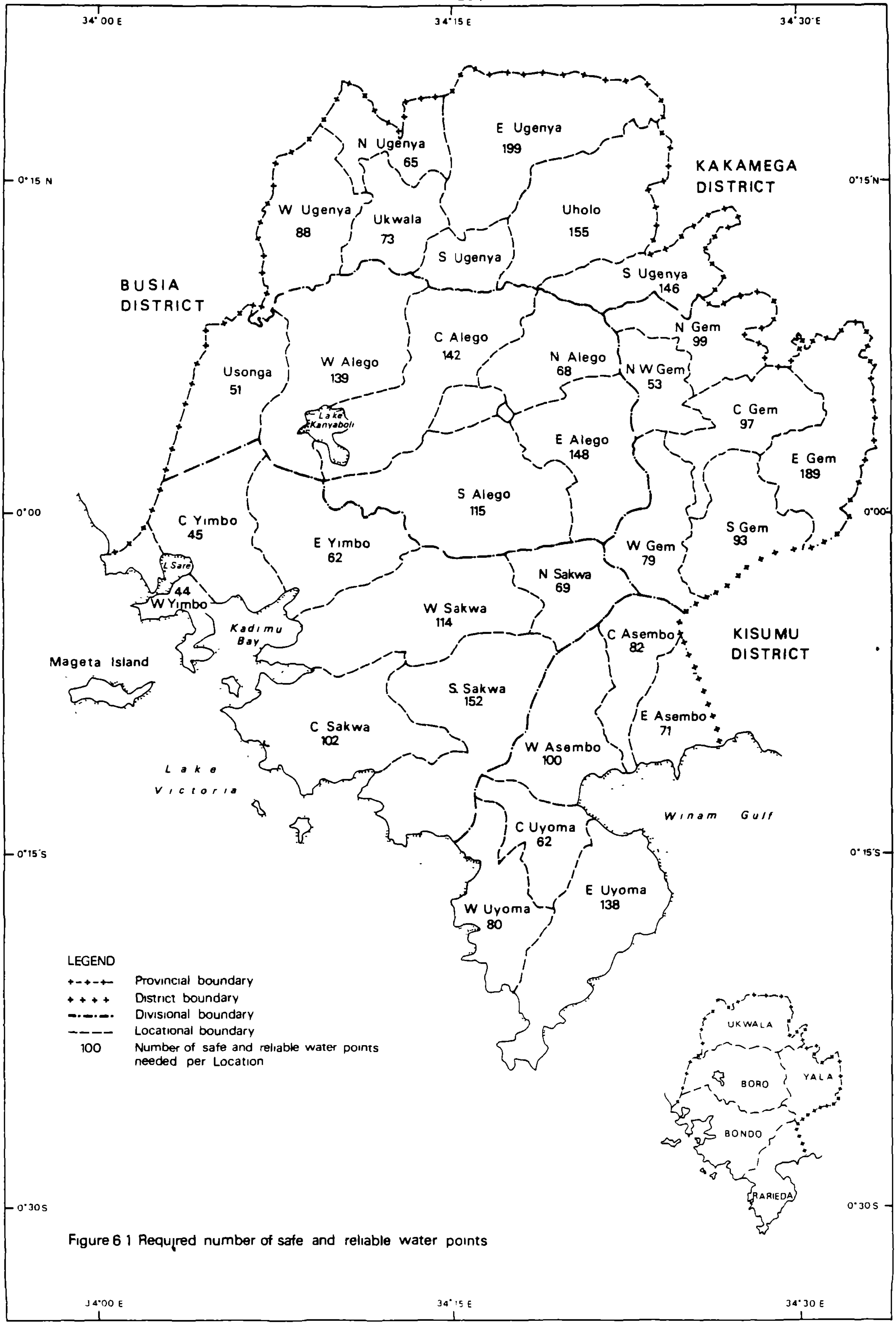


Figure 6 1 Required number of safe and reliable water points

6.2. TARGETS

Access to good quality drinking water, requires the presence of a safe and reliable public water point at a "reasonable" distance from somebody's home.
In Bondo and Rarieda Divisions, walking distances of less than 1.0 (km) are considered to be "reasonable". In Yala and Ukwala Divisions however such a distance would not be accepted. Most people in Yala and Ukwala Divisions have a natural water point within 500 (m) from their home.
People tend to use the most nearby water point irrespective of the quality of water which is available at that point.

The RDWSSP target is to have a safe and reliable communal water point within a distance of 500 (m) from each home.
Assuming that each safe and reliable water point will cover a circular area with a radius of 500 (m), the required number of safe and reliable water points is calculated using formula (6.1).

$$N = \frac{Ai}{0.785} \qquad (6.1)$$

N = Required number of safe and reliable water points

Ai = Inhabited area (km^2)

Most of the water points to be constructed in Siaya District are hand dug wells.
The water supply capacity of a hand dug well is limited. Most of the hand dug wells can supply up to 250 consumers.
This figure of 250 consumers per water point, is therefore used as a maximum.

$$N >= \frac{Ps}{250} \qquad (6.2)$$

P_s = Actual population having no private good water points.

Fig. 6.1. shows how many safe and reliable public water points are needed in each Location of Siaya District if both conditions as indicated in the formulas (6.1) and (6.2) are to be fulfilled
The total number of water points needed in Siaya District equals to 3,120.

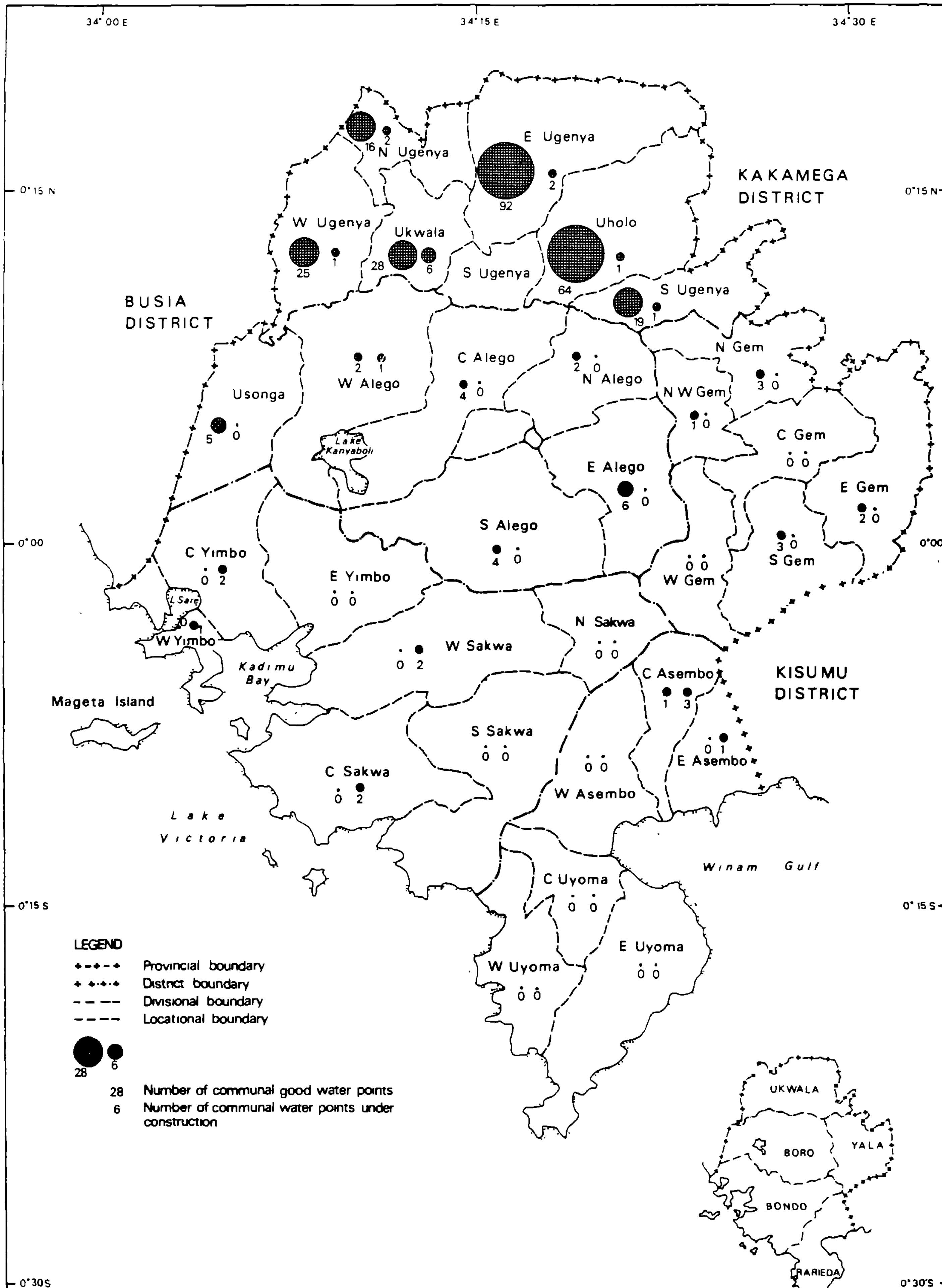


Figure 6 2 Good water points and water points under construction in Siaya District

6.3. WATER SUPPLY PLAN

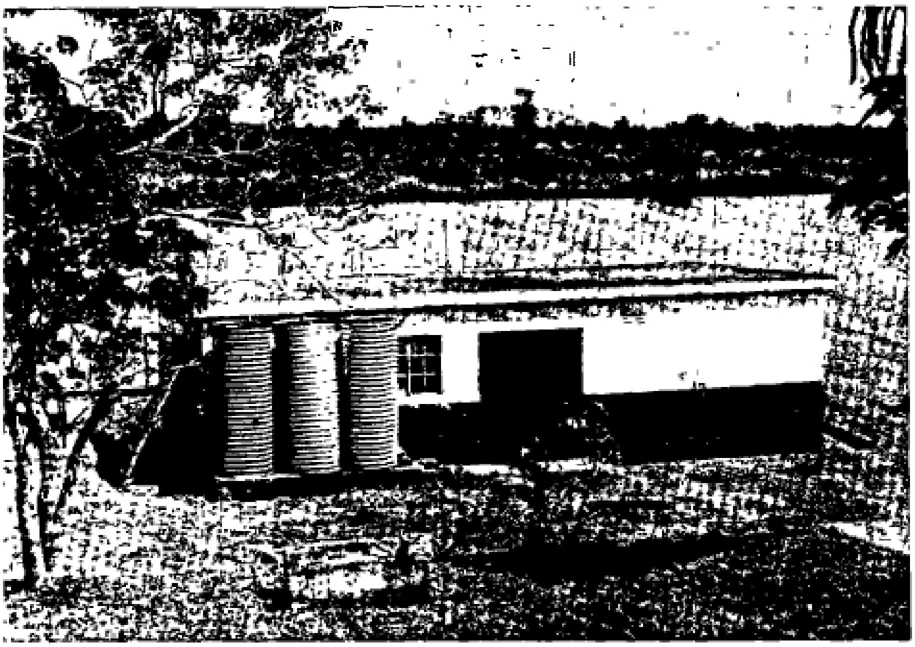
6.3.1. Good water points and water points under construction

The network of 3120 safe and reliable water points will comprise
- existing water points which were found to be safe and reliable,
- waterpoints which were found to be under construction,
- water points which have to be improved and
- new water points to be made(point sources or piped water supply taps).

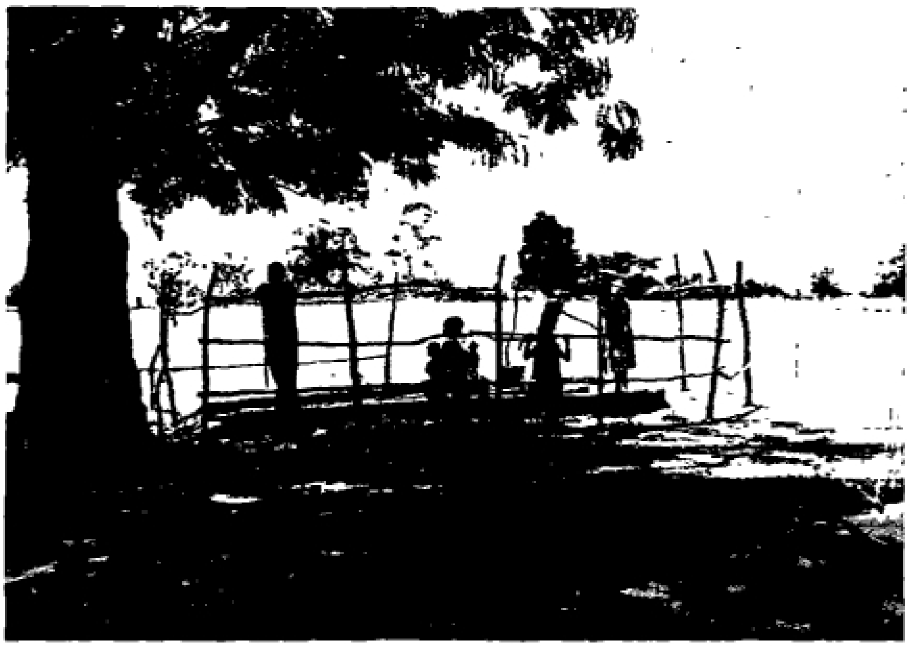
In part III of this report safe and reliable water points have been marked as "good water points".
About 330 existing water points were found to be "good".
Part of these good water points are used as communal facilities and do not need any rehabilitation.

During the inventory survey many wells and roof catchments were found to be under construction. Also part of these water points "under construction" will be used as communal facilities. With due support (technical advisory, delivery of materials e.g. hand pumps etc.), these water points will be safe and reliable in future.

Fig. 6.2 shows the number of communal good water points and the communal water points under construction in each Location.
Good water points, used as communal facilities, are almost exclusively found in Ukwala Division. This is mainly due to the large number of boreholes, wells and spring protections made by KEFINCO.
In the whole of Bondo and Rarieda Divisions there is only 1 good water point used as a communal facility.
All over the District there are only 25 communal water points under construction.
Half of them are located in Ukwala Division.



Mauna Dam Water Supply;
Irregular supply of water due to a lack of diesel.



Borehole made near Yenga Primary School (Ukwala Division) because Yenga Water Supply is not in operation.

6.3.2. Major improvement works

It is the RDWSSP policy to use ground water based point sources for domestic water supply. This means spring protection and rehabilitation or newly construction of hand dug, hand drilled and machine drilled wells.
The main advantages of using ground water based point sources are:

- No need for water treatment
- Using ground water offers the best guarantee for a permanent supply of water
- Requirements with respect to organization of operation and maintenance are limited.

No water treatment is needed

Most ground water is safe by virtue of its origin. It has stayed in the subsoil for longer periods causing a complete decay of pathogenic organism.

The best guaranteed permanent supply of water

Many surface water resources dry up regularly. Piped water supplies are irregularly in operation. Rain water is a very unreliable source for a domestic water supply system.

Operation and maintenance requirements are limited

Point source water supplies can be organized at community or users level. Existing social structures can therefore be used.

Fig. 3.2. shows that only in the northern and eastern parts of the District (Ukwala and Yala Divisions and the eastern part of Boro Division) ground water resources are used for domestic water supply. In Bondo and Rarieda Divisions and the southern part of Boro Division surface or rain water resources are used.

Fig. 4.15 shows the ground water potential of Siaya District.
The area south of the 1100 (mm) mean annual rainfall isohyet (Bondo, Rarieda and part of Boro Division), indicated as zone 1, has a poor ground water potential.
The area between the 1100 (mm) and 1500 (mm) isohyets, indicated as zone 2, has a fair ground water potential. Only the area north of the 1500 (mm) isohyet, zone 3, has good opportunities for using ground water.

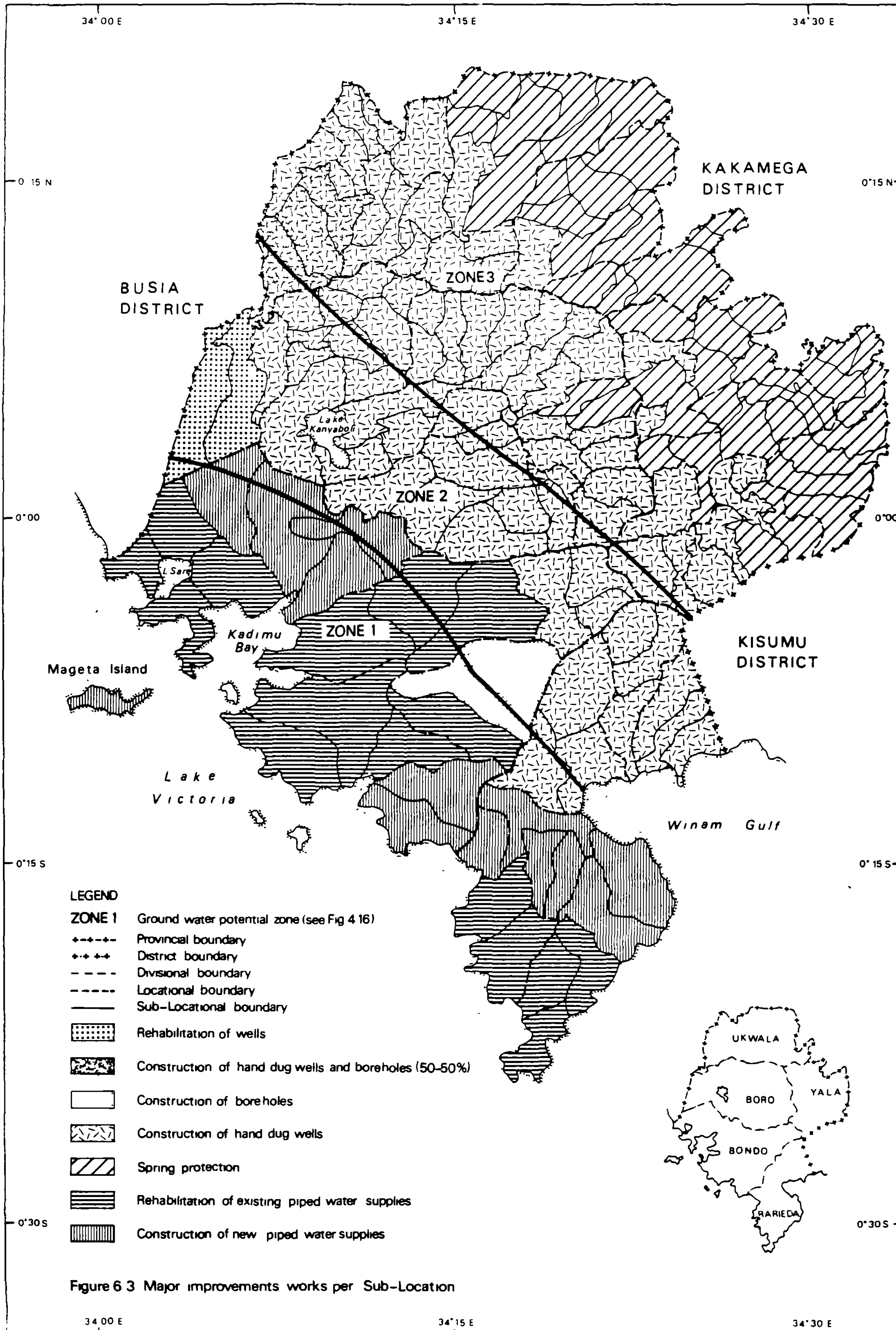


Figure 6 3 Major improvements works per Sub-Location

From both the inventory as well as the ground water survey it is concluded that use of ground water resources in zone 1 is impossible. Piped water supply using Lake Victoria and River Yala, and use of rain or surface water resources (roof catchments, ground catchments and dams) are the only feasible alternatives in this area.
In zone 2 ground water can be abstracted by making hand dug wells. In some areas machine drilling will be needed.
In zone 3, hand dug wells and spring protections are to be made.

Fig. 6.3 shows a more detailed view of the major improvement works in each Sub-Location.
In Bondo Division and the southern part of Rarieda Division , existing piped water supplies have to be improved. New piped water supplies are needed at Mageta Island, in the north-western part of Bondo Division and in the central part of Rarieda Division.
Rehabilitation of existing wells will be the major activity in the western part of Boro Division (Usonga Location).
The rest of zone 2 and a large part of zone 3 will be covered by making hand dug wells.
Spring protection will be the major activity in the eastern part of Ukwala Division and in Yala Division.

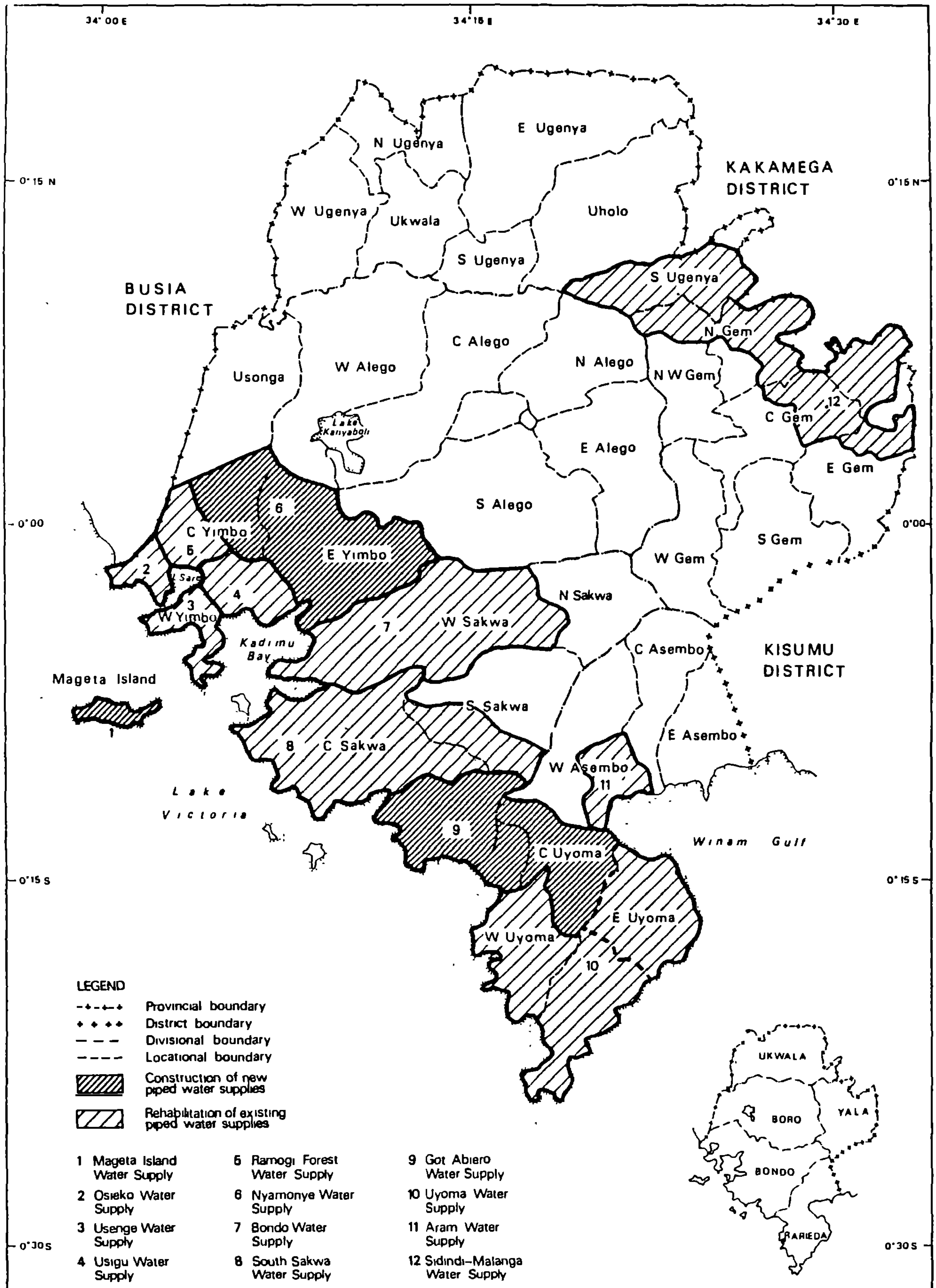


Figure 6 4 Rehabilitation and construction of piped water supplies in Siaya District

6.3.3. Piped water supply

Fig. 6.4 shows which existing piped water supplies have to be improved and where new piped systems have been planned.
Twelve (12) piped water supply projects have been identified.

Rehabilitation of the following existing schemes:

- Osieko Water Supply
- Usenge Water Supply
- Usigu Water Supply
- Ramogi Forest Water Supply
- Bondo Water Supply
- South Sakwa Water Supply
- Uyoma Water Supply
- Aram Water Supply
- Sidindi-Malanga Water Supply.

Construction of 3 new piped water supplies.

- Mageta Island Water Supply
- Nyamonye Water Supply
- Got Abiero Water Supply

Apart from Sidindi-Malanga Water Supply, all schemes mentioned are located in zone 1, having a poor ground water potential.
Rehabilitation of Sidindi-Malanga Water Supply is proposed in order to better utilize the existing water supply system.

Rehabilitation of Siaya Water Supply and construction of new piped water supplies in the major administrative or market centres such as Ukwala and Sigomere is supported by the project, but considered to belong to phase II of the Water Supply Plan "sufficient, safe and reliable water via private taps".

Section 3.3.8. of this report contains a detailed evaluation of piped water supply in Siaya District. Detailed descriptions of rehabilitation and construction works needed are given in the Divisional Reports.
In this paragraph it is sufficed to highlight the most important features of the piped water supplies mentioned.

Mageta Island Water Supply

A piped water supply system should be made on Mageta Island which is the most densely populated part of Bondo Division.
Water should be pumped from Lake Victoria. The water should be treated by coagulation/sedimentation followed by slow sand filtration. The distribution area equals 7 (km^2). The distribution system should at least have 10 public taps.

Osieko Water Supply

The broken pipes of Osieko Water Supply should be repaired. The planned distribution line to Got Agulu dispensary should be extended up to Got Agulu Market. Facilities should be made for chlorination of the supplied water.
The former pumping period of 6 hours a day should be extended to e.g. 12 hours a day. The distribution area equals 13 (km^2). The distribution system should at least have 9 public taps.

Usenge Water Supply

The total storage capacity should be enlarged and the distribution system should be extended. Water is nowadays only supplied to the hospital and one public tap at the market. Facilities should be made for chlorination of the water. The distribution area equals 20 (km^2). The distribution system should at least have 24 public taps.

Usigu Water Supply

The total storage capacity should be enlarged and the distribution system should be extended. Also for this water supply system facilities should be made for chlorination of the water. The distribution area equals 23 (km^2). The distribution system should at least have 20 public taps.

Ramogi Forest Water Supply

Ramogi Forest Research Station Water Supply is only used by the Research Station and some people living along the transmission main from the intake to the station. Also for this piped water supply there are ample opportunities for extension. Nowadays water is pumped only four times a week for about 4 hours.
Facilities have to be made for chlorination of the water. The distribution area equals 18 (km^2). The distribution system should at least have 7 public taps.

Nyamonye Water Supply

A new piped water supply system has to be built for Bar Kanyango Sub-Location and East Yimbo Location. The distribution area is about 100 km^2 in which about 15,000 people are living. Water should be pumped from River Yala. The intake should be made north of Nyamonye Market. Near the intake site treatment works have to be made. The treatment should consist of coagulation/sedimentation either followed by a combination of rapid sand filtration and chlorination or slow sand filtration.
Water should be pumped to Ogare hill west of Nyamonye.
The distribution system should contain 62 public taps.

Bondo Water Supply

Bondo Water Supply should be extended to cover the whole of W. Sakwa Location. The distribution area is 113 (km^2) in which about 20,000 people are living. One hundred (100) new water points have to be made. Fifty (50) % of the new water points are needed in Nyawita Sub-Location.

Major improvement works are the rehabilitation of the water treatment and a new transmission main to Bondo Town.
To extend the distribution system a new transmission main has to be laid from the treatment works near Ulonga to Usire hill from where the whole western part of West Sakwa Location can be supplied. The length of this new transmission main is about 4-5 (km).

South Sakwa Water Supply

Essential for the future of this project is that water will be pumped as soon as possible to the main storage tank at Serawongo hill and that the water will be distributed. Works needed are:

- the raw water intake from Lake Victoria has to be built,
- pump houses and treatment works are to be rehabilitated,
- distribution points (public taps) have to be built.

Extension of the distribution lines should be stopped for the time being.
Contrary to the design plans it is advised to limit the distribution system to Central Sakwa Location and East Migwena Sub-Location.
Got Abiero and Nyaguda Sub-Locations can better be supplied via the newly planned Got Abiero water supply.
At a later stage it can be taken into consideration to complete the Got Abiero line which is now under construction. Purpose of this line would be to enlarge the supply of water to Abiero hill to support the Got Abiero water supply system.

Limiting the distribution area to Central Sakwa Location and East Migwena Sub-Location the area to be covered equals 125 (km^2) in which nowadays about 22,000 people are living. The total number of public taps needed in this area is 121.

Got Abiero Water Supply

A new piped water supply system has to be built to cover the central and southern parts of South Sakwa Location (Got Abiero and Nyaguda Sub-Locations), Central Uyoma Location and the northern parts of West and East Uyoma (Kagwa , Ragengni and Katwenga Sub-Locations).
All attempts to make boreholes in this area have failed. The original plans have therefore been changed from borehole drilling to construction of a piped water supply.

It is advised to pump water from Lake Victoria (intake south from Kagwa School). The required capacity of the water supply system will probably exclude to use groundcatchments or dams in the Lower Ndate catchment ; an alternative however which is worthwhile to investigate in more detail.
The surface water should be treated by coagulation/sedimentation followed by either rapid sand filtration/chlorination or slow sand filtration. After treatment the water should be pumped to Abiero hill. The existing storage tank, built for South Sakwa Water Supply, can be used. New storage tanks are needed to enlarge the storage capacity at Abiero hill. From Abiero hill water will be distributed southwards to Kagwa and eastwards towards Anyuongi.
The distribution system of Got Abiero Water Supply will cover an area of about 162 (km^2). The distribution system should at least have 179 public water points.

Uyoma Water Supply

The existing Uyoma Water Supply has to be rehabilitated.
Main aspects of this rehabilitation are:

- A reduction of the distribution system. The northern part should be disconnected. Supply of water can best be done via the new Got Abiero Water Supply.

- Repair of distribution lines. A detailed study should be made to improve the distribution of water.

- Repair of diesel engines.

Next to a technical rehabilitation of the water supply system, institutional changes have to be made in order to create a long time sustainable operation and maintenance set up. Measures to be taken are:

- An increase of water charges. All distribution points should be metered. Flat rate charges should be changed in payment per (l) or (m^3).

- The project director and the operator of the water treatment plant should control the water revenues and be responsible for purchasing diesel and chemicals.

Money should be allocated to purchase spare parts, means of transport and tools for the staff responsible for maintenance of the distribution system.

Aram water supply

Aram water supply needs a better water treatment system. Incidentally the water is chlorinated. Facilities should be made for sedimentation , filtration and chlorination.
The distribution system should be extended from 2 to 8 public water points.

Sidindi-Malanga Water Supply

Technical improvements are minor and mainly aimed at improvement of the treatment works and the distribution of water from the main storage tank near Nyamninia.

Institutional changes however are major. Many water kiosks are supplied but not effectively used. The water treatment staff can not control water revenues, can not purchase and guarantee an adequate supply of chemicals and can not maintain the distribution system.
Measures to be taken are identical to those indicated for Uyoma Water Supply.

- All distribution points should be metered, no flat rate charging
- Operation staff should control revenues and should be responsible for purchasing electricity and chemicals.
- Money should be allocated to purchase spare parts, means of transport, tools etc. in order to maintain the distribution system.

6.3.4. <u>Rehabilitation of ground catchments and dams</u>

An adequate sanitary improvement of ground catchments and dams is hard to realize.
The upstream catchment area must be fenced and used in such a way that it is not polluted or contaminated. Also the reservoir should be fenced to exclude that the stored water is contaminated by cattle or due to washing and bathing.
A public tap and a cattle trought have to be made downstream to use the water. The public tap and the cattle trough are supplied via a pipe from the dam or ground catchment to the water point.

In practice this design always fails.
The upstream catchment area is too large to be fenced; it is often used by cattle.
Proper fencing of the water reservoir is often not feasible either. Cows searching for water will break through the fence.
The pipe between the reservoir and the public tap clogges easily.
Main problem is the pipe inlet at the reservoir site.

Rehabilitation of ground catchments and dams is therefore considered to be a second level improvement, subordinate to rehabilitation and construction of new piped water supplies.
Nevertheless it should be realized that most people living along Lake Victoria use ground catchments and dams for domestic water supply.
Also in future these people will use this type of water points.

Fig 65 Design for rehabilitation of ground catchments and dams

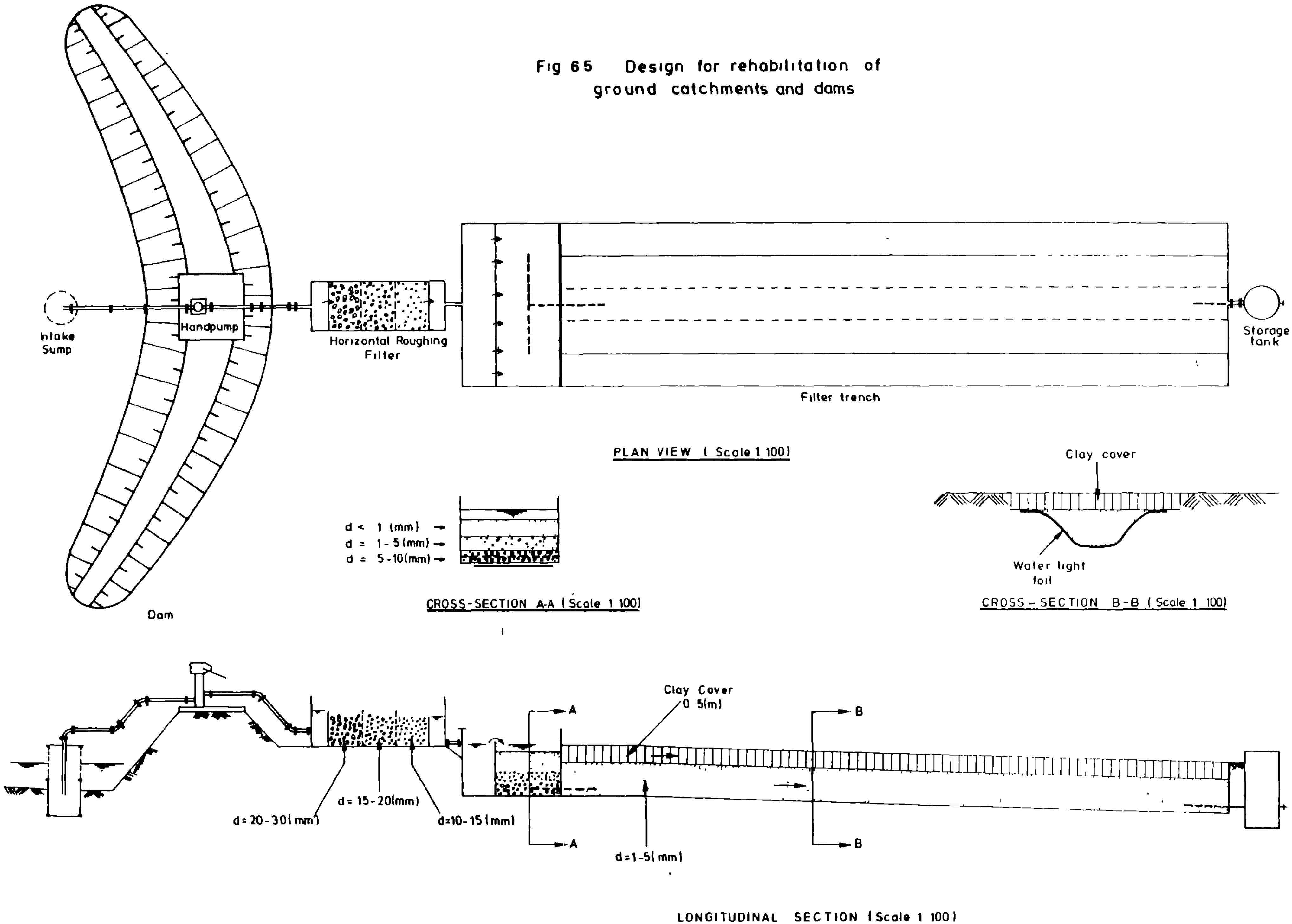


Fig. 6.5 shows a design for improvement of ground catchments and dams. It is based on the following 2 basic ideas.

- The water stored in a ground catchment or a dam is always polluted and there are no ways to exclude or prevent this pollution.
  The water should therefore be treated.

- On a yearly basis there is an evaporation surplus around Lake Victoria of 600-700 (mm/year).
  As a result many dams and ground catchments dry up regularly. Water losses can be reduced by deepening or by covering the storage reservoir.
  Deepening is part of the maintenance works for a ground catchment or a dam. The easiest way to "cover" the storage reservoir is to store the water in the underground.
  Underground storage after treatment enables to use the upstream open reservoir for polluting activities as cattle watering and washing. The underground storage can be used for drinking and cooking purposes.

Water is pumped or sucked via a siphon from a culvert intake and flows to a horizontal roughing filter. From the roughing filter it flows to a trench filter. The first part of this trench filter consists of a small slow sand filter. Passing the trench filter the water is stored in a small tank from which it can be abstracted with a pump or a tap.
Purpose of the culvert intake is to reduce the sediment load of the water. The culvert rings are permeable.
The horizontal roughing filter consists of 3 compartments containing filter materials. It is a course to fine filtration aimed at a further reduction of the sediment load to make the water suitable for slow sand filtration. The slow sand filter contains fine filter material. Clogging of the filter will happen over here. The clogging can be raised by skimming the sand surface with hand shovels removing the top layer to a depth of about 1-2 (cm). The trench filter is used as an underground storage. The retention time in the trench is 1-2 days which guarantees a decay of all pathogenic organism.

RDWSSP has no experience in rehabilitation of ground catchments and dams.
The design shown in Fig. 6.5. has never been implemented and deserves to be attempted in a second phase

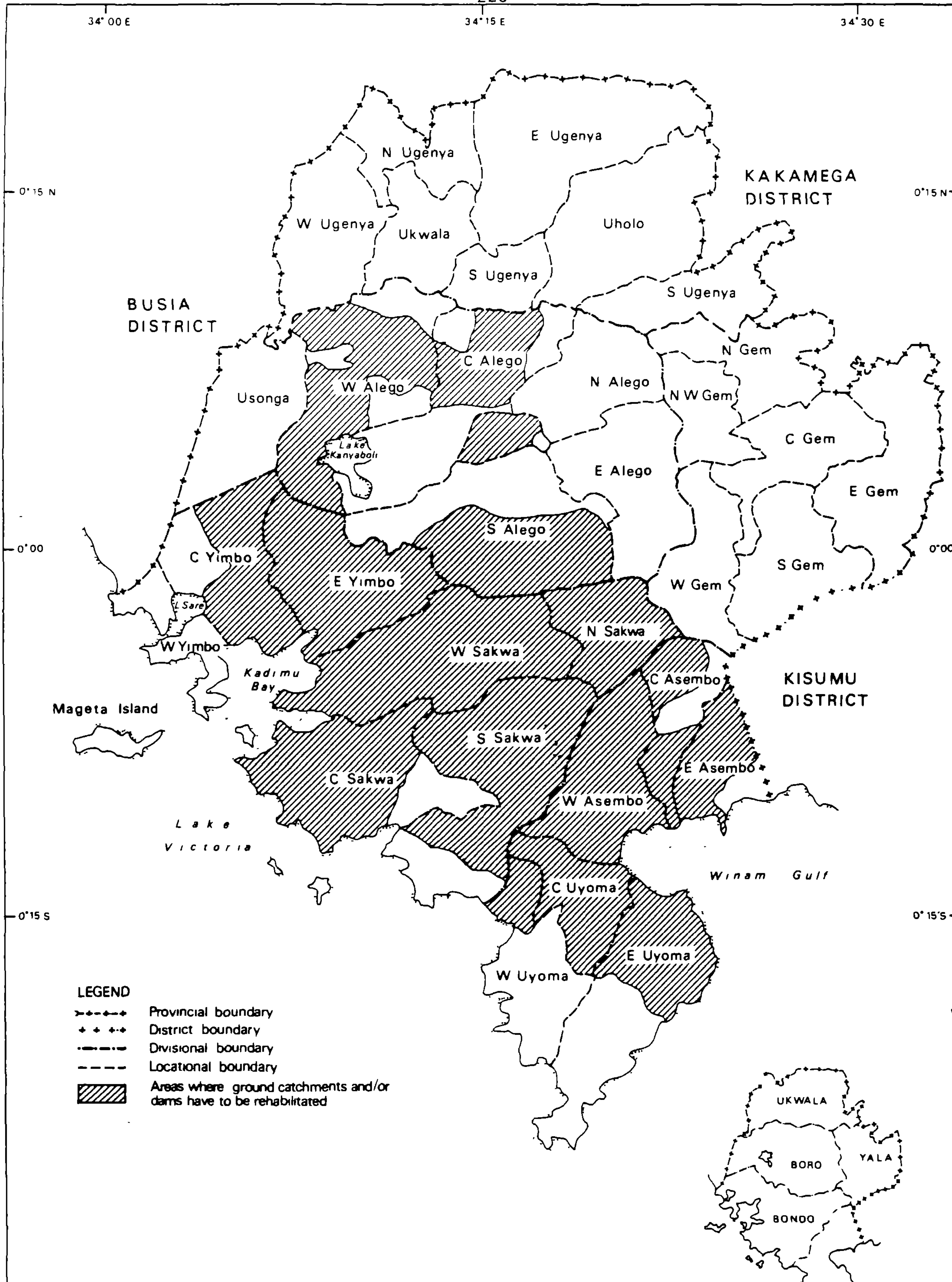


Figure 6 6 Areas where ground catchments and dams have to be rehabilitated.

Fig. 6.6. shows the areas where rehabilitation of ground catchments and dams is planned. It covers almost the whole of Bondo Division, the central and northern parts of Rarieda Division and the northern and southern parts of Boro Division.

Ground catchment west of Got Abiero (Bondo Division) recommended for rehabilitation.

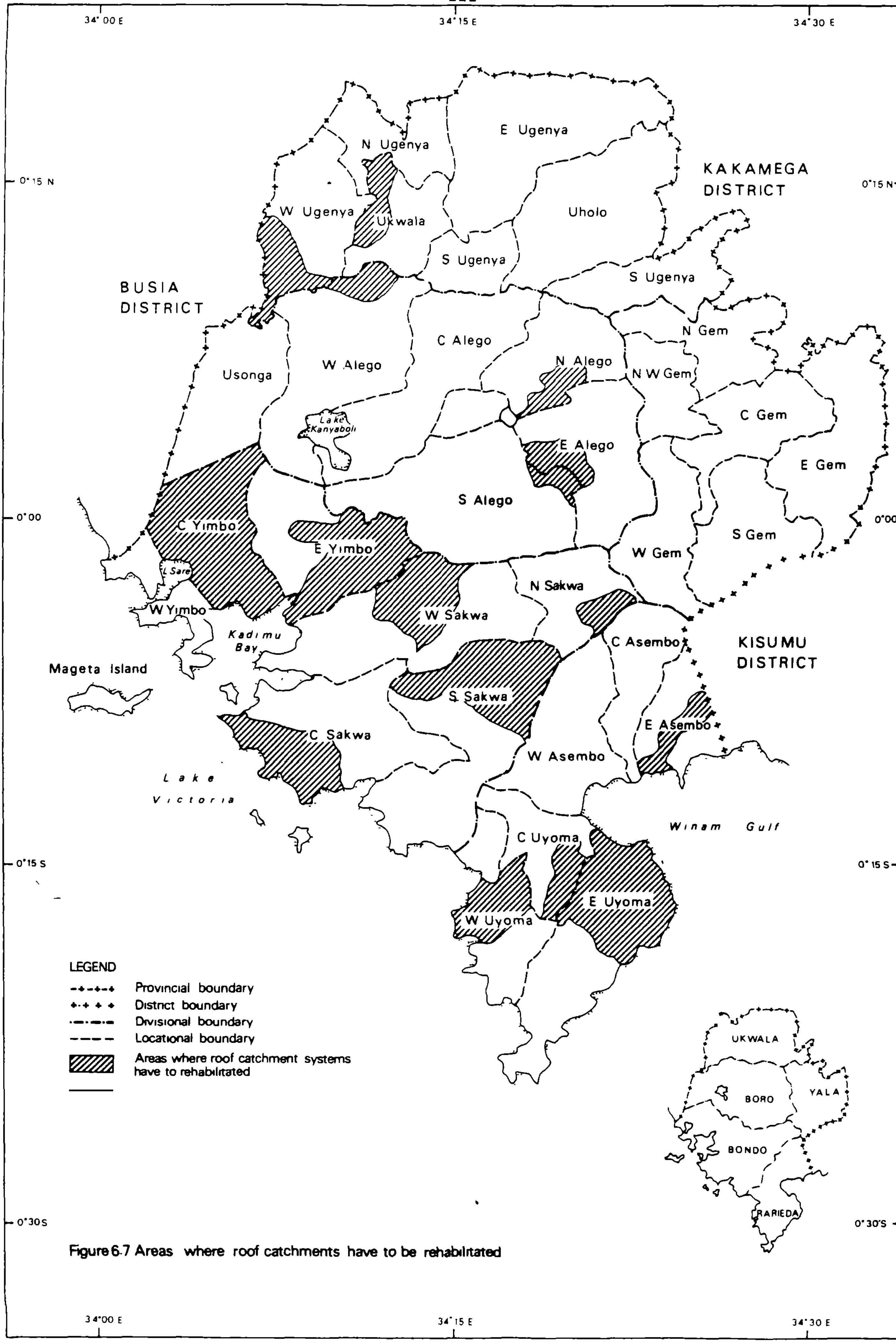


Figure 6.7 Areas where roof catchments have to be rehabilitated

6.3.5. Rehabilitation of roof catchments systems

Roof catchment water supply systems are "appropriate rural water supply facilities, to be used by a small group of consumers". Roof catchment water supply offers some big advantages

- Properly maintained there is no need for water treatment.
- Water is collected at the point where it is needed; at somebody's home.

Roof catchment water supply however also has some main disadvantages.

- A hard cover roof is needed to collect the rain water. Such a roof is often missing or its size is too small.
- The gutters and pipes must have a large size or diameter to divert as much as possible the water to a storage tank.
- The frequent occurrence of dry periods necessitates to store rain water in a tank.

RDWSSP plans to rehabilitate existing roof catchment systems of schools, churches, health centres etc., which have a limited number of consumers and sufficient roof size to supply these consumers.
Construction of new roof catchment systems is not taken into consideration. Construction of wells and springs is often more cost effective than construction of a new roof catchment system.

Fig. 6.7 shows in which areas roof catchments are planned to be rehabilitated.
Rehabilitation of existing roof catchment systems is mainly planned in Bondo and Rarieda Divisions.
Out of 20 roof catchment systems planned to be rehabilitated, 14 are located in these 2 Divisions.

Rehabilitation of a roof catchment system aims at removal of bottle necks, which block the effective use of the roof catchment system.
Some of these bottle necks are:

- gutters which are missing
- gutters which have to be aligned
- pipe connection between gutters and storage tank which is missing
- leaking storage tanks.

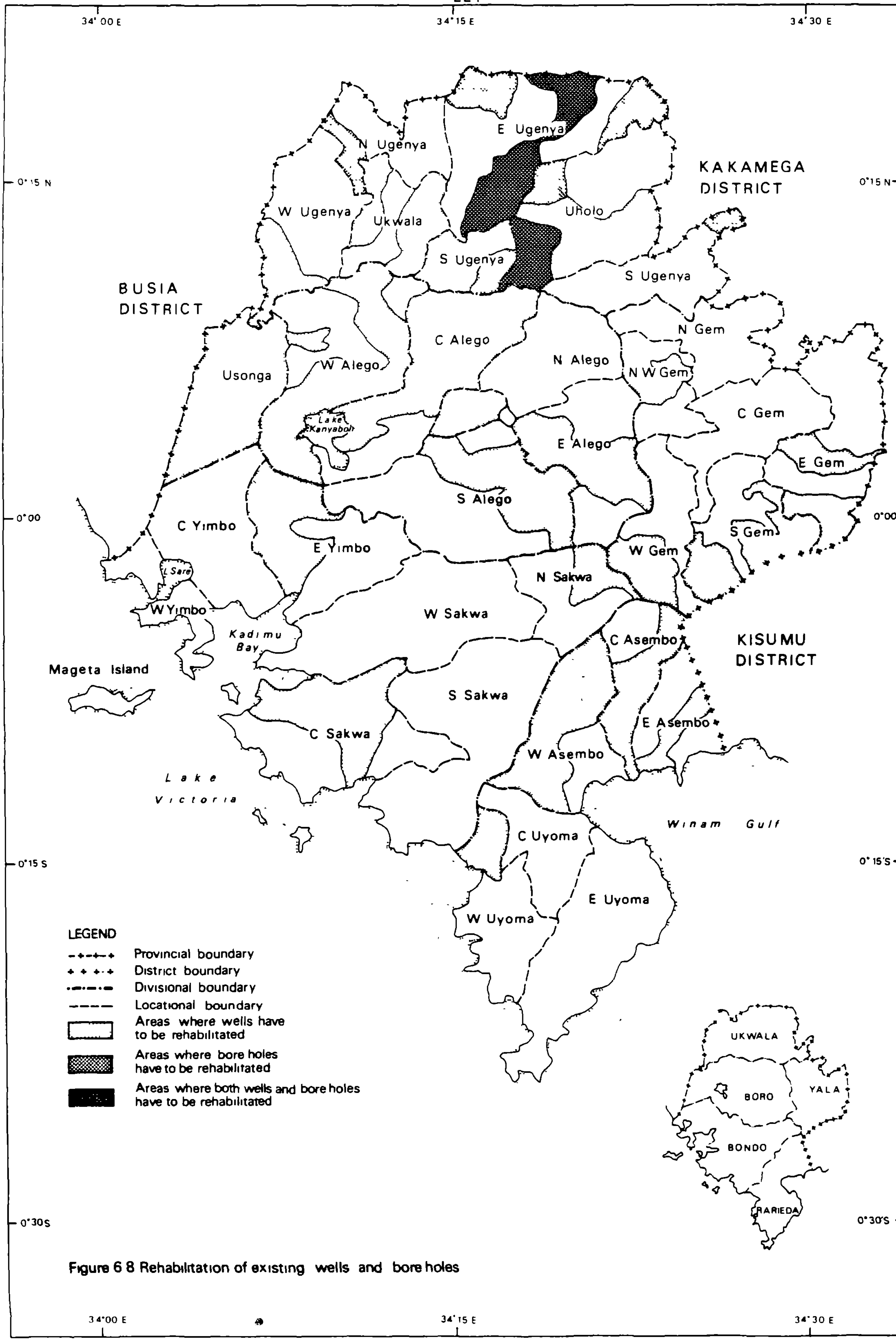


Figure 6 8 Rehabilitation of existing wells and bore holes

6.3.6. Rehabilitation and construction of wells and boreholes

Rehabilitation of existing wells and boreholes

Fig. 6.8 shows in which Sub-Locations, existing wells and boreholes have to be rehabilitated.
Most wells which need rehabilitation are located in the central zone (zone 2) (northern part of Rarieda Division, Boro Division and the southern part of Ukwala Division).
The required rehabilitation works range from a complete renewal (deepening, lining, installation of a cover and installation of a pump) to small repairs related to the superstructure or pump.
A total number of 116 wells are planned to be rehabilitated. Most of them (84, 72 %) are located in Boro Division. Most of the Boro wells are found in the western part of this Division (Usonga and West Alego Locations).
More than 55 % of the wells recommended for rehabilitation have a lining, about 40 % have a slab and 25 % have a pump of which however only a few are working.

In Ukwala Division 11 boreholes are recommended for rehabilitation.
Rehabilitation works include fencing, improved drainage, repair of slab, construction of a cattle trough and/or washing facilities, repair of a pump and installation of pump.
Repair of the pump or installation of a pump are the most frequently indicated problems.

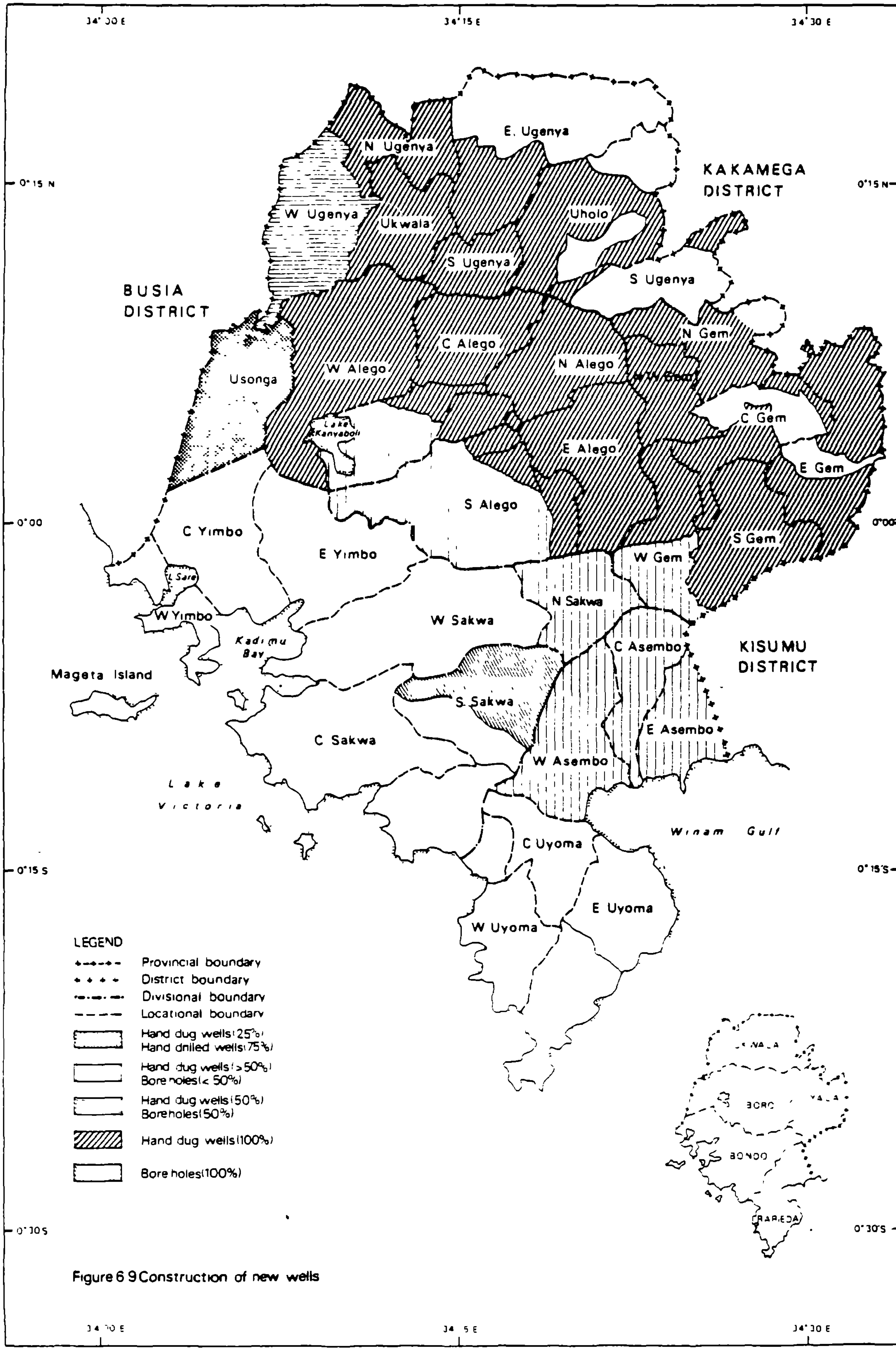


Figure 6.9 Construction of new wells

Construction of new wells and boreholes

Fig. 6.9 shows in which Locations new wells are needed.

In most parts of Boro, Ukwala and Yala Divisions a new well can be made by hand digging.
Construction of hand dug wells is foreseen at water hole sites, as shallow well type spring protections or as new point sources.

Machine drilled wells (boreholes) are needed in the extreme western part of Ukwala Division , the southern part of Boro Division , the eastern part of Bondo Division , the extreme south-western part of Yala Division and the northern part of Rarieda Division.

Construction of hand drilled wells is only possible in Usonga Location.

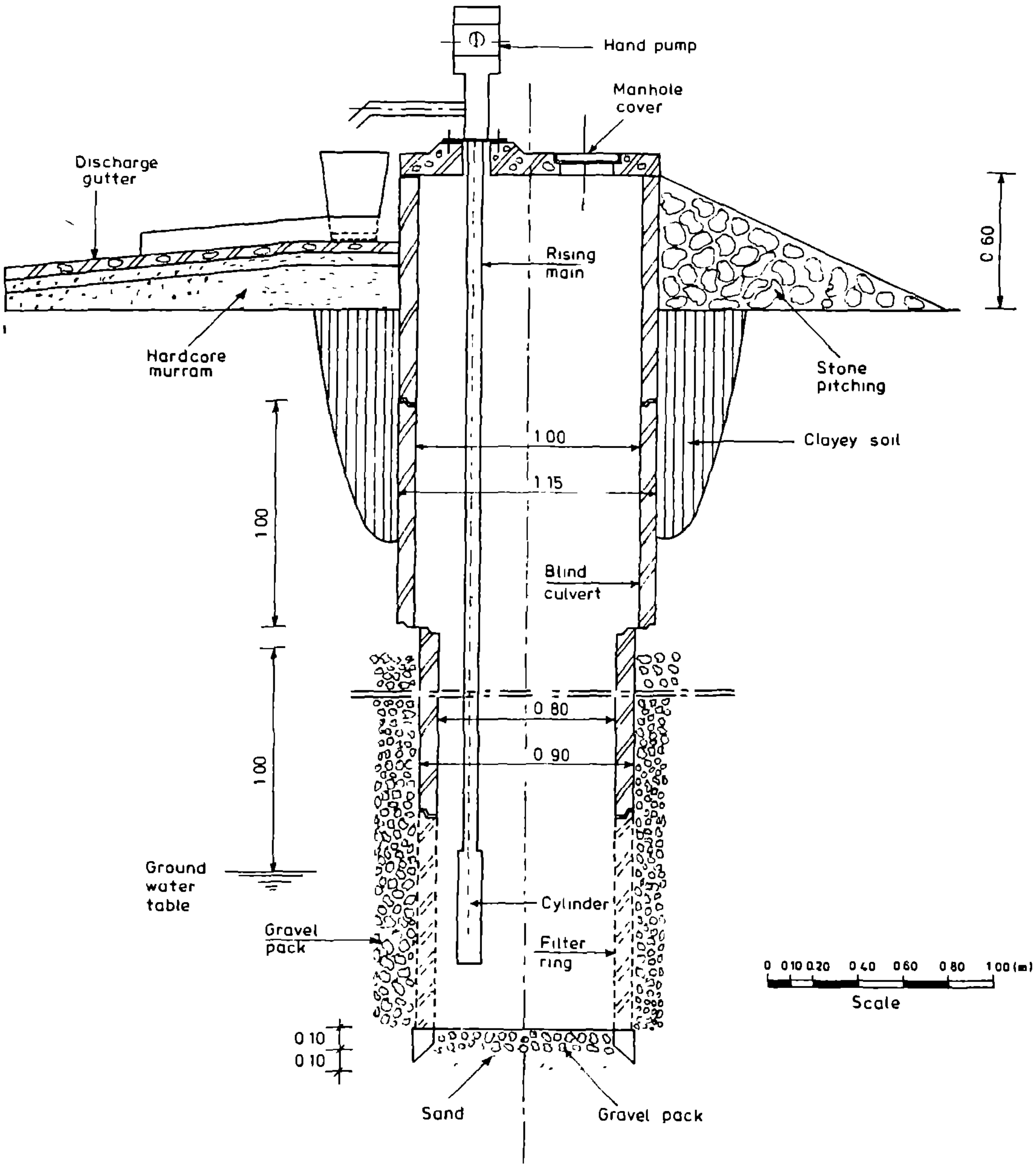


Figure 6 10 RDWSSP HAND DUG WELL DESIGN

Construction of hand dug wells

Design

Fig. 6.10 shows the RDWSSP design of a hand dug well.
Most characteristic is the top culvert which rises up to 0.60 (m) above the surrounding ground level. Buckets are put besides the covering slab to protect the well against surface runoff from entering into the well and exclusion of water splashing on the cover and anchor bolts.
A manhole in the concrete cover gives access to the well in case down hole activities are required.
SWN-80 hand pumps are installed at all wells. Finally the well site is fenced with barbed wire and cedar poles.

It is common practice to install in all new wells a lining.
The presence of a lining increases the life time of a well considerably. It also offers a better protection against polluted surface and sub-surface runoff from entering into the well (the upper part of the lining is impermeable).

RDWSSP commonly uses two types of well lining:

- Culverts.
  Pre-cast concrete rings (culverts) are used. Normally 1.15 (m) diameter reinforced rings are installed with porous concrete rings of the same diameter in the aquifer.
  Occasionally two different diameter concrete rings are used for telescoping (1.15 (m) and 0.95 (m) diameter). (see Fig. 6.10)

- Cast in-situ concrete lining.
  Step-wise a concrete lining is installed, while well digging continues till the ground water is reached. Under the water (0.95 (m) diameter) permeable culverts are installed to create a filter and to prevent collapsing of the hole.

Siting

Basically there are three ways of selecting a site for construction of a hand dug well.

1 A field reconnaissance of the area principally based on hydrogeological observations. These observations combined with the knowledge about the ground water level, the water quality of existing wells and ground water level fluctuations form the basis for the site selection.
  This selection method is generally only applicable in areas with a relatively high density of existing wells and therefore ample information on ground water characteristics.

Machine drilling.

2 Field surveys be means of hand-auger drilling.
In situations where ground water has been encountered but the yield of the test hole proved to be insufficient for a hand drilled production well. Only applicable where ground water is relatively shallow and the over burden exist of unconsolidated soft material without course rock fragments.

3 A geophysical field survey, which is generally applied in all other than above described situations.

Equipment

Simple hand tools are used for well digging such as: a small pick-axe, a hoe, a hammer, and a chisel.
The broken rock is lifted from the well by means of a rope and a bucket. Safety equipment includes a helmet, safety goggles and a harness to quickly lift the digger out of the hole if necessary.
A simple locally made wooden winch or a steel tripod with a wheel are used to ease the lifting of rock materials, and lowering of the equipment and digger.

Digging

Basically a vertical, round hole of about 1.6 (m) diameter is excavated. Until ground water is reached, digging is normally done by two men one operating in the well and the other one staying at the ground surface to lift soil and lower materials. If possible, digging is continued up to a depth of 3-5 (m) below the dry season water level.

Lining

Culverts are lowered using a winch and a steel tripod.

Dewatering

During the first few days after reaching the water table, dewatering is simply done with a bucket. When water becomes abundant and removal of the water with a bucket becomes impossible, a SWN-80 type hand pump with a 3" cylinder is installed in the hole.
When digging is done during or shortly after the rainy season, ground water levels are often high. Digging is sometimes stopped temporarily, to be continued during the dry season.

Labour

All construction activities including; digging, installation of the well lining and dewatering, are carried out by local contractors (generally two by the programme trained well-sinkers). Contracts are signed directly between the two well-sinkers and the RDWSSP. Payment is based on rates per foot digging and other constructing activities. The superstructures are constructed by local contractors too, according to designs and specifications of the RDWSSP.

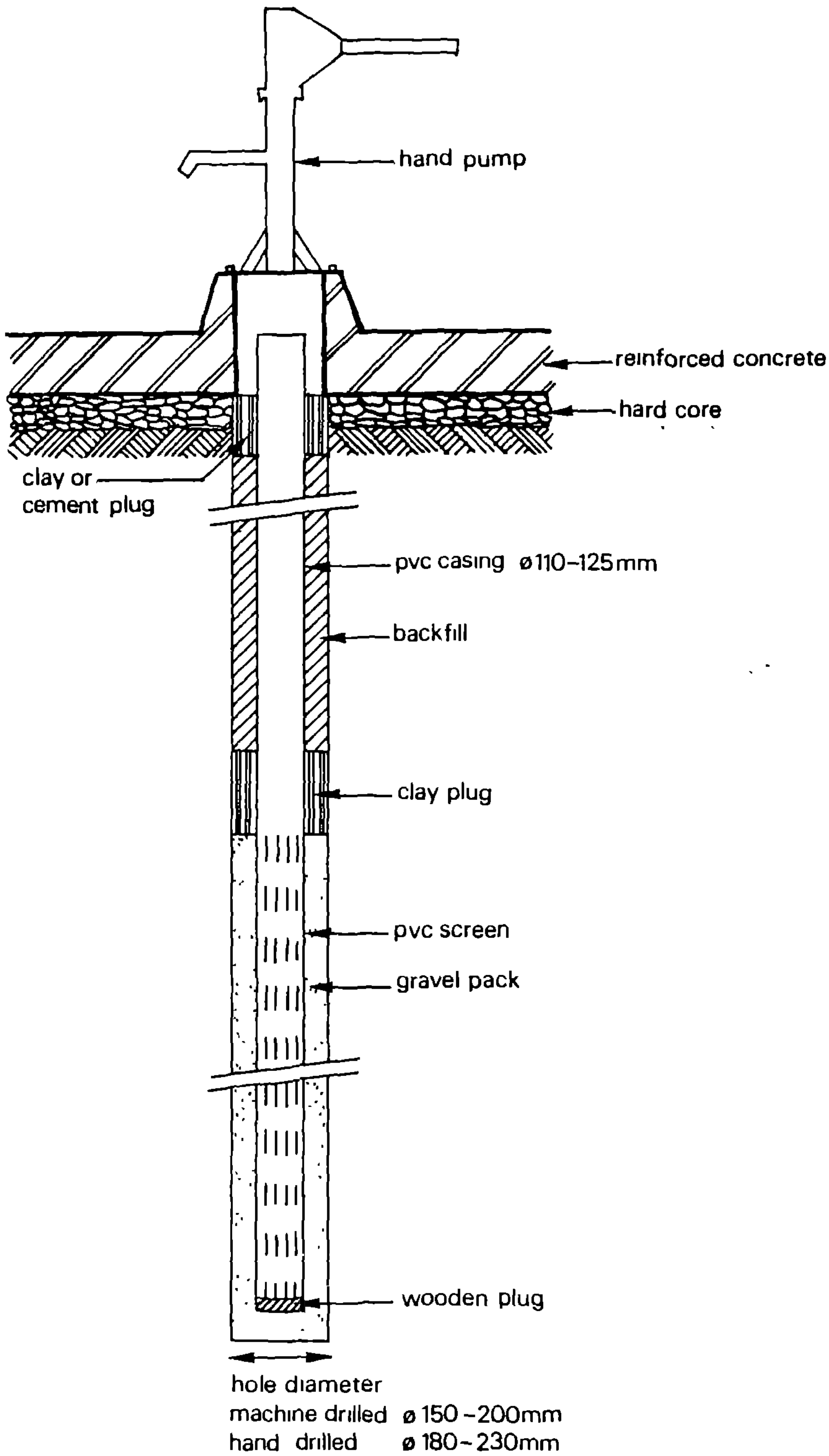


Figure 6.11 RDWSSP hand drilled well and bore hole design.

Construction of machine drilled wells

Design

Fig. 6.11 shows the RDWSSP design of a machine drilled well.
In all drilled boreholes, over the full length, PVC casings and screens are installed with a diameter of 110 or 125 (mm). Around the screens (with a slot opening of 0.6 - 0.8 (mm)) gravel pack is placed with a grain size ranging between 1.2 - 4.6 (mm).
The aquifer(s) is (are) sealed using clay or concrete, after which the borehole is back filled.
SWN-80 hand pumps are installed at all machine drilled wells.
Generally a barbed wire fence is constructed around the well.

Siting

Boreholes are made in areas where deep ground water (exceeding 25 (m))is expected. A geophysical survey is always executed. The various geophysical siting methods, developed and used by the RDWSSP, are explained in section 4.5.

Drilling

Borehole drilling, completion and test pumping is carried out by Kenya based borehole drilling contractors, according to bills of quantities and other specifications recorded in contracts drawn up by the RDWSSP. Water inspectors of the RDWSSP monitor, record and supervise the works.

The present sequence of activities in borehole drilling and testing is as follows:

- mobilisation to the site, erecting of the rig
- drilling with the 8" bit to the required depth
- flushing and cleaning of the hole
- well logging
- installation of pvc casing, screens, gravel pack, seals etc
- development
- test pumping and recovery measurement
- installation of 2-3 (m) of 8" steel casing for protection
- capping.

All activities are recorded by the drilling supervisors on a daily progress sheet

Drilling rate logging

A simple but useful log is the drilling rate log, which is recorded by the RDWSSP drilling supervisors monitoring the drilling. This log presents in a graphical way the number of minutes drilled per metre. On these logs a good correlation can be seen between the hardness or the grade of weathering of the rock types drilled. Drilling rates in water bearing zones are usually higher than drilling rates in aquicludes.

Geophysical well logging

Well logging is done with the ABEM SAS LOG 200 using the ABEM SAS 300 TERRAMETER master unit. With this equipment the following measurements can be made up to a depth of 200 (m):

- self potential
- short normal resistivity
- long normal resistivity
- long lateral resistivity
- fluid resistivity
- fluid temperature.

In principle all measurements except the long lateral logs are recorded. Readings are taken every metre.
Preferebly the logging is done after the flushing of the borehole, but well before the ground water level has reached it's static level.
In this way it is usually possible to obtain information about zones of ground water inflow from the water temperature and water resistivity logs.
The logging of a 50 (m) deep borehole will take up to about 2 hours only.

Test pumping

The pump tests performed on the completed and developed boreholes are essentially well performance tests.
The tests consist of pumping the borehole at various discharges (step drawdown test).

The tests have been standardized to 4 steps of 1 1/2 hours each. After the last step the recovery is measured. However it is of course possible to deviate from this routine, depending on the local circumstances.

During development, the approximate maximum yield is established which will be used as the maximum yield during the fourth step of the pump test.
The discharges of step 1, 2 and 3 will respectively be 1/4, 1/2 and 3/4 of the yield of step 4.

From this multiple rate test it is possible to establish the following parameters:

- specific well capacity
- maximum yield
- optimal well yield
- well efficiency.

Besides it is possible to estimate the order of magnitude of the aquifer transmissivity from the recovery measurements.

Construction of hand drilled wells

Design

Fig. 6.11 shows the RDWSSP design of a hand drilled well. Apart from a different diameter of the well, the design is identical to the one of a machine drilled well.

Siting

Siting of hand drilled wells is done by hand drilling of 10 (cm) diameter test holes. If an aquifer is struck, temporary casing and screen are installed, a short pump test is done and water samples are taken for analyses.
Usually a number of survey holes are drilled and tested, out of which the best well site can be selected.

Manpower

Because only a few hand drilled wells have been constructed so far, this operation has not yet been contracted out.
The drilling crew usually consists of at least 3 skilled RDWSSP workers and 4-6 helpers.
The foreman of the team is responsible for the actual construction of the well.

Drilling of the hole

Construction generally starts with the clearing and leveling of the drilling site (area of 10 x 10 (m)). Then a tripod is erected over the borehole location, which should always be at least 2 (m) away from an old survey hole.
The actual drilling commonly is started with a combination of the 230 (mm) diameter auger bit and the corresponding flight auger which is turned anti-clockwise into the ground by 4 men in a vertical position. When the ground water level is passed and the borehole starts caving, a casing has to be installed.

As caving usually occurs in layers of sand which cannot be drilled up with auger bits the borehole must be deepened by means of a bailer.

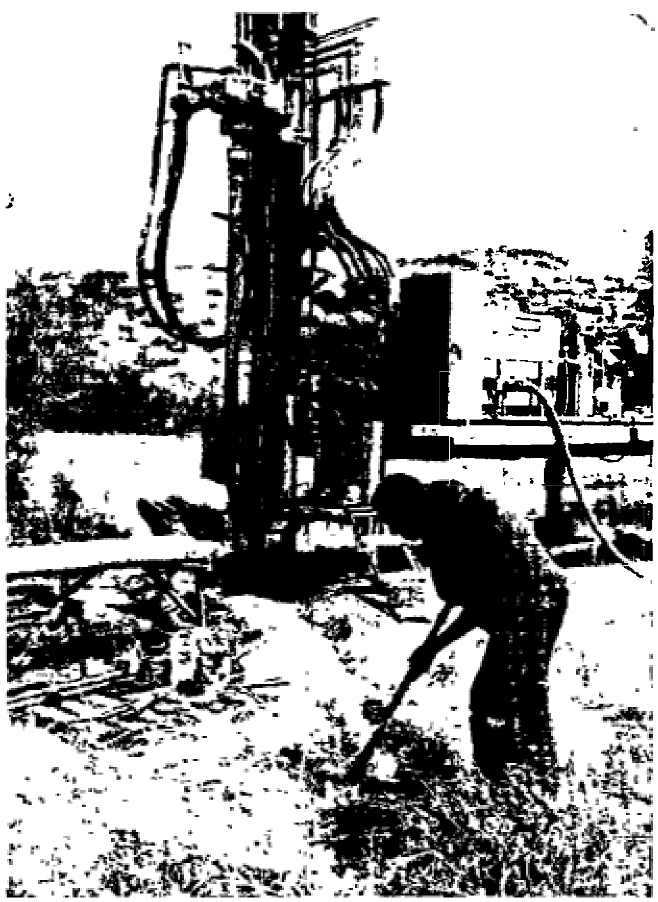
Spring protection.

Unless the well is to finish halfway through the aquifer, bailing is stopped as soon as a more solid layer is reached. Then drilling can be continued with the small size auger or riverside bit.

After completion of the hole, casing screens and gravel pack is installed in order to create a proper filter.
For a more detailed description of the hand drilling method is referred to Blankwaardt (Ref.3.).

Development and testing

To optimize the well performance the well is developed by pumping till the water becomes clear. A simple pump test is subsequently carried out by pumping for about one hour with a hand pump.



Borehole developing.

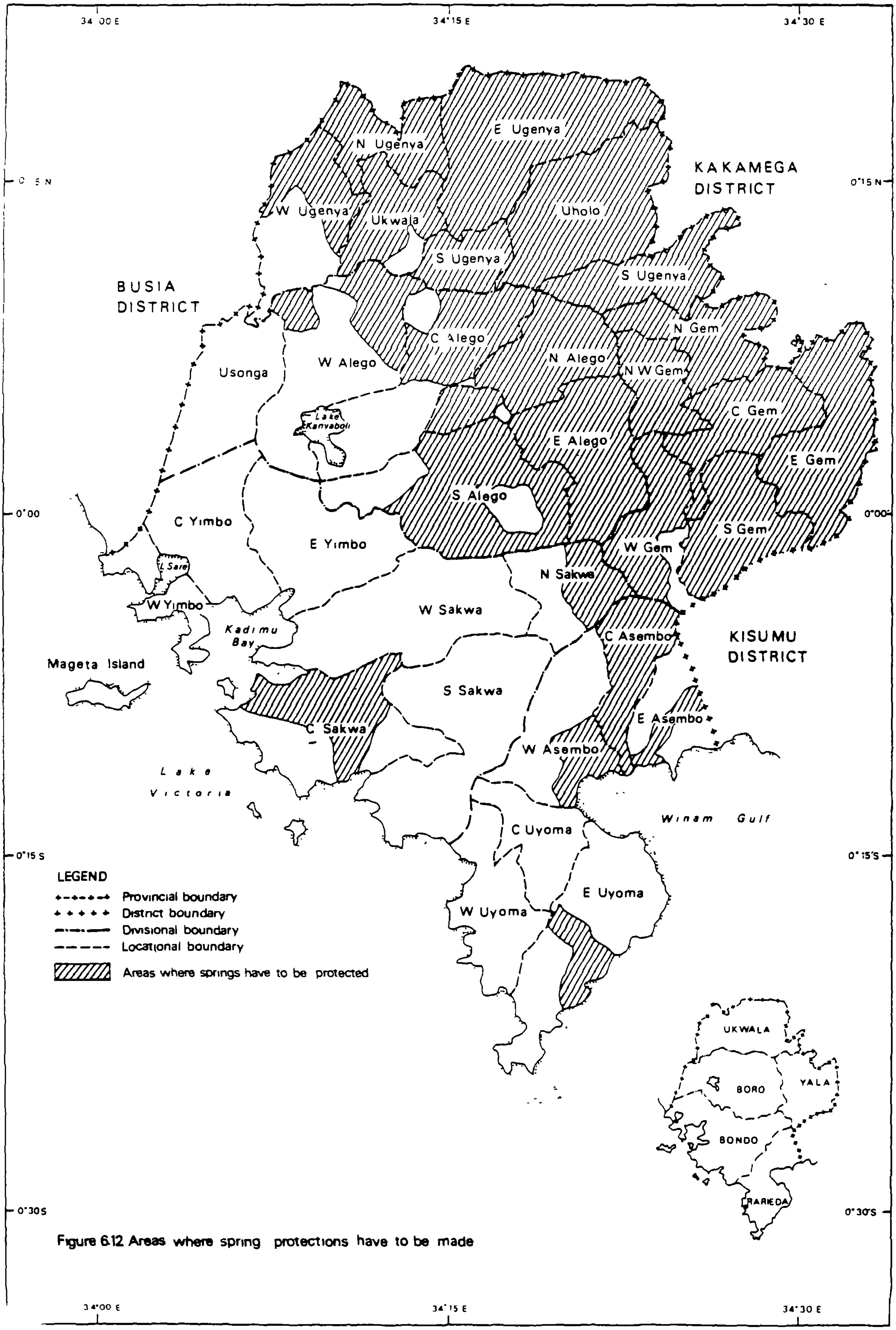


Figure 6.12 Areas where spring protections have to be made

6.3.7. Spring protection

Fig. 6.12 shows that spring protections are almost exclusively planned in zone 3, having a good ground water potential.

Spring protection includes:

- protection of the ground water from surface pollution;
- proper drainage of the outflowing spring water.

A proper drainage of the outflowing spring water can be obtained by digging a trench through which the water is evacuated. The trench should have sufficient slope.
At many sites however the terrain is too flat to fill a bucket and to drain the spilled water.
A frequently practiced solution is to stow the ground water via a retaining wall. Water emerges via a draw off pipe located above the spring eye which enables to fill the bucket and give the drainage gutter sufficient slope.
This "solution" however is strongly dissuaded because of the risk that the spring eye might shift to an other point. The final result will be a protected but dry spring.

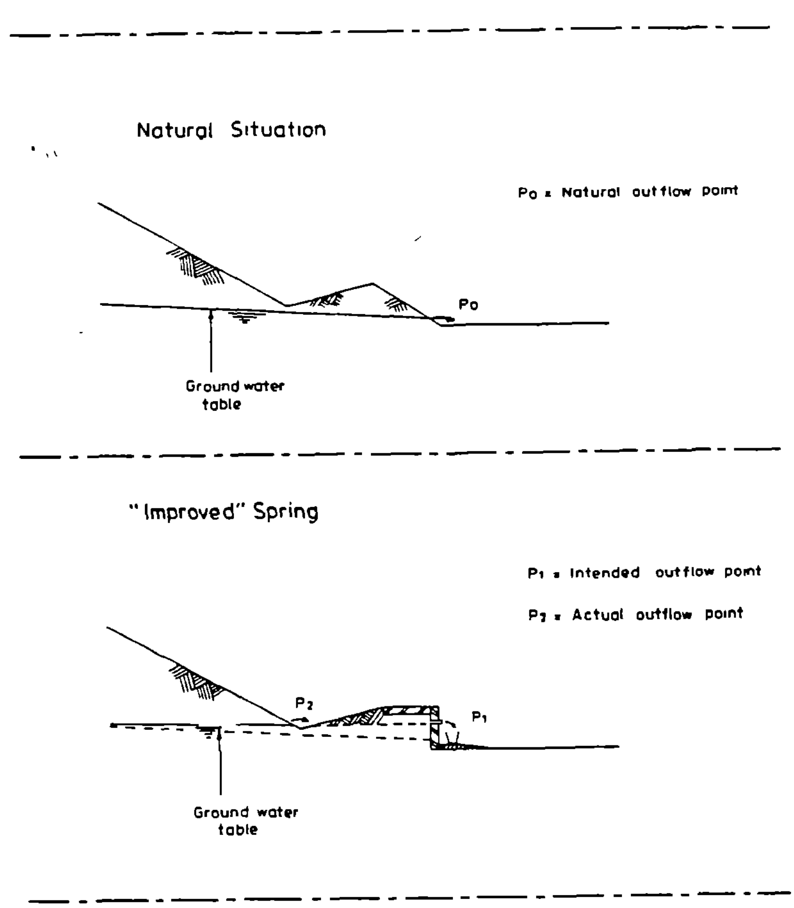


Figure 6.13 Spring Protection, retaining wall to stow ground water

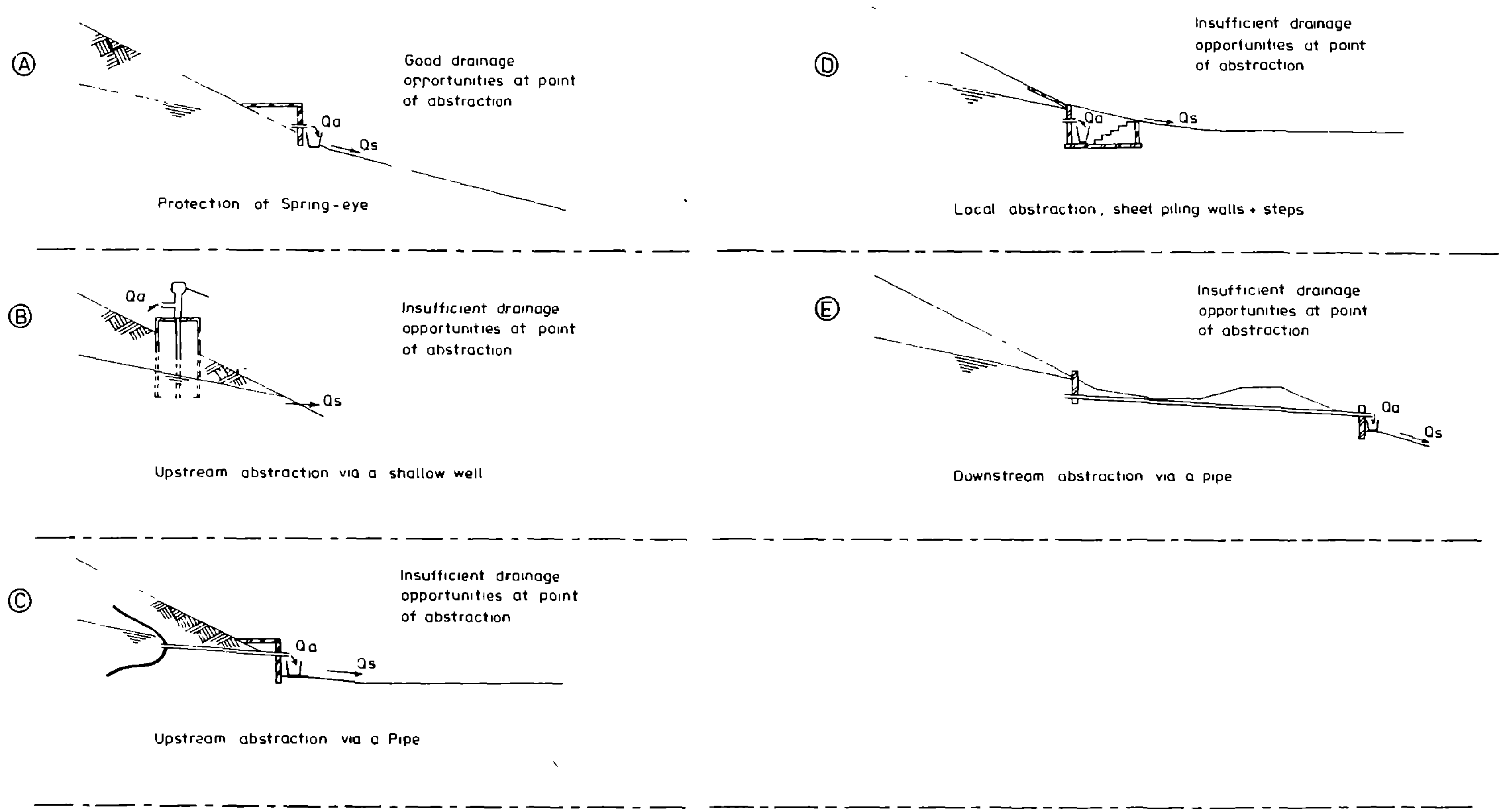


Figure 6 14 Spring Protection different type solutions

Fig. 6.14 shows different types of proper spring protections.

Fig. 6.14-A. shows the solution in case there are good drainage opportunities at the point where the spring is found. The "spring-eye" is covered and water is abstracted at that point.

Fig. 6.14-B. up to 6.14-E. shows different type solutions in case of insufficient drainage opportunities at the spring site.

Fig. 6.14-B. shows upstream abstraction of water using a shallow well. The main advantage of this solution is that water can be abstracted at the best point upstream. The well does not interfere with the ground water flow. The risk of a shifting spring eye is avoided. Main disadvantage of this solution is the need for a pump with related operation and maintenance problems.

Fig. 6.14-C shows the Kisii Valley Bottom solution. Upstream abstraction of the water which is piped to a level which enables to fill a bucket and drain the spilled water.
Main advantages of this solution are the low construction costs and the possibility to abstract water from different "spring-eyes. Main disadvantage is the risk that excavation works will cause a new outflow point.

Fig. 6.14-D. shows the alternative using steps to abstract the water from a point located under the ground water table.
Disadvantages of this solution are the costs (sheet piling walls have to be made which are expensive), the need for a tap valve, and the risk of a shifting outflow point.

Fig. 6.14-E. finally shows a solution where water is piped to a site having better opportunities for water abstraction and drainage. This better site should be close to the spring. Like type solution C, it gives the opportunity to use several spring-eyes.

Both RDWSSP as well as KEFINCO practise the type solutions A, B and E.

Spring protection,
Type solution D.

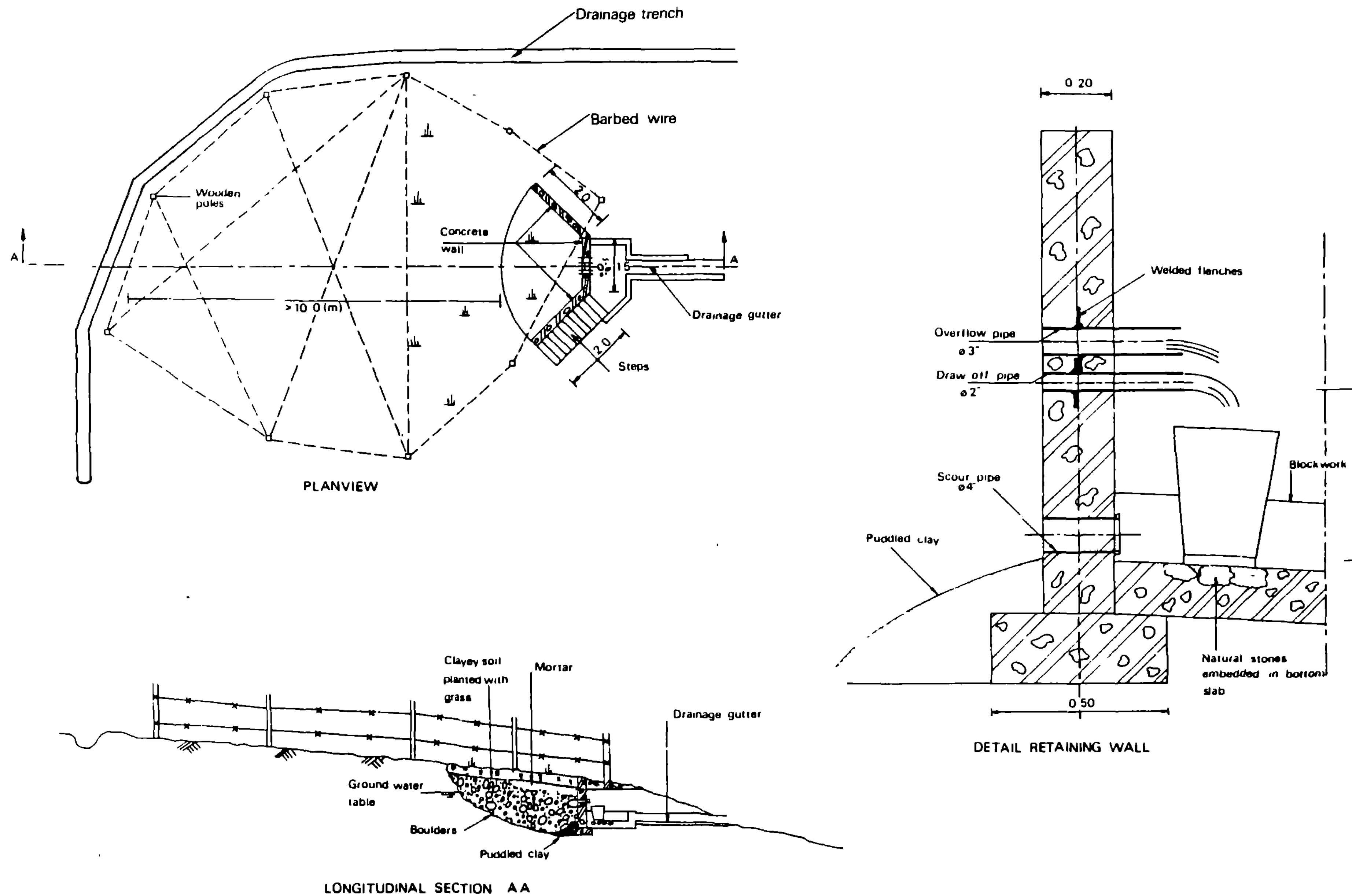


Figure 6 15 SPRING PROTECTION RDWSSP
GOOD DRAINAGE OPPORTUNITIES

Fig. 6.15 shows the RDWSSP design which is used in case of good drainage opportunities (type solution A).
The overflow pipe and draw off pipe are made at almost the same height. A scour pipe is installed to flush away any blockages of the pipes.
Hardcore, natural stones are embedded in the bottom slab to prevent that the slab is worn out by the water flowing from the pipes.
The area upstream is fenced with cedar poles and barbed wire. A drainage trench prevents polluted surface runoff from reaching the spring water.
Puddled clay is used to exclude that the concrete wall is undermined.

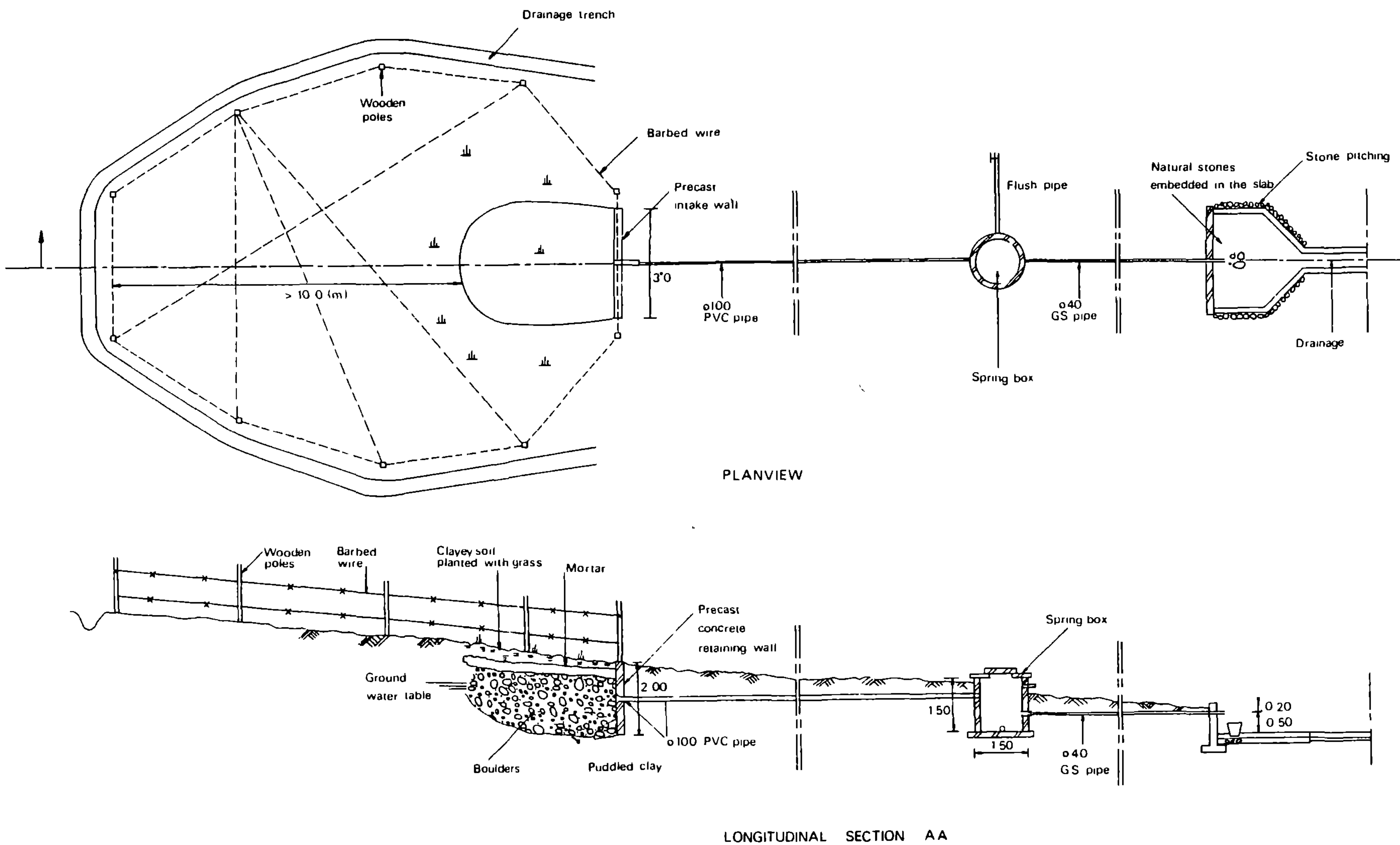


Figure 6 16 SPRING PROTECTION RDWSSP.
PIPED WATER ABSTRACTION

Fig. 6.16 shows the RDWSSP design of a piped spring protection (type solution E).
It has a precast intake wall with a pipe connection to a spring box. A large diameter pipe (100 mm PVC) is used to abstract a maximum flow of water from the spring.
The spring box acts as a sedimentation tank. Particles which are flushed from the spring are retained in the box.
Sediments are regularly flushed from the box via a flush pipe.
A small diameter pipe leads from the spring box to the public tap.

It is estimated that about 36 % of all springs to be improved, can be protected by making a gravity flow protection as indicated in Fig. 6.15.

At 64 % of the spring sites a shallow well has to be made (type solution B) or there should be good opportunities for piping the water to a site with better drainage opportunities.

Table 6.1 Water Supply Plan

Area	Required number of safe and reliable water points	Good water points and water points under cons.	Remaining number of water points to be improved or newly constructed	PIPED WATER SUPPLIES	RAIN WATER: Ground catchm.	RAIN WATER: Dams	RAIN WATER: Roof catch.	WELLS – HAND DUG WELLS: Rehab of wells	WELLS – HAND DUG WELLS: New wells	WELLS – HAND DUG WELLS: Water holes	WELLS – HAND DUG WELLS: Shallow well spring protect.	WELLS – HAND DRILLED WELLS	WELLS – BOREHOLES: Rehab of bore holes	WELLS – BOREHOLES: New bore holes	SPRINGS: Springs gravity flow protect.	TOTAL
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)
Bondo	588	7	581	410	20	30	9	3	32	2	2	0	0	67	6	581
Rarieda	533	5	528	273	15	14	5	7	165	19	11	0	0	19	0	528
Boro	663	18	645	0	4	9	4	84	368	31	101	15	0	25	4	645
Yala	610	13	597	37	0	0	0	8	184	16	252	0	0	11	89	597
Ukwala	726	241	485	20	0	0	2	14	162	3	87	0	11	26	160	485
Siaya District	3,120	284	2,836	740	39	53	20	116	911	71	453	15	11	148	259	2,836

6.3.8. Review of rehabilitation and construction works

Table 6.1 presents a breakdown per Division and type of water point of the rehabilitation and construction works which are planned. Column (4) shows how many safe and reliable water points are needed after subtraction of the existing good water points and water points which are already under construction.
Column (5) shows that rehabilitation and construction of piped water supplies is almost completely concentrated on Bondo and Rarieda Divisions.
This also applies for rehabilitation of rain and surface water systems as ground catchments, dams and roof catchments. (column 6,7 and 8).
Construction of wells is concentrated in Boro Division where 624 wells are planned (94% of all water points needed in Boro). Major components of well construction in Boro Division are;

- rehabilitation of wells (84) (column 9)
- construction of new hand dug wells (368) (column 10)
- construction of new hand dug wells at water hole sites (31) (column 11)
- shallow well spring protections (101) (column 12)
- hand drilled wells (15) (column 13).

Most boreholes are to be made in Bondo Division.
Only in Ukwala Division existing boreholes have to be rehabilitated (pump repair).
Spring protection is only important in Ukwala and Yala Divisions.

Table 6.2 Cost estimates for piped water supplies (data from literature)

Name of project or scheme	Cost estimate prepare by	Status	Year	Number of consumers	Distr. area	No of distr. points		Pumped or gravity	Capacity	Treatment	Construction Cost	Construction Cost 1988	Cost per capita	Cost per km2
						Private	Public							
					(km2)				(m3/day)		Ksh	Ksh	Ksh	Ksh
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)
Sakwa Water Supply	Cowi Consult	Prel.Design	1983	208100	773	18810	179	grav/pump	11,304	Yes	173,010,000	325,874,602	1,566	421,571
West Kenya Water Sup.Proj.Asembo	Norconsult A.S.	Prel.Design	1978	126906	237		100	pump	3,389	Yes	25,900,000	91,887,911	724	387,713
Bondo Water Supply	Otieno Odongo & Partners	Prel.Design	1981	30350	80			pump		Yes	19,292,000	46,811,039	1,542	585,138
Busia Hill Water Scheme		After compl.	1971	7000	55	17	16	pump		No	500,000	4,304,271	615	78,259
Mauna Dam Water Scheme		After compl.	1974	14000	75		44	pump		No	810,000	4,768,997	341	63,587
Maseno Kombewa Water Supply	Bish & Partners	Final Rep.	1974	104600	337		90	pump		Yes	13,560,000	79,836,548	763	236,904

6.4. CONSTRUCTION COSTS

6.4.1. Piped Water Supplies

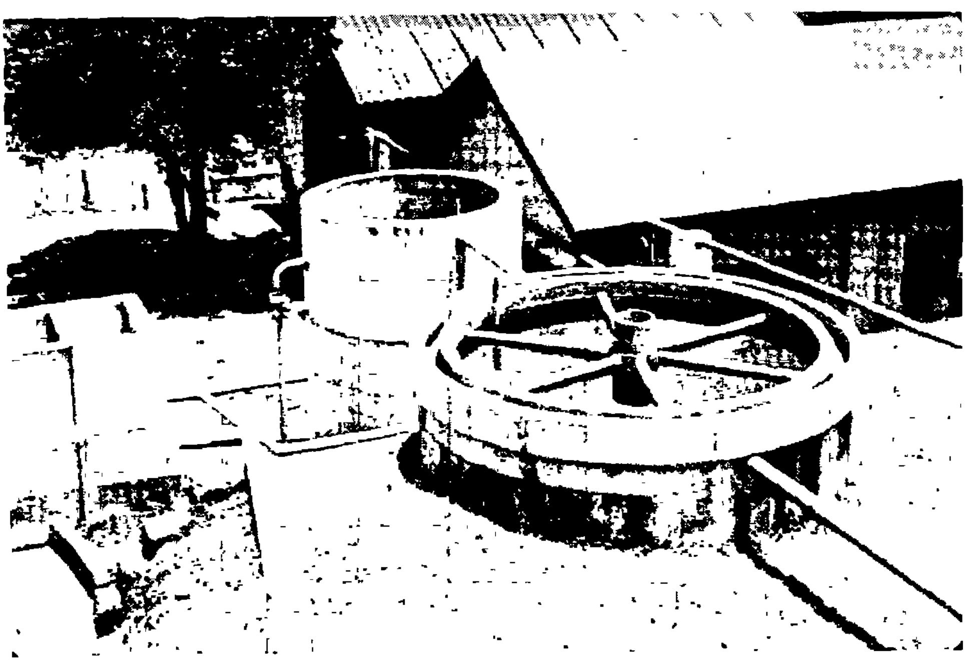
Piped water supplies have not been made by the project up till now. Hence , there is no detailed information available about the costs for improvement, extension or construction of piped water supplies.
Only a rough estimate can be given of the construction and rehabilitation costs.

Table 6.2 presents the estimated costs for new piped water supplies as found from literature. The construction costs as indicated in column 12 have been updated using a yearly price increase of 13.5 %. This figure is based on the average price increase of civil engineering works over the period from December 1972 up till December 1984 in which the civil engineering cost index rose from 100 (Dec. 1982) to 460 (Dec. 1984) (Ref. 6.).
Column 13 shows the updated cost figures (1988 price level).
Column 14 and 15 show the construction costs per capita and per (km^2) of distribution area.
The costs per (km^2) vary between less than Kshs 100,000/- to over Kshs 500,000/- per (km^2). On a average, the construction costs equal about Kshs 300,000/- per (km^2).

The average costs per (km^2) of Kshs 300,000/- , have been used to calculate the costs for making new piped water supplies in Siaya District. For rehabilitation , completion and extension of existing piped water supplies reduced costs figures per (km^2) are used. Both the actual condition of the existing schemes as well as the required improvement and extension works have been taken into account in reducing the per (km^2) costs of these schemes.
For rehabilitation of Sidindi-Malanga Water Supply a detailed cost estimate has been prepared.
Table 6.3 shows the unit costs figures as well as the total costs for the planned piped water supplies in Siaya District.

Intake.

Bondo Water Supply.



Sedimentation and filtration tank.

Table 6.3. Construction costs of piped water supplies planned to be rehabilitated or newly constructed in Siaya District

Piped water supply	Works needed	Unit costs (Ksh)	Total costs (Ksh)
Mageta Island Water Supply	New scheme	Kshs 300,000/km^2	2,100,000
Osieko Water Supply	Rehabilitation	Kshs 150,000/km^2	1,950,000
Usenge Water Supply	Rehabilitation	Kshs 150,000/km^2	3,000,000
Usigu Water Supply	Rehabilitation	Kshs 150,000/km^2	3,450,000
Ramogi Forest Water Supply	Rehabilitation	Kshs 150,000/km^2	2,700,000
Nyamonye Water Supply	New scheme	Kshs 300,000/km^2	30,000,000
Bondo Water Supply	Rehabilitation + major extension	Kshs 300,000/km^2	33,900,000
South Sakwa Water Supply	Compl. of scheme under constr.	Kshs 225,000/km^2	28,125,000
Got Abiero Water Supply	New scheme	Kshs 300,000/km^2	48,600,000
Uyoma Water Supply	Rehabilitation	Kshs 150,000/km^2	13,650,000
Aram Water Supply	Rehabilitation	Kshs 150,000/km^2	1,050,000
Sidindi-Malanga Water Supply	Rehabilitation	-	4,420,000
		Total	172,945,000

6.4.2. Roof catchments

Roof catchment water supply is a rather expensive type of water supply facility. Table 6.4 gives a breakdown of the construction costs of a large roof catchment system including a 50 (m^3) underground masonry storage tank and 160 (m) of roof gutters. Dependent on the water consumption such a roof catchment system can supply between 50 and 200 consumers.
The total costs excluding supervision are estimated at about Ksh 217,000/-.
Construction of new roof catchment systems is therefore not planned. It is advised to restrict the RDWSSP involvement to improvement of existing roof catchment water supplies.
The improvement is aimed at taking bottle necks away. Technical advises and small repairs are assumed to be given or done by the project. It is estimated that the "non owner" component paid by the project is about Kshs 5000/- per roof catchment system.
All other costs are paid by the owner of the roof catchment system.

Table 6.4 Construction cost of a roofcatchment water supply system.

		Total costs (Ksh)
Construction of a 50 (m^3) underground storage tank		84,000/-
Roof gutters , pipes , fittings and belongings		68,000/-
Man holes , inspection chambers and valve pits		15,000/-
Additional works (excavation tank , set up of construction site , sealing , painting , hard core backfilling , pump installation etc.)		50,000/-
	Subtotal	217,000/-

6.4.3. Ground catchments and dams

Table 6.5 presents cost estimates for rehabilitation of existing ground catchments and dams.
Rehabilitation includes deepening of the reservoir, planting the upstream catchment area, deepening and protection of spill way (dams) and construction of the water treatment system as described before.
The costs for improving a ground catchment are estimated at Kshs 224,000/-.
The costs for improving a dam are estimated at Kshs 406,000/-.

Table 6.5 Cost estimates for improvement of groundcatchments and dams

	Ground catchment	Dam
Culvert intake sump (3 culvert rings)	4,500	4,500
Low lift hand pump	15,000	15,000
Horizontal roughing filter		
Filter tank	18,000	18,000
Filter material	3,000	3,000
Slow sand filter		
Filter tank	15,000	15,000
Filter material	5,000	5,000
Filter trench		
Water-tight foil	1,500	1,500
Filter material + clay cover	5,000	5,000
Storage tank (2 blind culvert rings)	7,500	7,500
Piping materials	5,000	5,000
Sub-Total - Water treatment system	79,500	79,500
Planting catchment area	5,000	10,000
Deepening of dam reservoir	75,000	150,000
Improvement or construction of spillway	0	50,000
Sub-Total - Additional works	80,000	210,000
Contractors profit (15 %)	24,000	43,500
Design, supervision and administration (25 %)	39,900	72,400
Total	224,000	406,000

Remarks : Trench digging , planting deepening (as far as done by hand) are done by the community

Table 6.6 Construction costs of hand dug, hand drilled and machine drilled wells
(in Ksh ; price level June 1988 ; based on RDWSSP experiences)

Description		HAND DUG WELLS			HAND DRILLED WELLS	BOREHOLES		
		Well depth (m)				Borehole depth (m)		
		10	15	20		50	60	70
WELL	. Digging or drilling	5,000	8,100	11,700	5,000	65,000	78,000	91,000
	. Transport of hand dug or hand drill equipment	3,000	3,500	4,500	3,000	0	0	0
	. Lining (transport + installation)	12,900	17,900	22,900	2,000	10,000	12,000	14,000
	. Supervision	7,000	7,000	7,950	1,000	4,950	4,950	4,950
SUB TOTAL WELL		27,900	36,500	47,050	11,000	79,950	94,950	109,950
SUPER STRUCTURE	. Site clearance + excav.	5,200	5,200	5,200	5,200	5,200	5,200	5,200
	. Concrete works	5,000	5,000	5,000	5,000	5,000	5,000	5,000
	. Fencing	2,800	2,800	2,800	2,800	2,800	2,800	2,800
	. Mobilisation and transport slab/wall mould	1,500	1,500	1,500	1,500	1,500	1,500	1,500
	. Supervision	5,500	5,500	5,500	5,500	5,500	5,500	5,500
SUB TOTAL SUPERSTRUCTURE		20,000	20,000	20,000	20,000	20,000	20,000	20,000
PUMP *	. Pump head + stand	5,297	5,297	5,297	5,297	6,000	6,000	6,000
	. Pump cylinder	3,536	3,536	3,536	3,536	2,470	2,470	2,470
	. Rising main + pump rod	3,285	5,110	6,935	3,285	10,950	14,600	18,250
	. Various small items	400	400	400	400	400	400	400
	. Installation (incl.transp.	1,000	1,250	1,500	1,000	3,000	3,500	4,000
	. Supervision	700	700	700	700	700	700	700
SUB TOTAL PUMP		14,218	16,293	18,368	14,218	23,520	27,670	31,820
TOTAL COSTS		62,118	72,793	85,418	45,218	123,470	142,620	161,770

* Based on duty free imported equipment

* 1 Survey costs (Ksh 4000.- per site) not included
* 2 Costs of expatriate staff not included
* 3 Succes rate of well construction not included

6.4.4. Rehabilitation and construction of wells

Table 6.6 gives a review of the costs for making hand dug, hand drilled or machine drilled wells of different depths.
The cost figures as indicated are based on the ongoing RDWSSP construction programme which includes construction of hand dug wells in South Nyanza and Siaya District as well as borehole drilling in South Nyanza, Kisumu and Siaya District.
In the past hand drilled wells have been made in South Nyanza, (Macalder Division) , Kisumu (Kano plains) and Siaya District (Boro Division).

All RDWSSP construction works for hand dug wells ranging from transport of construction materials, culverts, pumps etc. up to culvert sinking, in situ casting of superstructures and pump installation are done by local contractors.
In calculating the unit prices as indicated in Table 6.5, the contractor's profit has been taken into account.
RDWSSP is responsible for design, supervision and administration. Supervision includes training of the contractor to fulfill the required construction and installation standards.

The costs for making machine drilled boreholes are based on drilling and testing of the holes by a qualified contractor, and comprise the following activities: set-up of equipment, drilling of an 8" borehole, inserting of casing and gravel pack, top grouting, development and test pumping.

Survey costs, for well siting are not included. On an average the survey costs equal about Kshs 4,000/- per site.
Depreciation of means of transport e.g. motor bikes used by supervisors is not included.

The costs of expatriate staff is not included.

Prices of the superstructure and pump installation are based on rates of Kenyan contractors. Prices of pump equipment and PVC casing are based on tax free imported materials.

Figures as indicated in Table 6.6 apply for successfully constructed wells. The success rate of well construction is not taken into account.

Construction of a hand dug well costs between Kshs 62,000/- and Kshs 85,000/-.
For a hand drilled well an amount of about Kshs 45,000/- is needed.
Borehole drilling is between Kshs 123,000/- and Kshs 162,000/-.

Table 6.7 Construction costs of spring protections
(in Ksh ; price level June 1988 ; based on RDWSSP experiences)

Description		Gravity flow protection	Shallow well protection
WELL	. Digging (labour)	-	2,700/-
	. Transport of equipment (Tripod, Dewatering pump)	-	3,000/-
	. Lining (transport + installation)	-	9,830/-
	. Supervision	-	4,000/-
SUB TOTAL WELL		-	19,530/-
SUPER STRUCTURE	. Site clearance + excav.	3,600/-	5,200/-
	. Concrete works	7,000/-	5,000/-
	. Fencing	1,400/-	2,800/-
	. Mobilisation + transport slab/wall mould	1,500/-	1,500/-
	. Supervision	5,500/-	5,500/-
SUB TOTAL SUPERSTRUCTURE		19,000/-	20,000/-
PUMP *	. Pump head + stand	-	5,297/-
	. Pump cylinder	-	3,536/-
	. Rising main + pump rod	-	1,460/-
	. Various small items	-	400/-
	. Installation (incl.transp.)	-	750/-
	. Supervision	-	700/-
SUB TOTAL PUMP		-	12,143/-
TOTAL COSTS		19,000/-	51,673/-

* Based on duty free imported equipment * 1 Costs of expatriate staff not included

6.4.5. Springs

Table 6.7 gives a review of the costs for making spring protections.
A so called gravity flow protection is rated at Kshs 19,000/-. This figure is based on the ongoing spring protection works in Kisii District.
If drainage opportunities at the spring site are insufficient a shallow well is made. The construction cost are assumed to be equal to a well with a maximum depth of 5 (m).
The costs of such a well are about Kshs 52,000/-.

Like hand dug wells, spring protections are made by local contractors.
Works range from transport of construction materials like sand, stone chippings and ballast to in situ casting of the retaining wall and spring cover.
RDWSSP is responsible for design, supervision and administration. Supervision includes training of the contractor to fulfill the required construction and installation standards.

Depreciation of means transport e.g. motor bikes used by supervisors is not included in the costs figures.

The costs of expatriate staff are not included.

Table 6.8 Review of Construction costs
Siaya District Water Supply Plan

AREA	PIPED WATER SUPPLIES Number	Unit Costs (Ksh)	Total Costs (1000) (*Ksh)
Bondo	410	292,500	119,925
Rarieda	273	178,022	48,600
Boro	0		0
Yala	37	114,054	4,220
Ukwala	20	10,000	200
Siaya District	740	233,709	172,945

AREA	SPRING PROTECTIONS — Gravity Flow Protections: Number	Unit Costs (Ksh)	Costs (1000) (*Ksh)
Bondo	6	19,000	114
Rarieda	0	19,000	0
Boro	4	19,000	76
Yala	89	19,000	1,691
Ukwala	160	19,000	3,040
Siaya District	259	19,000	4,921

AREA	ROOFCATCHMENTS			GROUNDCATCHMENTS			DAMS			TOTAL COSTS ROOFCATC. GROUNDC. DAMS (1000) (*Ksh)
	Number	Unit Costs (Ksh)	Costs (1000) (*Ksh)	Number	Unit Costs (Ksh)	Costs (1000) (*Ksh)	Number	Unit Costs (Ksh)	Costs (1000) (*Ksh)	
Bondo	9	5,000	45	20	224,000	4,480	30	406,000	12,180	16,705
Rarieda	5	5,000	25	15	224,000	3,360	14	406,000	5,684	9,069
Boro	4	5,000	20	4	224,000	896	9	406,000	3,654	4,570
Yala	0		0	0		0	0		0	0
Ukwala	2	5,000	10	0		0	0		0	10
Siaya District	20	5,000	100	39	224,000	8,736	53	406,000	21,518	30,354

AREA	TOTAL COSTS WATER SUPPLY PLAN (Ksh*1000)
Bondo	154,175
Rarieda	79,336
Boro	52,403
Yala	36,473
Ukwala	24,105
Siaya District	346,491

AREA	WELLS: Shallow Wells			Hand dug			Hand drilled			Machine drilled			TOTAL COSTS WELLS (1000) (*Ksh)
	Number	Unit Costs (Ksh)	Costs (1000) (*Ksh)	Number	Unit Costs (Ksh)	Costs (1000) (*Ksh)	Number	Unit Costs (Ksh)	Costs (1000) (*Ksh)	Number	Unit Costs (Ksh)	Costs (1000) (*Ksh)	
Bondo	4	51,673	207	35	96,073	3,363	0		0	67	206,889	13,862	17,431
Rarieda	30	51,673	1,550	172	93,674	16,112	0		0	19	210,770	4,005	21,667
Boro	132	51,673	6,821	452	81,297	36,018	15	45,218	678	25	169,580	4,240	47,757
Yala	268	51,673	13,848	192	75,572	14,510	0		0	11	200,315	2,203	30,562
Ukwala	90	51,673	4,651	176	73,979	13,020	0		0	37	124,490	3,184	20,855
Siaya District	524	51,673	27,077	1,027	80,840	83,023	15	45,218	678	159	172,913	27,493	138,271

6.4.6. Review of costs

Table 6.8 presents a review of the construction costs for the Siaya District Water Supply Plan.

A breakdown is given per Division and type of water supply.

The survey costs and the success rate of well construction have been taken into account. Also the fact that part of the wells are to be rehabilitated which makes them less costly (no survey etc.). As a result unit costs of well construction differ from one Division to each other.

The total costs of the water supply plan are estimated at Kshs 346,000,000.
Construction of wells and boreholes and construction of piped water supplies are the most expensive components of the Water Supply Plan (see Fig. 6.17 A).
About 45 % of the total costs has to be spend in Bondo Division (see Fig.6.17 B).

FIG. 6.17a CONSTRUCTION COSTS PER TYPE OF WATER POINT

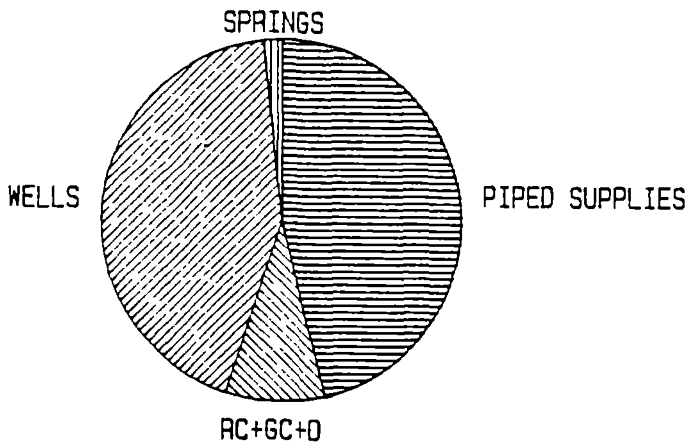
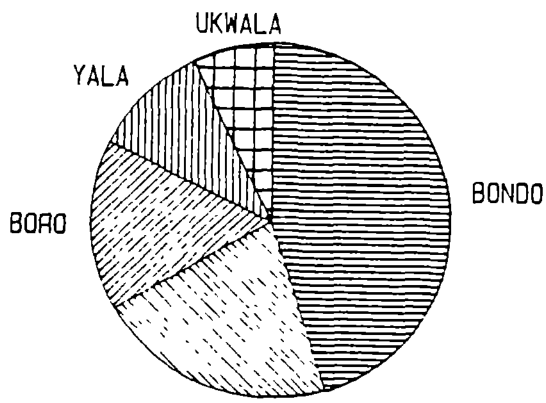


FIG. 6.17b CONSTRUCTION COSTS PER DIVISION

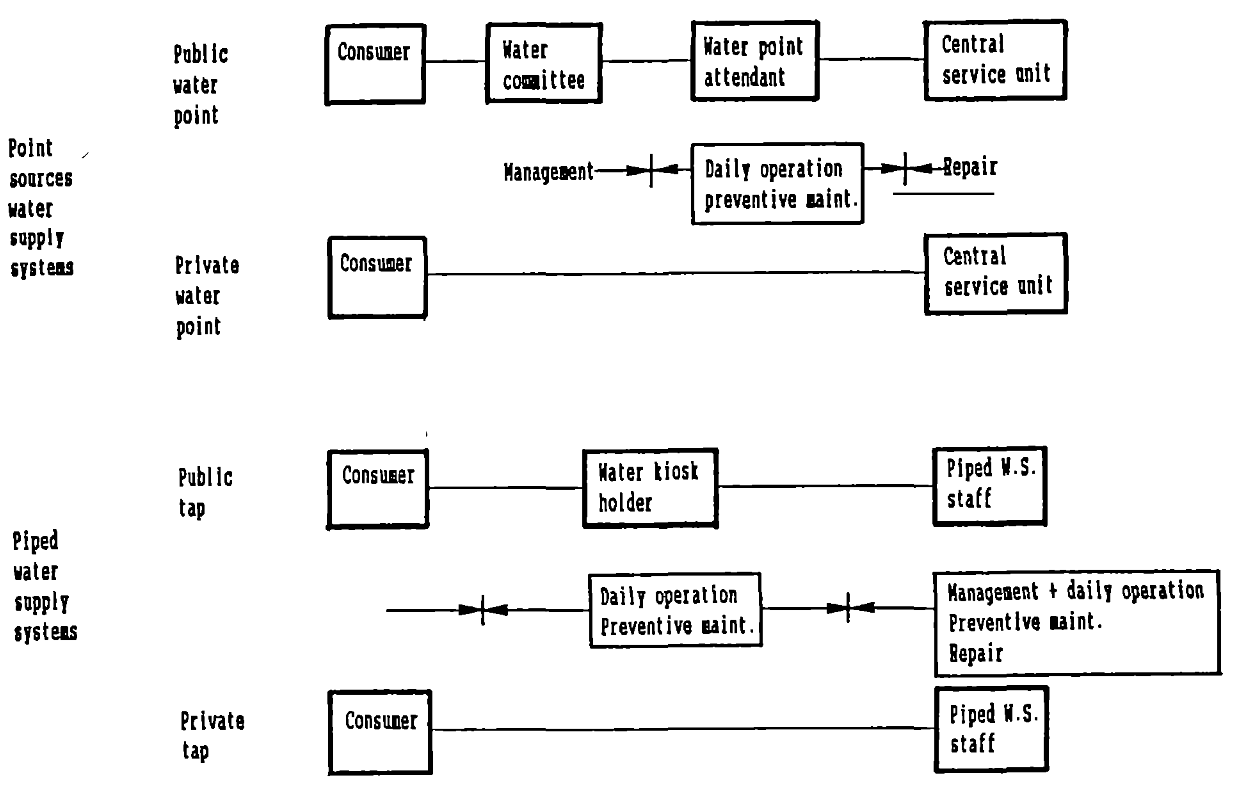


6.5. OPERATION AND MAINTENANCE

6.5.1. Organizational set-up

Fig. 6.18. shows how operation and maintenance of point source water supplies and piped systems should be organized.
For private water points both systems consist of the user at one hand and a central service unit or a central operation and maintenance unit at the other hand.
For communal water points there is a pump, spring or public tap attendant. He is responsible for small repairs and a proper use of the water points.
For a point source water supply system the attendant is supervised by a water committee consisting of user representatives. The attendant is paid by the water committee.
The attendant of a piped supply tap is infact a third party. He receives money for distributing water and he pays money for getting water from the distribution system.

Fig. 6.18. Management of operation and maintenance of rural piped water supplies



6.5.2. Point sources

There are of course differences between operation and maintenance of a spring and a ground catchment. In both cases however, operation and maintenance should include the following 4 components.

- Community mobilisation
- Community participation
- Daily operation, preventive maintenance
- Repair

Community mobilisation

Community mobilisation under the RDWSSP is carried out by community development extensionists. The extensionist selects, together with the community and the local authorities, which spring, dam or ground catchment has to be improved or the site where a new well has to be made.
Subsequently the RDWSSP survey crew will carry out a technical survey to approve the chosen site or to recommend a better one and to advise on the construction method.
It is essential that before, during and after the survey activities, the extensionist informs, guides and mobilises the community in order to have an optimum cooperation between the community and the survey team.

Once the construction site is selected, and the construction method chosen, the extensionist is to ensure that the community participates in the construction works and will feel responsible for future operation and maintenance tasks.

Community participation

Prior to the start of the construction works a number of preconditions have to be fulfilled.

- There are no disputes about the land where the water point is made. The community has free access to the water point.

- There is a water committee, registered by the Ministry of Culture and Social Services.

- The water committee has raised and banked a prescribed minimum amount of money for future maintenance of the water point.
  For a gravity flow protected spring a minimum amount of Kshs 1000.- is required. For water points having a pump this minimum amount has been fixed at Kshs 2000.-

Construction works are done in close cooperation with contractors which are supervised by RDWSSP. The community is involved in the following activities.

- Construction of a proper access road to the water point site to enable transport of construction materials and equipment to the site.
- The construction site should be cleared.
- The community brings local construction materials as stones used for back filling and stone pitching to the construction site.
- The community assists in finding accommodation for the construction crew.
- The community is responsible for trench digging and ground level excavation works (ground catchment and dams).

All other construction works are done by local contractors.

Before construction works are completed, the water committee has to appoint a water point attendant who will be responsible for daily operation, preventive maintenance and small repairs. In case of a well, the pump attendant has to be appointed before the pump is installed. The first task of the pump attendant will be to assist in installation of the pump (on the job training/instruction).

When the water point is completed the people are instructed to keep the water point and its surroundings clean and in a good state. A fence is placed around the wells and springs. It is the community's responsibility to keep the fence in good condition and to plant euphorbia or other hedges around it as additional protection of the site.

The upstream catchment area of ground catchments and dams has to be protected against soil erosion. Conservation requires a constant awareness to plant trees and to sow grass at places which have become bare.
If these measures are not taken, the dam or ground catchment will soon be silted.

Daily operation and preventive maintenance

The water committee is responsible for management of the water point which includes:

- management of the maintenance fund
- supervision of water point attendant
- organizing community maintenance works.

Programme extensionists advice the water committee about these management aspects.
Daily operation and preventative maintenance is done by the water point attendant.
Some of his tasks are:

- To open and to close the water point in case the water committee decides upon restricted use.

- To control people using the water point. Only those who contribute to the operation and maintenance fund are permitted to use the water point.

- To control upon the proper use of the water point (a correct pumping technique and use of taps, exclusion of vandalism).

- To keep the water point clean. (clearing of drainage gutters etc.).

- Preventative maintenance.
  Small repairs to the slab. Prevention that the slab is undermined. Trimming of the natural fence.

It is the projects experience that a well trained and motivated water point attendant is crucial for a proper functioning of the water point.

Repairs

From the day the community starts using the new water point a six months "guarantee" period commences. During this period the quality of the water point is tested in terms of adequacy of the source, quality of the water and the quality of the construction, equipment and materials used.
Any failure, shortcoming or breakdown which occurs during the first 6 months after completion, is solved or repaired by the RDWSSP without charging the community.
This guarantee period is also used to train the pump attendant and to educate the community in the benefits and proper use of the facility, in combination with proper sanitation.
At the end of this period the new water point is officially handed over to the community by signing a certificate of ownership.

In case of breakdowns or failures of the water point which can not be repaired by the water point attendant, the central service unit has to be called in.
The central service unit will be allocated in Siaya Town (DWE's office).
Field maintenance officers are stationed at the central service unit.

These maintenance officers are responsible for

- proper repair of the water point
- financial control of repairs done
- training of water point attendants

Additionally the maintenance officers inspect the quality of pump installation activities.

When a breakdown occurs, the steps taken towards repair basically are as follows:

- The water point committee reports a breakdown to the maintenance officer.

- The maintenance officer makes a visit to the site within 2 days.

- The maintenance officer diagnoses the breakdown, estimates the cost and hands over an order note for spares and tools to the well committee.

- The water point committee arranges transport of the tools and spares from the central spares depot to the water point site.

- The water point committee informs the maintenance officer that tools and spare parts are on the site and that a minimum of 3 labourers will be available.

- The maintenance officer carries out the repair within 2 days.

- The maintenance officer mails the invoice to the water point committee.

- The water point committee pays the invoice from their bank account.

At present corrective maintenance of water points is an interaction between the water point committees and the maintenance officers employed by the RDWSSP.
A maintenance system involving the private sector is not yet feasible, because of the relatively small number of water points to be maintained in the District, the limited number of breakdowns and the low density of new water points. When the number of water points, is increased to a few hundred per division, it might be feasible that corrective maintenance is undertaken by the private sector.
For the time being, maintenance has to be carried out by officers employed by the RDWSSP or the Ministry of Water Development.

6.5.3. Piped water supplies

Operation and maintenance of a piped water supply system has to be done by the piped water supply staff.
Operation and maintenance of MoWD schemes is partly done from the DWE's office. Irregular supply of diesel, long periods of pump breakdowns etc. are all characteristic for this set-up.
On the other hand, most piped water supply systems can not be operated or maintained by a local community. The piped distribution system is often too big (supply of water to different communities) while operation and proper maintenance of engines and pumps requires technical skills which are not available at community level.

The piped water supply staff can only do their work in a proper way if they have full control over money and means of transport as well as the authority to take measures of disconnection, water rationing etc. if needed.
The water supply should be headed by a managing director who is controlled by local authorities.

The only way to create a long term sustainable operation and maintenance set-up is to operate a piped water supply system which is cost effective . Everybody should pay for the water which is delivered. Charges should be in accordance with the costs for operation and maintenance of the water supply system.
In planning, design and construction of a piped water supply one should be fully aware of the fact that the consumers have to pay for the running costs of the new scheme.
Coagulation, sedimentation and filtration of water might be too expensive for a small community, while on the other hand even supply of raw water might be of great importance for a community.

The most sensitive part of a piped water supply system is the distribution network. In particular public taps are vulnerable for vandalism and mis-use which often leads to either no supply of water or a massive spillage of water.
At these public taps it is needed to have people who have an economic interest in the proper functioning of the water point.
It is therefore advised to work with tap attendants or water kiosk holders acting as a third party which are paid by the consumers for the water delivered. The kiosk holder pays to the piped water supply for getting water.
Such a system of water vending will only work if it is profitable for both consumers and kiosk holders to use the system.
The tap attendant is responsible for daily operation of the public tap. He opens and closes the water point at prescribed times. He checks on proper use of the taps. He implements small repairs.

The kiosk holder, reports cases of no supply of water (no income) or leakages (loss of income) immediately to the director of the piped water supply, who has to take action in order to exclude that his water revenues will decrease.

Some aspects are not covered by the proposed consumers-kiosk holder- piped supply staff set-up.
Such an aspect is the quality of the delivered water.
The consumers should organize themselves in a water committee which can discuss preventing problems with representatives of the MoWD (as a consulting agency) or with local authorities in order to take adequate measures to solve the problems.

PART VII

CONSTRUCTION OF POINT SOURCES

7.1. CONSTRUCTION OF WATER POINTS BY THE RDWSSP

Construction of water points started during the Pilot Phase of the Programme (1982-1984), when 6 wells were completed all fitted with a hand pump. From these, 3 were hand drilled and 3 were hand dug. Construction of water points under Phase I of the RDWSSP resumed in 1987 and by the end of October 1988 a total of 45 water points were completed, while construction is in progress at an additional 20 sites.

The location of constructed water points is shown in Figure 7.1. and a breakdown of water points constructed per Division is given in Table 7.1.

TABLE 7.1 NUMBER AND TYPE OF WATER POINTS COMPLETED UNDER THE RDWSSP (1-11-1988)

DIVISION	HAND DUG WELLS	HAND DRILLED WELLS	MACHINE DRILLED WELLS	TOTAL
BONDO	3	0	3	6
RARIEDA	4	0	2	6
BORO	17	3	0	20
YALA	11	0	0	11
UKWALA	2	0	0	2
SIAYA DISTRICT	37	3	5	45

The 1988 implementation programme of the RDWSSP furthermore anticipates in the construction of another 45 water points in Siaya District, of which at about 20 sites construction work has started already. The estimated total implementation target of Phase I in the District is summarized in Table 7.2.

TABLE 7.2. IMPLEMENTATION TARGET OF THE RDWSSP PHASE I FOR SIAYA DISTRICT (31-12-1988)

DIVISION	NR. OF COMPLETED WELLS (1.11.88)	WATER POINTS TO BE CONSTRUCTED IN 1988	TOTAL TARGETS
BONDO	6	23	29
RARIEDA	6	22	28
BORO	20	0(-4)	16
YALA	11	4	15
UKWALA	2	0	2
SIAYA DISTRICT	45	45	90

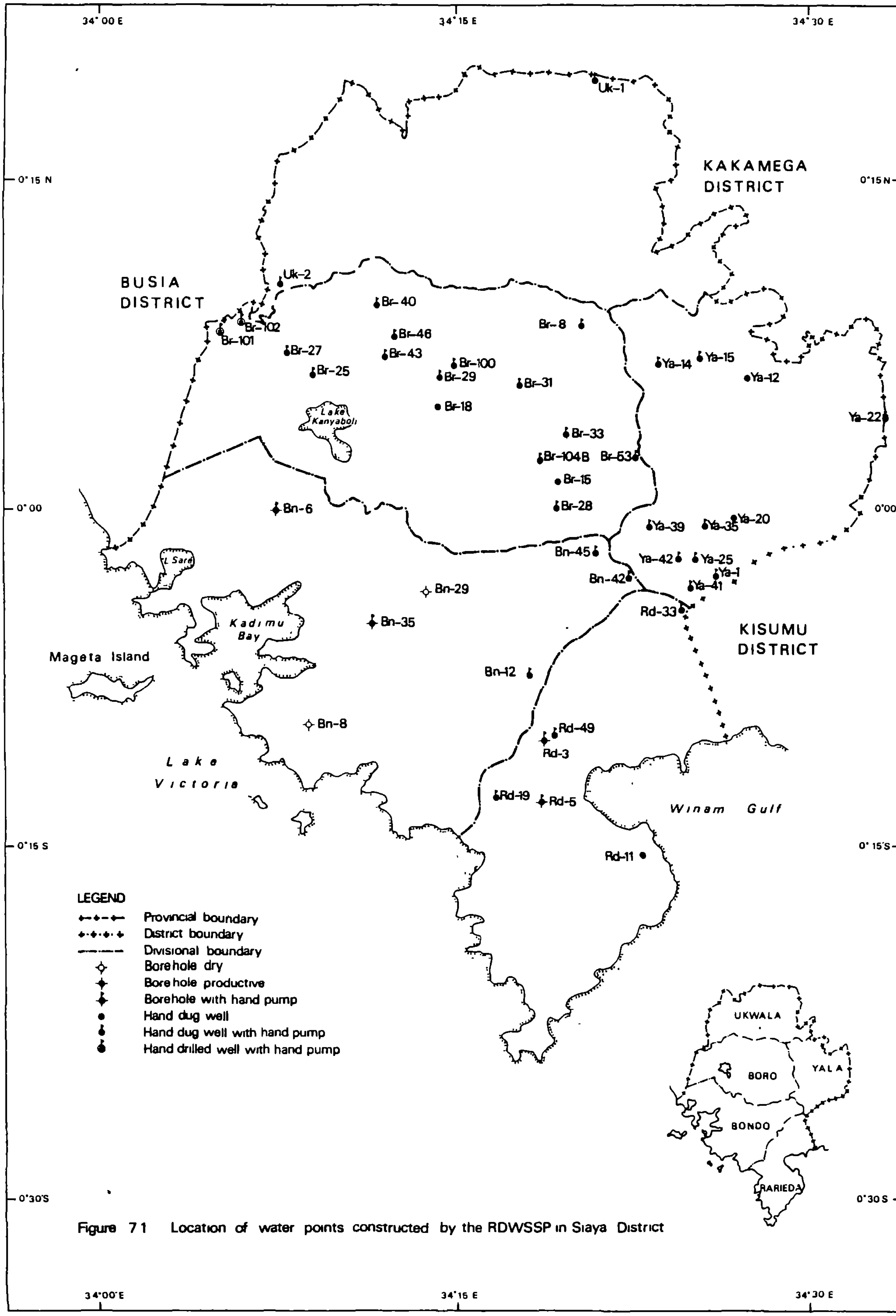


Figure 7 1 Location of water points constructed by the RDWSSP in Siaya District

With the above given implementation targets some remarks have to be made.

- In Ukwala Division the Kenya-Finland Rural Water Supply Development Programme (KEFINCO) has constructed already about 300 water points upto 1st September 1988. For this reason implementation activities of the RDWSSP will concentrate on the remaining 4 Divisions Bondo, Rarieda, Yala and Boro.

- Large areas of Bondo and Rarieda Divisions were found to be virtually without ground water potential, or are having saline ground water. For these two Divisions alternative water supply sources have to be developed (see Part VI section 6.3.2.).
  Hence additional water points are constructed in Boro and Yala Divisions to fulfill the target of 90 water points for Siaya District.

7.2. SERVICES FROM THE RDWSSP TO OTHER IMPLEMENTING ORGANIZATIONS

Besides the implementation of water points in Siaya District the RDWSSP has gathered a tremendous amount of data through various surveys and studies it has executed in the area during the period of 1982-1988.

The results obtained from these surveys and studies are not meant to serve only the implementation programme of the RDWSSP, but can also be made available to all other donors and organizations, who want to become active in rural water supply in Siaya District.

The following services and data can be supplied by the RDWSSP.

- Information on and rehabilitation recommendations for all existing rural water supplies.

- Geological and hydrogeological information, (areas with and without ground water potential).

- Criteria for the selection of target communities.

- Socio-economic information.

- Standard designs for wells, boreholes spring protections, etc.

- List of local contractors trained by the Programme.

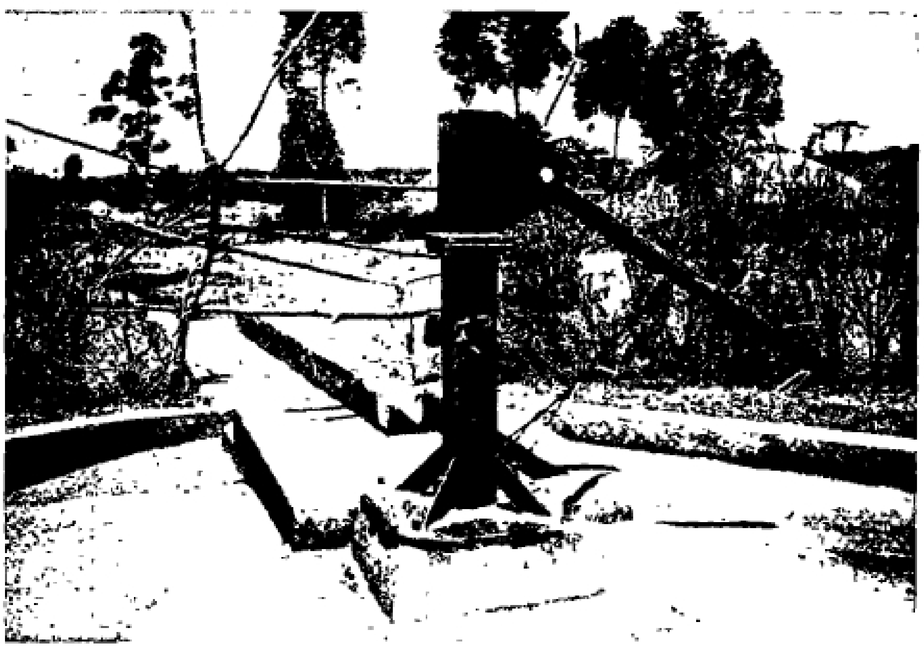
- Supply of hand pump equipment.

- Training programmes of staff and pump attendants.

- Professional advise on all matters concerning rural water supply.

Most information can be made available through a number of reports and manuals as:

- Five Divisional reports (including maps on hydrogeology and water supply situation) on water resources survey.
- A District report on water resources assessment.
- A socio-economic survey report of Siaya District.
- Maintenance guides and manuals for hand pump equipped wells.



SWN-80 Hand pump.

7.3. PROVISION OF RURAL WATER SUPPLY BY OTHER ORGANIZATIONS

7.3.1. The need for increased implementation of water points

With an expected total amount of 90 water points completed by the end of 1988 the RDWSSP presently is the largest rural domestic water supply programme in Siaya District (excluding KEFINCO in Ukwala Division).

It was concluded in the previous chapter (Part VI, section 6.3.) that the total number of safe and reliable water points required for the entire District amounts to about 3120. This number is by far exceeding the present output of the Programme.

With the present staffing and funding of the RDWSSP the maximum annual implementation output is between 200-300 water points per year. It is not likely that this target can or will be increased. Consequently there is a tremendous need for other implementing organizations to get involved in rural water supply in Siaya District.

During the past few years several governmental and non-governmental organizations have showed interest in supporting the development of rural water supply in the area.
Amongst others Ministry of Health, Ministry of Water Development, FGCSP/IFAD, CIDA, KEFINCO and CARE have been, or are presently active in Siaya District.
Further a number of church organizations mostly sponsored by foreign aid funds are involved in the implementation of water points such as DIOCESE OF MASENO SOUTH/WEST, DIOCESE OF KISUMU, and AGA KHAN FOUNDATION.

For a successful implementation strategy, it is absolutely necessary that a close coorporation exists between the LBDA's RDWSSP and the governmental and non-governmental organizations for the following reasons:

- Avoiding confusion among the receiving communities about policies and conditions.

- Standarization of methods and pump equipment to simplify future maintenance systems.

- Avoiding double spending of funds on information and data which is already available.

- Exchange of knowledge and expertise.

- Making fully and efficiently use of the wide range of documentation, data base systems on hydrology and hydrogeology, qualified and experienced staff available in the RDWSSP.

7.4. SUMMARY OF CONSTRUCTION ACTIVITIES BY IMPLEMENTING ORGANIZATIONS IN SIAYA DISTRICT

Besides the RDWSSP and the MoWD (mainly involved in the construction of piped water supplies) the following organizations have been active (or will be) in the provision of water supply in the rural areas of Siaya District.

- MINISTRY OF HEALTH
- FGCSP/IFAD
- CARE
- RURAL DEVELOPMENT FUND
- DIOCESE OF KISUMU
- DIOCESE OF MASENO SOUTH/WEST
- KEFINCO

The types of water points constructed by these organizations include: dug wells, spring protections, roof catchment systems and extensions of existing piped supplies with a few communal water points.

The numbers of water points completed by these organizations till so far is shown in Table 7.3.

TABLE 7.3. SUMMARY OF COMPLETED WATER POINTS BY VARIOUS ORGANIZATIONS IN SIAYA DISTRICT

DIVISION NAME	MINISTRY OF HEALTH	KEFINCO	DIOCESES MAS.SOUTH /WEST	CARE	IFAD/ FGCSP	RURAL DEV. FUND
BONDO	10	-	1	2	4	4
RARIEDA	2	-	4	2	-	3
BORO	63	-	-	1	22	17
YALA	6	-	-	2	6	5
UKWALA	38	289	-	-	-	6
SIAYA DIST.	119	289	5	7	32	35

7.5. PROJECT DESCRIPTIONS OF ORGANIZATIONS ACTIVE IN RURAL WATER SUPPLY

7.5.1. Ministry of Health

After the cholera outbreak in the early 1970's the Ministry of Health embarked on a large scale rural water supply programme in Nyanza Province. About 400 wells were constructed from which 119 in Siaya District.

All these shallow wells had been hand dug and were partly or completely lined with concrete rings (culverts). Many were also completed with a concrete cover, fitted with a steel lockable manhole cover and a hand pump.

In 1982 a survey was carried out to determine the number of wells which could be rehabilitated. The survey revealed the following:

- Between 200 and 300 of these wells were viable for rehabilitation.
- Less than 10 % of the installed hand pumps were still operational.
- Due to the lack of proper dewatering equipment, the majority of the wells were not dug deep enough. This had resulted in rather low yields and/or drying up during the dry season.

The numbers of wells dug by the Ministry of Health per Division are shown in Table 7.3.

7.5.2. FGCSP/IFAD

Background

The "Farmers Groups and Community Support Project" was originally identified by an IFAD Mission in June 1983.
A joint project proposal prepared by IFAD/WHO/UNICEF, (Report - November, 1983), was prepared and submitted to the Belgian authorities.
On the strength of this document, the Belgian Government agreed to fund this project from the "Survival Fund of the Third World". A fund whose objectives are to ensure the survival of persons threatened by hunger, malnutrition and underdevelopment in regions of the Third World.

Project Financing

The FGCSP is financed mainly by a grant of Kshs 51.2 million from the Belgium Survival Fund. These funds are channeled through the International Fund for Agricultural Development (IFAD). The Government of Kenya's contribution to the programme is Kshs 3.4 million. A contribution of Kshs 3.3 million is expected to come from the community groups representing their own contribution in cash or kind from the assisted group projects.

Project Management and Organization

The District Development Committee (DDC) and its technical sub-committee, the District Executive Committee (DEC) are the main decision making bodies for the FGCSP. The District Commissioner and the District Planning Unit have overall responsibility for Implementation and Monitoring of the entire programme. The District administration i.e District Treasury, Supplies Office handle the accounting procedures and the procurement of goods and services on behalf of the programme.

Objectives

The FGCSP is an Integrated Rural Development Programme whose objectives are based on the concept of community participation in all the cycles of project implementation. Farmers Groups must clearly understand their needs, identify projects that will address to their needs, plan the projects and be prepared to implement and maintain them without outside support.

The following components are funded:-

- Agriculture
- Credit and Input Supply
- Health
- Water
- Fisheries
- Community Development Training Programme
- Training component under G.T.I. Maseno
- Coordination, Monitoring and Evaluation.

Water Component

The Implementation of the water component began in November, 1986 and is targeted to take five years. The planned outputs and activities during this period are:-

- Construction of 270 hand dug wells and protection of 90 springs.

- Preparation and commencement of a Training programme for the operation and maintenance of hand pump equipped wells.

- Monitoring the use of hand pumps.

The population served by hand pump wells and protected springs is expected to be around 90,000 persons by the end of the implementation period.

All the implementing activities are carried out by the MoWD, through the District Water Engineer of Siaya District in close cooperation with the RDWSSP.

In Table 7.4 a break down is given of the implementation activities up to date and Table 7.5 shows the implementation targets for 1989.

TABLE 7.4. COMPLETED AND ON-GOING WATER PROJECTS IN SIAYA DISTRICT BY THE FGCSP/IFAD

DIVISION	CONSTRUCTED		UNDER CONSTRUCTION	
	HAND DUG WELLS	SPRING PROTECTION	HAND DUG WELL	SPRING PROTECTIONS
BONDO	4	0	1	0
RARIEDA	0	0	3	0
BORO	21	1	7	0
YALA	1	5	3	0
UKWALA	0	0	0	0
SIAYA DISTRICT	26	6	14	0

TABLE 7.5. PLANNED NUMBER OF WATER POINTS FOR 1989 IN SIAYA DISTRICT BY THE FGCSP/IFAD

DIVISION	HAND DUG WELLS	SPRING PROTECTIONS	DRILLED BOREHOLES
BONDO	21	5	1
RARIEDA	23	4	2
BORO	22	7	1
YALA	24	8	0
UKWALA	0	0	0
SIAYA DISTRICT	90	24	4

7.5.3. CARE

Between 1968 and 1988, CARE Kenya has been assisting community projects in a number of Districts in Kenya.
The projects are funded by CARE International.
The goals of the projects were as follows.

- to provide greater quantities of water through more reliable and accessible systems,
- to reduce the amount of time women spent on collecting water.

The water projects carried out up to September 1988 in Siaya District are summarized in Table 7.6.

TABLE 7.6. COMPLETED AND ON-GOING WATER PROJECTS IN SIAYA DISTRICT BY CARE KENYA.

DIVISION	PIPED TAP POINTS	PUMP INSTALLED	DAMS	ROOF CATCHMENTS
BONDO	-	-	-	2
RARIEDA	-	-	-	2
BORO	-	1	-	-
YALA	2	-	-	1
UKWALA	-	-	-	-
SIAYA DISTRICT	2	1	-	5

From mid-1988 onward, CARE is concentrating on water activities in three Districts i.e. Bungoma, Busia and Embu.
There are no plans to continue activities in Siaya District in the future.

7.5.4. Diocese of Maseno West/Maseno South

Introduction

Recently the former working area of the Diocese of Maseno South has been split up into the Diocese of Maseno west, covering Siaya District and Diocese of Maseno South, covering Kisumu District Kisii District and part of South Nyanza District.

Strategy

Water projects can be requested and initiated by communities with the Diocese. The policy of the Diocese for starting a water project (a hand dug well) is comparable with the policy of the RDWSSP and consist of the following conditions.

- Land ownership should be clarified and be in the position of the well committee.

- The project and well committee should be registered as self help project with the Ministry of Culture and Social Services.
- The committee should raise and contribute to the Diocese an amount of Kshs 2000/= prior construction activities commences.
- Two helpers are to be provided and paid by the well committee to assist the construction works.
- After completion of the well an amount of Kshs 1000/= has to be raised and banked by the community for future maintenance.
- Two persons have to be selected who will act as pump attendant.
- The committee should charge a small fee for the collected water but is free to set up their own system and rates.

Project activities

Since 1982, the Diocesan Water Programme has implemented one or two dug wells annually. Five were completed in Siaya District, and one is still under construction.
In cooperation with other Diocesan departments some roof catchment projects were initiated and spring protections were constructed.
Further the Diocese took part in some small scale piped supply schemes.
The water projects are funded by a German sponsor called Tear Fund/The Evangelical Alliance Relief.

Future activities

A proposal was sent to a German Donor Agency applying for funds to establish a shallow well Programme and other water supply possibilities in Nyanza Province. This Programme also intends to improve sanitation facilities.

Further the Diocese plans to make a number of boreholes drilled by a drilling rig which was recently donated to the CPK.

The implementation plan consist of

- 20 spring protections
- 45 boreholes
- 25 roof catchments

The Diocese hopes to have completed 45 water points in Siaya District by the end of 1989.

7.5.5. Diocese of Kisumu

Strategy

The Catholic Diocese of Kisumu considers the efforts aimed at the accessibility to and the availability of clean water supply as only one element of the integrated approach to rural development, which starts with general development education and other key components including basic health care and improved food production.
The integrated development approach is finally aimed at alleviating the situation of the poor rural communities and to assist these communities to reach a level of self-sufficiency and self-reliance.
The community based water programme emphasizes community involvement and full participation of the beneficiaries in all project phases, from project initiative and identification through planning and implementation to final project follow-up and evaluation.

The activities of the water programme are concentrated in poor rural areas, focusing on the implementation of small scale community water projects such as dug wells, spring protections, small earth dams and rainwater catchments. The projects require maximal community participation and minimal recurrent expenditure, thus ensuring that the projects are sustainable by the communities.

Project activities

Since the start of the rural water supply activities in 1985 a number of water points has been constructed mainly in Kisumu District.
Till so far no construction activities of point sources have been carried out in Siaya District.
However about 25 community sites in Boro Division have been selected where a hand dug well will be constructed.
In close cooperation with the RDWSSP these sites have been geophysically surveyed and construction will start as soon as skilled manpower and funds are available.
Further in Siaya District the Diocese is intensively involved in the supervision of construction works on the South Sakwa Water Supply. The S.S.W.S. is a self help project in Bondo Division, where the cost have to be paid by the communities, supported by MoWD and donors (Misereor, of West Germany and Cebemo of the Netherlands).

7.5.6. Rural Development Fund

Introduction and background

Based on a request in 1982 by the then Provincial Commissioner of Nyanza Province, the Government of Denmark agreed to give financial assistance for rehabilitation of existing wells, dug during the cholera outbreak in 1974 to 1976.

Objectives

The main objective of the project was to provide a clean and safe water supply in order to improve the health of the communities.

It was agreed that the project should concentrate on renovation of the existing wells, which needed repair on pumps, limited repair of the well lining or well cover.

Also it was agreed that other type of water resources should be given consideration, such as protection of springs and roof catchments.

In principle it was agreed that only wells and springs which had an established well committee were to be included in the programme and before construction could start a self-help contribution of Kshs 600/= was to be paid to the District Treasury.

Project set up

As the wells to be rehabilitated were under the Ministry of Health jurisdiction, it was decided that the programme in the Districts should be undertaken and implemented under the Ministry of Health with the District Public Health Officer being the responsible officer.

Under this set up it was agreed that the Ministry of Health were to provide and pay for skilled manpower and supervision during the construction of the wells. Costs of materials, transport and to some extend unskilled manpower were to be met by the project account.

Based upon previous experience where too many wells have been dug too shallow and springs have been protected and improved, but later dried up, it was recommended that no sites were to be embarked on until all available information on occurrence and quality of the ground water is obtained from the data base which is now existing at the Lake Basin Development Authority or their consultants DHV, Consulting Engineers in Kisumu.

Projects completed

Since the start of the Programme in 1982, in Siaya District a total of 28 hand pump operated wells have been completed.
Further 7 springs were protected.
Table 7.7 summarizes the completed water points.

TABLE 7.7. COMPLETED WATER PROJECTS IN SIAYA DISTRICT BY THE RURAL DEVELOPMENT FUND

DIVISION	REHABILITATION DUG WELLS	SPRING IMPROVEMENTS
BONDO	4	-
RARIEDA	2	1
BORO	14	3
YALA	4	1
UKWALA	4	2
SIAYA DISTRICT	28	7

Future planning

The Programme is due to be phased out by the financial year 1988/1989.
Hence apart from completion of on-going projects, no further projects are planned.

7.5.7. KEFINCO

The Kenya-Finland Rural Water Supply Development Project (KEFINCO) was initiated in 1980 as a development cooperation between the governments of Kenya and Finland.
The project phase I which was to cover Western Province started the same year with the preparation of a Water Supply Development Plan for the project area up till the year 2005.
The objective was to provide the entire population of the area with a safe supply of water, sufficient for the demands of domestic and livestock consumption.

With a calculated consumption rate of 30 lts/capita/day through hand pumps and 70 lts/capita/day through piped schemes, it was proposed to serve 1.556 million people in 2005 through 7180 wells and 1400 protected springs. Furthermore it is proposed to serve 125.000 people through 11 mainly new piped schemes in designated urban and rural centres, and some 25 existing piped schemes are planned to be augmented and/or rehabilitated.

The implementation of the Water Supply Development Plan began at the end of 1983.
It was decided to cover a part of Siaya District, coinciding with 90 % of the area of Ukwala Division.

Upto mid 1988 the total implementation output in Ukwala Division is as follows:

- More than 110 machine drilled boreholes*
- 95 spring protections
- 89 hand dug wells*

7.5.8. Aga Khan Foundation

Project background

Aga Khan Foundation through the Aga Khan Health Service (AKHS), has a number of hospitals in different parts of the world. Primary Health Care was adopted as a strategy within AKHS. Aga Khan Hospital Kisumu was chosen to initiate a pilot experimental project in Primary Health Care in 1981.

In 1982, AKHS and AKF co-sponsored the Kisumu PHC Planning Seminar at which the Local government health services, Central of Health, Provincial Administration, the Municipality of Kisumu, Lake Basin Development Authority, WHO, Ford Foundation, African Medical Research Foundation (AMREF) and AKHS were represented.

The seminar identified two areas for Primary Health Care; North Nyakach and Kajulu Locations in Kisumu District.

In July 1983, the proposal was finally adopted. It was to be an experimental 7 year project.

Projects completed

Up to date in Kisumu District a total of 28 water projects have been completed. At the same time a number of water projects are in various stages of construction.
In Siaya District 4 wells were constructed in and around Saradidi (Rarieda Division). The wells were dug by and under supervision of staff of the Aga Khan Primary Health Care Project, but funded by the Saradidi Health Centre.
There are no further plans for future implementation by the AKF in Siaya District.

* In reality the number of constructed wells and boreholes by KEFINCO is larger, but in this report only the water points are considered, which are prsently in use. Further, the boreholes drilled for piped water supplies have been excluded.

7.5.9. CIDA

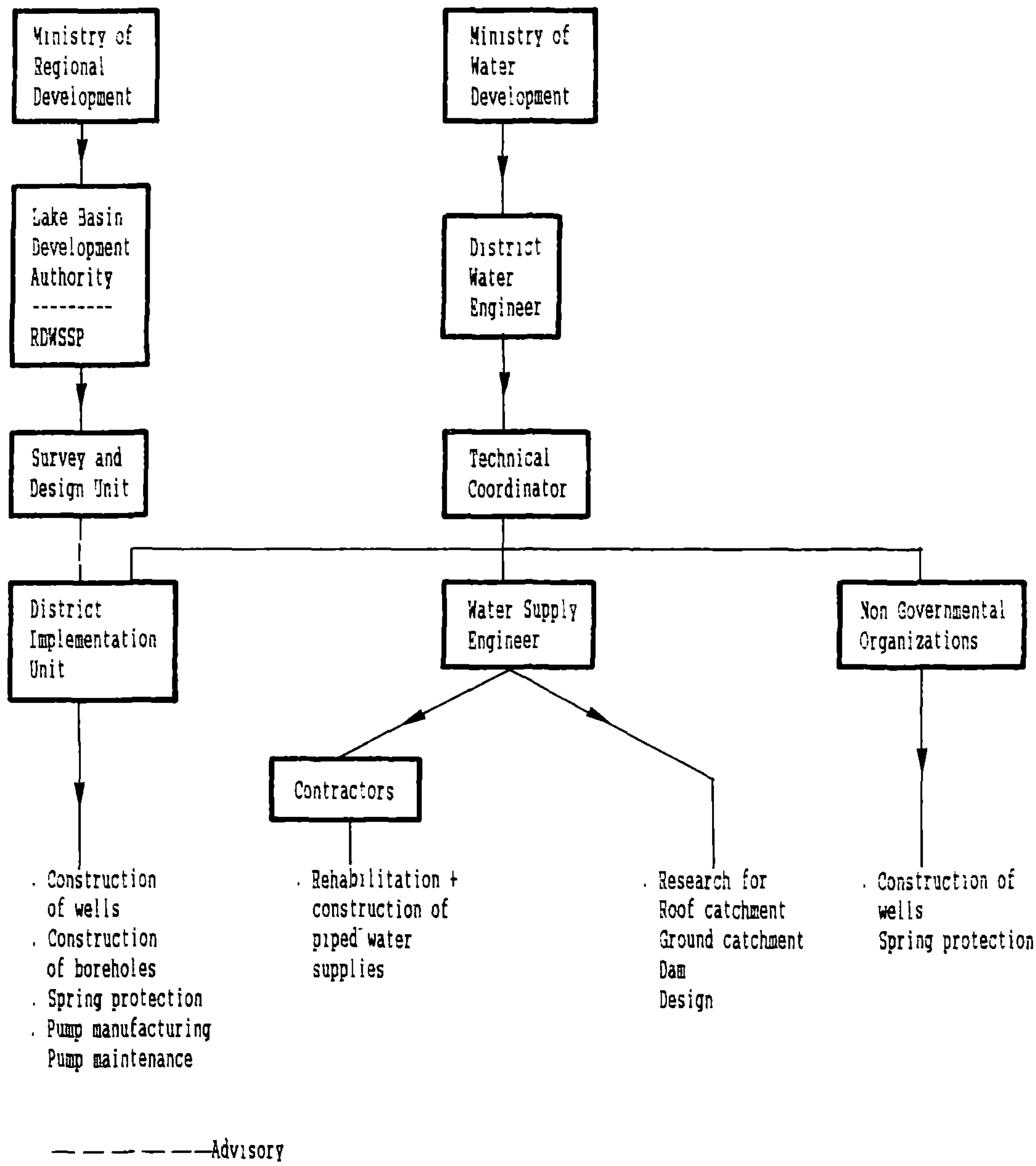
Between 1979 and 1983 CIDA, in cooperation with the MoWD initially supported investigations of water resources and the construction of piped supply systems.
This resulted in a number of reports (a.o. Report of Ker, Priestman and Ass. "Inventory and Assessment of Existing Piped Water Supplies" in Western and Nyanza Provinces, 1980).

Later on during the project, the implementation of piped schemes shifted from the design and construction of new schemes, to rehabilitation of existing schemes.

PART VIII

EVALUATION, RECOMMENDATIONS AND SHORT TERM MEASURES

FIG. 8.1. Organization of implementation works
Siaya District Water Supply Plan



8 EVALUATION, RECOMMENDATIONS AND SHORT TERM MEASURES

Comparing, the Water Supply Plan as described in Part VI with the ongoing construction activities as described in Part VII, it is concluded that there is a sincere need for proper coordination of design and implementation activities.

* All efforts aimed at improvement of rural water supply in Siaya District should be coordinated.
  The Water Supply Plan includes different kind of activities implemented by MoWD, NGOs, LBDA, private contractors etc.

  A proper coordination of activities is needed.
  It is advised to assign a Technical Coordinator under the District Water Engineer who will be responsible for the coordination.

* Nine (9) piped water supplies have to be rehabilitated. In most cases, rehabilitation includes a complete renewal or a major extension of an existing water supply system. In addition 3 new piped schemes have to be built.
  The works needed are beyond the capacity of the existing district organizations involved in piped water supply (MoWD, NGOs and communities).

  It is therefore advised to work with private contractors which are fully responsible for the implementation of the required rehabilitation and construction works. Design and supervision of implementation works have to be done by a well experienced Water Supply Engineer assisted by water technicians of the DWEs office. The Water Supply Engineer should work directly under the Technical Coordinator.

* Construction of 259 spring protections, 1551 hand dug wells and 15 hand drilled wells necessitates to enlarge the capacity of the existing RDWSSP District Implementation Unit. Well construction should be intensified and a spring protection unit should be started.

* About 148 boreholes have to be made. Borehole drilling is and will be done by local contractors.
  Borehole siting and supervision of drilling works require the input of a Hydrogeologist of the Survey and Design unit of RDWSSP.

* Part of the Water Supply Plan is to rehabilitate existing roof catchments and to improve ground catchments and dams.

  Research with respect to the design criteria of roof catchment water supply systems have been started.More research however is needed.

Short duration rainfall analyses should be made to find better design criteria for the roof gutters and pipe connection to the storage tank. Self registrating rainfall recorders should be installed at some strategic points to measure 5 min. rainfall amounts. High rainfall intensities should be analysed to draw up design rules for roof gutters applicable for Siaya District.
Long series of real time daily rainfall amounts should be analysed to improve the storage tank design.
The existing network of rainfall stations (daily recording) should be checked and improved.

Fig. 6.5. shows a preliminary design for improvement of existing ground catchments and dams.
This design deserves to be implemented. Based on the experiences obtained , it can be further improved.

The Water Supply Engineer who will be in charge of the piped water systems should also be responsible for this research work.

Fig. 8.1. presents a diagram showing the position of the Technical Coordinator, the Water Supply Engineer , the contractors, the District Implementation Unit and the advisory role of the RDWSSP Survey and Design Unit.

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ANNEXES:

5.1. Water quality data, Lake Victoria
5.2. River gauging stations Siaya District, Station characteristics and minimum flows
5.3. Water quality data, Siaya rivers

Annex 5.1 Water quality data , Lake Victoria

Sampling point	Date	Colour	Turbid.	Deposit	pH	T.D.S	Conduct.	Alkalinity Total	Hardness Total	Ca	Mg	Mn	Fe	CL	F	NO3-N	SO4	Heavy metals	Zn	Silica	CO2
		Hazen units	JTU			mg/l	uS/cm	mg/l CaCO3	mg/l CaCO3	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l SiO2	mg/l
South Sakwa W.S.	03-06-82	5	0.8	Debris	7.0	64	90	44	26	4.8	3.4	Nil	1.0	8.0	0.4	Nil	Nil	<0.001	<0.01	5.0	2.0
Osieko W.S.	21-12-81	5	Nil	Debris	7.5	55	95	48	32	5.6	4.3	Nil	0.5	5.0	0.3	4.0	Nil	<0.001	<0.01	10.0	3.0
Usigu W.S.	09-09-81	5	1.5	Debris	7.0	61	93	52	24	2.4	4.3	0.5	0.8	2.0	0.3	Nil	Nil	<0.001	0.3	Nil	5.0
Kapiyo W.S.	11-12-81	5	Nil	Nil	6.9	65	108	50	30	8.0	2.4	Nil	0.2	1.0	0.3	Nil	Nil	<0.001	<0.01	5.0	5.0
Asembo Bay Shore	27-03-74	<5	Nil	Silt	7.7	100	160		30	8.8	2.0	Nil	Nil	9.0	0.5	Nil	Nil	ND			1.0
Asembo Bay Shore	25-02-75	<5	Nil	Nil	7.8	120	170		46	9.6	5.3	Nil	0.8	6.0	0.5	1.1	4.0	<0.001			2.0
Asembo Bay Shore	25-02-75	<5	Nil	Silt	8.3	110	165		40	11.2	2.9	Nil	0.4	6.0	0.4	0.5	1.0	<0.001			Nil
Asembo Bay off shore	08-07-75	30	3.5		7.8		114		46	9.6	5.3	0.1	0.2	6.0	0.5	0.3	1.2			24	
Asembo Bay off shore	08-07-75	30	3.0		7.9		113		50	8.8	6.8	0.1	0.2	7.0	0.5	0.2	1.0			28	
Asembo Bay off shore	08-07-75	30	3.0		7.8		114		47	8.0	6.6	0.1	0.7	7.0	0.5	0.2	1.0			24	
Asembo Bay off shore	08-07-75	30	3.5		7.9		113		53	9.6	7.0	Nil	0.2	7.0	0.5	0.6	1.4			24	
Asembo Bay off shore	08-07-75	30	3.2		7.8		113		58	9.6	5.8	0.1	0.2	8.0	0.5	0.3	1.1			24	
Asembo Bay off shore	08-07-75	30	3.0		7.9		180		49	9.6	6.1	0.2	0.2	35.0	0.5	0.2	3.5			24	
Asembo Bay off shore	08-07-75	30	3.0		7.9		113		47	9.6	5.6	0.2	0.2	7.0	0.5	0.2	1.1			24	
Asembo Bay off shore	08-07-75	30	3.0		7.7		112		46	9.6	5.3	0.2	0.1	7.0	0.6	0.3	1.0			24	
Asembo Bay off shore	08-07-75	30	3.0		7.7		115		45	9.6	5.1	0.1	0.2	7.0	0.5	2	1.1			24	
Asembo Bay off shore	08-07-75	30	3.0		7.6		114		45	9.6	5.1	0.5	0.1	6.0	0.5	0.3	1.1			24	
Asembo Bay off shore	08-07-75	30	3.0		7.5		112		49	9.6	6.1	Trace	0.2	7.0	0.6	0.5	1.2			24	
Asembo Bay off shore	08-07-75	30	3.2		7.9		112		44	9.6	4.9	0.2	0.1	6.0	0.5	0.2	1.2			24	
Asembo Bay off shore	08-07-75	30	3.0		7.5		113		44	9.6	4.9	Trace	0.2	7.0	0.5	0.3	1.1			24	

Annex 5.2 River gauging stations Siaya District ,
Station characteristics and minimum flows

Catchment area	River	Gauging Station	Map Ref	Site Location STN Lat.	STN Long.	Station opened	Station closed	Years of operation	Size of catchment area	Low flows 1/10 years		1/20 years		1/25 years		Remarks
						(year)	(year)	(year)	(km2)	(m3/s)	(l/s/km2)	(m3/s)	(l/s/km2)	(m3/s)	(l/s/km2)	
Nzoia	Nzoia	1 EE-01	101/3	00:10:40 N	34:13:30 E	1963	-	24	11849	14.0	1.18	12.0	1.01	11.5	0.97	* 22 years of daily gauge height registrations have been used to calculate minimum flows.
Nzoia	Safu	1 EE-02	101/3	00:13:30 N	34:14:10 E	1978	-	19	56	0.06	1.07					* 5 years of daily gauge height registrations have been used to calculate minimum flows.
Nzoia	Nzoia	1 EF-01	101/3	00:07:25 N	34:05:25 E	1974	-	13	12676							* Data unreliable.
Nzoia	Gaula	1 EF-02	101/3	00:10:50 N	34:10:15 E	1977	-	10	80	0.07	0.88					* 4 years of daily gauge height registrations have been used to
Nzoia	Uludhi	1 EG-01	101/4	00:08:45 N	34:19:30 E	1974		13	124							* No rating curve available.
Nzoia	Wuoroya	1 EG-02	101/3	00:09:00 N	34:14:35 E	1974	-	13	525							* Most water levels under lower limit rating curve.
Nzoia	Wuoroya	1 EG-03	101/4	00:09:45 N	34:19:10 E	1974	-	13	201	0.4	1.9					* 10 years of daily gauge height registrations have been used
Yala	Yala	1 FE-01	102/3	00:08:00 N	34:34:30 E	1960	-	27	1896	3.0	1.6					* 17 years of daily gauge height registrations have been used to calculate minimum flows.
Yala	Zaaba	1 FF-02	102/3	00:03:30 N	34:37:40 E	1959	-	28	46	0.1	2.2					* 14 years of daily gauge height registrations have been used to calculate minimum flows.
Yala	Edzawa	1 FF-03	102/3	00:05:40 N	34:33:30 E	1960	-	27	262	0.6	2.3					* 16 years of daily gauge height registrations have been used to calculate minimum flows.
Yala	Yala	1 FG-01	102/3	00:05:10 N	34:32:25 E	1947	-	40	2388	3.0	1.3	2.2	0.9	2.00	0.84	* 38 years of daily gauge height registrations have been used. to calculate minimum
Yala	Yala	1 FG-02	115/2	00:02:35 S	34:15:55 E	1958	-	29	2864	3.4	1.19					* 9 years of daily gauge height registrations have been used to calculate minimum flows.
Yala	Yala	1 FG-03	115/1	00:00:00	34:08:45 E	1970	-	17	2878							* No rating curve available.

Annex 5.3. Water quality data , Siaya rivers

River	Sub-catch	Sampling point Number	Longitude	Latitude	Altitude	Date	Temp	Colour	Turbid.	pH	Conduct.	Alkalinity Total	Hardness Total	NO3-N	NH3-N	CL	F	Mn	Fe	PO4	SO4	O2	B.O.D	CO2
					(M)		C	pt/Co units	NTU		uS/cm	mg/l CaCO3	mg/l CaCO3	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l
Yala	1-FG	SP-00				19-03-87						60	47	0.3			0.7			0.9				
Yala	1-FG	SP-00				19-03-87						45	43	1.3			0,6			1.3				
Yala	1-FG	SP-01	34:10:00E	0:01:18N	1160	16-10-87	24.2			7.3	80	104	96	ND	0.80	0.6	0.8	0.05	2.0			7.4	90	11.0
Yala	1-FG	SP-02	34:15:54E	0:02:36S	1180	16-10-87	24.2		53	7.5	80	88	52	2.0	0.50	0.7	0.7	ND	1.9			7.9	35	5.0
Yala	1-FG	SP-03	34:20:54E	0:10:36S	1200	16-10-87	27.2		45	7.0	80	110	45	1.0	1.60	1.0	0.8	0.01	2.0			7.7	60	11.0
Yala	1-FG	SP-04	34:20:06E	0:10:48S	1240	16-10-87	28.3		62	6.9	80	56	44	1.0	0.70	0.5	0.7	ND	1.9			7.3	125	4.0
Yala	1-FG	SP-05	34:26:42E	0:00:48N	1240	21-10-87	24.1		52	7.3	80	117	77		0.60	1.0	0.6	ND	0.1				170	11.0
Yala	1-FG	SP-05				03-11-87	25.4		39	7.0	101	44	22	1.0	0.50	0.3		ND	2.0			10.4	215	8.0
Yala	1-FG	SP-06	34:27:24E	0:00:42N	1240	21-10-87	25.0		52	6.5	100	106		0.1	0.60	1.0	0.7	ND	0.1			7.8	155	12.0
Yala	1-FG	SP-06				03-11-87	25.5		49	7.1	100	39	22	1.0	0.60	0.2		0.15	0.5			9.9	160	10.0
Yala	1-FG	SP-07	34:29:06E	0:01:48N	1260	03-11-87	25.4		51	7.5	100	44	21	0.1	0.55	4.0		0.02	1.9			10.0	200	12.0
Dhenena	1-FG	SP-08	34:28:12E	0:01:30N	1260	21-10-87	25.0		60	7.2	100	111	87	9.0	0.70	2.0	0.7	0.02	0.1			9.0	235	12.0
Dhenena	1-FG	SP-08				03-11-87	25.5		142	7.5	300	104	80	9.0	ND	4.0		0.50	2.0			9.5	215	12.0
Yala	1-FG	SP-09	24:28:12E	0:01:36	1260	21-10-87	24.0		59	7.0	100	189	98	7.0	0.90	0.9	0.7	0.01	0.1			8.9	185	8.0
Yala	1-FG	SP-10				21-10-87	25.0		72	7.2	100	75	58	ND	0.90	0.9	0.7	ND	0.2			8.6	150	
Yala	1-FG	SP-10				03-11-87	26.0		44	6.9	100	29		1.0	0.60			ND	1.9			9.4	220	8.0
Yala	1-FG	SP-12	34:32:06E	0:05:12S	1380	21-10-87	25.0		77	7.1	70	129	88	1.5	1.10	2.0	0.7	ND	0.8			8.0	135	2.0
Yala	1-FG	SP-12				03-11-87	26.0		53	7.1	100	27	21	0.9	0.60			0.05	2.0			9.8	220	8.0
Yala	1-FG	SP-13	34:10:48E	0:01:48N	1400	06-10-84	21.0		94	7.1	80	42		1.9	0.70	4.0		0.20	0.9	0.3	6.0		7	
Yala	1-FG	SP-13				20-08-85	20.3		33	7.2	78	35	22	1.3	0.27	1.5		0.02	1.5	0.3		7.2		4.4
Yala	1-FG	SP-13				16-03-87	22.0		250	6.8		68			0.90	ND		ND	0.2	0.1		3.7		
Yala	1-FE	SP-14	34:14:54E	0:01:30N	1550	30-11-83				7.3	92					2.8				0.1		8.0		
Yala	1-FE	SP-14				13-12-83			31	7.7	115	65		<0.5	0.50	<0.1				0.0		7.7		
Yala	1-FE	SP-14				20-03-87	22.8		65	7.2		59	35		0.30	ND	0.3	0.10	1.4	0.2		4.3		
Yala	1-FE	SP-14				01-09-85			32	7.6	80	33												
Yala	1-FE	SP-14				24-08-85	19.0		45	7.2	103	49	21									8.3		
Yala	1-FE	SP-14				05-08-85	26.0	140	94	7.5	90	37	24	2.0	1.20		0.8	0.05	1.4	1.5				

Annex 5.3. Water quality data , Siaya rivers (cont.)

River	Sub-catch	Sampling point Number	Longitude	Latitude	Altitude	Date	Temp	Colour	Turbid.	pH	Conduct.	Alkalinity Total	Hardness Total	NO3-N	NH3-N	CL	F	Mn	Fe	PO4	SO4	O2	B.O.D	CO2
		-			(M)	-	C	pt/Co units	NTU		uS/cm	mg/l CaCO3	mg/l CaCO3	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l
Yala	1-FE	SP-15	34;18;54E	0:03:42N	1700	19-03-87	21.0		60	7.1		42	35		0.38	0.8		0.05	0.0	0.3		4.3		
Yala	1-FE	SP-15				20-03-86	21.5	72	19	7.5	91	42	33		ND	5.0	0.3	0.03	1.0			8.8		1.5
Yala	1-FE	SP-15				12-01-84	19.3	50	34	8.6	81	39	30		0.57	2.0	ND	0.02	1.5			8.5		ND
Yala	1-FE	SP-15				29-10-85	20.0	40	30	7.4	93	47	25		0.04	2.0	0.2	0.08	0.7			7.8		3.9
Yala	1-FE	SP-15				25-09-85	19.2	60	37	7.7	82	41	25		ND	2.5	0.3	0.02	0.9			7.9		2.2
Yala	1-FE	SP-15				29-07-85	17.8	42	34	7.8	73	35	22		0.01	2.0	0.2	0.03	1.1			9.5		
Yala	1-FE	SP-15				11-06-85	18.5	100	54	7.9	93	34	29		0.02	2.0	0.2	0.04	1.3			9.2		1.3
Yala	1-FE	SP-15				30-04-85	19.1	82	33	7.0	87	39	25		0.03	5.1	0.2	0.02	1.5			8.0		2.5
Yala	1-FE	SP-15				03-04-85	20.8		41	7.2	79	27	19		0.02	7.0	0.2	0.06	1.9			8.5		
Yala	1-FE	SP-15				24-08-85	17.3		40	7.1	96	65	25									8.1		
Kimondi-Moko	1-FD	SP-16	34:20:12E	0;02:48	1860	18-03-86	20.1	87	22	7.3	97	45	35		0.02	3.2	0.3	0.04	0.8			9.1		2.6
Kimondi-Moko	1-FD	SP-16				30-04-85	17.8	100	51	7.0	120	47	34		0.03	3.9	0.2	0.03	1.4			8.6		2.8
Kimondi-Moko	1-FD	SP-16				03-04-85	18.7		45	7.3	94	47	35		0.00	7.2	0.1	0.09	2.0					
Kimondi-Moko	1-FD	SP-16				24-09-85	18.1	110	88	7.6	112	52	40		0.06	2.5	0.3	0.03	1.1			8.5		2.9
Kimondi-Moko	1-FD	SP-16				22-07-85	17.2	80	88	8.0	90	51	39		0.04	2.3	0.6	0.08	2.5			10.8		ND
Kimondi-Moko	1-FD	SP-16				11-01-86	18.9	60	27	8.8	130	52	37		0.25	<1.0	ND	0.02	1.5			9.0		ND
Mokong	1-FD	SP-17	34:20:24E	0:02:42N	1860	10-06-85	20.1	112	116	7.3	142	70	51		0.02	3.5	0.3	0.07	1.1			7.2		4.5
Nzoia	1-EE	SP-18	34:13:15E	0:10:30N	1180	20-08-85	22.0	125	66	7.2	112	45	32	2.4	0.52	1.9		0.22	1.6	0.05		7.4		
Nzoia	1-EE	SP-18				16-03-87	24.6		80	7.5		52	28		0.55	1.6	0.3	ND	1.2	ND		3.7		
Nzoia	1-EE	SP-18				03-10-84			60	7.3	130	66		6.0	0.60	6.0	ND	0.70	0.0	0.3	5.0		3.8	
Nzoia	1-EE	SP-18				03-10-84	27.5		52	7.6												6.8		
Nzoia	1-DA	SP-19	34:47:00E	0:36:00N	1460	22-08-85	19.1			7.4	124	136												
Nzoia	1-DA	SP-19				01-10-84			41	7.9	135	74		1.8	0.27	3.4	ND	ND	0.9	0.6	ND			
Nzoia	1-DA	SP-19				18-03-87	23.1		155	7.5		62	50	0.9	0.31	0.9	0.1	ND	0.2	0.22		3.8		
Nzoia	1-DA	SP-20	34:47:00E	0:36:00N	1460	18-03-87	23.3		170	7.5		64	46	ND	0.35	1.9	0.2	0.10	1.8			3.7		
Little Nzoia	1-BD	SP-21	35:07:00E	0:49:05N	1860	18-03-87	19.8		80	7.4		88	61	0.4	0.22	ND	0.25	0.55	0.85	0.16		3.1		
Nzoia	1-BE	SP-22	35:06:48E	0:52:30N	1830	22-08-85	17.2		72	7.1	136	85	36											
Nzoia	1-BE	SP-22				18-03-87	21.0		58	7.4		74	65		0.17	0.4	0.2	0.50	0.08	0.12		3.8		
Nzoia	1-DD	SP-23	34:28:45E	0:06:08N	1178	17-03-87	23.9		200	7.2		110	69	0.9	0.3	1.2	0.15	0.30	0.65	0.1		3.6		
Nzoia	1-DD	SP-24	34:28:45E	0:06:08N	1178	17-03-87	24.4		205	7.2		70	50	0.1	0.6	1.1	0.2	ND	0.2	0.1		3.1		
Nzoia	1-DD	SP-24				21-08-85	20.6		81	7.3	105	49	27			2.8						7.5		
Nzoia	1-DD	SP-24				02-06-88	25.0			7.5	100	57	38	N.D								5.1	307.0	2.1
Nzoia	1-EF	SP-25	34:00:00E	0:05:00N	1138	05-10-84	21.0		57	7.5	120	66		1.2	0.95	5.2	ND	ND	0.02	0.23	1.0		3.7	
Nzoia	1-EE	SP-26	35:23:52E	0:16:38N	1240	02-06-88	25.0			7.0	100	57	35	0.1								4.5	207.1	1.5
Nzoia	1-EE	SP-27	34:12:57E	0:10:14N	1178	02-06-88	26.0			7.0	120	46	33	1.0								2.8	118.8	3.5
Nuoroya	1-EG	SP-28	34:12:57E	0:09:14N	1178	02-06-88	27.0				100	54	38	ND								5.5	119.1	2.1