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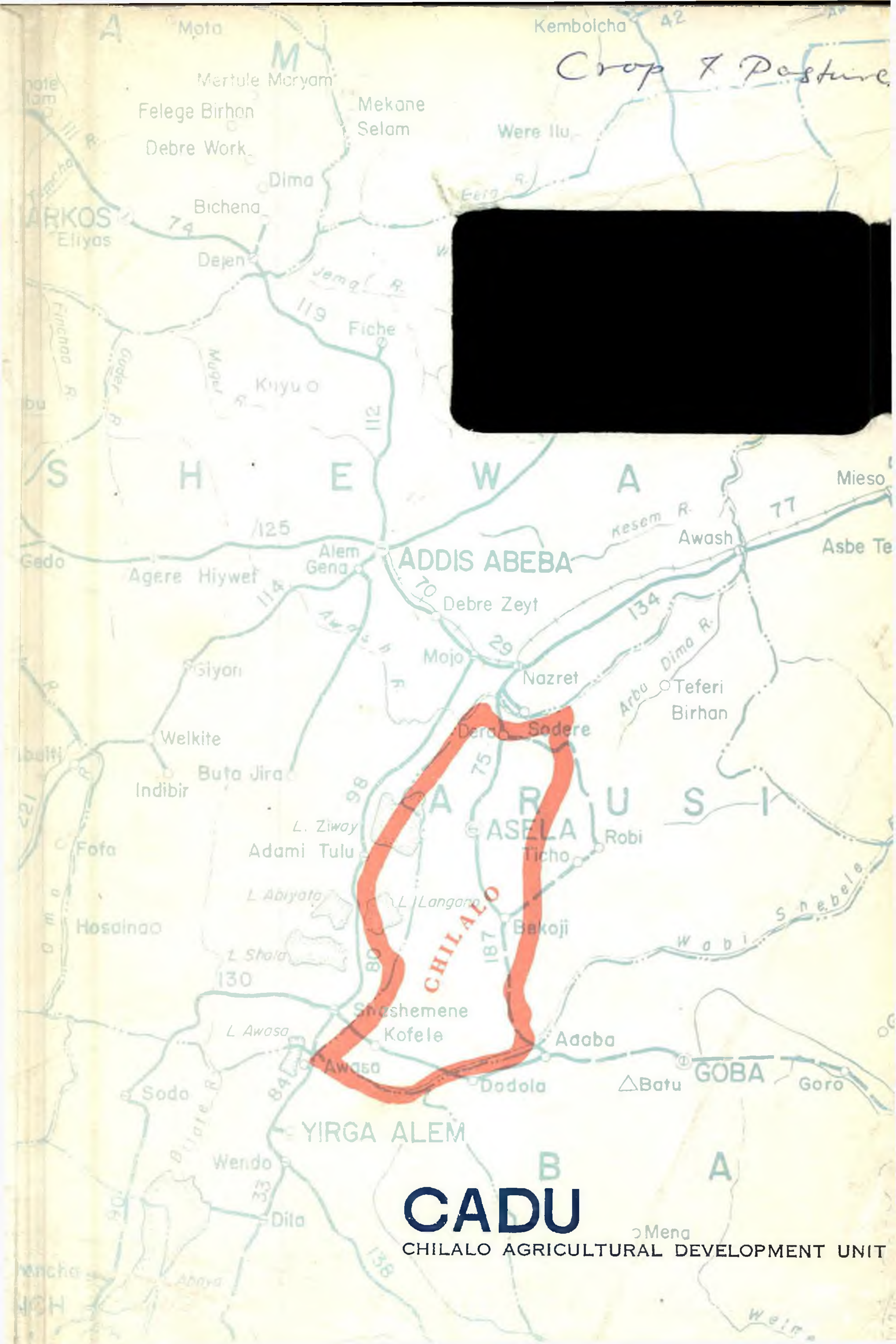


# CADU

## CHILALO AGRICULTURAL DEVELOPMENT UNIT

# A MASTER PLAN FOR WATER RESOURCES AND SUPPLIES IN THE CHILALO AWRAJA

BY

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## 1 THE WATER DEVELOPMENT PROGRAMME, ITS AIMS AND GOALS

When the Chilalo Agricultural Development Unit (CADU) was briefed by the Swedish International Development Authority (SIDA) the question of water had to be considered. In my first report, "Reconnoitering survey of thw water resources in Chilalo Awraja, March, 1967", I proposed an earth dam at Asella providing both the CADU project centre and the town with water.

As most of the Chilalo Awraja has a pronounced shortage of water during the greater part of the year, the following water development programme was approved by CADU:

1) investigation of natural water resources, both ground water and surface water,

2) research work on simple and cheap water supplies, including study of costs,

3) implementation of water supplies starting with demonstration objects.

These three activities, which are partly interrelated, should follow like three waves. The stage reached by the time of writing this report is shown in fig. 1 on the next page.

The programme aims to:

1) estimate the available water resources and the demand for water, now and in the future,

2) propose suitable water supplies adapted to local conditions,
3) help the people to start construction of water supplies, on the basis of self-help.

The advantages which are expected to come out of the water development programme can be summarized under the following five headings.

1) Regional planning. Especially in a country with a lack of water, a plan for available water resources and possible artificial water supplies is necessary for the planning of communities and economic projects.

2) Changed settlement. Dry and unproductive areas can be utilized if new and economic water supplies can be introduced. And these dry areas, which people otherwise have to leave during the dry season, can be inhabited all the year round.

# TIME SCHEDULE

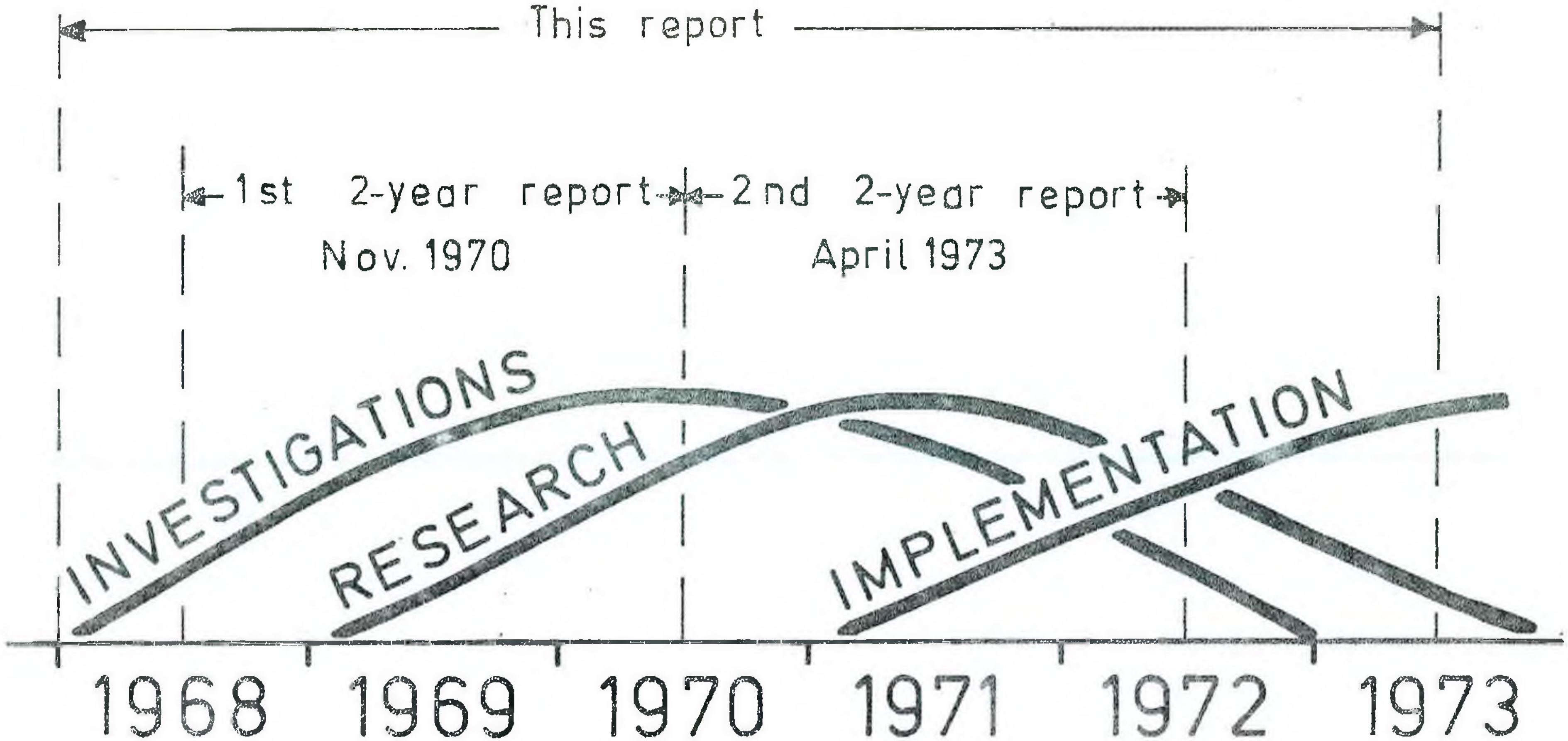



Fig. 1

3) Economic development. For an increase in the production of milk and meat, water must be available without moving the cattle to remote water holes either daily or every second day. Commonly the water resources are not large enough for irrigation. In many areas, however, improved water supplies can create the possibility of cultivation vegetables all year round.

4) Social development. The women need not carry heavy water vessels long distances every day. These working hours, now used for carrying water, can be utilized for more productive work. For the nomadic people, new water wells and a more static life create greater possibilities to send the children to school. When the nomads cannot have their children in schools, they are shut off from social and cultural development.

5) Sanitary advantages. The collection of surface water is a first step in water development, the next will be a purification of the water. New wells, of course, give clean and healthy ground water. Availability of water can increase personal hygiene and sanitary conditions.

## 2 ORGANIZATION AND BUDGET

When the water development started, no map of the Chilalo Awraja existed. There was no knowledge of natural conditions, except some meteorological records from missions. Nothing was known of the quantity and quality of rivers or of the availability of ground water.

The reactions of people regarding water were not known. There were no water supply facilities (except piped water for half the week in the provincial capital, Asella, with more than 12,000 inhabitants). Personnel had to be taught and trained. Equipment had to be purchased from abroad. As a consultant I had to start from the beginning and built up an organization.

Fig. 2, upper part (p. 5) shows the organization during four years of mainly investigation and research. During the fourth year a second rig was bought for the implementation of drilling wells, at the request of the people and paid for by the people. During the fifth year the investigation and research programme gave place to an implementation programme which involved changing the organization as shown in fig. 2, lower part. The hydrometrist and the assistant for research work had to be trained for surveying and construction work. One of the three drilling foremen is acting as head of drilling activities and can also temporarily take the place of other foremen or mechanics.

During 1971/72 the staff had the following constitution and monthly salaries in Eth. $.

| | | |
|---|---|---|
| 1 | Head (Swedish engineer, to be replaced by the Ethiopian Assistant Head) | |
| 2 | Assistant Head (and Organizer of new water supplies) | Eth.$495:- |
| 3 | Engineer for design and construction | " $545:- |
| 4 | Draftsman, later also supervisor of construction | " $380:- |
| 5 | Acting Hydrometrist, later field assistant for surveying also | " $110:- |
| 6 | Technical Assistant for research work, later also for construction | " $120:- |
| 7 | Swedish Supervisor for the ground water unit, to be replaced by one of the three Ethiopian drilling foremen | |
| 8-10 | Three drilling foremen | 2 x Eth. $495<br>1 x " $450 |
| 11-12 | Two head drillers | Eth.$125:- |
| 13-14 | Two drillers | " $110:-<br>75:- |
| 15 | Pump mechanic | " $130 |
| 16 | Assistant pump mechanic | " $ 60 |
| 17-18 | Workshop mechanic, also acting as storekeeper | " $300:- |
| 19 | Assistant workshop mechanic | " 70:- |

# ORGANIZATION CHART

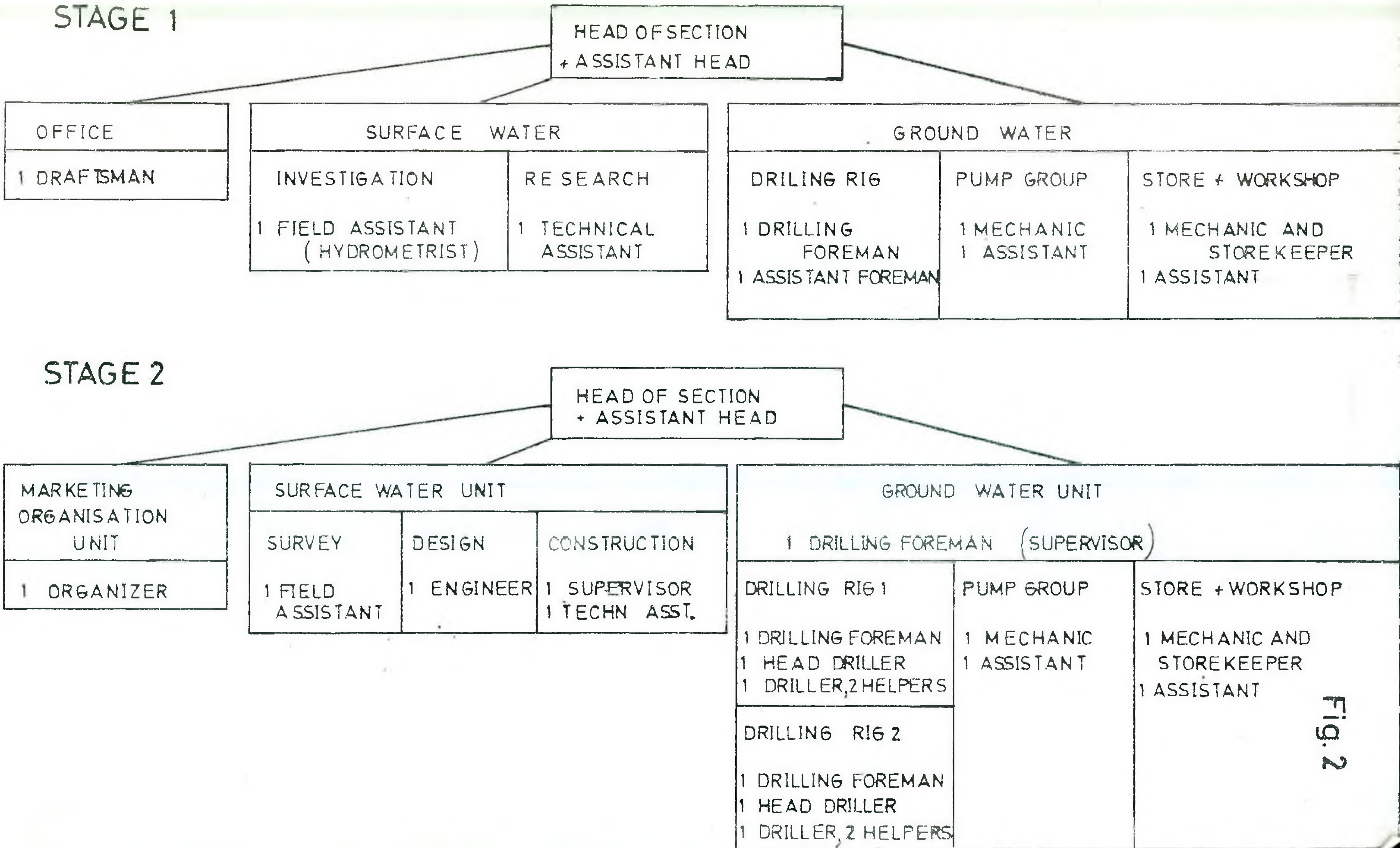



Fig. 2

The biggest handicap has been discontinuities in the work caused by repeated and sudden changes of Heads of the Section, and difficulties in filling the post of Assistant Head. The Heads have included Ato Yeshiwas Bekele, Mr. Göran Hanson, Ato Habte Selassie, Mr. Olle Schönbeck and Mr. Stefan Grönberg. The Ethiopians left when they got scholarshipa abroad; the Swedes wanted to continue their education at home. For the continuity of the work, it was necessary to have a consultant in the background. During the first years I visited the project two weeks a year, during later years three weeks twice a year. As circumstances have not always turned out as expected, some details of the programme have been changed as work progressed, specially in the implementation programme. In broad outline, however, the original plan of operation for the 5-year period 1968/69 - 1972/73 has been followed (table 1, p. 7).

In the budget there are no clerical costs because the water development section can utilize the common facilities of the CADU project. These facilities also include garage, office in Addis Ababa, local representation of extension agents, etc.

# 3 INVESTIGATIONS

## 3.1 Perennial rivers

### 3.1.1 Mapping of rivers

Aerial pictures with an approximate scale of 1:6,666 have been put together to make a map, which has been photographically reduced to a more appropriate scale (fig. 3, p.8). The map is subject to some projection errors, but it provides a serviceable basis, for the drawing of perennial rivers & other geographical features in this report. The term "perennial rivers" here also includes small streams which do not dry up totally at any time as far as the present local population can remember.

### 3.1.2 Discharge of rivers

The discharge has been investigated in rivers regarded to be perennial. Once a week the flows have been measured with a current meter. During the dry season over-flow gauges have been used in small rivers.

Table 1 Budgets 1968/69 - 1972/73

| | 1967/68 |
|---|---|
| **Personnel** | |
| Swedish staff and consultant | |
| Ethiopian staff | |
| Locally employed | |
| Temporary workers, overtime | |
| Total | (a) |
| **Services** | |
| Travel and transportation | |
| Other services | |
| Unforseen | |
| Total | |
| **Materials** | |
| for drilling wells and construction workshop | 76,100 |
| Fuel, oil, lubricants | |
| Sundry and unforseen | |
| Total | |
| **Equipment for implementation** | |
| Pipes, etc. for wells | |
| Pumps, engines | |
| Windmills | |
| Pond-lining materials | |
| Sundries | |
| Total | |
| **Subsidy** | |
| for borehole failures | |

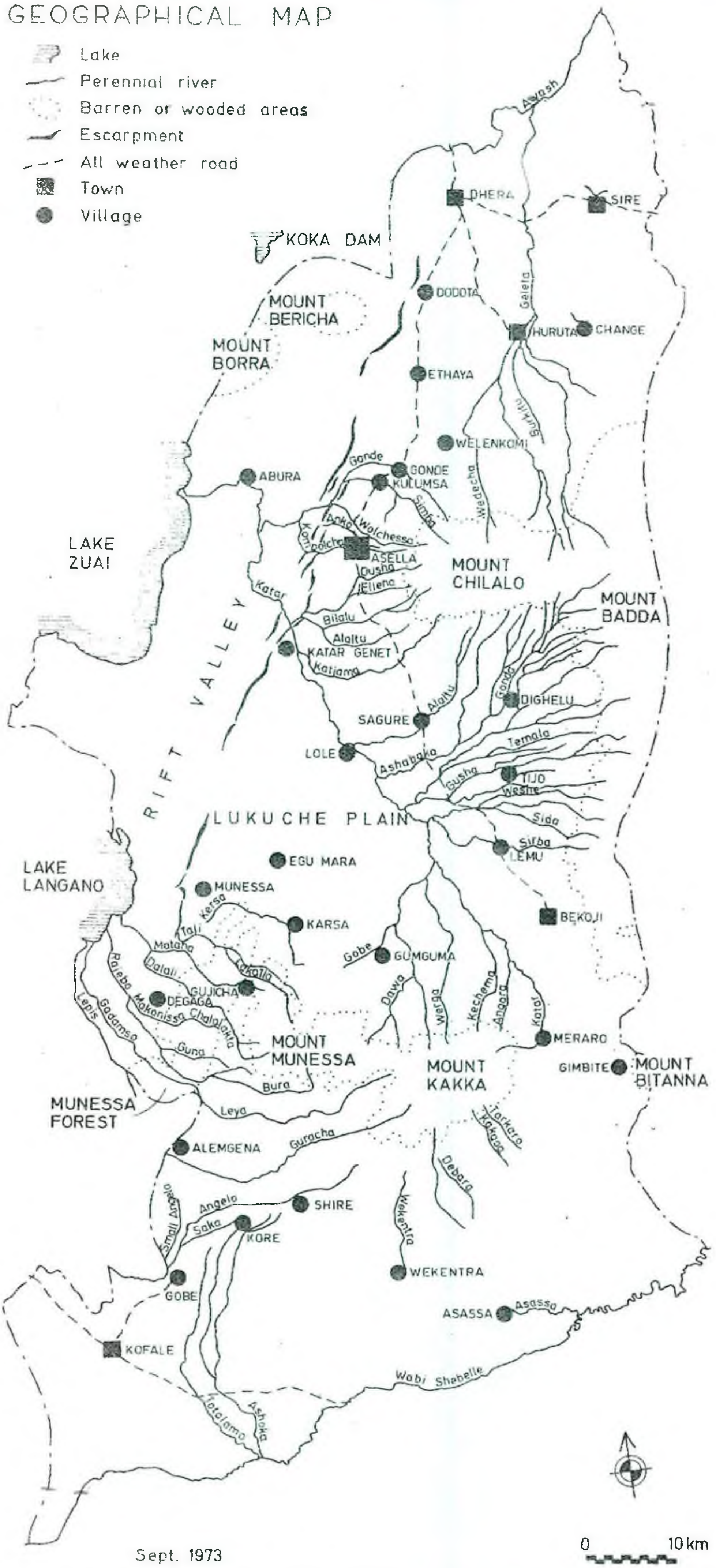
(a) Included in CADU's land survey.

(b) This year the purchases were delayed & change
Governments.

| 1st 2-year period | | 2nd 2-year period | | 5th year | |
|---|---|---|---|---|---|
| | | | | 1972/73 | |
| 1968/69 | 1969/70 | 1970/71 | 1971/72 | investi-gation, research | implemen-tation |
| | | 71,000 | 82,248 | 131,532 | |
| | | 18,160 | 34,200 | 37,620 | |
| | | 9,378 | 17,160 | 11,451 | 7,424 |
| | | 3,900 | 9,716 | 7,542 | 3,146 |
| (a) | (a) | 92,438 | 143,324 | 188,145 | 10,570 |
| 13,491 | 12,615 | 25,500 | 46,000 | 23,000 | 18,700 |
| 2,500 | 2,500 | 8,000 | 12,840 | 9,640 | 3,200 |
| 0 | 0 | 1,000 | 5,900 | 3,710 | 2,190 |
| 15,991 | 15,115 | 34,500 | 64,740 | 36,350 | 24,090 |
| 17,100 | 14,800 | 26,300 | 36,000 | 20,000 | 44,500 |
| 3,400 | 5,000 | 1,500 | 1,500 | 1,500 | - |
| 2,500 | 3,000 | 3,000 | 5,000 | 3,500 | 1,500 |
| 1,000 | 1,000 | 1,000 | 6,300 | 4,800 | 2,500 |
| 24,000 | 23,800 | 31,800 | 48,800 | 29,800 | 48,500 |
| | 10,100 | 50,875 | 17,500 | | 8,000 |
| | 15,700 | 12,000 | 14,000 | | 14,000 |
| | 0 | 20,000 | 6,500 | | 6,500 |
| | 0 | 0 | 11,000 | | 0 |
| | 500 | 17,350 | 1,000 | | 0 |
| 23,700 | 26,300 | 100,225 (b) | 50,000 | | 28,500 |
| - | - | 7,500 | 25,000 | | 25,000 |

ed because of new agreements between the Ethiopian and Swedish

Fig. 3


GEOGRAPHICAL MAP
Lake
Perennial river
Barren or wooded areas
Escarpment
All weather road
Town
Village
Awash
DHERA
SIRE
KOKA DAM
DODOTA
Geleta
HURUTA
CHANGE
MOUNT BERICHA
MOUNT BORRA
ETHAYA
Bukhu
WELENKOMI
Gonde
GONDE
KULUMSA
ABURA
Simfa
Wedecha
Anka
Wolchessa
Kompolcha
ASELLA
LAKE ZUAI
MOUNT CHILALO
Dusha
Elleno
Katar
RIFT VALLEY
Bilalu
Alaltu
KATAR GENET
Katjama
MOUNT BADDA
Gonde
DIGHELU
SAGURE
Alaltu
Temala
LOLE
Ashabaka
Gusha
TIJO
Weshe
Sida
LUKUCHE PLAIN
Sirba
LEMU
EGU MARA
LAKE LANGANO
MUNESSA
Kersa
KARSA
BEKOJI
Tali
Matana
Dalali
Gobe
GUMGUMA
Lakalla
GUJICHA
DEGAGA
Raleba
Lepis
Gadamsa
Hokonissa
Chalalaka
Dawa
Werga
Kechema
Angara
Katal
MERARO
Guna
MOUNT MUNESSA
MOUNT KAKKA
GIMBITE
MOUNT BITANNA
Bura
MUNESSA FOREST
Leya
Tarkaro
Kakasa
ALEMGENA
Guracha
Debara
Small Angelo
Angelo
SHIRE
Saka
KORE
Wekentra
WEKENTRA
GOBE
ASASSA
Asassa
KOFALE
Wabi Shebelle
Tatalamo
Ashoka
0
10 km
Sept. 1973

During the first 2-year period 1968/69 - 1969/70 twenty rivers in the northeastern half of Chilalo were measured; during the second 2-year period 1970/71 - 1971/72 ten rivers in the southwestern half of Chilalo. In five rivers in the border zones of the Chilalo Awraja measurements from other authorities have been utilized. Single or short-period observations have been made of seven rivers, five of which dry up every year in all but the upper parts. The regular measurements of the discharge have been described and the values have been represented in graphs and tables in the 2-year reports.

One of these graphs, that of the Makanissa River, has been reproduced in this report as fig. 4 on the next page. The daily variations in water quantity and suspended load are compared with the precipitation at Degaga. During the rainy season there is a regular flood in July-September, starting in June and ending in October. After that during the long dry season there is constant small flow. In March-May a small rainy season can increase the flow of the rivers. The occurrance of this flow, however, varies greatly from year to year, and from one area to another.

In table 2 (p. 11) I have put together some data from the rivers measured:

1) during one year the monthly flows of February (end of dry season), March (small rainy season), August (peak of large rainy season) and November (beginning of dry season),

2) observed maximum and minimum flows during a 2-year period,

3) the ratios between maximum and minimum flows. The most important figures are the minimum flows, as these represent the capacity of a river as a water supply. The map in fig. 5 (p. 12) shows the observed minimum flows of the perennial rivers. Except the border rivers in the north and in the south — the Awash and the Wabe Shebelle Rivers respectively, there is only one rather large river, the Katar River. This river flows through the central part of the Chilalo Awraja like an artery.

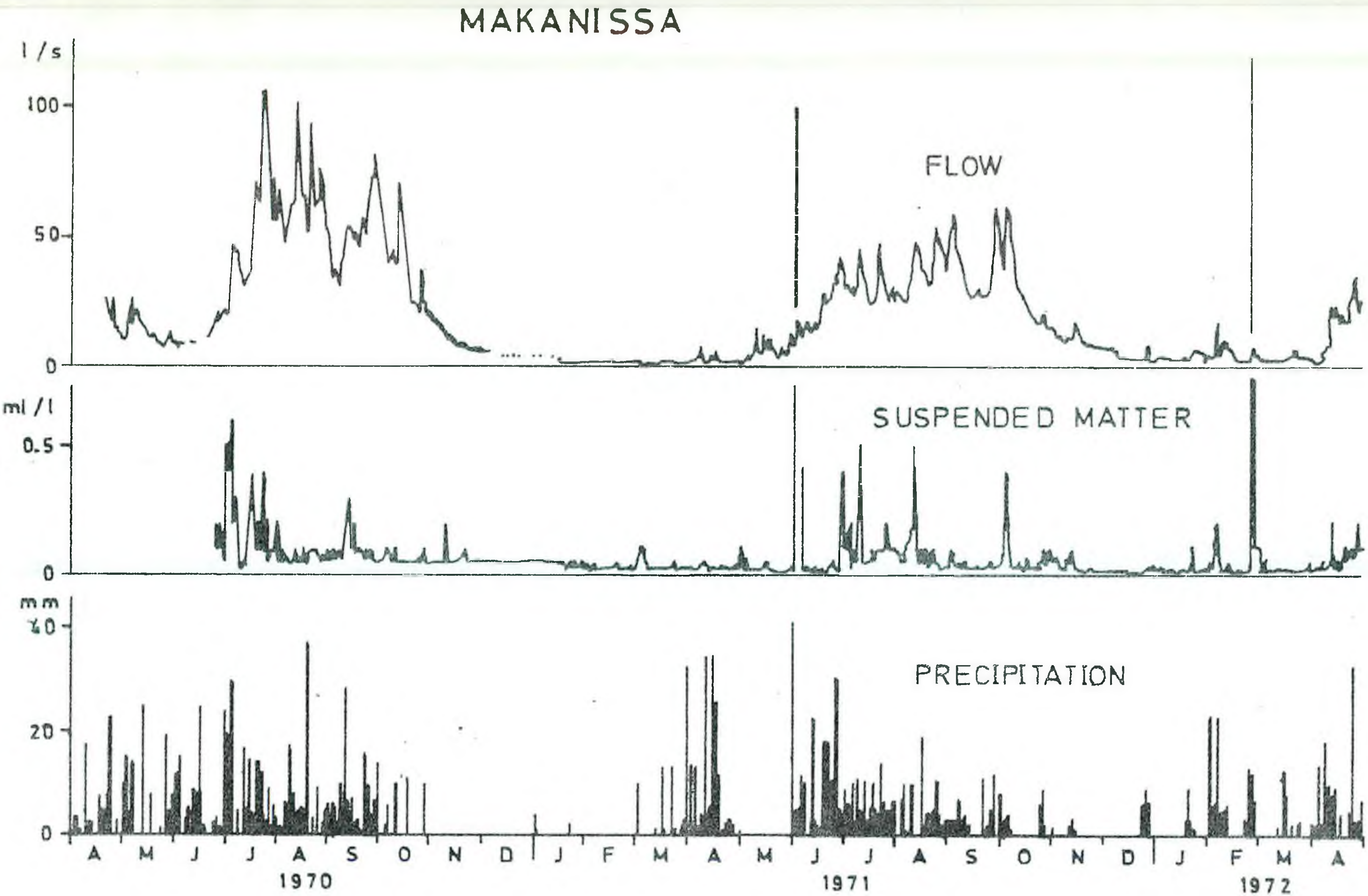

MAKANISSA
l / s
100
50
0
FLOW
ml / l
0.5
0
SUSPENDED MATTER
mm
40
20
0
PRECIPITATION
A M J J A S O N D J F M A M J J A S O N D J F M A
1970
1971
1972

Fig. 4

Table 2 Monthly maximum and minimum flows (l/s) in rivers

| Rivers | Year | Feb. | March | Aug. | Nov. | Years | Max. | Min. | Max/Min |
|---|---|---|---|---|---|---|---|---|---|
| Geleta | 1971 | 500 | 2,030 | 7,320 | 420 | 1970 - 71 | 159,600 | 200 | 798 |
| Wedesha | 1969 | - | 263 | 2,275 | - | Feb. 1967 | 4,700 | 21 | 224 |
| Gonde | " | 519 | 125 | 177 | 319 | Feb. 1968 | 10,800 | 6 | 1,800 |
| Simba | " | 306 | 77 | 1,660 | 111 | " | 7,000 | 7 | 1,000 |
| Wolchessa | " | 305 | 90 | 525 | 7 | " | 2,410 | 0.2 | 12,050 |
| Anko | " | 6 | 32 | 272 | 5 | " | 680 | 0.1 | 6,800 |
| Kompolcha (a) | " | 29 | 16 | 365 | 8 | " | 850 | 0.5 | 1,700 |
| Dusha | " | 5 | 18 | 453 | 10 | " | 1,925 | 0.1 | 19,250 |
| Ellena | " | 4 | 6 | 113 | 4 | " | 290 | 1 | 290 |
| Bilalu | " | 13 | 27 | 595 | 13 | " | 2,725 | 1 | 2,725 |
| Alaltu | " | 7 | 9 | 361 | - | " | 1,510 | 1 | 1,510 |
| Katjama | " | 11 | - | 709 | 66 | " | 2,450 | 3 | 817 |
| Sagure Alaltu | " | 18 | 27 | (797) | (47) | " | 6,450 | 3 | 2,150 |
| Ashabaka | " | (1,076) | 1,129 | 8,980 | 918 | " | 36,000 | 368 | 98 |
| Temala | " | 693 | 748 | (4,384) | 520 | " | 8,040 | 204 | 39 |
| Gusha | " | (565) | 556 | 2,284 | 193 | " | 6,100 | 140 | 44 |
| Weshe | " | (284) | 218 | 1,546 | 130 | " | 12,300 | 71 | 173 |
| Sida | " | (391) | 522 | 4,097 | 130 | " | 6,210 | 172 | 36 |
| Sirba | " | 84 | 110 | 733 | 45 | " | 1,755 | 10 | 176 |
| Katar at Hoffy | 1971 | 680 | 1,050 | 13,990 | 830 | 1970 - 71 | 110,000 | 109 | 1,009 |
| Katar at Abura | " | 1,730 | 4,090 | 39,610 | 4,070 | " | 165,850 | 1,550 | 107 |
| Karsa (b) | " | 4 | 7 | 139 | 10 | Apr. 1970-Apr. 1972 | 780 | 0 | - |
| Taji | " | 2 | 5 | 122 | 8 | | 325 | 0.5 | 650 |
| Matana | " | 2 | 7 | 114 | 5 | " | 510 | 0.5 | 1,020 |
| Dalali | " | 3 | 15 | 96 | 12 | " | 300 | 1 | 300 |
| Makanissa | " | 2 | 6 | 38 | 11 | " | 105 | 1 | 105 |
| Guna | " | 4 | 4 | 34 | 6 | " | 90 | 3 | 30 |
| Rajebo | " | 15 | 29 | 308 | 25 | " | 820 | 8 | 103 |
| Gadamso | " | 7 | 87 | 594 | 23 | " | 1,210 | 5 | 242 |
| Adoftu (b) | " | - | 9 | 136 | 6 | " | 570 | 0 | - |
| Lepis | " | 4 | 60 | 397 | 53 | " | 930 | 1 | 930 |
| Totolamo | 1967 | 103 | 344 | 2,739 | - | 1967, 1972 | 5,220 | 50 | 104 |
| Ashoka | " | 23 | 92 | 1,594 | - | " | 3,700 | 10 | 370 |
| Asassa | 1970 | 1,130 | 1,190 | 1,366 | 1,305 | 1970 - 71 | 3,100 | 1,145 | 3 |

(a) below water intake, at that time, to Asella

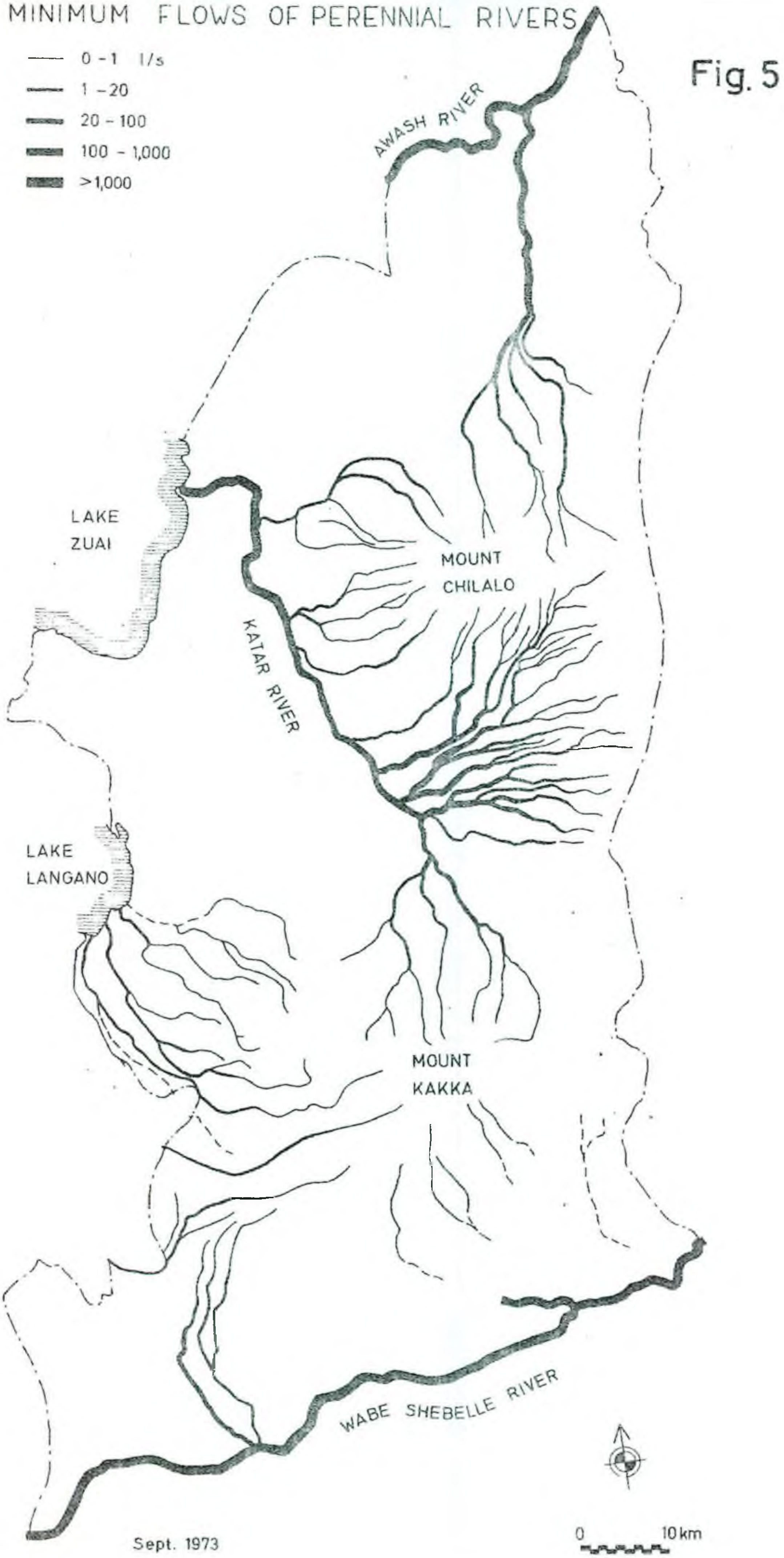
(b) dried up down stream of the gauging site

During the observation period 1968-1972 the annual flows have been different as evident from figures on next page 11a

## Geleta River. Monthly Volumes in Mill. Cubic Metres (1968 - 1972)

| Year | J | F | M | A | M | J | J | A | S | O | N | D | Total | Minimum | Ratios Total | Ratios Minimum |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1968 | 3.35 | 7.28 | 5.65 | 24.48 | 7.47 | 6.48 | 17.34 | 24.42 | (24.42) (a) | 13.92 | 4.21 | 3.45 | (142.47) | 3.35 | 1.9 | 4.7 |
| 1969 | 3.74 | 6.94 | 24.61 | 5.19 | 6.68 | 6.82 | 35.22 | 28.06 | 27.23 | 4.89 | 2.74 | 2.11 | 154.23 | 2.11 | 2.0 | 2.9 |
| | M | J | J | A | S | O | N | D | J | F | M | A | | | | |
| 1970-71 | 7.92 | 3.50 | 26.36 | 75.70 | 29.99 | 6.15 | 1.93 | 1.53 | 1.40 | 1.22 | 1.42 | 3.39 | 160.51 | 1.22 | 2.1 | 1.7 |
| 1970-71 | 5.45 | 10.48 | 13.91 | 19.61 | 14.53 | 2.00 | 1.08 | 0.73 | 0.72 | 1.46 | 1.61 | 4.84 | 76.42 | 0.72 | 1 | 1 |

(a) = estimation



MINIMUM FLOWS OF PERENNIAL RIVERS
0 - 1 l/s
1 - 20
20 - 100
100 - 1,000
>1,000
Fig. 5
AWASH RIVER
LAKE ZUAI
MOUNT CHILALO
KATAR RIVER
LAKE LANGANO
MOUNT KAKKA
WABE SHEBELLE RIVER
Sept. 1973
0 10 km

The many streams from the Chilalo Mountain and the Munessa-Kakka Mountains are collected into larger rivers, or dry up creating large areas without water. The drying-up is not only due to evaporation but also consumption and water loss into the rock below the river bed.

3.1.3 Quality of river

3.1.3.1 Temperature

The water temperature of perennial rivers was measured in November 1966. On the plateau, from the Gonde River in the north to the Upper Katar in the south, temperatures between 8° and 18°C were observed. In the Rift Valley the water temperature was 18° - 25°C.

3.1.3.2 Sediment load and erosion

As the eroded earth layers consist of clay and silt and no layers of coarse sand exist upstream of the rivers, the sediment load likewise consists of clay and silt. This material is suspended in the river water. Samples of the water have been taken at the measuring sites once a week.

During the peaks of the flows coarse silt and fine sand are suspended in the river water. The following table shows the percentages of different size fractions during high water peaks:

| Rivers | clay < 0.002 mm | silt 0.002-0.006 mm | 0.006-0.02 mm | 0.02-0.06 mm | fine sand > 0.06 mm |
|---|---|---|---|---|---|
| Dusha | 5 | 23 | 35 | 23 | 14 |
| Simba | 3 | 10 | 34 | 27 | 26 |
| | 2 | 3 | 8 | 13 | 74 |
| Lower Katar | 5 | 12 | 26 | 28 | 29 |
| | 2 | 4 | 12 | 22 | 60 |

The suspended material consists to a minor degree of organic matter. The content of organic carbon has been determined by wet combustion of samples from some rivers:

| Rivers | number of samples | carbon % by weight of total suspended matter |
|---|---|---|
| Dusha | 3 | 5.2 - 8.6 |
| Simba | 4 | 1.2 - 2.3 |
| Lower Katar | 3 | 3.0 - 3.6 |

The rivers receive more suspended matter from the plateau after heavy rains of some duration. The rainfalls and therefore, also the high peaks of clay content are often of local extent. A few peaks every year typically reach about 2 ml/l, or more. These high peaks last only for some hours. The highest peaks often appear at the beginning of periods with high flows, especially at the beginning of the large rainy season. The order is first rain, then outwash of clay particles from the ground and lastly the peak of the high water.

Table 3 on the next page shows maximum and minimum amounts of suspended matter in ml/l during the same periods as table 2. The largest observed amounts are 24 and 30 ml/l.

For a closer study of the fluctuation of the load, the amount of suspended matter has been measured day by day in seven rivers. Makanissa River in fig. 4 can serve as an example. Throughout most of the year the amount of suspended matter is low, below 0.2 ml/l; periodically it will reach 0.3-0.5 ml/l. In spite of the low amount of suspended matter the rivers look more or less dirty all the year.

For these rivers measured every day the total amount of suspended matter has been calculated month by month and per year (table 4, p. 16 ).

Table 3 Maximum and minimum amounts of suspended matter (ml/l) in rivers

| Rivers | Year | Maximum amounts Feb. | May | Aug. | Nov. | Year | Minimum amounts (a) Feb. | May | Aug. | Nov. |
|---|---|---|---|---|---|---|---|---|---|---|
| Geleta | 1964 | - | - | 24.0 | - | 1969 | - | 0.4 | - | - |
| Wedecha | 1969 | - | 0.2 | - | - | " | - | 0.2 | - | - |
| Gonde | " | 9.5 | 0.2 | 2.5 | 0.3 | " | 0.1 | 0.03 | 0.05 | 0.2 |
| Simba | " | 0.6 | 0.9 | 30.0 | 0.2 | " | 0.1 | 0.01 | 0.1 | 0.01 |
| Wolchessa | " | 3.0 | 0.65 | 1.5 | 0.1 | " | 0.05 | 0.01 | 0.1 | 0.1 |
| Anko | " | 0.6 | 2.9 | 0.7 | 0.1 | " | 0.2 | 0.05 | 0.1 | 0.1 |
| Kompolcha | " | 0.6 | 0.4 | 0.5 | 0.2 | " | 0.3 | trace | 0.1 | 0.2 |
| Dusha | " | 0.3 | 1.2 | 1.8 | 0.15 | " | 0.04 | 0.01 | 0.05 | trace |
| Ellena | " | 0.1 | 0.2 | 0.5 | 0.1 | " | 0.03 | 0.02 | 0.05 | 0.05 |
| Bilalu | " | 0.1 | 0.45 | 0.2 | 0.1 | " | 0.05 | 0.01 | 0.1 | 0.1 |
| Alaltu | " | 0.2 | 0.3 | 0.4 | 0.2 | " | 0.1 | 0.02 | 0.1 | 0.06 |
| Katjama | " | 0.2 | 0.35 | 0.4 | 0.2 | " | 0.1 | 0.01 | 0.1 | 0.1 |
| Sagure Alaltu | " | 0.3 | 0.4 | 1.0 | 0.2 | " | 0.1 | 0.01 | 0.1 | 0.02 |
| Ashabaka | " | 0.15 | 0.1 | 2.5 | 0.5 | " | 0.01 | 0.01 | 0.1 | trace |
| Temala | " | 0.2 | 1.0 | 0.6 | 0.4 | " | 0.1 | 0.1 | 0.1 | 0.4 |
| Gusha | " | 0.4 | 1.3 | 1.0 | 0.1 | " | 0.2 | 0.1 | 0.1 | 0.1 |
| Weshe | " | 1.0 | 0.2 | 0.5 | 0.1 | " | 0.1 | 0.1 | 0.1 | 0.1 |
| Sida | " | 0.5 | 0.25 | 0.5 | 0.3 | " | 0.1 | 0.01 | 0.1 | 0.3 |
| Sirba | " | 0.3 | 0.65 | 0.5 | 0.2 | " | 0.2 | 0.02 | 0.1 | 0.2 |
| Upper Katar | " | 0.1 | 1.0 | 0.2 | 0.3 | " | 0.01 | 0.8 | 0.2 | 0.3 |
| Karsa | Apr.1970-Apr.1972 | 0.1 | 0.7 | 1.5 | 0.1 | April 1970/72 | - | - | 0.05 | - |
| Taji | " | 0.6 | 0.3 | 0.4 | 0.05 | " | 0.03 | 0.02 | 0.05 | 0.03 |
| Matana | " | 0.06 | 0.5 | 0.3 | 0.05 | " | - | 0.02 | 0.1 | - |
| Dalali | " | 0.1 | 0.6 | 0.3 | 0.01 | " | 0.02 | 0.02 | 0.05 | - |
| Makanissa | " | 2.0 | 0.1 | 0.5 | 0.2 | " | - | - | 0.02 | 0.03 |
| Guna | " | 0.4 | 0.2 | 0.2 | 0.1 | " | 0.01 | 0.03 | 0.05 | - |
| Rajebo | " | 1.3 | 0.4 | 1.2 | 4.0 | " | 0.1 | 0.3 | 0.05 | - |
| Gadamso | " | 0.5 | 0.4 | 0.2 | 0.5 | " | - | 0.02 | 0.05 | - |
| Adoftu | " | 0.2 | 0.5 | 0.2 | 0.05 | " | - | 0.02 | 0.06 | 0.01 |
| Lepis | " | 0.5 | 1.3 | 0.4 | 4.0 | " | - | 0.03 | 0.02 | - |

(a) down to Upper Katar in the table the month of December instead of November

Table 4 Total amount of suspended matter ($m^3$) in seven rivers month by month and for the whole year

| RIVERS | YEAR | F | M | A | M | J | J | A | S | O | N | D | J | F | M | A | yearly total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Simba | Feb. 1969-Jan. 1970 | 277 | 682 | 99 | 257 | 1,049 | 1,881 | 4,121 | 7,020 | 727 | 112 | 131 | 156 | | | | 16,512 |
| Dusha | Apr. 1969-Mar. 1970 | 5 | 6 | 74 | 11 | 79 | 325 | 131 | 71 | 8 | 11 | 8 | 9 | | | | 738 |
| Ashabaka | Feb. 1969-Jan. 1970 | 182 | 391 | 604 | 157 | 286 | 3,277 | 7,900 | 2,251 | 334 | 357 | 311 | 489 | | | | 16,539 |
| Karsa | May 1970-Apr. 1971 | | | | 28 | 11 | 205 | 100 | 363 | 19 | 2 | 0.5 | 0.1 | 0.2 | 0.01 | 0.6 | 729 |
| Makanissa | " | | | | 3 | 4 | 27 | 11 | 111 | 5 | 1 | 0.5 | 0.2 | 0.1 | 0.1 | 0.1 | 163 |
| Rajebo | " | | | | 12 | 7 | 95 | 270 | 129 | 44 | 14 | 7 | 7 | 3 | 4 | 30 | 622 |
| Lepis | " | | | | 34 | 23 | 1,280 | 1,285 | 103 | 33 | 5 | 3 | 1 | 0.7 | 0.5 | 1 | 2,769 |

Table 5 Annual transport of suspended matter in seven rivers, annual denudation and rate of erosion

| Rivers | Year | Annual transport of suspended matter, $m^3$ | Annual denudation of land, $m^3/km^2$ | Rate of erosion, mm/100 years |
|---|---|---|---|---|
| Simba | Feb. 1969-<br>Jan. 1970 | 16,512 | 483 | 48.3 |
| Dusha | Apr. 1969-<br>Mar. 1970 | 738 | 33.5 | 3.4 |
| Ashabaka | Feb. 1969-<br>Jan. 1970 | 16,539 | 79.1 | 7.9 |
| Karsa | May 1970-<br>Apr. 1971 | 729 | 5.6 | 0.6 |
| Makanissa | " | 163 | 12.1 | 1.2 |
| Rajebo | " | 622 | 8.4 | 0.8 |
| Lepis | " | 2,769 | 63.1 | 6.3 |

Table 6 Transport of salts (TDS = total dissolved solids) in seven rivers during the month of September

| Rivers | Area $km^2$ | Monthly flow l/s | TDS mg/l | Ton/ month | Ton/$km^2$ | year of observation |
|---|---|---|---|---|---|---|
| Simba | 34 | 214 | 84 | 46.6 | 1.37 | 1968 |
| Dusha | 22(19) | 270 | 74 | 51.8 | 2.35 | 1968 |
| Ashabaka | 209 | 2,349 | 78 | 474.9 | 2.27 | 1968 |
| Karsa | 131 | 104 | 74 | 20.0 | 0.15 | 1971 |
| Makanissa | 14 | 38 | 82 | 8.1 | 0.58 | 1971 |
| Rajebo | 74 | 141 | 92 | 33.6 | 0.45 | 1971 |
| Lepis | 44 | 350 | 78 | 70.8 | 1.61 | 1971 |

From a consideration of the suspended matter and the discharge areas of the rivers, the denudation of land and the erosion rate have been calculated (table 5, p. 17). The soil erosion is smallest in the forested areas (annually about 10 $m^3/km^2$). Hitherto the soil erosion has been insignificant in Chilalo, but the mechanized agriculture will probably increase the erosion. The high amounts of suspended matter from the Simba River(representing around 500 $m^3/km^2$) is an omen of the future.

3.1.3.3 Chemical quality

Table 7 (p. 21) shows the results of chemical analyses of samples taken in perennial rivers during September or October.

Table 6 (p. 17) shows the transport of salts (total dissolved solids = TDS) in seven rivers during the month of September. The concentrations are rather similar in the different rivers, but as these affect different areas, the rate of weathering in $tons/km^2$ is different.

3.1.3.3.1 Local differences

In northeastern Chilalo the water samples have been taken in March or April and in September or October, i.e. the ends of the dry and rainy seasons respectively. In southwestern Chilalo the sampling has been repeated in September a second year. The differences between different seasons and years (table 8, p. 22) are astonishing small.

Rivers in different parts of Chilalo are similar to each other. In the rivers from the Encoulo Range on the eastern border of the Chilalo Awraja, the calcium and magnesium values are higher than in other areas, due to the presence of basaltic rock with minerals rich in calcium and magnesium.

The amount of chloride is possibly somewhat higher in most of the tributaries of the Katar River than in most of the streams entering into Lake Langano. In the last mentioned area the amount of fluoride increases from north to south. All these differences, however, are small and do not significantly affect the quality as consumption or irrigation water.

3.1.3.3.2 Consumption water

Regarding the concentration of dissolved substances, the water is drinkable in all rivers. This means that potability analyses are commonly not necessary for river water. In table 10 with appendix (p. 23- 25) criteria for consumption water and explanations of chemical analyses are given.

The presence of nitrogen compounds shows that most rivers are polluted, which is also evident from the bacteriological tests.

The low hardness makes the water well suited for laundry purposes though precipitation of scale in vessels or boilers might happen in some areas. The bicarbonate content is low in all rivers except the Asassa River.

The $SiO_2$ content is usually below 25 mg/l but it is high in the tributaries of the Wabe Shebelle River (above 50 mg/l).

3.1.3.3.3 Irrigation water

In a consideration of irrigation water the chemical quality has to be taken into account. Among other things the salinity and the relation between certain elements are important.

The salinity can be expressed as total amount of dissolved solids (TDS). If this concentration does not exceed 500 mg/l (table 7, p 21) the TDS can be regarded as acceptable.

The suitability of the water for irrigation purposes also depends on the relation between, on the one hand calcium & magnesium ions and, on the other hand sodium ions. The latter must not overwhelmingly predominate, if the former are to be adsorbed on the soil particles, maintaining good soil structure and permeability. The sodium adsorption ratio has been calculated, thus:

$$SAR = \frac{Na}{\sqrt{(Ca + Mg) / 2}} \quad \text{eqivalents per million(1)}$$

and is shown in the last column of table 7 (p. 21). As the ratio is far below 6, the water is suitable for irrigation with -out undue base exchange and consequent accumulation of sodium and deflocculation of the clay.

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(1) The p.p.m. (or mg/l) values of the tables showing chemical analyses can be expressed in equivalents per million by multiplying by a factor: for Ca 0.04990, for Mg 0.08224 and for Na 0.04350.

Table 7 Chemical quality of river water

| RIVERS | Sampling date | pH | TDS mg/l | TH °F | P as $PO_4$ mg/l | N as $NO_3$ mg/l | Ca ppm |
|---|---|---|---|---|---|---|---|
| Gonde | 30/9 1968 | 7.5 | 105 | 2.4 | - | 0.02 | 5.8 |
| Simba | " " | 7.4 | 84 | 1.2 | - | 0.03 | 4.8 |
| Wolchessa | " " | 7.2 | 98 | 2.0 | - | trace | 5.6 |
| Anko | 1/10 1968 | 7.1 | 75 | 1.4 | - | " | 2.4 |
| Kompolcha | " " | 7.2 | 72 | 1.2 | - | 0.01 | 3.2 |
| Dusha | " " | 6.8 | 74 | 1.1 | - | trace | 8.2 |
| Ellena | " " | 7.1 | 63 | 1.2 | - | " | 3.2 |
| Bilalu | " " | 7.4 | 58 | 0.8 | - | 0.06 | 4.0 |
| Alaltu | " " | 7.0 | 72 | 1.0 | - | trace | 3.2 |
| Katjama | " " | 7.2 | 98 | 1.6 | - | " | 4.8 |
| Sagure Alaltu | " " | 7.2 | 78 | 2.0 | - | " | 5.6 |
| Ashabaka | " " | 7.5 | 78 | 2.0 | - | 0.01 | 5.6 |
| Temala | " " | 7.4 | 81 | 2.2 | - | trace | 5.3 |
| Gusha | " " | 7.3 | 85 | 2.4 | - | " | 7.2 |
| Weshe | " " | 7.5 | 88 | 2.5 | - | 0.01 | 6.4 |
| Side | " " | 7.2 | 87 | 2.2 | - | trace | 5.6 |
| Sirba | " " | 7.4 | 84 | 2.4 | - | " | 7.9 |
| Upper Katar | 4/10 1968 | 7.2 | 82 | 2.4 | - | " | 5.7 |
| Lower Katar | 3/10 1968 | 7.3 | 80 | 2.0 | - | 0.01 | 4.8 |
| Karsa | 15/9 1971 | 7.1 | 74 | 1.4 | 0.05 | 0.02 | 4.8 |
| Taji | " " | 6.9 | 64 | 1.4 | 0.24 | 0.01 | 4.8 |
| Matana | " " | 7.3 | 62 | 1.4 | 0.05 | 0.02 | 4.0 |
| Dalali | " " | 7.1 | 74 | 1.0 | 0.45 | 0.01 | 1.6 |
| Makanissa | " " | 7.0 | 82 | 1.3 | 0.32 | trace | 4.4 |
| Guna | " " | 7.4 | 64 | 1.4 | 0.23 | 0.01 | 4.2 |
| Rajebo | " " | 7.6 | 92 | 2.5 | 0.01 | 0.06 | 4.8 |
| Gadamso | " " | 7.4 | 66 | 1.75 | 0.33 | 0.05 | 3.4 |
| Adoftu | " " | 7.4 | 62 | 1.75 | 0.27 | 0.01 | 3.0 |
| Lepis | " " | 7.3 | 78 | 2.0 | 0.28 | 0.05 | 3.4 |
| Totolamo | 10/10 1972 | 7.2 | 150 | 1.6 | 0.2 | 0.04 | 4.8 |
| Ashoka | " " | 7.3 | 110 | 2.0 | 0.1 | 0.20 | 5.6 |
| Asassa | " " | 7.9 | - | 6.9 | - | 0.09 | 16.0 |

| Mg ppm | Na ppm | K ppm | $HCO_3$ ppm | Cl ppm | $SO_4$ ppm | $NO_3$ ppm | $SiO_2$ ppm | F ppm | SAR |
|---|---|---|---|---|---|---|---|---|---|
| 2.3 | 4.7 | 2.8 | - | 7.1 | - | - | 32.0 | - | 0.4 |
| 0.5 | 6.3 | 2.0 | - | 7.1 | - | - | 25.9 | - | 0.7 |
| 1.5 | 6.8 | 3.5 | - | 10.6 | - | - | 33.5 | - | 0.7 |
| 1.2 | 5.1 | 1.3 | - | 7.1 | - | - | 23.4 | - | 0.7 |
| 0.8 | 4.7 | 1.3 | - | 5.7 | - | - | 22.4 | - | 0.6 |
| 0.1 | 3.4 | 2.5 | - | 10.6 | - | - | 21.2 | - | 0.3 |
| 0.6 | 4.7 | 1.3 | - | 7.1 | - | - | 18.3 | - | 0.6 |
| 0.8 | 4.3 | 2.0 | - | 7.1 | - | - | 4.8 | - | 0.6 |
| 0.1 | 5.1 | 1.8 | - | 14.2 | - | - | 18.0 | - | 0.8 |
| 1.0 | 5.1 | 1.5 | - | 10.6 | - | - | 17.3 | - | 0.6 |
| 1.5 | 5.9 | 1.5 | - | 10.6 | - | - | 19.3 | - | 0.6 |
| 0.9 | 5.5 | 1.3 | - | 5.7 | - | - | 23.9 | - | 0.6 |
| 1.2 | 5.9 | 1.5 | - | 10.6 | - | - | 22.5 | - | 0.6 |
| 1.5 | 6.8 | 1.8 | - | 8.5 | - | - | 15.8 | - | 0.6 |
| 2.2 | 7.5 | 2.3 | - | 7.1 | - | - | 27.5 | - | 0.7 |
| 1.8 | 5.5 | 1.5 | - | 10.6 | - | - | 22.5 | - | 0.5 |
| 1.0 | 6.4 | 1.7 | - | 10.6 | - | - | 22.5 | - | 0.6 |
| 1.4 | 5.9 | 2.5 | - | 10.6 | - | - | 23.4 | - | 0.6 |
| 1.2 | 5.5 | 2.5 | - | 7.1 | - | - | 25.8 | - | 0.6 |
| 0.5 | 4.8 | 1.6 | 24.4 | 5.3 | - | 2.2 | 21.0 | 0.2 | 0.6 |
| 0.5 | 5.2 | 1.6 | 21.4 | 7.1 | - | 2.8 | 21.0 | 0.3 | 0.6 |
| 0.9 | 5.6 | 1.4 | 27.5 | 5.3 | - | 1.1 | 21.0 | 0.3 | 0.7 |
| 0.5 | 4.4 | 1.2 | 27.5 | 5.3 | - | 1.1 | 21.0 | 0.3 | 0.8 |
| 0.5 | 5.2 | 1.6 | 15.3 | 5.3 | - | 3.1 | 25.0 | 0.3 | 0.6 |
| 0.7 | 4.8 | 1.3 | 21.4 | 5.3 | - | 2.0 | 22.0 | 0.4 | 0.6 |
| 2.0 | 6.4 | 1.8 | 30.5 | 5.3 | - | 1.1 | 27.0 | 0.4 | 0.6 |
| 0.4 | 5.2 | 1.7 | 21.4 | 5.3 | - | 1.7 | 19.0 | 0.4 | 0.7 |
| 0.6 | 6.0 | 2.1 | 21.4 | 5.3 | - | 2.0 | 21.0 | 0.5 | 0.8 |
| 0.6 | 7.2 | 2.3 | 24.4 | 7.1 | - | 1.7 | 25.5 | 0.5 | 0.9 |
| 1.0 | 10.4 | 2.8 | 48.8 | 6.9 | - | 4.0 | 83 | 0.1 | 1.1 |
| 1.5 | 10.8 | 3.3 | 48.8 | 6.9 | - | 4.0 | 54 | 0.1 | 1.0 |
| 7.0 | 18.0 | 5.3 | 122 | 6.9 | - | 10.0 | 69 | 0.3 | 0.9 |

Table 8 Differences between different seasons and years regarding quality of river water

| Rivers | Sampling date | pH | TDS mg/l | TH °F | N as $NO_4$ mg/l | N as $NO_2$ mg/l | Ca ppm | Mg ppm | Na ppm | K ppm | $HCO_3$ ppm | Cl ppm | $SO_4$ ppm | $NO_3$ ppm | $SiO_2$ ppm | F ppm | SAR |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Comparison of 2 years | Sep. 1968 | 7.3 | 85.4 | 1.5 | - | - | 5.5 | 0.7 | 9.0 | 1.7 | 36.4 | 6.7 | - | - | 20.1 | 0.4 | 1.0 |
| | | ±0.19 | ±44.3 | ±0.44 | - | - | ±1.62 | ±0.54 | ±3.42 | ±0.33 | ±4.7 | ±0.76 | - | - | ±2.34 | ±0.1 | - |
| | Sep. 1971 | 7.3 | 66.8 | 1.3 | 0.22 | 0.03 | 3.8 | 0.7 | 5.5 | 1.7 | 22.9 | 5.7 | - | 1.9 | 20.6 | 0.4 | 0.7 |
| | | ±0.22 | ±16.7 | ±0.31 | ±C.14 | ±0.02 | ±1.02 | ±0.47 | ±0.84 | ±0.34 | ±4.1 | ±0.76 | - | ±0.68 | ±7.35 | ±0.1 | - |
| Comparison of 2 seasons | Oct.-Nov. | 7.3 | 81.2 | 1.8 | - | 0.02 | 5.2 | 1.1 | 5.5 | 1.9 | 48.8 | 9.0 | - | trace | 22.5 | - | 0.6 |
| | | ±0.18 | ±11.5 | ±0.57 | - | ±0.02 | ±1.58 | ±0.60 | ±0.99 | ±0.61 | ±0.99 | ±2.32 | - | trace | ±6.02 | - | - |
| | Mar. - Apr. | 7.5 | 77.2 | 2.5 | - | 0.04 | 5.5 | 2.6 | 5.7 | 2.4 | 53.7 | 7.9 | - | trace | 18.0 | - | 0.5 |
| | | +0.23 | +24.5 | ±0.94 | - | ±0.04 | +1.98 | +1.24 | +1.44 | +0.61 | ±13.2 | +2.26 | - | - | +4.60 | - | - |

Table 9 Chemical quality of lake water

| Rivers | Sampling date | pH | TDS mg/l | TH °F | N as $NO_4$ mg/l | N as $NO_2$ mg/l | Ca ppm | Mg ppm | Na ppm | K ppm | $HCO_3$ ppm | Cl ppm | $SO_4$ ppm | $NO_3$ ppm | $SiO_2$ ppm | F ppm | SAR |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Zuai | 17/11 1972 | 7.9 | 260 | 6.7 | 0.48 | 0.28 | 15.6 | 6.8 | 56 | 9.0 | 214 | 13.8 | 4.4 | - | 50 | 1.1 | 0.5 |
| | 17/4 1973 | 8.1 | 354 | - | 1.46 | 0.08 | 15.2 | 10.0 | 69 | 14.2 | 225 | 17.7 | - | - | 65 | 0.2 | 3.4 |
| Langano | 17/11 1972 | 9.1 | 1,090 | 2.5 | 0.03 | 0.03 | 4.8 | 3.2 | 337 | 36 | 634 | 179 | 3.0 | - | 77 | 11.3 | 29.2 |
| | 15/4 1973 | 9.0 | 1,266 | - | 0.22 | 0.05 | 4.8 | 2.7 | 449 | 25 | 560 | 191 | trace | - | 94 | 7.5 | 40.7 |

Table 10 Consumption water standards for varions purposes.
Approximate upper limits
(mainly from Davis and de Wiest: Hydrogeology, 1970).

| | Human drinking | Household and food | Boiler water (low pressure) |
|---|---|---|---|
| pH | 9.5 | 6.5 - 7.0(a) | |
| Total dissolved solids (TDS), mg/l | 500 (-1,500) | 500 (-1,000) | 2,000 |
| Total hardness (TH), °F | - | 12.5 - 25 | 25 - 50 |
| Silica ($SiO_2$),ppm | - | 50 | 25 |
| POLLUTION TEST | | | |
| Nitrogen (N) as ammonium ($NH_4$), mg/l | 0.1 - 1.3 | 0.1 - 1.3 | - |
| Nitrogen (N) as nitrite ($NO_2$), mg/l | 0.01 - 0.15 | 0.01 - 0.15 | - |
| CATIONS | | | |
| Calcium (Ca), ppm (b) | 200 | 75 | 40 |
| Magnesium (Mg), ppm | 125 | 50 | 20 |
| Sodium (Na), ppm | 200 | 300 | 50 |
| Potassium (K), ppm | - | - | - |
| ANIONS | | | |
| Bicarbonate ($HCO_3$), ppm | 200 - 500 | 300 | 50 |
| Chloride (Cl), ppm | 200 - 600 | 300 | - |
| Sulphate ($SO_4$), ppm | 200 - 400 | 200 | - |
| Nitrate ($NO_3$), ppm | 20 (5-10) | 40 | - |
| Fluoride (F), ppm | 1.5 | 1.5 | - |

(a) lower limit

(b) ppm = concentrations in parts per million, about the same as mg/l

Appendix giving the meanings of the chemical analyses (tables 7-9) and the approximate limits given (table 10).

Hydrogen ion concentration. (pH)
Because of the way pH is expressed, a larger concentration gives a smaller value. Also, a change of one pH unit represents a 10-fold variation; this means that tenth of a unit can be significant. Acidity (lower than 7) varies with dissolved carbon dioxide, mostly derived from the atmosphere and from plants in the ground. Commonly the water is alkalinized by the presence of calcium. As a rule the pH-values obtained by laboratory tests are some tenths too high, because carbon dioxide has escaped after the sampling. Bearing this in mind, only one river might have a real pH value near the lower limit of 6.5, which is the approximate limit for corrosion of iron in pipes, vessels, etc.

Total dissolved solids (TDS)
By evaporating a water sample in an oven at 180 $^{\circ}C$ and weighing the residue, the content of dissolved solids can be determined. The TDS can also be calculated by adding all determined anions and cations, as listed in table 10. (As bicarbonate is converted into carbonate during the evaporation, the bicarbonate values of the table must be lowered — multiplied by 0.4917). When comparing the results of the two methods differences of 10 - 20 mg/l can be disregarded. Most people detect a salty taste at 400 - 500 mg/l, but in dry areas people can accept more than 2,000 mg/l.

Total hardness (TH)
Total hardness is commonly defined as the contents of calcium plus magnesium, the latter being multiplied by 1.65. This sum should be multiplied by 0.14 to give TH expressed in degrees centigrades (so called German hardness = $^{\circ}dH$), which can be converted to French hardness expressed in $^{\circ}F$ ($^{\circ}dH \times 1.78 = {}^{\circ}F$). On the other hand $^{\circ}F \times 0.56 = {}^{\circ}dH$.

Silica ($SiO_2$), together with Ca and Mg, can cause scale in vessels and boilers.

Pollution test
By oxidation processes bacteria break down the proteins of organic material into ammonium ($NH_4$), nitrite ($NO_2$) and in the completely oxidized state nitrate ($NO_3$) radicals. If $NH_4$ exceeds 0.02 - 0.5 mg/l, the water is likely to be polluted. To convert into N multiply $NH_4$ by 0.8; for $NO_2$ multiply by 0.3.

Anions

Calcium, magnesium, sodium and potassium (Ca, Mg, Na and K) are the most common anions in water. Commonly the amount of each element has no significance in the evaluation of consumption water. Ca and Mg are determined for hardness, Ca and Na for irrigation. K is needed for a rough check on the accuracy of the analyses (see TDS above).

Iron (Fe) & manganese (Mn)are not shown in the table. As they are soluble only in acid water, iron and manganese generally have acceptable concentrations in the rivers, lower than the limits of 0.3 and 0.1 mg/l respectively. An exeption is the Dusha River with iron content of 0.2 - 0.4 mg/l.

Cations

Bicarbonate ($HCO_3$) precipitates if water is aerated or warmed, e.g. in vessels or boilers. River water can have a sufficient concentration for this to happen only if fed mainly by ground water.

Chloride (Cl) in large concentrations gives the water a salty taste and accelerates the corrosion of iron. Such large concentrations have not been found. Abnormally large concentrations of chloride at the same time as nitrogen compounds may indicate pollution by people or animals.

Sulphate ($SO_4$). The concentrations are not enough to give a bitter taste.

Nitrate ($NO_3$) in concentrations higher than 5 - 10 mg/l is a warning that a pollution might exist. This can be confirmed by a bacteriological test. Concentrations higher than 45 mg/l can cause a children's disease (cyanosis). The highest measured value is 19 mg/l.

Fluoride (F) in higher concentration than 1.5 mg/l is said to cause mottled enamel on children's teeth. F can cause skeletal defects when present in large amounts, perhaps larger than 3 - 4 mg/l. Dangerous amounts of fluoride do not appear in the investigated rivers but they do occur in Lake Langano and sometimes in ground water.

3.1.3.4 Sanitary quality

Water samples have been taken at the end of the dry season, when the sanitary quality of the rivers is supposed to be at its worst. Table 11 (p. 27) shows high amounts of bacteria in all the rivers.

The total plate dount includes both intestinal and earth bacteria, more than 100 per ml is a warning and more than 1,000 a sign that the water is not suitable as human drinking water. The presumptive coliform count shows amounts higher than 10, which is the maximum permissible index according to international standards for drinking water. Escherichia coli is present in all water samples taken.

Thus there is evidence of faecal pollution in all rivers. This pollution is mainly caused by cattle drinking in or crossing the rivers. At present not much can be done to avoid this pollution of the river water. In time people might learn to prevent pollution by cattle or to disinfect the human drinking water.

The rivers show large differences regarding results of the bacteriological tests. Organisms/ml in the total plate count is not lower than 2,600 in the cultivated areas, but commonly lower than 1,000 in the forested areas. In the cultivated areas the bacterial pollution seems to be more severe in the small rivers than in the large.

3.2 Lakes

3.2.1 Appearance of lakes

There are only two lakes, both situated on the floor of the Rift Valley. Lake Zuai extends over 230 $km^2$, Lake Langano is much smaller.

Lake Zuai is situated on old lake sediments and has flat shores. Two rather large rivers feed into the lake.

Lake Langano is situated in a more rocky area with signs of volcanic activity (fumaroles and hot spring). The inflowing rivers are small.

Table 11 Bacteriological tests of rivers and lakes, analysis by Central Laboratory

| Rivers | Sampling date | Total plate count at 37°C after 48 hours (organisms/ml) | Presumptive coliform count (organisms/100ml) |
|---|---|---|---|
| Geleta | 6/4 1970 | 5,000 | greater than 180 |
| Wedecha | 6/4 | 10,400 | " " 180 |
| Gonde | 6/4 | 12,800 | " " 180 |
| Simba | 6/4 | 2,600 | " " 180 |
| Wolchessa | 6/4 | 3,600 | " " 180 |
| Anko | 6/4 | 12,400 | " " 180 |
| Kompolcha | 6/4 | 12,000 | " " 180 |
| Dusha | 6/4 | 3,200 | " " 180 |
| Ellena | 31/3 | 13,800 | " " 180 |
| Bilalu | 31/3 | 18,600 | " " 180 |
| Alaltu | 31/3 | 36,000 | " " 180 |
| Katjama | 31/3 | 23,000 | " " 180 |
| Sagure Alaltu | 31/3 | 40,000 | " " 180 |
| Ashabaka | 31/3 | 6,400 | " " 180 |
| Temala | 31/3 | 18.400 | " " 180 |
| Gusha | 31/3 | 10,200 | " " 180 |
| Weshe | 31/3 | 9,600 | " " 180 |
| Sida | 6/4 | 6,400 | " " 180 |
| Sirba | 31/3 | 23,200 | " " 180 |
| Upper Katar | 6/4 | 9,200 | " " 180 |
| Karsa | 12/3 1972 | greater than 5,000 | " " 160 |
| Taji | 12/3 | " 5,000 | " " 160 |
| Matana | 12/3 | 500 | " " 160 |
| Dalali | 12/3 | 640 | " " 160 |
| Makanissa | 12/3 | 700 | 92 |
| Guna | 12/3 | 800 | greater than 160 |
| Rajebo | 12/3 | 980 | 18 |
| Gadamso | 12/3 | 420 | 28 |
| Adofty | 12/3 | 2,200 | 92 |
| Lepis | 12/3 | 4,000 | 92 |
| Totolamo | 15/11 | less than 5,000 | greater than 160 |
| Ashoka | 15/11 | " 5,000 | " " 160 |
| Asassa | 15/11 | " 5,000 | " " 160 |
| Lakes | | | |
| Zuai | 17/11 1972 | " 5,000 | " " 160 |
| Langano | | " 5,000 | " " 160 |

Note: Escherichia coli was present in all samples except in the one fom Lake Langano

3.2.2 Quality of lake water

3.2.2.1 Chemical quality

The above mentioned differences between the lakes influence the water quality. Lake Langano has a larger concentration of salts and a high amount of fluoride.

The water of Lake Zuai is drinkable from the chemical point of view, That of Lake Langano has a salty taste (TDS = 1,090 mg/l and sodium = 337 mg/l). It is not advisable to use the Langano water over extended periods as drinking water or for food because of the very high concentration of fluoride ( 7.5 - 11.3 mg/l).

The Langano water with TDS = 1,090 mg/l can possibly have adverse effects on some crops. According to the graph fig. 44 (p. 158) a TDS value of 1,090 mg/l can be translated into a conductivity of 1,100 micromhos per cm at 25°C, which according to the diagram fig. 45 demands the SAR value (sodium adsorption ratio) be lower than 4 to be satisfactory for almost all soils. Even in this respect the Langano water (SAR = 3.1) is near the limit for a good irrigation water.

3.2.2.2 Sanitary quality

No lake water is well suited as drinking water (table 11, p. 27).

The bacteriological quality has also been tested by Mr. P. O. Nilsson, CADU, who found the Lake Langano water well suited for swimming, but not the water of Lake Zuai. In the latter case there also is a risk of bilharzia, at least along the shores with littoral and aquatic vegetation.

## 3.3 Springs

### 3.3.1 Appearance of springs

A spring is a ground water flow reaching the surface. Due to geological features and the long dry season, perennial springs are few in Chilalo. The lava and tuff beds of the plateau consist of rather homogenous layers and are fissured, thus permitting the ground water to sink to lower levels. The clay layers above the rocks do not form aquifers.

Springs occur in three different situations (fig. 6, p. 30)

1) at the foot of rocky valley sides, where the valley is deep enough to reach the ground water table,

2) when permeable strata in or on the rock are cut by valleys,

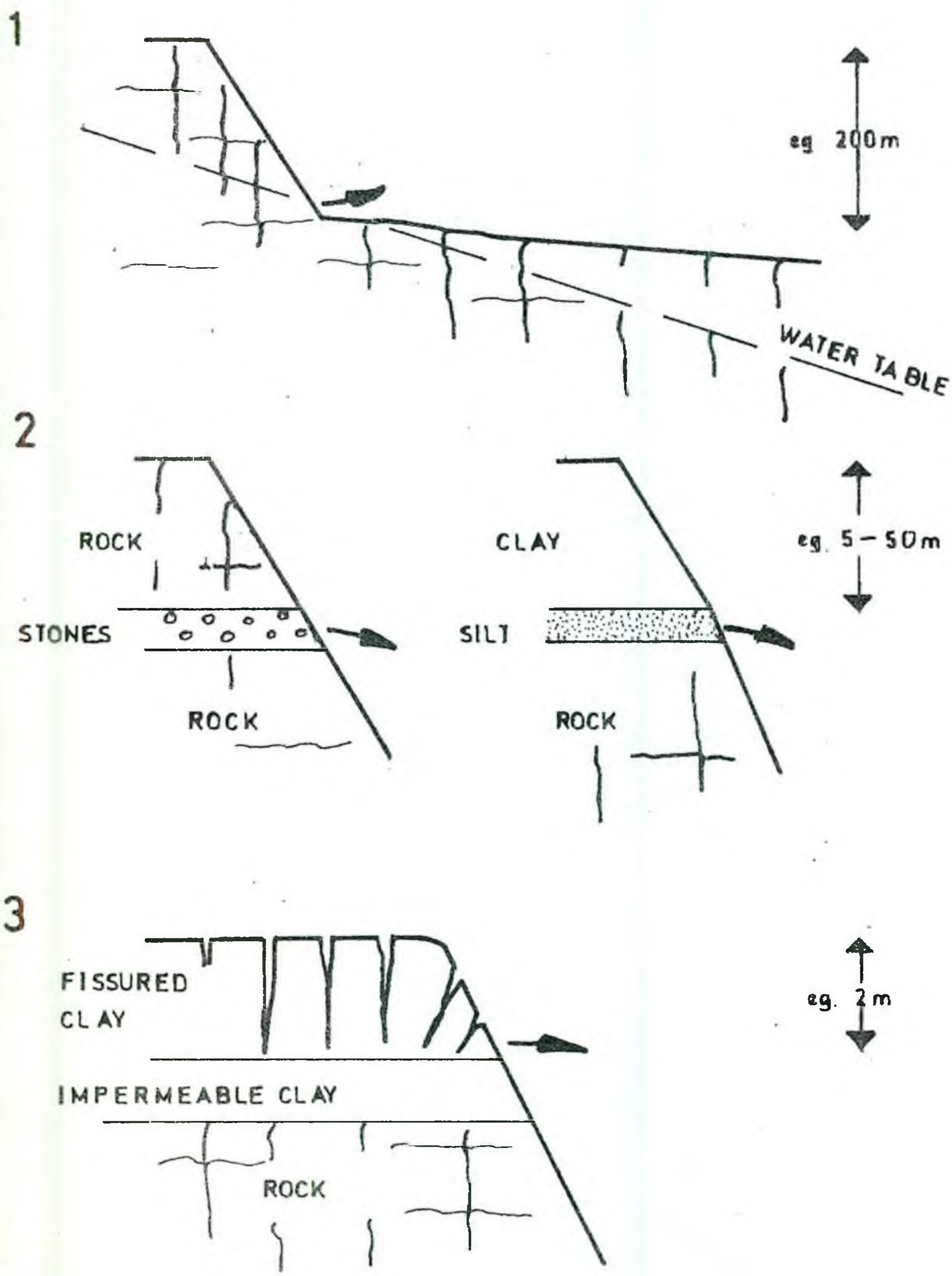
3) if a clay layer free of fissures is overlain by a fissured clay, with fissures reaching down to the impermeable clay layer.

The largest springs are the Burkito Springs and those associated with the Conde and sassa Rivers. All three belong to type 1 fig. 6. The Gonde River disappears into the ground some kms from its source and comes out upstream of the road at the village of Gonde. During the underground passage the chemical quality of the river is not much changed (compared to other rivers, table 7, p. 21). Only some hundred metres downstream of the springs, there is a large faecal pollution (table 11, p. 27).

The geology of the Burkito Springs is illustrated in fig. 7 (p. 21). The chemical tests show (table 12, p.33), that this ground water probably infiltrates on the plateau. Because of this it is similar to deep ground water found in the drilled wells on the plateau. The altitude of the plateau is 2,000 - 2,400 metres, the altitudes of the springs 1,780, 1,755 and 1,745 metres above sea level.

Fig. 6

# TYPES OF SPRINGS



The ground water character of the Asassa River is indicated by the even flow all the year (table 2, p. 11) and the chemical tests (table 7, p 21). Also in this case the water is polluted downstream of the springs (table 11, p 27). Fig. 8 shows a section through the area of the Asassa spring.

Perennial springs of type 2 with permeable layers in the rock are rare. The town of Sire has utilized small springs coming from unconsolidated strata 50 metres below the plateau surface. The aquifer is a sandy and stony layer over - and underlain by layers of clay. A similar type of confined aquifer exists in valleys north of the Gonde River, but the flow disappears after a long dry season. In the Kofale area there is a thin layer of fine sand between the bedrock and the clay above. In cuttings a scanty spring flow can appear.

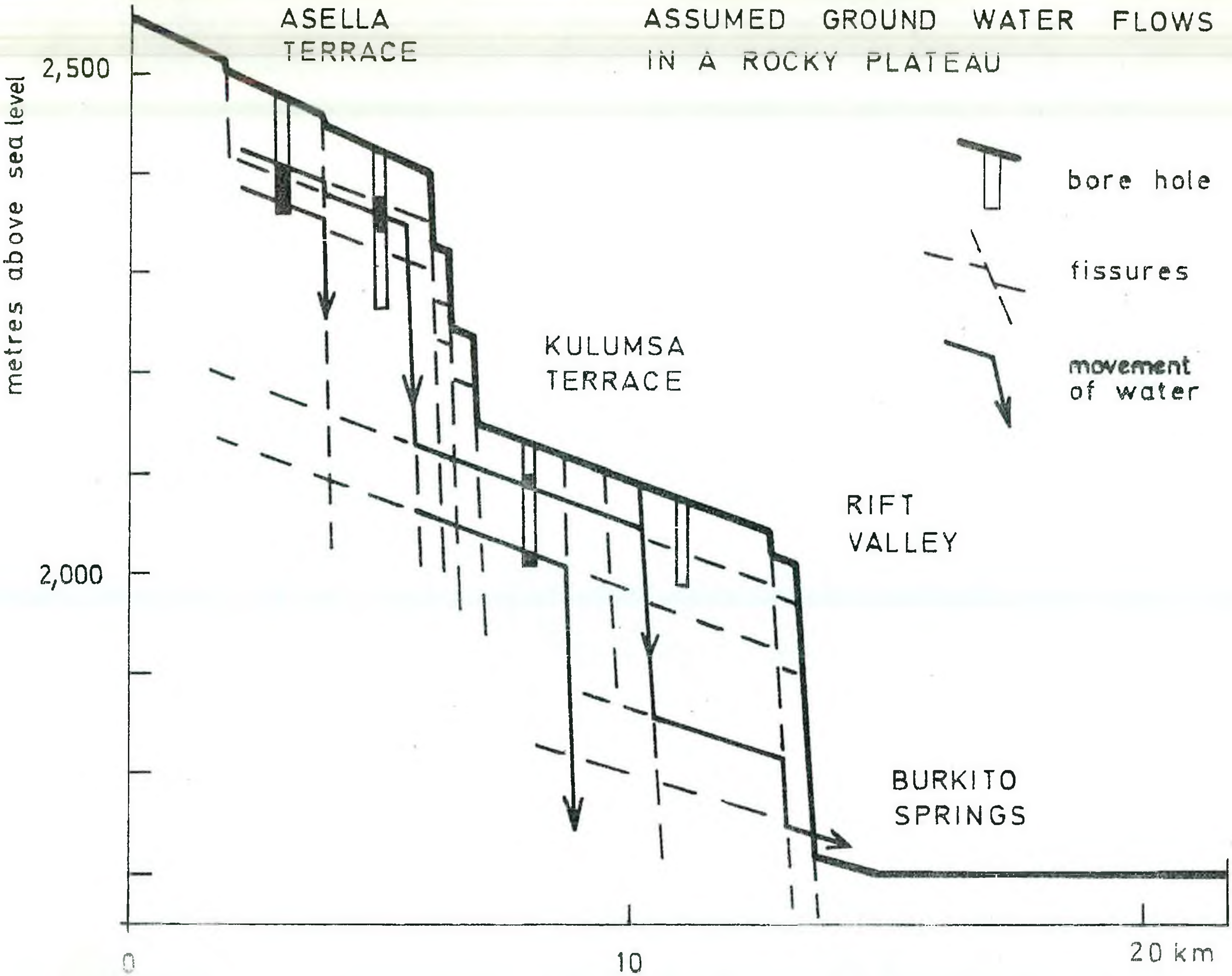
Type 3, ground water collected in fissured clay overlying unfissured clay appears during and after the rainy season. For example in a valley near the Katjama River there is a spring coming out from the black clay on the red clay. Unfortunately this type of spring does not last all the dry season. An exception exists in the valley of the Jirma River northeast of Munessa. Several very small flows (less than 0.5 l/s) appear in a fissured red clay on an impermeable green clay 2 metres below the surface of the red clay. The rock below is dry.

Springs are also utilized by the villages of Change and Dighelu and by the town of Bekoji (3 l/s).

To summarize, there are potential spring water resources only at Gonde, Burkito and Asassa (minimum discharges 6 l/s, 100 l/s and 1,150 l/s respectively).

### 3.3.2 Quality of springs

As spring water is clear and clean, without suspended clay particles and without bacteriological pollution, it is suitable as drinking water.



ASSUMED GROUND WATER FLOWS
IN A ROCKY PLATEAU
ASELLA
TERRACE
KULUMSA
TERRACE
RIFT
VALLEY
BURKITO
SPRINGS
bore hole
fissures
movement
of water
metres above sea level
2,500
2,000
0
10
20 km


Fig. 7

Table 12 Analyses of surface water and ground water between Mount Chilalo and Lake Zuai

| Water sample | pH | Ca p.p.m. | Mg p.p.m. | Na p.p.m. | K p.p.m. | $SiO_2$ p.p.m. |
|---|---|---|---|---|---|---|
| Rainwater | | | | | | |
| Asella | 6.6 | 2.9 | 0.2 | 0.3 | 0.5 | - |
| | 6.6 | 3.3 | 0.3 | 1.3 | 0.7 | - |
| Rivers on the plateau | | | | | | |
| Anko River | 7.1 | 2.4 | 1.2 | 5.1 | 1.3 | 23 |
| Wolchessa River | 7.2 | 5.6 | 1.5 | 6.8 | 3.5 | 34 |
| Boreholes on the plateau | | | | | | |
| No. 13 | 7.0 | 12.9 | 2.0 | 19.0 | 2.7 | 29 |
| No. 14 | 7.6 | 12.9 | 2.4 | 18.0 | 2.0 | 28 |
| Escarpment springs | | | | | | |
| Burkito Springs | 7.6 | 13.9 | 4.9 | 7.6 | 3.7 | 36 |
| " " | 7.6 | 13.5 | 5.0 | 7.8 | 3.8 | 42 |
| " " | 7.6 | 13.5 | 5.0 | 8.2 | 3.85 | 41 |
| Boreholes in Rift Valley | | | | | | |
| No. 49 | 7.7 | 14.8 | 6.1 | 36.0 | 6.4 | 69 |
| No. 52 | 7.7 | 28.9 | 9.0 | 40.0 | 7.5 | 52 |
| No. 53 | 7.9 | 24.5 | 5.6 | 36.5 | 5.9 | 72 |
| No. 55 | 8.0 | 18.7 | 9.0 | 36.0 | 8.3 | 72 |

## 3.4 Ground water

### 3.4.1 Investigation programme

#### 3.4.1.1 Goals

The most important questions are to find out:

1) if there are any large ground water basins in the valley as receivers of ground water flow, e.g. close to Lake Zuai,

2) if any utilisable water table exists between the high plateaux and the large valleys, e.g. between the Chilalo plateau and Rift Valley,

3) how geologic features affect the occurance of ground water, e.g. existence of permeable and impermeable layers.

Of interest is water not too deep to be available through drillings, e.g. 100 - 200 metres.

#### 3.4.1.2 Drilling sites

Drillings for investigation purpose have been made on the following principles:

1) Along typical profiles crossing the Awraja:
   a) one longitudinal section along the road from the Awash River in the north to the Wabe Shebelle River in the south (fig. 10-11, p. 38-39).
   b) one cross section from Kulumsa on the Chilalo plateau to Lake Zuai (fig. 14, p. 47).

2. Outside the profiles in dry areas far from perennial rivers (see the map fig. 9, p. 36):
   a) on the plateau north of the Gonde River
   b) on the Luckuche Plain southwest of the Katar River (fig. 8, p. 35).
   c) in the Rift Valley north and south of the Katar River
   d) in the large valley basin north of the Wabe Shebelle River.

3. If possible the boreholes have been sited in such a way that they can be useful as water supplies or for demonstration purposes.

4. Other circumstances have also influenced the selection of drilling sites, e.g. the possibilities of finding the landowner and having a contract permitting people to use the well.

MEASURED GROUND WATER TABLE IN THE BASIN OF THE WABE SHEBELLE RIVER

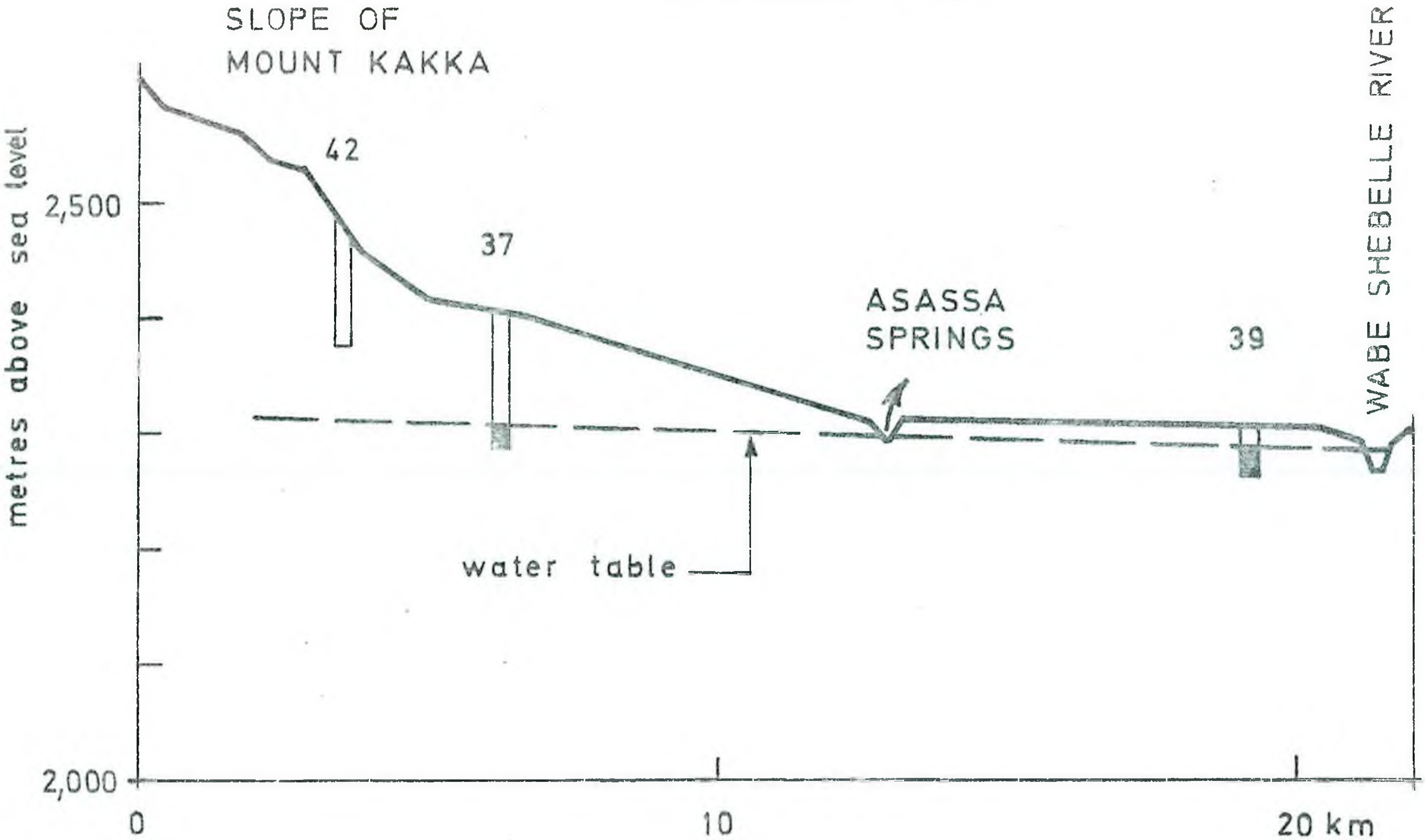
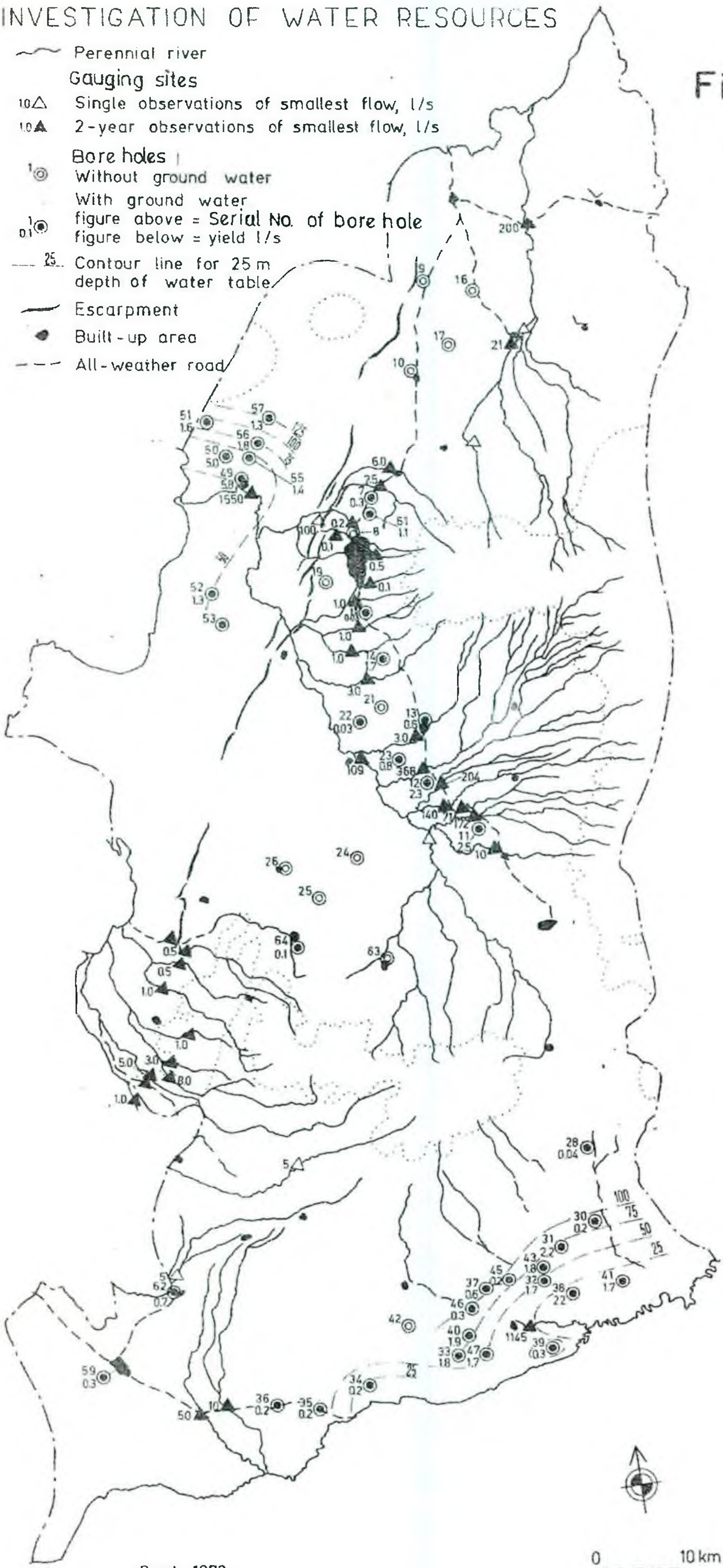



Fig.8

Fig.9


INVESTIGATION OF WATER RESOURCES
Perennial river
Gauging sites
10 △ Single observations of smallest flow, l/s
1.0 ▲ 2-year observations of smallest flow, l/s
Bore holes
1 ◎ Without ground water
With ground water
1 / 0.1 ◉ figure above = Serial No. of bore hole
figure below = yield l/s
25 Contour line for 25 m depth of water table
Escarpment
Built-up area
All-weather road
Sept. 1973
0
10 km

3.4.1.3 Drilling tools

During the reconnoitering survey in 1967 a small core drilling machine, type COSMA-BUS, was used in the Rift Valley. Samples of unconsolidated sediments and rocks were taken down to a maximum depth of 60 m. A 2" casing was inserted in five boreholes.

For the 5-year programme starting in May 1968 a Swedish cable-tool rig, type AXBE II, has been used to a maximum depth of 266 m. Samples have been taken with the bailer in every new layer of sediment or rock. Notes are made by the drilling foreman on the character of different layers, e.g. degree of difficulty of drilling, colour and if known the type of sediment or rock. If water is struck, a 6" casing is left in the borehole.

During and/or at the end of the drilling the approximate yield is tested by pumping continously for at least 24 and commonly 48 hours. Before the installation of an expensive pump, the well is tested by long-term test pumping for some weeks.

Technical data from drillings and test pumpings are given in table 13 (p. 40-41). More details can be found in the 2-year reports. The sites and yields have been marked on the map fig. 9 (p. 36).

3.4.2 Appearance of ground water

3.4.2.1 Geologic features

The Pre-Cambrian basement rock (of gneisses and granites) is covered by thick lava beds and hardened ashes (tuffs) from Tertiary time. The Rift Valley sank down between large escarpments in the west and east; elsewhere lava poured out forming thick layers and high volcano mountains, now with peaks around 4,000 metres above sea level. The first lava eruptions of basalt created Mount Badda and a range of volcanos to the north and south, now the eastern border of the Chilalo Awraja. West of this range there are younger volcanos of trachyte:

LONGITUDINAL SECTION FROM THE AWASH RIVER TO THE WABE SHEBELLE RIVER SHOWING BOREHOLES AND WATER TABLES

CONTINUED Fig.11 →

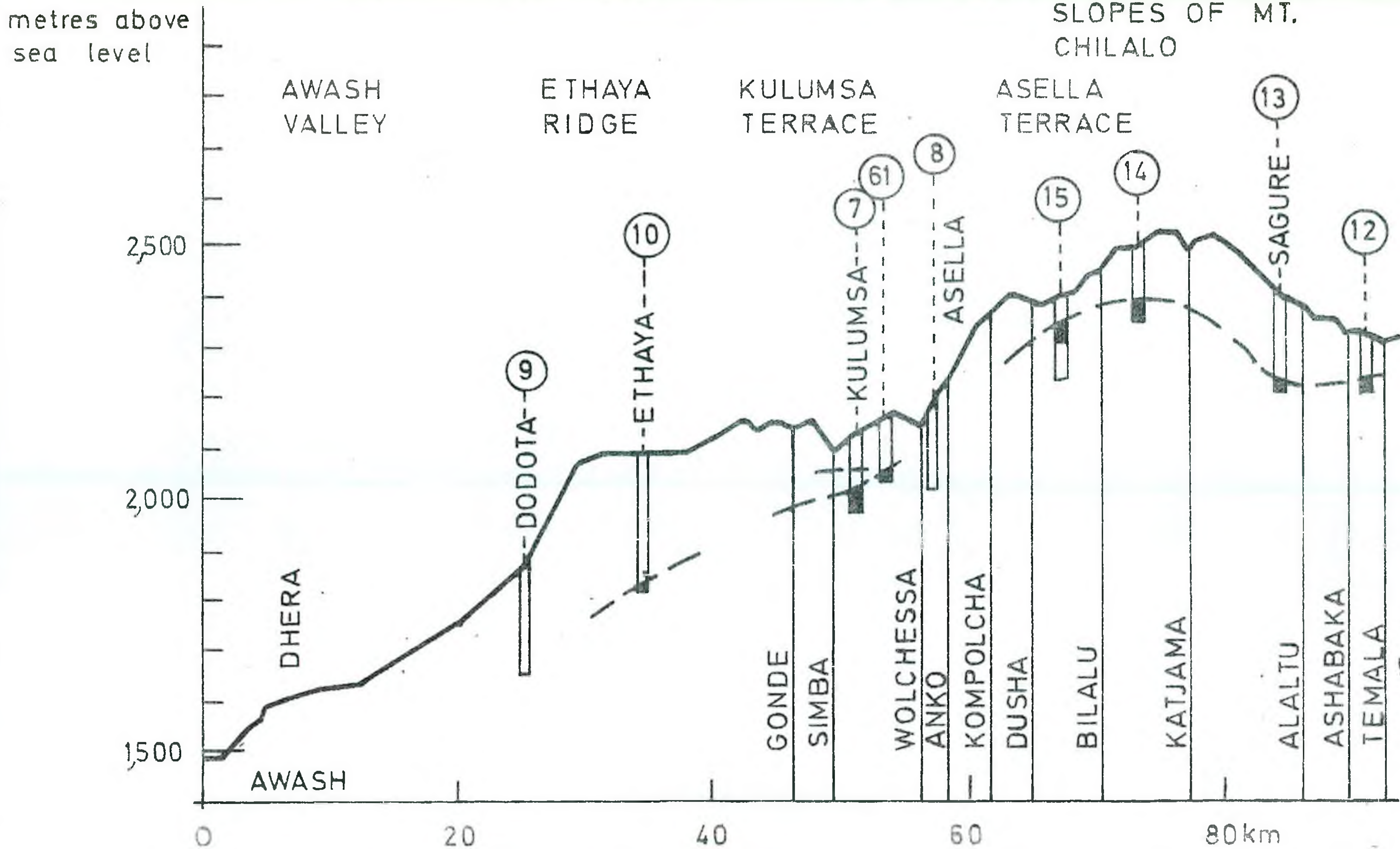
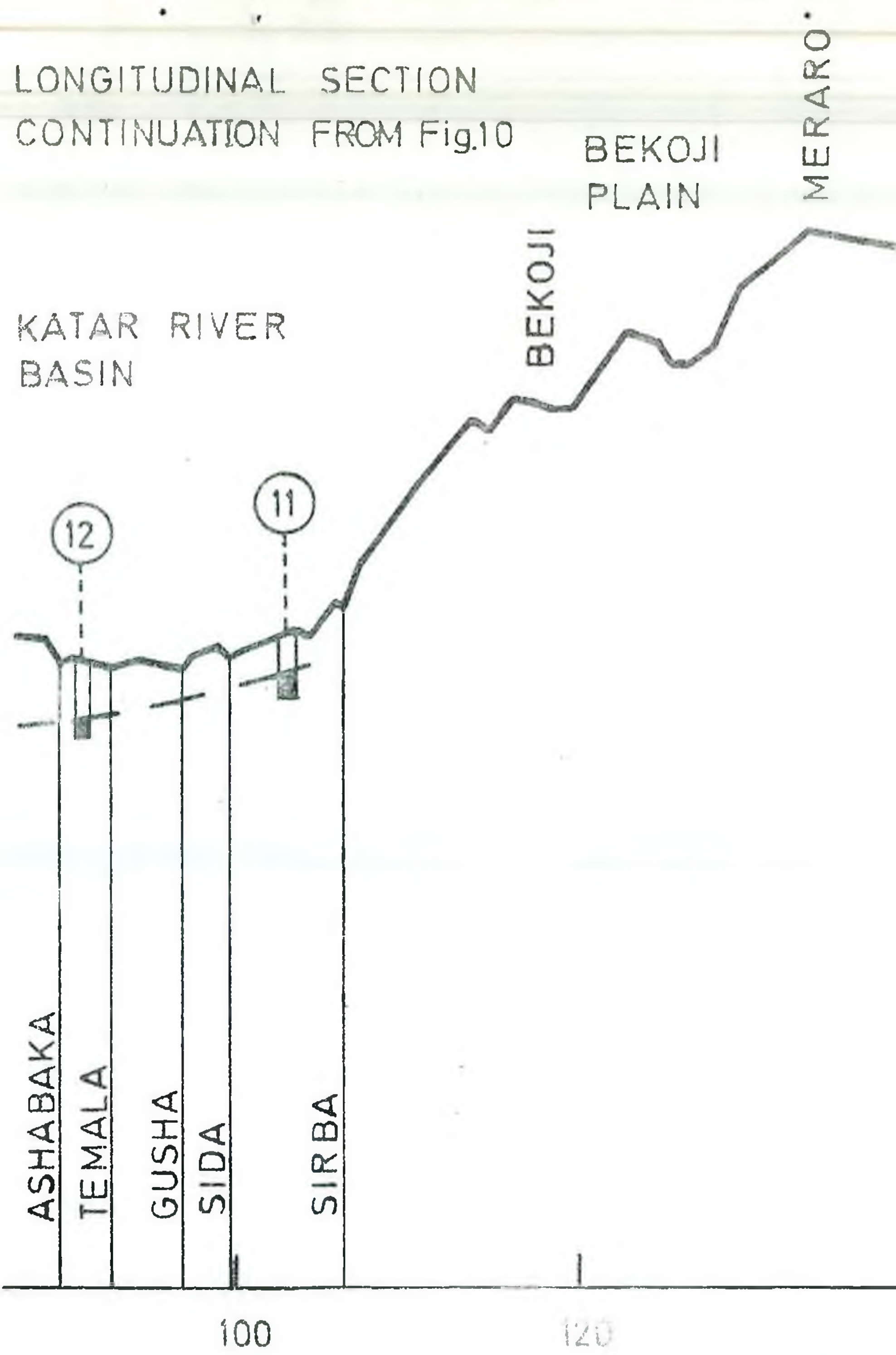
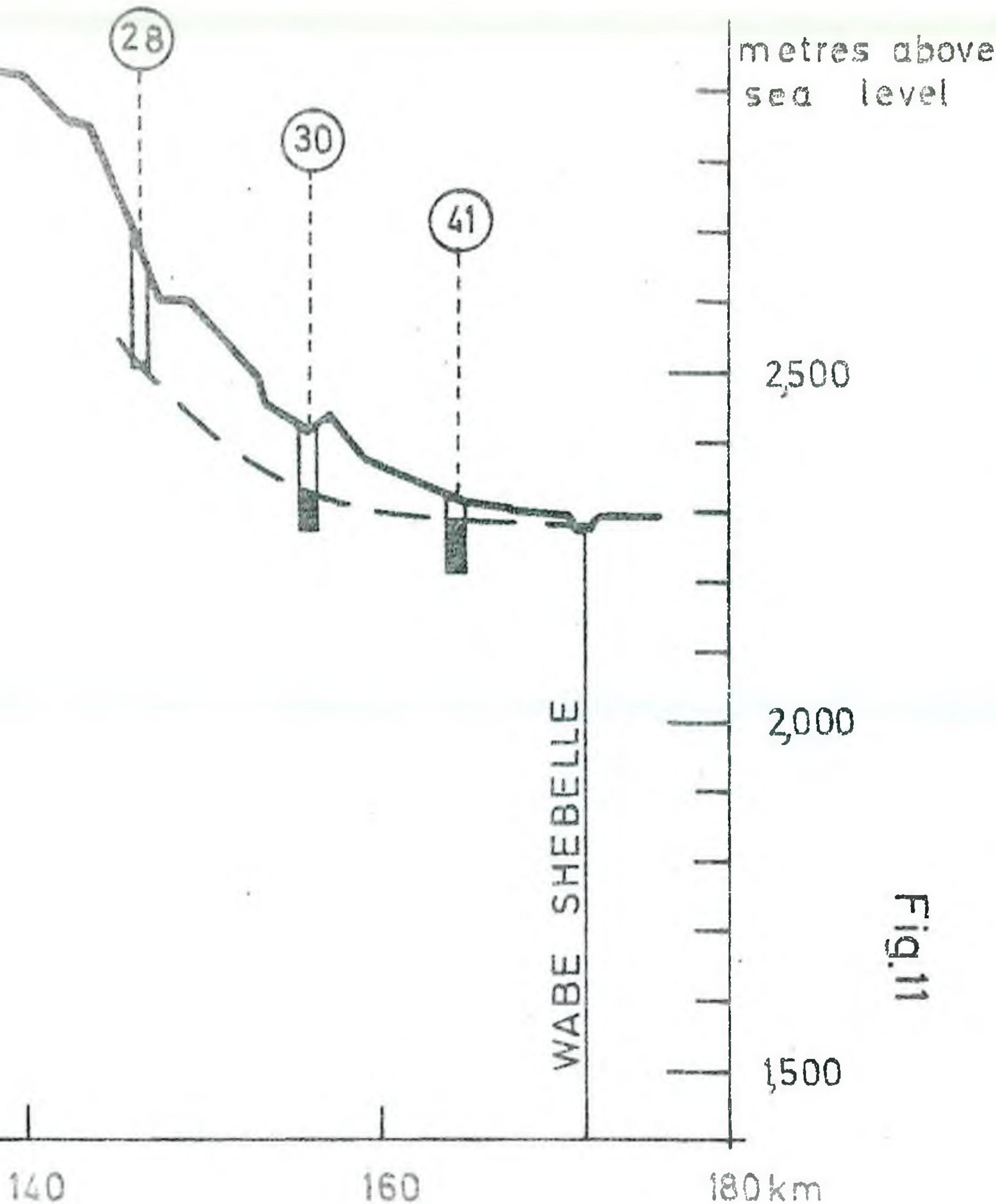



Fig.10


LONGITUDINAL SECTION
CONTINUATION FROM Fig.10
KATAR RIVER
BASIN
BEKOJI
BEKOJI
PLAIN
MERARO
12
11
ASHABAKA
TEMALA
GUSHA
SIDA
SIRBA
100
120



28
30
41
metres above sea level
2,500
2,000
1,500
WABE SHEBELLE
140
160
180 km


Fig. 11

Table 13 Technical data from drillings and test pumpings

m/t.h = metres per total working hour
m/d.h = metres per drilling hour
b = before test pumping
a = after test pumping
m a.s = metres above sea level

| Bore-hole No. | Alti-tude, m a.s. | Drilled depth, m | Drilling speed, m/t.h | Drilling speed, m/d.h | Depth of water m, b | Depth of water m, a | Yield l/h | Yield l/s |
|---|---|---|---|---|---|---|---|---|
| 7 | 2,130 | 120 | 0.31 | 0.84 | 78.0 | 90.0 | 960 | 0.3 |
| 8 | 2,200 | 150 | 0.50 | 0.69 | - | - | 0 | 0 |
| 9 | 1,440 | 200 | 0.47 | 0.53 | - | - | 0 | 0 |
| 10 | 2,110 | 266 | 0.40 | 0.54 | - | - | poor | poor |
| 11 | 2,350 | 80 | 0.39 | 0.66 | 46.3 | 45.9 | 9,000 | 2.5 |
| 12 | 2,330 | 100 | 0.33 | 0.93 | 79.0 | - | 8,400 | 2.3 |
| 13 | 2,420 | 183 | 0.31 | 0.48 | 168.3 | 168.3 | 2,400 | 0.6 |
| 14 | 2,480 | 115 | 0.39 | 0.70 | 72.0 | 72.5 | 6,000 | 1.7 |
| 15 | 2,420 | 152 | 0.33 | 0.44 | 48.0 | 72.0 | 100 | 0.03 |
| 16 | 1,800 | 200 | 0.49 | 0.63 | - | - | 0 | 0 |
| 17 | 2,110 | 200 | 0.59 | 0.71 | - | - | 0 | 0 |
| 19 | 2,230 | 97 | 0.22 | 0.27 | - | - | 0 | 0 |
| 21 | 2,420 | 168 | 0.65 | 0.76 | - | - | 0 | 0 |
| 22 | 2,365 | 125 | 0.36 | 0.51 | 50.5 | 63.0 | 120 | 0.03 |
| 23 | 2,405 | 151 | 0.23 | 0.30 | 94.8 | 120.0 | 2,800 | 0.8 |
| 24 | 2,440 | 175 | 0.37 | 0.49 | - | - | 0 | 0 |
| 25 | 2,525 | 200 | 0.44 | 0.62 | - | - | 0 | 0 |
| 26 | 2,550 | 250 | 0.35 | 0.49 | - | - | 0 | 0 |
| 28 | 2,575 | 44 | 0.13 | 0.23 | 39.4 | 42.5 | 140 | 0.04 |
| 30 | 2,410 | 104 | 0.21 | 0.39 | 91.0 | 96.0 | 600 | 0.2 |
| 31 | 2,380 | 83 | 0.37 | 0.66 | 56.0 | 56.0 | 8,000 | 2.2 |
| 32 | 2,345 | 55.5 | 0.30 | 0.60 | 42.5 | 42.5 | 6,000 | 1.7 |
| 33 | 2,370 | 85 | 0.23 | 0.59 | 71.0 | 71.0 | 6,500 | 1.8 |
| 34 | 2,410 | 35 | 0.11 | 0.18 | 21.0 | 30.0 | 500 | 0.1 |
| 35 | 2,430 | 84 | 0.26 | 0.54 | 64.7 | 64.7 | 550 | 0.2 |
| 36 | 2,475 | 70 | 0.27 | 0.57 | 52.3 | 52.3 | 800 | 0.2 |
| 37 | 2,410 | 117 | 0.23 | 0.39 | 106.0 | 106.0 | 2,000 | 0.6 |
| 38 | 2,325 | 50 | 0.57 | 0.43 | 16.5 | 16.5 | 8,000 | 2.2 |
| 39 | 2,320 | 55 | 0.43 | 1.62 | 28.0 | 48.0 | 1,000 | 0.3 |

Table 13 contd.

| Bore-holc No. | Alti-tude, m a.s. | Drilled depth, m | Drilling speed, | | Depth of water m | | Yield | |
|---|---|---|---|---|---|---|---|---|
| | | | m/t.h | m/d.h. | b | a | l/h | l/s |
| 40 | 2,395 | 106 | 0.32 | 0.54 | 91.0 | 91.0 | 6,800 | 1.9 |
| 41 | 2,300 | 44 | 0.22 | 1.22 | 23.0 | 23.0 | 6,000 | 1.7 |
| 42 | 2,485 | 109 | 0.16 | 0.27 | - | - | 0 | 0 |
| 43 | 2,360 | 75 | 0.41 | 0.83 | 56.7 | 62.2 | 6,600 | 1.8 |
| 44 | 2,400 | 165 | 0.34 | 0.60 | - | - | 0 | 0 |
| 45 | 2,385 | 93 | 0.27 | 0.48 | 79.8 | 66.8 | 600 | 0.2 |
| 46 | 2,370 | 83 | 0.24 | 0.37 | 90.5 | 78.9 | 1,200 | 0.3 |
| 47 | 2,350 | 64 | 0.35 | 0.71 | 79.8 | 66.8 | 6,000 | 1.7 |
| 48 | | 126 | 0.48 | 0.68 | - | - | 0 | 0 |
| 49 | 1,635 | 63 | 0.34 | 0.66 | 27.0 | 27.0 | 21,000 | 5.8 |
| 50 | 1,650 | 91 | 0.25 | 0.63 | 52.8 | 52.8 | 18,000 | 5.0 |
| 51 | 1,680 | 102 | 0.32 | 0.69 | 83.0 | 86.0 | 5,600 | 1.6 |
| 52 | 1,675 | 70 | 0.32 | 1.06 | 52.4 | 52.4 | 4,500 | 1.3 |
| 53 | 1,735 | 136 | 0.30 | 0.59 | 108.0 | 108.0 | - | - |
| 55 | 1,650 | 63.5 | 0.33 | 0.71 | 42.8 | 42.8 | 5,000 | 1.4 |
| 56 | 1,660 | 78 | 0.17 | 0.37 | 52.8 | 52.8 | 6,500 | 1.8 |
| 57 | 1,770 | 160 | 0.30 | 0.59 | 128.0 | 128.0 | 4,800 | 1.3 |
| 59 | 2,620 | 51 | 0.19 | 0.85 | 21.0 | 42.0 | 900 | 0.3 |
| 60 | | 113 | 0.37 | 0.39 | - | - | 0 | 0 |
| 61 | 2,150 | 105 | 0.17 | 0.28 | 80.0 | 80.0 | 4,000 | 1.1 |
| 62 | | 68.5 | 0.19 | 0.46 | 28.0 | 28.0 | 2,500 | 0.7 |
| 63 | 2,540 | 100 | 0.66 | 1.04 | - | - | 0 | 0 |
| 64 | 2,700 | 123 | 0.35 | 0.58 | 104.5 | 120.0 | 500 | 0.1 |

Mount Chilalo and Mount Kakka (1). In the volcanos must layers are sloping. Percolated water is streaming out from the mountain areas. As the precipitation is large on the mountains above the tree limit about 3,000 m above sea level, the recharge of ground water is important.

Around the volcanos ashes rained down and were re-deposited and hardened into the tuffs of the plateau land and Rift Valley. In the sequence of strata containing tuffs alternating with lava beds, these carry ground water, sometimes at different depths. The plateau 2,400 - 2,000 metres above sea level consists of terraces separated by small steps (faults), where water is lost to deeper levels. The plateau is cut by deep river valleys, but as a rule the ground water table is struck deep below the stream beds.

During the long periods between volcanic eruptions the rocks weathered into clay, which was transported to lower parts of the plateau. Thus unconsolidated layers of clay alternate with ash and lava beds in the large basins of the Katar River and the Wabe Shebelle River. Here drillings have struck water on the lava beds.

In the Wabe Shebelle basin the alternating strata of unconsolidated sediments and lava beds cannot be followed from borehole to borehole. In the lower part of the basin, up to 2,360 metres above sea level, it is the clay deposits which predominate; higher up it is the lava beds. Layers of sand and gravel occur up to 2,380 metres above sea level. Layers of sand and weathered lava, under-and over-lain by clay or impermeable lava beds, cause confined aquifers with a piezometric surface some metres higher.

1) For more information on the geology see publications in Bull, Geophys Obs., Addis Ababa; written by P.A.Mohr, especially "Geological report on the Lake Langano and adjacent plateau regions"

The floor of the Rift Valley, 1,600 - 1,800 metres above sea level, consists of ridges (horsts), separated by basins (grabens), along faults parallel to the large escarpment. This topography is broken by trachytic or rhyolitic volcanos, which erupted during Quaternary times. The floor of the Rift Valley has been covered by water, at least 25 metres above the present level of Lake Zuai, which discharged to the north. During this time rivers filled up the higher basins with silt. In the lower and larger basins mainly clay was deposited. Fluviatile or aeolian sand layers in silt and clay or good aquifers.

At present the Chilalo Awraja is relatively stable seismically. Hot water has been found in boreholes of the Wabe Shebelle valley. A large amount of gas poured out through the northernmost borehole north of Lake Zuai.

3.4.2.2 Hydraulic gradients & depths of water table

A schematized section shows the nature of the ground water flow from high to low altitudes in Chilalo (fig. 12, p. 43). Tritium ($H_3$) analyses, sampled during April 1973, seem to confirm the pattern, but they also show that in the large flow scheme of fig. 12 there are differentiated local flows with water of different age.

Older water successively mixed with younger water:

| | No. | Tritium units(1) |
|---|---|---|
| Borehole on the plateau | | |
| at Kulumsa, well No.7 | StT 2977 | 1.00 ± 0.5 |
| Escarpment springs | | |
| at Burkito, flow No.2 | StT 2975 | 3.20 ± 0.5 |
| flow No.3 | StT 2976 | 3.00 ± 0.5 |
| Boreholes in Rift Valley | | |
| well No.52 | StT 2982 | 5.00 ± 0.5 |
| well No.55 | StT 2984 | 6.00 ± 0.6 |
| Younger water in separate flow: | | |
| Escarpment springs | | |
| at Burkito, flow No. 1 | StT 2974 | 14.00 ± 2.0 |
| Borehole in Rift Valley | | |
| well No.53 | StT 2983 | 13.00 ± 0.8 |

(1) one tritium unit (TU) is a concentration of one atom of $H_3$ for every $10^{18}$ total hydrogen atoms

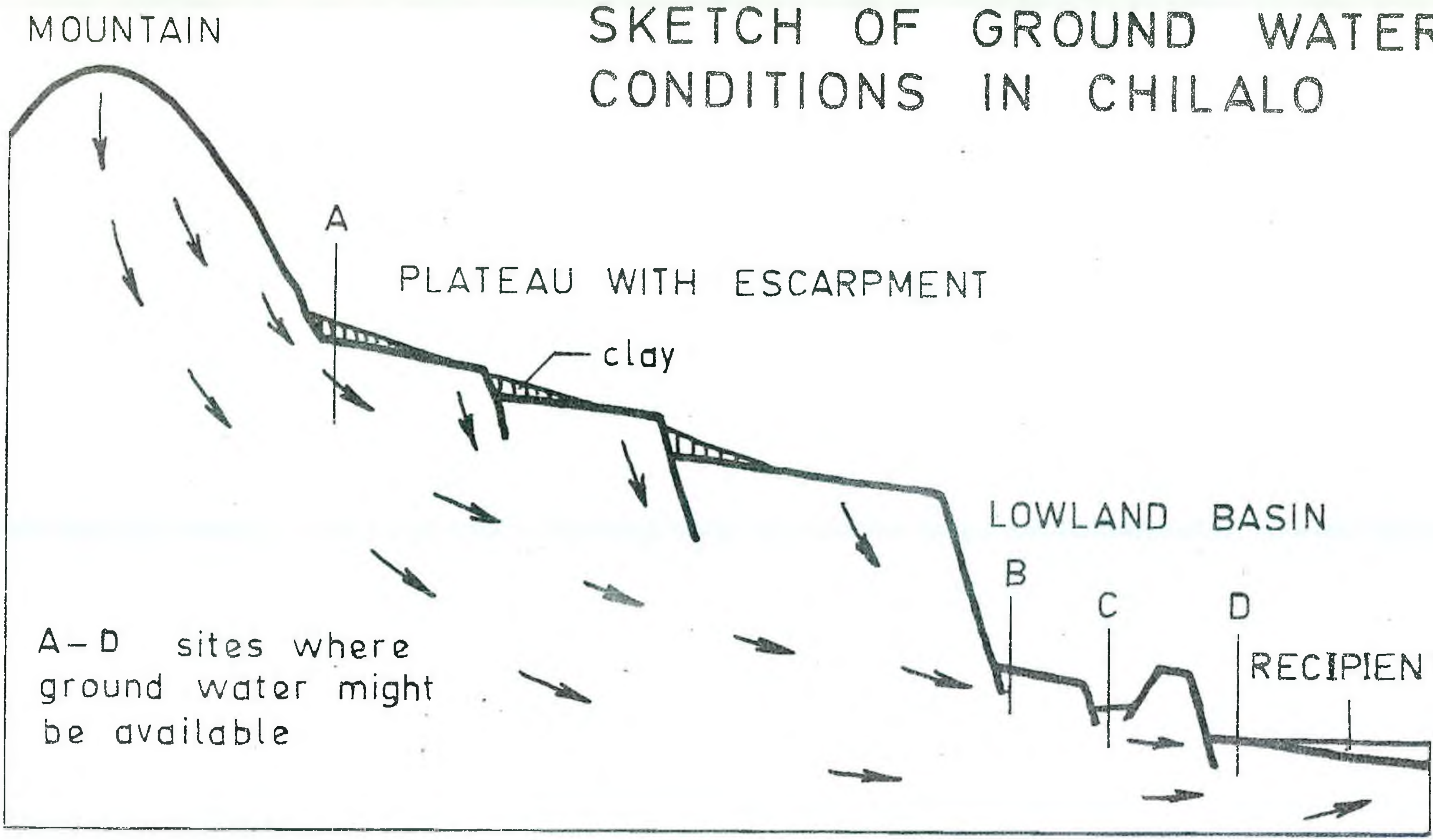

SKETCH OF GROUND WATER CONDITIONS IN CHILALO
MOUNTAIN
A
PLATEAU WITH ESCARPMENT
clay
LOWLAND BASIN
B
C
D
RECIPIENT
A – D sites where ground water might be available

Fig.12

Below are given some more details regarding the ground water conditions from the high mountains through the plateaux down to the large valley basins.

The large precipitation on the high mountains partly sinks into the ground and thus to lower levels below the flat lands outside the mountains. At the foot of the mountains it might be possible to catch the ground water before it has sunk too deep, e.g. as at borehole 64 at the Karsa Mission at the foot of Mount Munessa. In such cases the local topography must be considered, as the ground water flow to a large extent follows the main features of the topography.

On the Chilalo plateau water is available at depths of 45-170 m, at least in certain topographic and geologic situations. Also on the plateau the ground water flow to a large extent follows the topography as does the surface water. Therefore, good sites for drilling are flat basins or broad valleys with a large precipitation and discharge area. Basins between volcano ridges also collect water (e.g. borehole 57). Sometimes a fault can cut permeable layers, thus damming ground water(e.g. borehole 7). The following sites should be avoided: on hills and ridges (e.g. borehole 8); on plateau terraces near escarpments (e.g. borehole 9); near or in deep and narrow valleys (e.g. boreholes near and in the valley of the Simba River). In valley bottoms it is often preferable to avoid the lowest part. A sketch showing different situations, suitable and not suitable, is given in fig. 13 (p. 45).

Ground water is not springing out from the large escarpment between the plateau and Rift Valley, except at the foot near the Anko River. The water disappears through fractures to deeper levels.

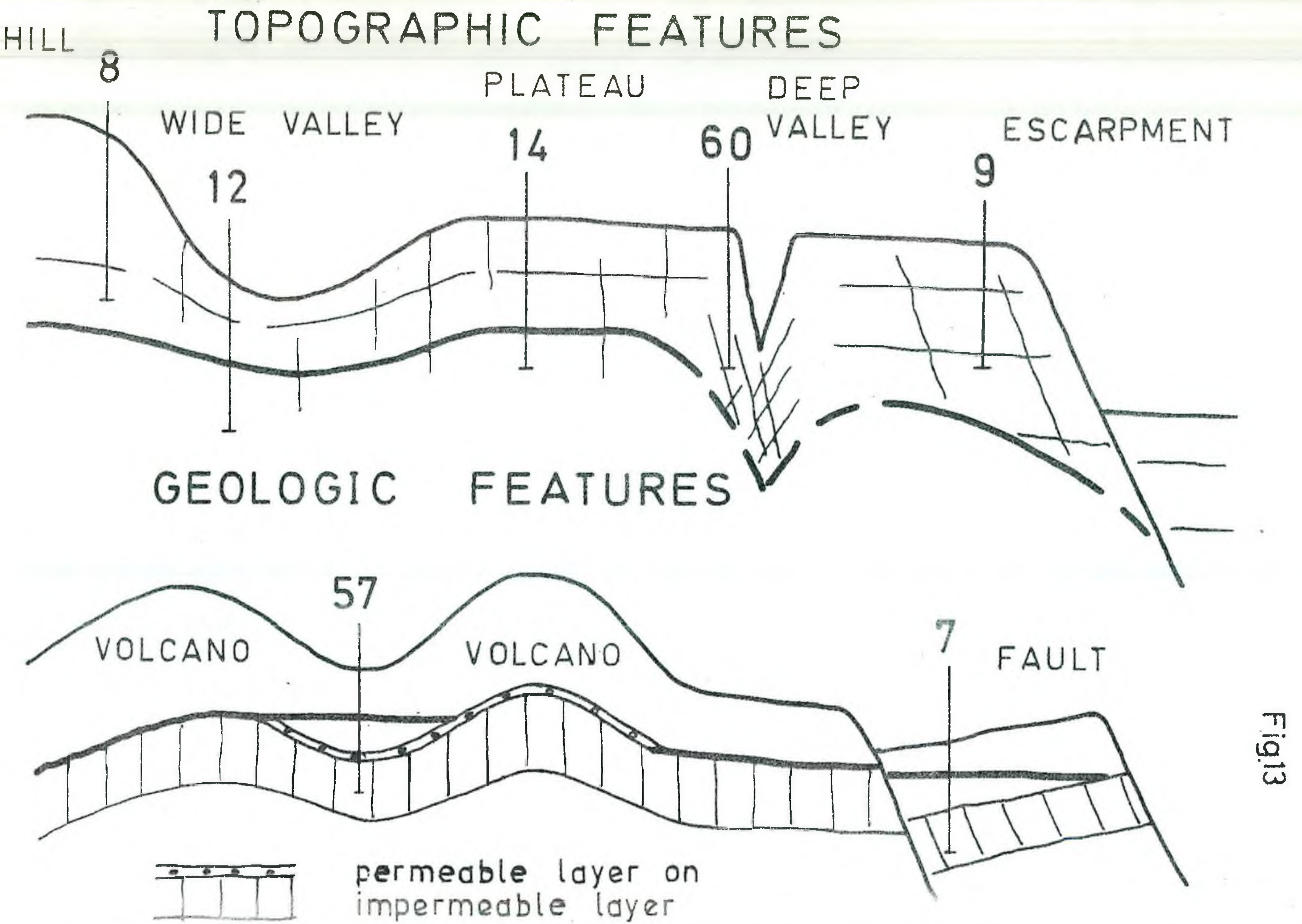

TOPOGRAPHIC FEATURES
HILL
8
WIDE VALLEY
12
PLATEAU
14
60
DEEP VALLEY
ESCARPMENT
9
GEOLOGIC FEATURES
57
VOLCANO
VOLCANO
7
FAULT
permeable layer on impermeable layer

Fig.13

According to drillings no water table is available within a depth of 200 m on the Lukuche plateau between the Katar River and the Käkka-Munessa Mountains. The same is true in the Ethaya plateau north of the Gonde River and in the connecting Dodota area sloping towards the town of Dhera.

In the graben landscape of the Rift Valley, between the border escarpment of the Chilalo plateau and the Lake Zuai, every basin that is filled up by unconsolidated sediments has its own characteristic water table, the level of which seems to be determined by some kind of general hydraulic gradient (section fig. 14, p. 47).

The receivers of ground water are the lakes Zuai and Langano and the Wabe Shebelle River. These lakes and this river determine the position of the adjacent water tables; close by it is near the ground surface, further away up the slopes it is deeper. In parts of the Rift Valley and Wabe Shebelle valley sufficient drillings have been made to permit the drawing of contour lines for depths to the piezometric water table (map fig. 9, p. 36). On the low and flat areas round the lakes ground water can be reached by digging through the unconsolidated sediments down to the level of the lake.

3.4.2.3 Fluctuation of water table

The fluctuations of the water table have been measured only in a few boreholes during the first years of investigation. Commonly the water table seems to be fairly stable during the year; possibly with a lowering of the water table approximately 0.5-1 m at the end of the dry season.

3.4.2.4 Yield of ground water wells

The yields are shown in table 13(p. 40-41) and on the map fig. 15 (p. 48).

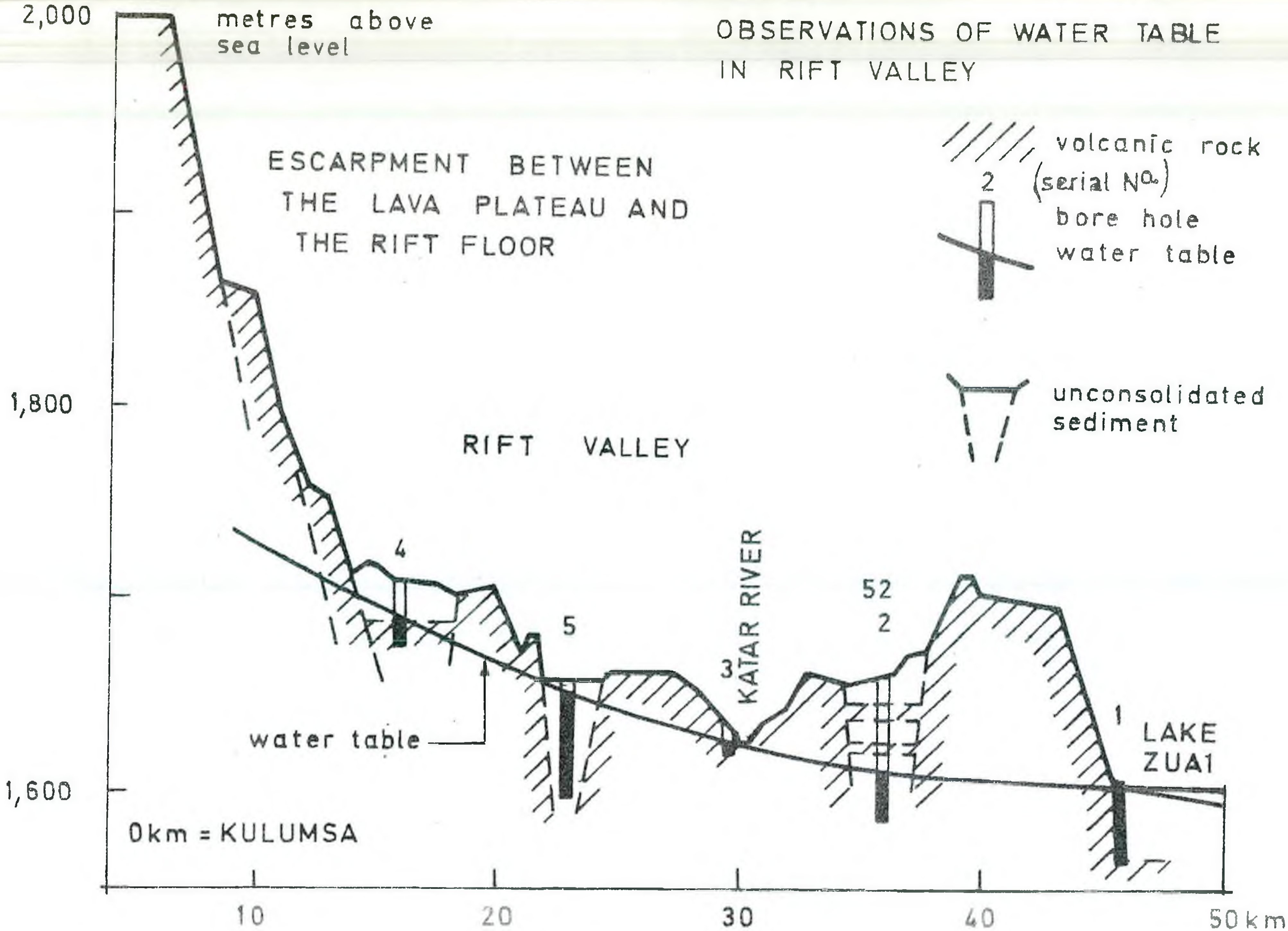
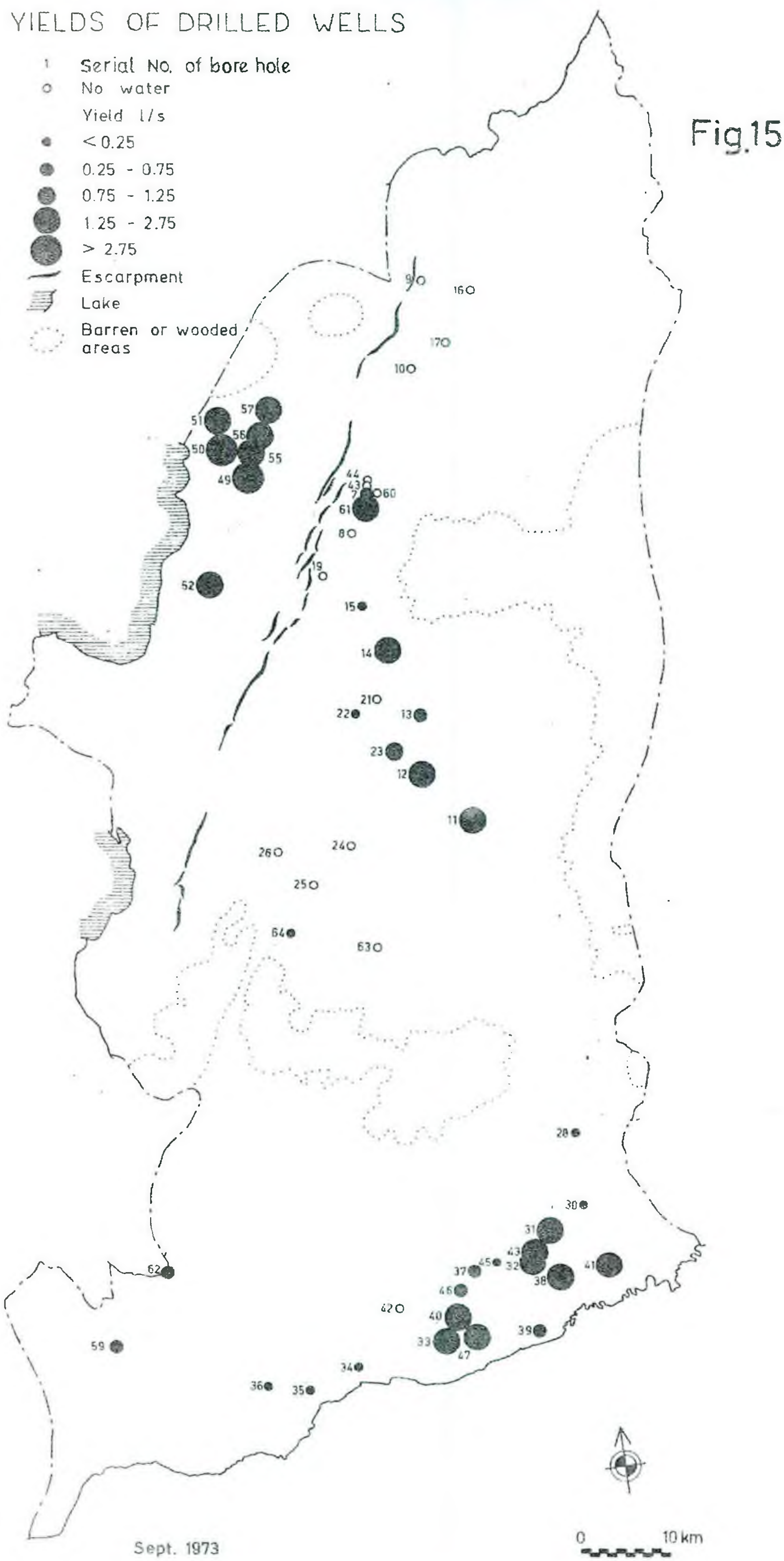

2,000
metres above sea level
OBSERVATIONS OF WATER TABLE IN RIFT VALLEY
ESCARPMENT BETWEEN THE LAVA PLATEAU AND THE RIFT FLOOR
volcanic rock
2 (serial No.)
bore hole
water table
unconsolidated sediment
1,800
RIFT VALLEY
4
5
KATAR RIVER
3
52
2
1
LAKE ZUAI
water table
1,600
0km = KULUMSA
10
20
30
40
50km

Fig14


YIELDS OF DRILLED WELLS
Serial No. of bore hole
No water
Yield l/s
< 0.25
0.25 - 0.75
0.75 - 1.25
1.25 - 2.75
> 2.75
Escarpment
Lake
Barren or wooded areas
Fig.15
9
16
17
10
51
57
56
50
55
49
44
43
7
60
61
8
19
52
15
14
21
22
13
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37
41
38
46
42
40
39
33
47
34
59
62
36
35
0
10 km
Sept. 1973

The largest yields, 1 l/s and more, are found in the largest valley basins: the Rift Valley, the Wabe Shebelle valley and the valley in the part of the Katar basin between Sagure and Bekoji. These basins are the discharge areas for ground water that has infiltrated in the connected plateau and mountain areas.

On the plateaux the yield commonly is small. Exceptions are No. 14 (Sagure) and 61 (Kulumsa), In these cases the aquifer is a layer of either porous basalt or trachyte , both of which have a high permeability, corresponding to that of a sediment of uniform gravel or sand.

### 3.4.3 Quality of ground water

#### 3.4.3.1 Physical quality

For drinking purposes ground water is considered to be better than surface water as regards cleanness and hygiene. The water of the wells has no suspended matter. Tt is colorless, odourless and tasteless.

The temperatures as measured are 15-17°C on the Chilalo plateau (except borehole 10 with 24°C) and 15-19°C in the Rift Valley (except borehole 57 in the volcanic Arba valley with 35°C). In the Wabe Shebelle valley there is a limited area with temperatures 23-24°C (map fig. 16, p. 50).

#### 3.4.3.2 Chemical quality

The results of all the tests are consolidated in table 14 (p. 51-52).

##### 3.4.3.2.1 Local differences

Regarding hardness, bicarbonate and dissolved matter there are differences between river water and ground water:

# TEMPERATURE (°C) AND TDS IN BORE HOLES OF THE ASASSA AREA

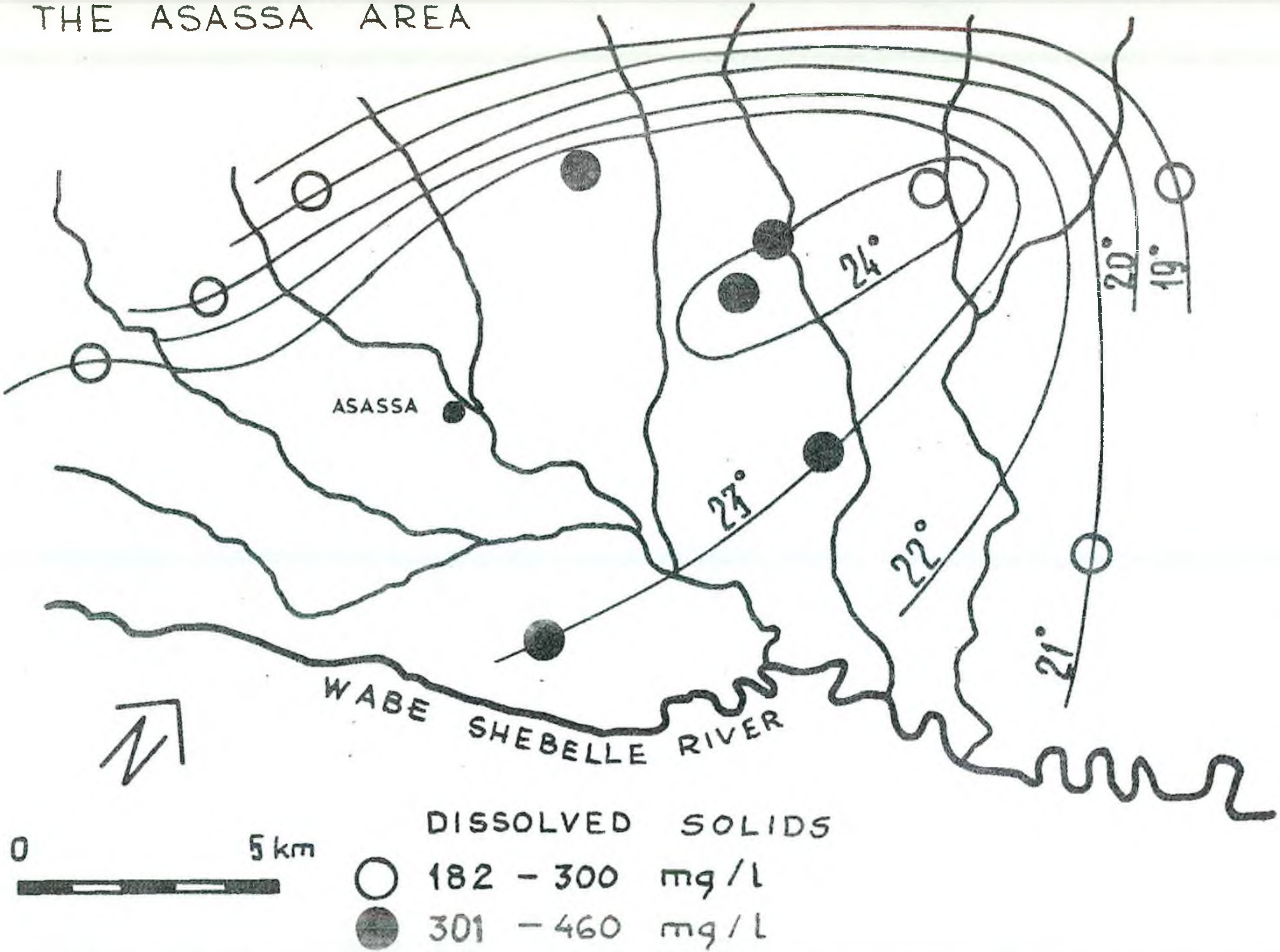



Fig.16

Table 14 Chemical quality of ground water

| Borehole | pH | TDS mg/l | TH $^oF$ | N as $NH_4$ mg/l | N as $NO_2$ mg/l | Ca ppm | Mg ppm | Na ppm | K ppm | $HCO_3$ ppm | Cl ppm | $SO_4$ ppm | $NO_3$ ppm | $SiO_2$ ppm | F ppm | SAR |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 7 | 7.7 | 326 | 15.2 | 0 | 0.01 | 46.0 | 8.8 | 21.5 | 6.0 | 231.8 | 7.1 | 0 | trace | 121 | 1.15 | 0.8 |
| 10 | 7.7 | 540 | 21.2 | 0 | 0.08 | 31.6 | 32.7 | 11.2 | 17.6 | 514.8 | 8.9 | 0 | " | 90 | 1.5 | 0.3 |
| 11 | 8.1 | 230 | 12.6 | 0 | trace | 33.7 | 10.2 | 22.0 | 3.7 | 202.8 | 3.6 | 0 | " | 51 | 0.1 | 0.9 |
| 12 | 8.3 | 130 | 9.0 | 0 | " | 21.6 | 8.8 | 15.0 | 4.3 | 134.2 | 5.3 | 0 | " | 52 | 1.1 | 0.7 |
| 13 | 7.0 | 118 | 4.0 | 0 | " | 12.9 | 2.0 | 19.0 | 2.7 | 97.6 | 3.6 | 0 | " | 29 | 0.1 | 1.3 |
| 14 | 7.6 | 125 | 4.2 | 0 | " | 12.9 | 2.4 | 18.0 | 2.0 | 91.5 | 7.1 | 0 | 0 | 38 | 0.35 | 1.2 |
| 15 | 7.4 | 167 | 4.9 | 0 | " | 16.2 | 2.2 | 10.8 | 1.9 | 79.3 | 7.1 | 0 | 0 | 99 | 0.1 | 0.7 |
| 22 | 8.4 | 330 | 20.6 | 0 | 0.01 | 48.1 | 20.9 | 19.5 | 6.1 | 167.1 | 7.1 | 25.0 | 0 | 59 | 1.5 | 0.6 |
| 23 | 7.65 | 285 | 16.1 | 0 | 0.05 | 44.9 | 11.8 | 24.0 | 5.1 | 254.0 | 7.1 | 0 | 0 | 65 | 1.5 | 0.8 |
| 28 | 7.8 | 250 | 8.6 | 0.53 | 0.09 | 38.5 | 12.2 | 24.4 | 1.6 | 176.9 | 28.4 | - | 10.0 | 45 | 1.0 | 0.9 |
| 30 | 8.1 | 200 | 7.7 | 0 | 0.01 | 17.1 | 8.4 | 10.2 | 5.2 | 170.8 | 17.7 | - | 2.5 | 48 | 0.4 | 0.5 |
| 31 | 7.7 | 260 | 11.7 | 0 | 0.30 | 26.5 | 12.4 | 25.3 | 6.8 | 201.3 | 10.6 | 0 | 4.4 | - | 0.8 | 1.0 |
| 32 | 7.7 | 320 | 11.2 | 0.68 | 0.23 | 28.5 | 10.0 | 35.3 | 9.9 | 237.9 | 14.2 | trace | 0.3 | 100 | 1.1 | 1.4 |
| 34 | 8.0 | 367 | 21.8 | 0 | 0.02 | 65.0 | 1.4 | 20.0 | 7.0 | 256.2 | 13.0 | 0 | 4.0 | 130 | 1.9 | 3.6 |
| 35 | 7.8 | 300 | 11.0 | 0 | 0.03 | 32.0 | 7.0 | 14.0 | 4.0 | 183.0 | 7.1 | 0 | 1.8 | 143 | 0.5 | 0.6 |
| 38 | 8.1 | 310 | 11.0 | 0 | 0.02 | 28.1 | 9.7 | 32.0 | 8.8 | 178.9 | 10.3 | 0 | 5.3 | 75 | 0.6 | 1.3 |
| 39 | 8.1 | 345 | 16.3 | trace | 0.02 | 50.1 | 9.2 | 68.0 | 8.8 | 311.1 | 35.5 | 14.8 | 1.4 | 66 | 1.0 | 2.3 |
| 40 | 8.2 | 198 | 7.1 | 0 | 0.02 | 17.2 | 6.8 | 16.8 | 4.7 | 109.8 | 7.1 | 0 | 1.2 | 58 | 0.5 | 0.9 |

Table 14 continued

| Boreholes | PH | TDS | TH °F | N as $NH_4$ | N as $NO_2$ | Ca | Mg | Na | K | $HCO_3$ | Cl | $SO_4$ | $NO_3$ | $SiO_2$ | F | SAR |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 41 | 8.2 | 256 | 9.9 | 0.20 | 0.21 | 26.9 | 7.8 | 25.2 | 7.5 | 183.0 | 8.9 | 8.2 | 4.0 | 68 | 0.5 | 1.1 |
| 43 | 8.1 | 466 | 12.0 | 0 | 0.02 | 35.3 | 7.8 | 11. | 10.5 | 350.8 | 35.5 | 15.6 | 9.9 | 72 | 0.4 | 4.4 |
| 45 | 8.0 | 344 | 14.4 | 0 | 0.07 | 25.3 | 13.3 | 32.0 | 7.5 | 183.0 | 14.2 | 41.2 | 5.8 | 73 | 0.2 | 1.2 |
| 46 | 7.8 | 182 | 8.0 | 0.02 | 0.02 | 20.4 | 711 | 20.1 | 3.5 | 134.2 | 9.6 | 0 | 1.3 | 82 | 0.02 | 1.0 |
| 47 | 7.9 | 250 | 10.2 | 0.05 | 0.03 | 26.1 | 9.0 | 12.9 | 32.0 | 176.9 | 13.8 | 0 | 2.2 | 102 | 0.2 | 0.6 |
| 49 | 7.7 | 264 | 6.2 | 0.68 | 0.04 | 14.8 | 6.1 | 36.0 | 6.4 | 164.7 | 6.9 | 0 | trace | 69 | 1.8 | 2.0 |
| 50 | 7.5 | 288 | 5.2 | 0.12 | 0.03 | 15.2 | 3.4 | 62.4 | 12.3 | 225.7 | 6.9 | 0 | 1.2 | 102 | 2.1 | 3.8 |
| 51 | 7.5 | 312 | 5.8 | 1.15 | 0.04 | 16.8 | 3.9 | 35.2 | 8.2 | 213.5 | 6.9 | 0 | trace | 90 | 2.2 | 3.2 |
| 52 | 7.8 | 398 | 11.0 | 0.35 | 0.01 | 28.0 | 9.7 | 70 | 5.0 | 292.8 | 14.0 | 0 | 0.5 | 120 | 1.25 | 2.9 |
| 55 | 6.1 | 420 | - | 0.92 | 0.01 | 14.4 | 9.7 | 48 | 8.4 | 130.0 | 13.3 | 5.8 | 0 | 148.5 | 1.0 | 2.4 |
| 56 | 7.5 | 360 | 10.2 | 0 | 0.02 | 23.0 | 11.0 | 47 | 9.5 | 244.0 | 7.0 | 0 | trace | 143 | 2.0 | 2.0 |
| 57 | 7.2 | 1,155 | 24.6 | 0.02 | 0.14 | 62.0 | 2.0 | 312 | 20.0 | 1,012.6 | 13.0 | 0 | 5.6 | 218 | 4.9 | 10.6 |
| 59 | 6.8 | 278 | - | 0.65 | 0.04 | 8.8 | 3.0 | 19.0 | 4.0 | 73.2 | 10.0 | 0 | 0.5 | 180 | 0.2 | 1.4 |
| 61 | 7.0 | 194 | 8.0 | 0.13 | 0.13 | 22.0 | 6.1 | 24.8 | 5.2 | 128.1 | 13.8 | 0 | 19.0 | 83 | 0.3 | 1.2 |
| 62 | 7.0 | 260 | - | 0.46 | 0.02 | 4.0 | 2.4 | 27.0 | 4.1 | 61.0 | 13.3 | 0 | 0.5 | 148 | 1.2 | 2.6 |
| 64 | 7.1 | 280 | - | 1.17 | 0.03 | 8.2 | 3.4 | 11.3 | 6.8 | 79.3 | 13.3 | 0 | 2.5 | 130 | 0.2 | 0.8 |
| Dug wells | | | | | | | | | | | | | | | | |
| Abura | 8.2 | 308 | 7.2 | 0 | 0.03 | 21.3 | 4.6 | 28.0 | 3.2 | 86.6 | 10.6 | 0 | 9.6 | 80 | 1.5 | 1.4 |
| Djila | 7.0 | 321 | 35.5 | 0.32 | 0.01 | 60.0 | 45.0 | 21.0 | 63.9 | 345.4 | 120.5 | 0 | 0.3 | 105 | 3.4 | 0.5 |
| Springs | | | | | | | | | | | | | | | | |
| Burkito | 7.8 | 162 | 0 | 0.07 | trace | 12.8 | 5.1 | 20.8 | 3.5 | 103.7 | 10.6 | 0 | trace | 68 | 0.14 | 1.2 |

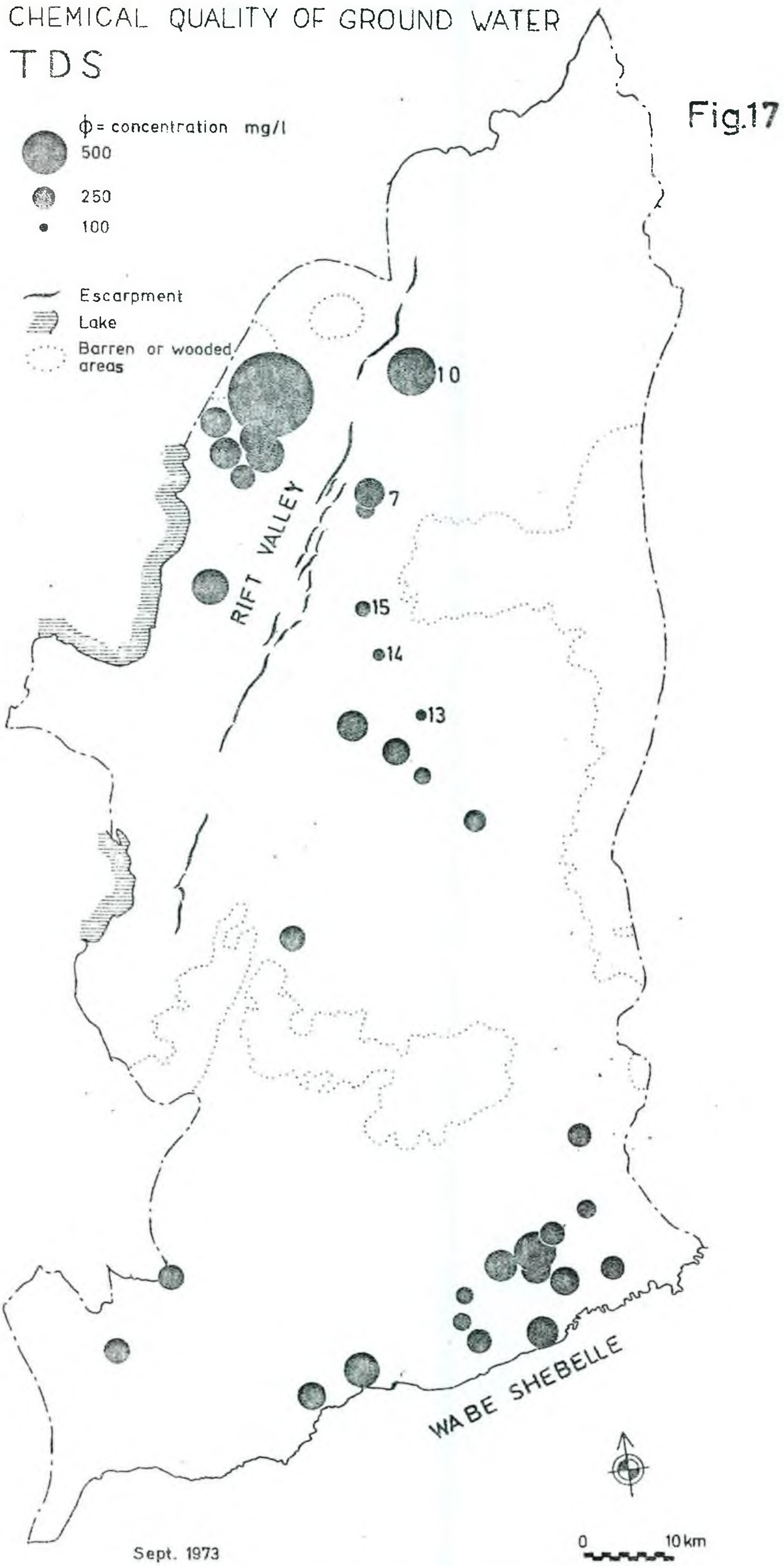
| | pH | Total hardness °F | Bicarbonate ppm | Dissolved solids mg/l |
|---|---|---|---|---|
| <u>All testdd rivers</u> (except the Gonde and Asassa Rivers = ground water) | 6.8-7.8 | 0.8-4 | 15 - 49 | 54 - 150 |
| All drilled wells | 7.0-8.4 | 4-25 | 29 - 218 | 112-1,155 |

The total hardness of 4°F seems to be an approximate upper limit to rivers, according to the figures obtained.

Ground water has larger amounts of dissolved ions and shows larger differences than river water. The evaporation concentrates dissolved solids, and the increasing acidity increases the dissolved matter and the total hardness. Also long transport and/or slow circulation of the ground water increases the salts dissolved from sediments and fissures in rocks.

Therefore, it is to be expected that water from the Chilalo plateau south of Asella (boreholes 13-15) will have a smaller salt concentration than water from the Rift Valley (boreholes 49 - 56). See map fig. 17, p. 54 ). But some parts of the Chilalo plateau with scanty yield and slow water circulation have high amounts of dissolved matter and high total hardness (boreholes 7 and 10).

In the Wabe Shebelle valley the local ground water flow in the valley section east of Asassa (boreholes 32, 38, 39, 43, 45) has larger amounts than in other parts of the valley. The high amounts appear in an area with a ground water of high temperature (fig. 16 p, 50).


CHEMICAL QUALITY OF GROUND WATER
TDS
Fig.17
ϕ = concentration mg/l
500
250
100
Escarpment
Lake
Barren or wooded areas
10
7
RIFT VALLEY
15
14
13
WABE SHEBELLE
Sept. 1973
0
10 km

During the passage through the earth ion exchange and adsorption change the proportion of the different ions. As chloride does not take much part in such processes, it is used as a comparison standard (1) (table 15, p. 56 ). In the ground water calcium and magnesium decrease with increased amount of total dissolved solids.

Because so many factors have an influence on the chemical quality, local variations are considerable.

3.4.3.2.2 Consumption water

The water quality can be regarded as good or acceptable for drinking water. With the exception of borehole 57 the highest amount of dissolved matter in drilled wells is 466 mg/l (salty taste above 500 mg/l), disregarding borehole 10 with its poor water quantity. In several boreholes nitrogen compounds possibly indicate some pollution. The fluoride content might be considered rather high in parts of the Rift Valley and Wabe Shebelle valley (more than 1.5 mg/l in boreholes 34, 50, 52 and 56). The amount of 4.9 mg/l in borehole 57 is considerable.

Because of rather large concentrations of bicarbonates of calcium and magnesium the ground water is sometimes "hard", e.g. the Kofale water (borehole 59). The hardness means that the water requires more soap than normal for washing clothes. In water pipes and in vessels for boiling water carbonates can be precipitated. The high amounts of silica can also cause scale in vessels and boilers.

(1) following 6 Jacks: 'Chemistry of ground water in a district in southern India', J. Hydrol., 1973.

Table 15 Ratios between ion concentrations in all water samples

| | Number of samples | Total dissolved solids mg/l | Ratios Ca/Cl | Mg/Cl | Na/Cl | K/Cl |
|---|---|---|---|---|---|---|
| River water | 28 | 0 - 99 | 0.29 | 0.09 | 1.34 | 0.22 |
| | 3 | 100 - 249 | 0.34 | 0.16 | 1.92 | 0.39 |
| | 0 | 250 - 499 | - | - | - | - |
| Ground water | 0 | 0 - 99 | - | - | - | - |
| | 8 | 100 - 249 | 1.47 | 0.72 | 4.49 | 0.50 |
| | 19 | 250 - 499 | 1.29 | 0.67 | 5.44 | 0.74 |

No treatment of the ground water is needed for human consumption. Chemical analysis of drilled well water are not very necessary, if the taste is good. Exceptionally might testing be necessary regarding fluoride in the Rift Valley.Fluor and calcium concentrations are connected to each other, as the chemical compound is often calcium fluoride (fig. 18, p.58).

3.4.3.2.3 Irrigation water

For the evaluation of ground water for irrigation, the SAR-coefficient has been calculated and is shown in the last column of table 14 (p. 51-52). As total dissolved solids are below 500 mg/l and sodium adsorption ratio below 6, all ground water from drilled wells is suitable for irrigation.

3.4.4.2.4 Changes after pumping boreholes

An important question is the change of quality after pumping for some time. In table 16 (p. 59) are shown the results of long-term test pumpings. The pH value and hardness have not changed much or have decreased. The same applies to nitrate and fluoride. Also the sodium adsorption ratio has increased. These changes indicate an addition of rather more superficial ground water, but the water is still acceptable for consumption purposes.

Fig.18

# RELATION BETWEEN Ca AND F

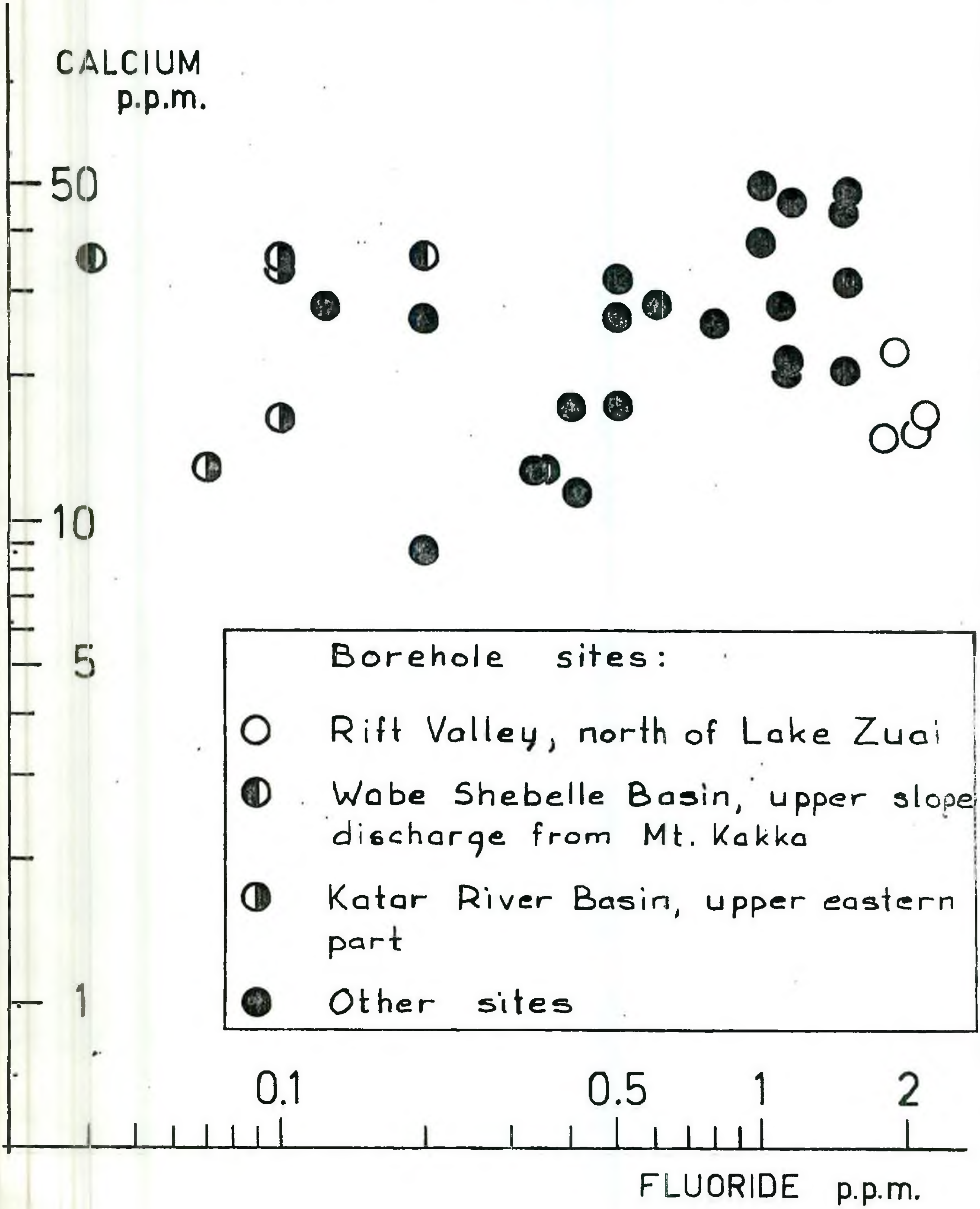


Table 16 Chemical quality of ground water before and afte

| Bore-hole | | pH | TDS mg/l | Alk. °F | H °F | N as $NH_4$ mg/l | N as $NO_2$ mg/l | Ca ppm |
|---|---|---|---|---|---|---|---|---|
| 12 | before | 8.3 | 180 | 11.0 | 9.0 | 0 | trace | 21.6 |
| | after | 7.65 | 175 | 10.5 | 7.4 | 0 | trace | 20.8 |
| | diff. | -0.65 | - 5 | -0.5 | -1.6 | ± 0 | - | -0.8 |
| 14 | before | 7.6 | 125 | 7.5 | 4.2 | 0 | trace | 12.9 |
| | after | 7.4 | 112 | 6.0 | 4.0 | trace | 0.01 | 11.2 |
| | diff. | -0.2 | -13 | -1.5 | -0.2 | ± 0 | +0.01 | -1.7 |
| 32 | before | 7.7 | 320 | 19.5 | 11.2 | 0.68 | 0.23 | 28.5 |
| | after | 7.6 | 320 | 19.0 | 11.4 | 0.38 | 0.02 | 24.3 |
| | diff. | -0.1 | ± 0 | -0.5 | +0.2 | -0.30 | 0.21 | -4.2 |
| 40 | before | 8.2 | 198 | 9.0 | 7.1 | 0 | 0.02 | 17.2 |
| | after | 7.7 | 194 | 11.0 | 6.9 | 0.05 | 0.02 | 16.8 |
| | diff. | -0.5 | - 4 | +2.0 | -0.2 | +0.05 | ± 0 | -0.4 |
| 49 | before | 7.7 | 264 | 13.5 | 6.2 | 0.68 | 0.04 | 14.8 |
| | after | 7.2 | 244 | 12.0 | 6.4 | 0.68 | 0.04 | 16.4 |
| | diff. | -0.5 | -20 | -1.5 | +0.2 | ± 0 | ± 0 | +1.6 |
| 51 | before | 7.5 | 312 | 17.5 | 5.8 | 1.15 | 0.04 | 16.8 |
| | after | 7.6 | - | 16.5 | 6.1 | 0 | 0.01 | 18.0 |
| | diff. | +0.1 | - | -1.0 | -1.7 | -1.15 | -0.03 | +1.2 |
| 56 | before | 7.5 | 360 | 20.0 | 10.2 | 0 | 0.02 | 23.0 |
| | after | 7.5 | 398 | 21.0 | 9.2 | 0 | 0.01 | 22.4 |
| | diff. | ± 0 | +38 | +1.0 | -1.0 | ± 0 | -0.01 | -0.6 |
| 62 | before | 7.0 | 260 | - | - | 0.35(a) | 0.02 | 4.0 |
| | after | 7.1 | 250 | - | - | 0(a) | 0.01 | 4.7 |
| | diff. | +0.1 | -10 | - | - | -0.35 | -0.01 | +0.7 |

(a) ammonia

r long-term test pumping

| Mg ppm | Na ppm | K ppm | $HCO_3$ ppm | Cl ppm | $SO_4$ ppm | $NO_3$ ppm | $SiO_2$ ppm | F ppm |
|---|---|---|---|---|---|---|---|---|
| 8.8 | 15.0 | 4.3 | 134.2 | 5.3 | 0 | trace | 52.0 | 1.1 |
| 5.4 | 17.2 | 4.7 | 128.1 | 10.6 | 0 | 0 | 51.8 | 1.5 |
| -3.4 | + 2.2 | +0.4 | - 6.1 | +5.3 | ±0 | - | -0.2 | +0.4 |
| 2.4 | 18.0 | 2.0 | 91.5 | 7.1 | 0 | 0 | 38.1 | 0.35 |
| 2.9 | 13.8 | 1.9 | 73.2 | 5.7 | 0 | 0.4 | 33.8 | 0.4 |
| +0.5 | -4.2 | -0.1 | -18.3 | -1.4 | ± 0 | +0.4 | -4.3 | +0.05 |
| 10.0 | 35.3 | 9.9 | 237.9 | 14.2 | trace | 0.3 | 100.0 | 1.1 |
| 11.7 | 40.1 | 11.3 | 231.8 | 14.2 | 0 | 4.5 | 88.0 | 1.0 |
| +1.7 | +4.8 | +1.4 | - 6.1 | ±0 | - | +4.2 | -12.0 | -0.5 |
| 6.8 | 16.8 | 4.7 | 109.8 | 7.1 | 0 | 1.2 | 58.0 | 0.5 |
| 6.5 | 17.2 | 4.5 | 134.2 | 7.1 | 0 | 2.2 | 68.0 | 0.4 |
| -0.3 | +0.4 | -0.2 | +24.4 | ± 0 | ±0 | +1.0 | +10.0 | -0.1 |
| 6.1 | 36.0 | 6.4 | 164.7 | 6.9 | 0 | trace | 69.0 | 1.8 |
| 0.7 | 34.0 | 6.4 | 146.4 | 3.5 | 0 | trace | 73.0 | 1.7 |
| -5.4 | -2.0 | ± 0 | -18.3 | -3.4 | ±0 | + 0 | +4.0 | ±0.1 |
| 3.9 | 55.2 | 8.2 | 213.5 | 6.9 | 0 | trace | 90 | 2.2 |
| 3.6 | 84.0 | 6.0 | 199.3 | 6.7 | 115.2 | 1.2 | 155 | 1.8 |
| -0.3 | +29.8 | -2.2 | - 4.2 | -0.2 | 115.2 | ±1.2 | ± 65 | -0.4 |
| 11.0 | 47.0 | 9.5 | 224.0 | 7.0 | 0 | trace | 143.0 | 2.0 |
| 8.7 | 57.0 | 8.9 | 256.2 | 6.7 | 0 | 4.3 | 154.0 | 1.9 |
| -2.3 | +10.0 | -0.6 | +12.2 | -0.3 | ±0 | +4.3 | +11.0 | -0.1 |
| 2.4 | 27.0 | 4.1 | 61.0 | 13.3 | 0 | 0.5 | 148 | 1.2 |
| 1.0 | 21.0 | 6.7 | 60.0 | 6.3 | 0 | 0 | 133.5 | 0.6 |
| -1.4 | -6.0 | ±2.6 | -1.0 | - 7.0 | ± 0 | -0.5 | -14.5 | -0.6 |

# 4 THE NATURAL WATER RESOURCES AND THE DEMAND OF WATER, NOW AND IN THE FUTURE

## 4.1 Available water resources

During the four years of investigation, the water resources have beem explored. The map fig. 19 (p. 61) shows the available water resources within the Chilalo Awraja at present.

On the map perennial rivers and their tributaries are shown with zones 1 kilometre broad on each side; such a distance is considered by the people to be short for carrying water in the rural areas. Another reason for demarcating such zones is that livestock cannot use grass efficiently without water being within suitable walk distance, ideally not more than 0.8 km (according to FAO Agricultural studies No. 16). On the gauging sites of the map fig. 9 (p. 36), marked by triangles, the smallest yield obtained by measurements has been figured in l/s. This quantity represents the capacity of the river without any damming. The quantity thus shown is commonly representative of only the two years of measuring; it may be either larger or smaller during other years.

Downstream of the gauging sites, the water quantity can decrease through seepage, evaporation and consumption. Thus the Anko River can dry up on the plateau towards the escarpment. On the Rift floor the Simba River may also dry up in some years. The Karsa River, coming from the Munessa Mountain, and the rivers on the southern side of the Kakka Mountain dry up in their lower parts during the end of the dry seasons.

The aim of the drillings was not primarily to construct wells for villages or groups of farmers, but to determine, on geological evidence,

1) the presence of ground water,
2) the depth of the water table, and
3) the probable yield of the well.

On the map fig. 9 (p. 36) the boreholes have been marked with numbers, together with the approximate yield in l/s. With reference again to the map fig. 19, where the depth to the water table, according to the drilling results, is less than 100 metres, the areas between the perennial rivers have been marked with small circles on the map.


WATER RESOURCES
Border river or Lake 1 km zone
Perennial river 1 km zone
Artificial water supply 1 km zone
Built-up area
Ground water within 20 m
Ground water within 100 m
Fig.19
0
10 km
Sept. 1973

In two areas, in the Rift Valley and in the Wabe Shebelle valley, water is available everywhere but in other areas only in carefully selected borehole sites. At first, wells should be made in depressions of the plateau or in broad river valleys rather than on hills, ridges or crests of escarpments (p. 46 and fig. 13, p. 45).

Close to Lake Zuai, and in the Kofale district, water is available by digging wells. On the map fig. 19 areas with depths of the water table less than 20 metres have been marked with large circles.

The densly lined areas of the map fig. 19 mark a walk distances of 1 km from the artificial water supplies constructed to date.

For a master plan the consumption demand has to be studied on a basis of existing natural water resources, lakes and perennial flows without dams. This was the situation when CADU started. The map fig. 20 (p. 63) shows a division of the Chilalo Awraja into 52 areas of natural water resources. Small springs have not been considered on the map, but otherwise the population in each area will be dependent for water, on the lake or river system shown as associated with that area.

## 4.2 Present consumption of water

### 4.2.1 Pattern of water consumption

Water is collected during day-light hours. To find out if there are any differences during the day, the collecting of water per hour has been measured at 14 wells during 21 days at the end of the dry season in March - April 1973. A special report has been written by Mr. Stefan Grönberg: "A small study on water consumption per capita at boreholes with hand pumps," June 6th, 1973.

Overall, the average water collecting per hour varies little, but there are local differences (fig. 21, p. 64). In the Asassa area (wells 32 etc.), where the present settlers were normads some years ago the water collecting is roughly constant during the different hours of the day. Other wells in the Wabe Shebelle valley do not show the same pattern (wells 34 etc.). These wells are situated on roads, so the water collecting can be influenced by the traffic.

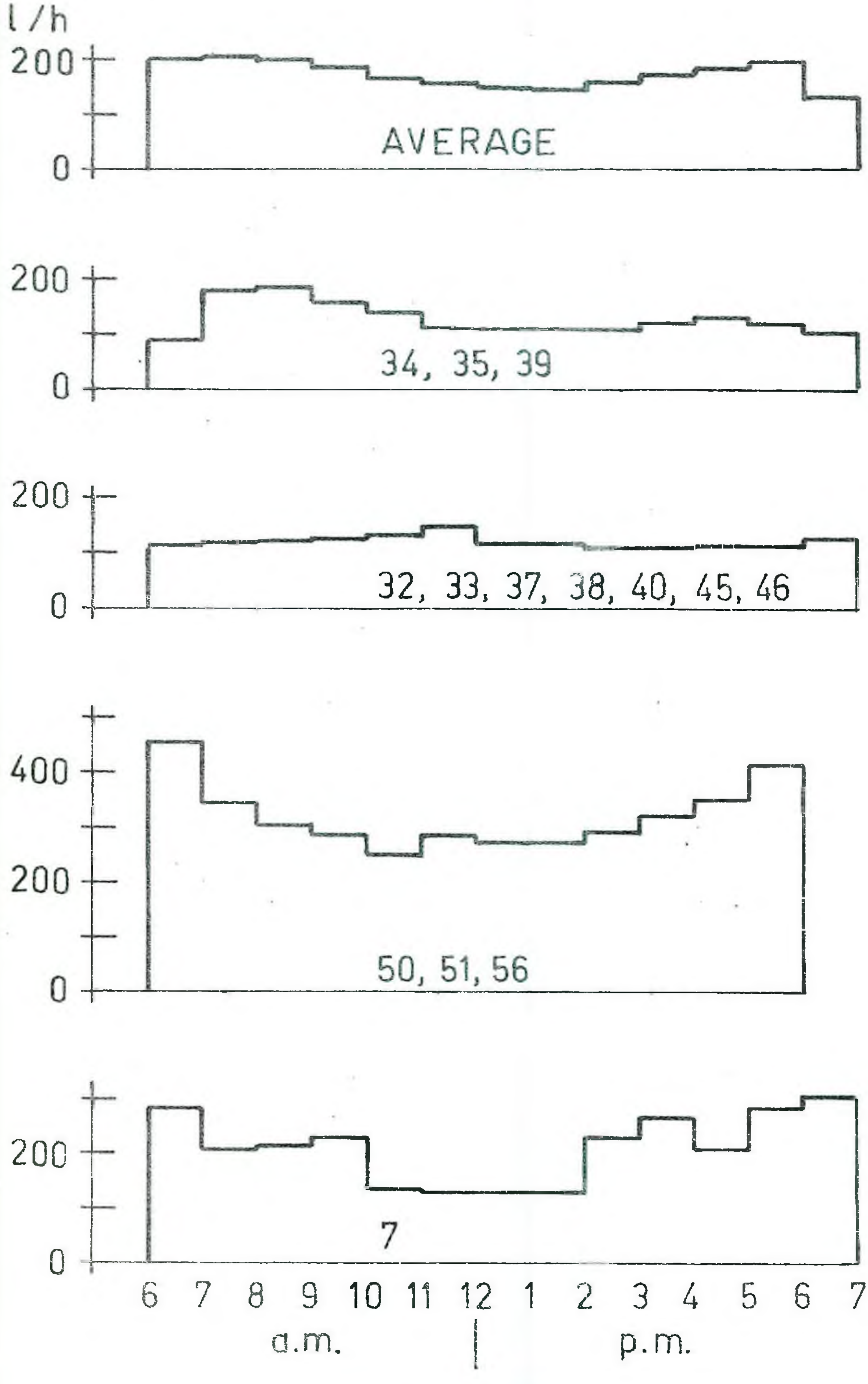
# THE DEPENDENCE OF SUB-AREAS NUMBERED 1-52 ON PARTICULAR SECTIONS OF THE RIVER AND LAKE SYSTEMS

Fig. 20


Sept. 1973

Fig. 21

# COLLECTING OF WATER PER HOUR FROM 14 DRILLED WELLS



In the hot Rift Valley (wells 50 etc.) the water collecting is concentrated in the early morning and late afternoon hours. At Kulumsa (well 7), where people are employed by the near by Kulumsa farm, the women do not carry water before and during lunch time,10 a.m. - 2 p.m.

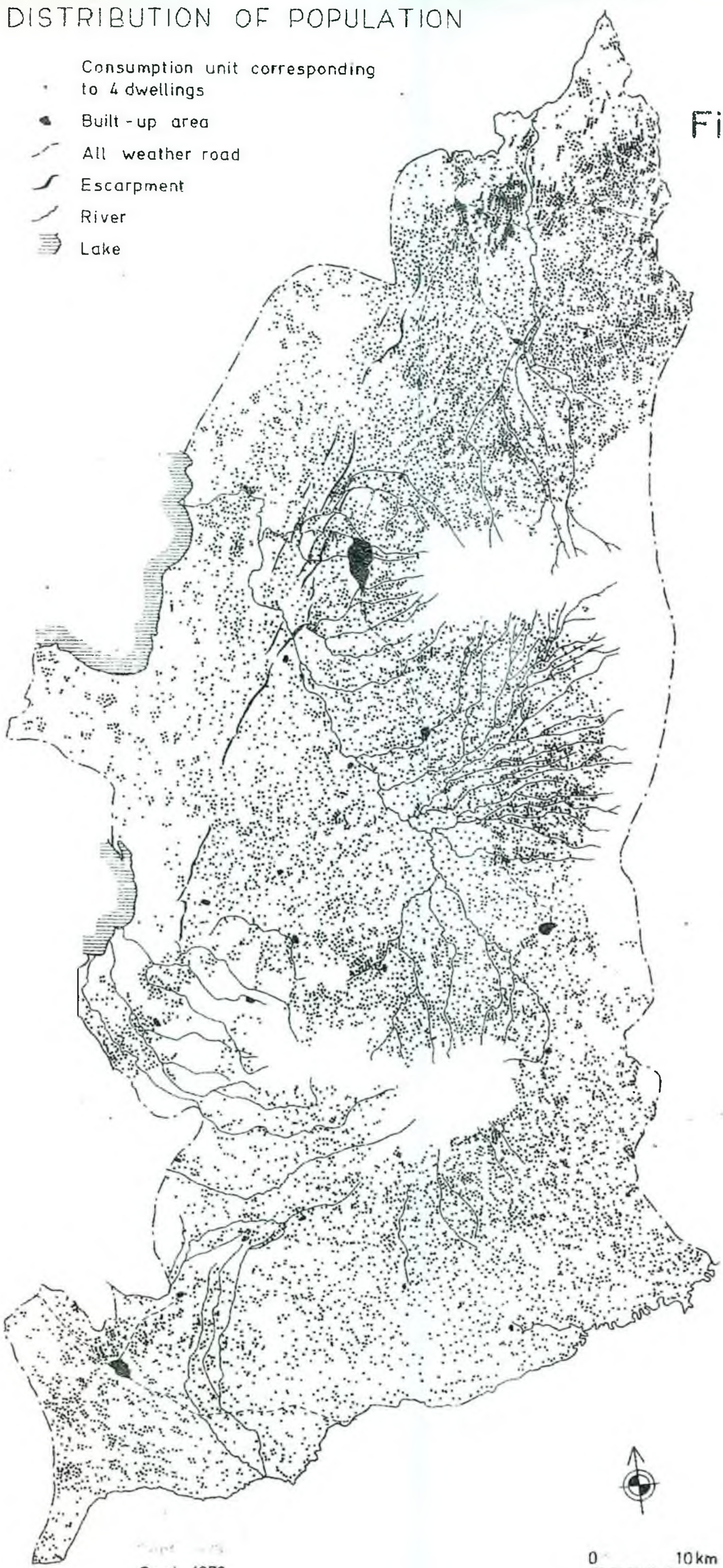
4.2.2 Calculation of water consumption

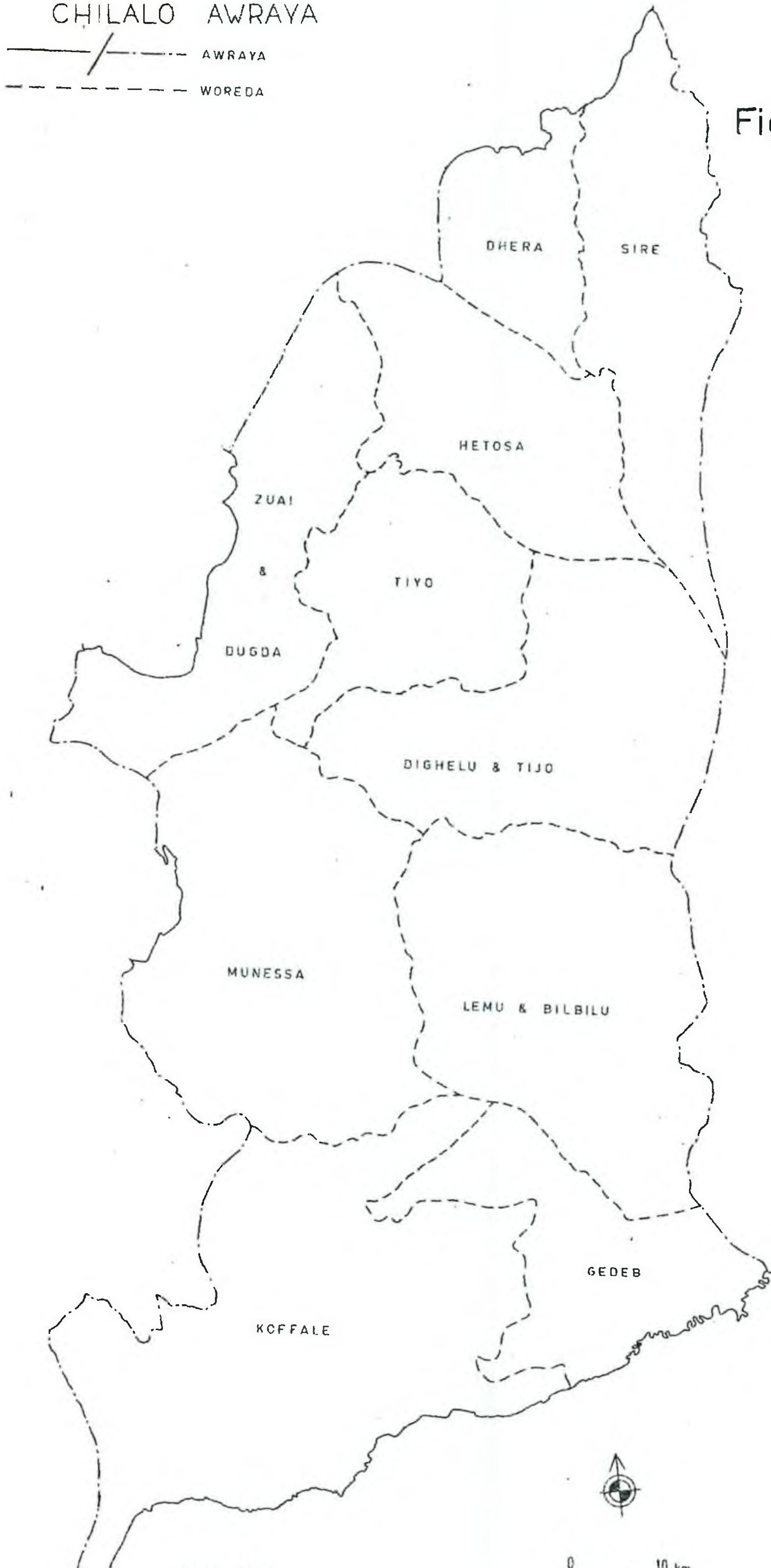
To obtain an idea of the population distribution and the size of water consumption, the aerial photographs from 1967 have been used to construct a photo-mosaic, which as a draft has shown the positions of huts and other dewllings. The map in fig. 22 (p. 66) is a condensation of the draft map, every dot prepresenting a "consumption unit" of 4 dwellings.

The white areas of the map are barren or wooded areas without people. There are thinly populated stripes of land along the large rivers and lakes. Larger areas, thinly populated, are the dry plains of the Rift Valley, the Wabe Shebelle valley and the Katar River basin. The densly populated areas are the plateau round the Chilalo Mountain, the slopes of the Kakka Mountain, some plains in the Awash valley in the north, some slopes west of the Munessa forest and some parts of the Kofale district.

By virtue of the Governor General's census for people and livestock in 1970 the number of people and livestock in every woreda is known (woredas shown on the map fig. 23, p. 67). By counting the number of consumption units consisting of 4 dwellings it has been possible to calculate the number of persons per dwelling and the number of livestock per person (table 17, p. 68).

Using the distribution map fig. 22 it has also been possible to count the number of consumption units within each of the 52 areas of natural water supplies fig. 20. With the aid of the number of persons per dwelling and the number of livestock per person, the present demand of consumption water was calculated for the 52 areas of natural water supplies (table 18, p. 69-74).


DISTRIBUTION OF POPULATION
Consumption unit corresponding to 4 dwellings
Built - up area
All weather road
Escarpment
River
Lake
0
10 km
Sept. 1973
Fig. 22



CHILALO AWRAYA
AWRAYA
WOREDA
DHERA
SIRE
HETOSA
ZUAI
&
DUGDA
TIYO
DIGHELU & TIJO
MUNESSA
LEMU & BILBILU
GEDEB
KOFFALE
0
10 km
Sept. 1973

Fig. 23

Table 17 Population and livestock in Woredas

| POPULATION | Zuai and Dugda | Dhera | Sire | Munessa | Kofale | Gedeb | Hetosa | Tiyo | Dighelu and Tijo | Lemu and Bilbilu | Totals and averages |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Total population: | 29,848 | 29,987 | 47,340 | 32,432 | 63,946 | 28,270 | 34,577 | 43,005 | 38,945 | 47,787 | 396,137 |
| rural areas | 28,748 | 20,987 | 42,890 | 30,232 | 59,476 | 27,170 | 32,977 | 28,405 | 35,885 | 43,587 | 350,357 |
| built-up areas | 1,100 | 9,000 | 4,450 | 2,200 | 4,470 | 1,100 | 1,600 | 14,600 | 3,060 | 4,200 | 45,780 |
| Number of persons per hut in rural areas | 9.0 | 6.4 | 6.1 | 5.5 | 7.3 | 6.9 | 5.9 | 8.4 | 6.4 | 6.0 | 6.6 |
| LIVESTOCK | | | | | | | | | | | |
| Total large livestock: | 61,200 | 32,900 | 47,600 | 44,720 | 135,720 | 59,040 | 33,465 | 50,025 | 37,080 | 97,850 | 599,600 |
| rural areas | 61,024 | 31,460 | 46,888 | 44,368 | 135,005 | 58,864 | 33,209 | 47,689 | 36,590 | 97,178 | 592,275 |
| built-up areas | 176 | 1,440 | 712 | 352 | 715 | 176 | 256 | 2,336 | 490 | 672 | 7,325 |
| Total small livestock: | 32,562 | 9,613 | 38,724 | 39,652 | 46,248 | 43,853 | 19,326 | 36,060 | 38,532 | 77,111 | 381,681 |
| rural areas | 32,485 | 8,983 | 38,412 | 39,498 | 45,935 | 43,776 | 19,214 | 35,038 | 38,318 | 76,817 | 378,476 |
| built-up areas | 77 | 630 | 312 | 154 | 313 | 77 | 112 | 1,022 | 214 | 294 | 3,205 |
| Number of livestock per person in rural areas: | | | | | | | | | | | |
| large livestock a) | 2.1 | 1.5 | 1.1 | 1.5 | 2.3 | 2.2 | 1.0 | 1.7 | 1.0 | 2.2 | 1.7 |
| small livestock b) | 0.9 | 0.4 | 0.9 | 1.3 | 0.8 | 1.6 | 0.6 | 1.2 | 1.1 | 1.8 | 1.1 |
| built-up areas: | | | | | | | | | | | |
| large livestock | | | | | | | | | | | 0.16 |
| amall livestock | | | | | | | | | | | 0.07 |

a) large livestock = cattle, horses, mules, donkeys b) small livestock = sheep and goats

Table 18 Comparison of water (l/s) in the 52 areas of the map fig. 20 (footnotes on p. 00)

| AREAS / WOREDAS | 2 | | | 1 | | 3 | | 4 | | | 5 | | 6 | 7 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Sire | Hetosa | Dhera | Sire | Dhera | Hetosa | Dhera | Hetosa | Tiyo | Zuai & Dugda | Tiyo | Zuai & Dugda | Tiyo | Tiyo |
| CONSUMPTION UNITS | | | | | | | | | | | | | | |
| Number of consumption units in rural areas | 675 | 128 | 8 | 895 | 372 | 720 | 66 | 324 | 67 | 27 | 152 | 21 | 58 | 27 |
| Number per consumption units: | | | | | | | | | | | | | | |
| Persons | 24 | 24 | 26 | 29 | 26 | 24 | 26 | 24 | 33 | 36 | 33 | 36 | 33 | 33 |
| Large livestock | 27 | 24 | 38 | 27 | 38 | 24 | 38 | 24 | 55 | 76 | 55 | 76 | 55 | 55 |
| small livestock | 22 | 14 | 11 | 22 | 11 | 14 | 11 | 14 | 41 | 32 | 41 | 32 | 41 | 41 |
| Number of consumption units in built-up areas | 29 | - | - | 156 | - | 13 | 231 | 54 | 24 | - | 18 | - | - | - |
| Number of consumption units: | | | | | | | | | | | | | | |
| persons | 24 | - | - | 24 | - | 24 | 26 | 24 | 33 | - | 33 | - | - | - |
| large livestock | 4 | - | - | 4 | - | 4 | 4 | 4 | 5 | - | 5 | - | - | - |
| small livestock | 2 | - | - | 2 | - | 2 | 2 | 2 | 2 | - | 2 | - | - | - |
| WATER DEMAND/UNIT IN RURAL AREAS (litres/day): | | | | | | | | | | | | | | |
| persons (1) | 240 | 240 | 260 | 240 | 260 | 240 | 260 | 240 | 330 | 360 | 330 | 360 | 330 | 330 |
| large livestock (2) | 540 | 480 | 760 | 540 | 760 | 480 | 760 | 480 | 1,100 | 1,520 | 1,100 | 1,520 | 1,100 | 1,100 |
| small livestock (3) | 44 | 28 | 22 | 44 | 22 | 28 | 22 | 28 | 82 | 64 | 82 | 64 | 82 | 82 |
| Total demand/unit in rural areas (litres/day) | 824 | 748 | 1,042 | 824 | 1,042 | 748 | 1,042 | 748 | 1,512 | 1,944 | 1,512 | 1,944 | 1,512 | 1,512 |
| WATER DEMAND/UNIT IN RURAL AREAS (litres/day): | | | | | | | | | | | | | | |
| persons | 240 | - | - | 240 | - | 240 | 260 | 240 | 330 | - | 330 | - | - | - |
| large livestock | 80 | - | - | 80 | - | 880 | 80 | 80 | 100 | - | 100 | - | - | - |
| small livestock | 4 | - | - | 4 | - | 4 | 4 | 4 | 4 | - | 4 | - | - | - |
| Total demand/unit in built-up areas (litres/day) | 324 | - | - | 324 | - | 324 | 344 | 324 | 434 | - | 434 | - | 434 | 434 |
| TOTAL WATER DEMAND ($m^3$/day): | | | | | | | | | | | | | | |
| rural areas | 556.2 | 95.7 | 8.3 | 737.5 | 387.6 | 538.6 | 68.8 | 242.4 | 101.3 | 52.5 | 229.8 | 40.8 | 87.7 | 40.8 |
| built up areas | 9.4 | - | - | 50.5 | - | 4.2 | 79.5 | 17.5 | 10.4 | - - | 7.8 | - | - | - |
| Total | 565.6 | 95.7 | 8.3 | 788.0 | 387.6 | 542.8 | 148.3 | 259.9 | 111.7 | 52.5 | 237.6 | 40.8 | 87.7 | 40.8 |
| TOTAL CONSUMPTION ($m^3$/day) | 669.6 | | | 1,175.6 | | 691.1 | | 424.1 | | | 278.4 | | | |
| TOTAL CONSUMPTION during 12 hours (l/s) | 15.5 | | | 27.2 | | 16.0 | | 9.8 | | | 6.4 | | 2.0 | 0.9 |

| | 8 Tiyo | 9 Tiyo | 10 Tiyo | 11 Tiyo | 12 Tiyo | 13 Tiyo | 14 Tiyo | 14 Dghelu & Tiyo | 15 Tiyo | 15 Degelu & Tiyo | 16 Degelu & Tiyo | 17 Degelu & Tiyo | 18 Degelu & Tiyo | 19 Degelu & Tiyo |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| CONSUMPTION UNITS | | | | | | | | | | | | | | |
| Number of consumption units in rural areas | 10 | 67 | 90 | 39 | 46 | 56 | 109 | 75 | 58 | 168 | 280 | 307 | 119 | 116 |
| Number per consumption units: | | | | | | | | | | | | | | |
| persons | 33 | 33 | 33 | 33 | 33 | 33 | 33 | 26 | 33 | 26 | 26 | 26 | 26 | 26 |
| large livestock | 55 | 55 | 55 | 55 | 55 | 55 | 55 | 26 | 55 | 26 | 26 | 26 | 26 | 26 |
| small livestock | 41 | 41 | 41 | 41 | 41 | 41 | 41 | 27 | 41 | 27 | 27 | 27 | 27 | 27 |
| Number of consumption units in built-up areas | - | - | - | - | - | - | - | - | - | 77 | 12 | - | 19 | - |
| Number per consumption units: | | | | | | | | | | | | | | |
| persons | - | - | - | - | - | - | - | - | - | 26 | 26 | - | 26 | - |
| large livestock | - | - | - | - | - | - | - | - | - | 4 | 4 | - | 4 | - |
| small livestock | - | - | - | - | - | - | - | - | - | 2 | 2 | - | 2 | - |
| WATER DEMAND/UNIT IN RURAL AREAS (litres/day): | | | | | | | | | | | | | | |
| persons (1) | 330 | 330 | 330 | 330 | 330 | 330 | 330 | 260 | 330 | 260 | 260 | 260 | 260 | 260 |
| large livestock (2) | 1,100 | 1,100 | 1,100 | 1,100 | 1,100 | 1,100 | 1,100 | 520 | 1,100 | 520 | 520 | 520 | 520 | 520 |
| small livestock (3) | 82 | 82 | 82 | 82 | 82 | 82 | 82 | 54 | 82 | 54 | 54 | 54 | 54 | 54 |
| Total demand/unit in rural areas (litres/day) | 1,512 | 1,512 | 1,512 | 1,512 | 1,512 | 1,512 | 1,512 | 834 | 1,512 | 834 | 834 | 834 | 834 | 834 |
| WATER DEMAND/UNIT IN BUILT-UP AREAS (litres/day) | | | | | | | | | | | | | | |
| persons | - | - | - | - | - | - | - | - | - | 260 | 260 | - | 260 | - |
| large livestock | - | - | - | - | - | - | - | - | - | 80 | 80 | - | 80 | - |
| small livestock | - | - | - | - | - | - | - | - | - | 4 | 4 | - | 4 | - |
| Total demand/unit in built-up areas (litres/day) | - | 434 | 434 | - | - | - | - | - | - | 344 | 344 | - | 344 | - |
| TOTAL WATER DEMAND ($m^3$/day): | | | | | | | | | | | | | | |
| rural areas | 15.1 | 101.3 | 136.1 | 59.0 | 69.6 | 84.7 | 164.8 | 62.6 | 87.7 | 140.1 | 233.5 | 256.0 | 99.2 | 96.7 |
| built-up areas | - | - | - | - | - | - | - | - | - | 26.5 | 4.1 | - | 6.5 | - |
| Total | 15.1 | 101.3 | 136.1 | 59.0 | 69.6 | 84.7 | 164.8 | 62.6 | 87.7 | 166.6 | 237.6 | 256.0 | 105.7 | 96.7 |
| TOTAL CONSUMPTION ($m^3$/day) | | | | | | | 227.4 | | 254.3 | | | | | |
| TOTAL CONSUMPTION during 12 hours (l/s) | 0.3 | 2.3 | 3.2 | 1.4 | 1.6 | 2.0 | 5.3 | | 5.9 | | 5.5 | 5.9 | 2.4 | 2.2 |

| AREAS | 20 | | 21 | 22 | | 23 | | 24 | 25 | | 26 | | 27 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| WOREDAS | Dighelu & Tiyo | Lemu & Bilbilo | Lemu & Bilbilo | Lemu & Bilbilo | Munessa | Lemu & Bilbilo | Gedeb | Gedeb | Gedeb | Koffale | Gedeb | Koffale | Gedeb | Koffale |
| CONSUMPTION UNITS | | | | | | | | | | | | | | |
| Number of consumption units in rural areas | 139 | 53 | 195 | 1,241 | 141 | 314 | 230 | 260 | 217 | 105 | 155 | 10 | 32 | 260 |
| Number per consumption units: | | | | | | | | | | | | | | |
| persons | 26 | 24 | 24 | 24 | 22 | 24 | 28 | 28 | 28 | 29 | 28 | 29 | 28 | 29 |
| large livestock | 26 | 53 | 53 | 53 | 33 | 53 | 60 | 60 | 60 | 66 | 60 | 66 | 60 | 66 |
| small livestock | 27 | 42 | 42 | 42 | 29 | 42 | 44 | 44 | 44 | 22 | 44 | 22 | 44 | 22 |
| Number of consumption units in built-up areas | - | - | 13 | 163 | - | - | - | - | - | - | 39 | - | - | 10 |
| Number per consumption units: | | | | | | | | | | | | | | |
| persons | - | - | 24 | 24 | -- | - | - | - | - | - | 28 | - | - | 29 |
| large livestock | - | - | 4 | 4 | - | - | - | - | - | - | 4 | - | - | 5 |
| small livestock | - | - | 2 | 2 | - | - | - | - | - | - | 2 | - | - | 2 |
| WATER DEMAND/UNIT IN RURAL AREAS (litres/day); | | | | | | | | | | | | | | |
| persons (1) | 260 | 240 | 240 | 240 | 220 | 240 | 280 | 280 | 280 | 290 | 280 | 290 | 280 | 290 |
| large livestock (2) | 520 | 1,060 | 1,060 | 1,060 | 660 | 1,060 | 1,200 | 1,200 | 1,200 | 1,320 | 1,200 | 1,320 | 1,200 | 1,320 |
| small livestock (3) | 54 | 84 | 84 | 84 | 58 | 84 | 88 | 88 | 88 | 44 | 88 | 44 | 88 | 44 |
| Total demand/unit in rural areas (litres/day) | 834 | 1,384 | 1,384 | 1,384 | 938 | 1,384 | 1,568 | 1,568 | 1,568 | 1,654 | 1,568 | 1,654 | 1,568 | 1,654 |
| WATER DEMAND/UNIT IN BUILT-UP AREAS (litres/day): | | | | | | | | | | | | | | |
| persons | - | - | 240 | 240 | - | - | - | - | - | - | 280 | - | - | 290 |
| large livestock | - | - | 80 | 80 | - | - | - | - | - | - | 80 | - | - | 100 |
| small livestock | - | - | 4 | 4 | - | - | - | - | - | - | 4 | - | - | 4 |
| Total demand/unit in built-up areas (litres/day) | - | - | 324 | 324 | - | - | - | - | - | - | 364 | - | - | 394 |
| TOTAL WATER DEMAND ($m^3$/day): | | | | | | | | | | | | | | |
| rural areas | 115.9 | 73.4 | 269.9 | 1717.5 | 132.3 | 434.6 | 360.6 | 407.7 | 340.3 | 173.7 | 243.0 | 16.5 | 50.2 | 430.0 |
| built-up areas | - | - | 4.2 | 52.8 | - | - | - | - | - | - | 14.2 | - | - | 3.9 |
| Total | 115.9 | 73.4 | 274.1 | 1770.3 | 132.3 | 434.6 | 360.6 | 407.7 | 340.3 | 173.7 | 257.2 | 16.5 | 50.2 | 433.9 |
| TOTAL CONSUMPTION ($m^3$/day) | 189.3 - | | | 1,902.6 | | 795.2 | | - | 514.0 | | 273.7 | | 484.1 | |
| TOTAL CONSUMPTION during 12 hours (l/s) | 4.4 | | 6.3 | 44.0 | | 18.4 | | 9.4 | 11.9 | | 6.3 | | 11.2 | |

| AREAS / WOREDAS | 28 Gedeb | 28 Kof-fale | 29 Kof-fale | 30 Kof-fale | 31 Kof-fale | 32 Kof-fale | 33 Gedeb | 34 Kof-fale | 35 Kof-fale | 35 Mune-ssa | 36 Mune-ssa | 37 Mune-ssa | 38 Mune-ssa |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| CONSUMPTION UNITS | | | | | | | | | | | | | |
| Number of consumption units in rural areas | 42 | 178 | 305 | 227 | 361 | 397 | 44 | 142 | 62 | 106 | 20 | 102 | 10 |
| Number per consumption units: | 28 | 29 | 29 | 29 | 29 | 29 | 28 | 29 | 29 | 22 | 22 | 22 | 22 |
| persons | 28 | 29 | 29 | 29 | 29 | 29 | 28 | 29 | 29 | 22 | 22 | 22 | 22 |
| large livestock | 60 | 66 | 66 | 66 | 66 | 66 | 60 | 66 | 66 | 33 | 33 | 33 | 33 |
| small livestock | 44 | 22 | 22 | 22 | 22 | 22 | 44 | 22 | 22 | 29 | 29 | 29 | 29 |
| Number of consumption units in built-up areas | - | - | 17 | 107 | - | 20 | - | - | - | - | - | - | - |
| Number per consumption units: | | | | | | | | | | | | | |
| persons | - | - | 29 | 29 | - | 29 | - | - | - | - | - | - | - |
| large livestock | - | - | 5 | 5 | - | 5 | - | - | - | - | - | - | - |
| small livestock | - | - | 2 | 2 | - | 2 | - | - | - | - | - | - | - |
| WATER DEMAND/UNIT IN RURAL AREAS (litres/day) | | | | | | | | | | | | | |
| persons (1) | 280 | 290 | 290 | 290 | 290 | 290 | 280 | 290 | 290 | 220 | 220 | 220 | 220 |
| large livestock (2) | 1,200 | 1,320 | 1,320 | 1,320 | 1,320 | 1,320 | 1,200 | 1,320 | 1,320 | 660 | 660 | 660 | 660 |
| small livestock (3) | 88 | 44 | 44 | 44 | 44 | 44 | 88 | 44 | 44 | 58 | 58 | 58 | 58 |
| Total demand/unit in rural areas (litres/day) | 1,568 | 1,654 | 1,654 | 1,654 | 1,654 | 1,654 | 1,568 | 1,654 | 1,654 | 938 | 938 | 938 | 938 |
| WATER DEMAND/UNIT IN BUILT-UP AREAS (litres/day) | | | | | | | | | | | | | |
| persons | - | - | 290 | 290 | - | 290 | - | - | - | - | - | - | - |
| large livestock | - | - | 100 | 100 | - | 100 | - | - | - | - | - | - | - |
| small livestock | - | - | 4 | 4 | - | 4 | - | - | - | - | - | - | - |
| Total demand/unit in built-up areas (litres/day) | - | - | 394 | 394 | - | 394 | - | - | - | - | - | - | - |
| TOTAL WATER DEMAND ($m^3$/day); | | | | | | | | | | | | | |
| rural areas | 65.9 | 294.4 | 504.5 | 375.5 | 597.1 | 656.6 | 69.0 | 234.9 | 102.5 | 99.4 | 18.8 | 95.7 | 9.4 |
| built-up areas | - | - | 6.7 | 42.2 | - | 7.9 | - | - | - | - | - | - | - |
| Total | 65.9 | 294.4 | 511.2 | 417.7 | 597.1 | 664.5 | 69.0 | 234.9 | 102.5 | 99.4 | 18.8 | 95.7 | 9.4 |
| TOTAL CONSUMPTION ($m^3$/day) | 360.3 | | | | | 733.5 | | | 201.9 | | | | |
| TOTAL CONSUMPTIONS during 12 hours (l/s) | 8.3 | | 11.8 | 9.7 | 13.8 | 17.0 | | 5.4 | 4.7 | | 0.4 | 2.2 | 0.2 |

| | 39 Munessa | 40 Munessa | 41 Munessa | 42 Munessa | 43 Munessa | 44 Munessa | 44 Lemu & Bilbilo | 44 Deghelu & Tiyo | 45 Munessa | 46 Munessa | 46 Dighelu & Tiyo | 46 Tiyo | 46 Zuai & Dugda | 47 Zuqi & Dugda | 48 Zuai & Dugda |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| CONSUMPTION UNITS | | | | | | | 186 | | | | 702 | | | | |
| Number of consumption units in rural areas | 35 | 67 | 36 | 92 | 446 | 89 | 29 | 68 | 123 | 106 | 135 | 88 | 373 | 256 | 58 |
| Number per consumption units: | | | | | | | | | | | | | | | |
| persons | 22 | 22 | 22 | 22 | 22 | 22 | 24 | 26 | 22 | 22 | 26 | 33 | 36 | 36 | 36 |
| large livestock | 33 | 33 | 33 | 33 | 33 | 33 | 53 | 26 | 33 | 33 | 26 | 55 | 76 | 76 | 76 |
| small livestock | 29 | 29 | 29 | 29 | 29 | 29 | 42 | 27 | 29 | 29 | 27 | 41 | 32 | 32 | 32 |
| Number per consumption units in built-up areas | 14 | - | 5 | - | 82 | - | - | 10 | - | - | - | 24 | 31 | - | - |
| Number per consumption units: | | | | | | | | | | | | | | | |
| persons | 22 | - | 22 | - | 22 | - | - | 26 | - | - | - | 33 | 36 | - | - |
| large livestock | 4 | - | 4 | - | 4 | - | - | 4 | - | - | - | 5 | 6 | - | - |
| small livestock | 2 | - | 2 | - | 2 | - | - | 2 | - | - | - | 2 | 3 | - | - |
| WATER DEMAND/UNIT IN RURAL AREAS (litres/day) | | | | | | | | | | | | | | | |
| persons (1) | 220 | 220 | 220 | 220 | 220 | 220 | 240 | 260 | 220 | 220 | 260 | 330 | 360 | 360 | 360 |
| large livestock (2) | 660 | 660 | 660 | 660 | 660 | 660 | 1,060 | 520 | 660 | 660 | 520 | 1,100 | 1,520 | 1,520 | 1,520 |
| small livestock (3) | 58 | 58 | 58 | 58 | 58 | 58 | 84 | 54 | 58 | 58 | 54 | 82 | 64 | 64 | 64 |
| Total demand/unit in rural areas (litres/day) | 938 | 938 | 938 | 938 | 938 | 938 | 1,384 | 834 | 938 | 938 | 834 | 1,512 | 1,944 | 1,944 | 1,944 |
| WATER DEMAND/UNIT IN BUILT-UP AREAS (litres/day) | | | | | | | | | | | | | | | |
| persons | 220 | - | 220 | - | 220 | - | - | 260 | - | - | - | 330 | 360 | - | - |
| large livestock | 80 | - | 80 | - | 80 | - | - | 80 | - | - | - | 100 | 120 | - | - |
| small livestock | 4 | - | 4 | - | 4 | - | - | 4 | - | - | - | 4 | 6 | - | - |
| Total demand/unit in built-up areas (litres/day) | 304 | - | 304 | - | 304 | - | - | 344 | - | - | - | 434 | 486 | - | - |
| TOTAL WATER DEMAND ($m^3$/day): | | | | | | | | | | | | | | | |
| rural areas | 32.8 | 62.8 | 33.8 | 86.3 | 418.3 | 83.5 | 40.1 | 56.7 | 115.4 | 99.4 | 112.6 | 133.1 | 725.1 | 497.7 | 112.8 |
| built-up areas | 4.3 | - | 1.5 | - | 24.9 | - | - | 3.4 | - | - | - | 10.4 | 15.1 | - | - |
| Total | 37.1 | 62.8 | 35.3 | 86.3 | 443.2 | 83.5 | 40.1 | 60.1 | 115.4 | 99.4 | 112.6 | 143.5 | 740.2 | 497.7 | 112.8 |
| TOTAL CONSUMPTION ($m^3$/day) | | | | | | | 183.7 | | | | 1,095.7 | | | | |
| TOTAL CONSUMPTION during 12 hours (l/s) | 0.9 | 1.5 | 0.8 | 2.0 | 10.3 | | 4.3 | | 2.7 | | 25.4 | | | 11.5 | 2.6 |

| A R E A S | 49 | | 50 | | 51 | 52 |
|---|---|---|---|---|---|---|
| W O R E D A S | Zuai & Dugda | Hetosa | Hetosa | Dhera | Dhera | Sire |
| CONSUMPTION UNITS | | | | | | |
| Number of consumption units in rural areas | 63 | 22 | 193 | 269 | 104 | 193 |
| Number per consumption units: | | | | | | |
| persons | 36 | 24 | 24 | 26 | 26 | 24 |
| large livestock | 76 | 24 | 24 | 38 | 38 | 27 |
| small livestock | 32 | 14 | 14 | 11 | 11 | 22 |
| Number of consumption units in built-up areas | - | - | - | - | 115 | - |
| Number per consumption units: | | | | | | |
| persons | - | - | - | - | 26 | - |
| large livestock | - | - | - | - | 4 | - |
| small livestock | - | - | - | - | 2 | - |
| WATER DEMAND/UNIT IN RURAL AREAS (litres/day): | | | | | | |
| persons (1) | 360 | 240 | 240 | 260 | 260 | 240 |
| large livestock (2) | 1,520 | 480 | 480 | 760 | 760 | 540 |
| small livestock (3) | 64 | 28 | 28 | 22 | 22 | 44 |
| Total demand/unit in rural areas (litres/day) | 1,944 | 748 | 748 | 1,042 | 1,042 | 824 |
| WATER DEMAND/UNIT IN BUILT-UP AREAS (litres/day): | | | | | | |
| persons | - | - | - | - | 260 | - |
| large livestock | - | - | - | - | 80 | - |
| small livestock | - | - | - | - | 4 | - |
| Total demand/unit in built-up areas (litres/day) | - | - | - | - | 344 | - |
| TOTAL WATER DEMAND ($m^3$/day): | | | | | | |
| rural areas | 122.5 | 16.5 | 144.4 | 280.3 | 108.4 | 159.0 |
| built-up areas | - | - | - | - | 39.6 | - |
| Total | 122.5 | 16.5 | 144.4 | 280.3 | 148.0 | 159.0 |
| TOTAL CONSUMPTION ($m^3$/day) | 139.0 | | 424.7 | | 148.0 | |
| TOTAL CONSUMPTION during 12 hours (l/s) | 3.2 | | 9.8 | | 3.4 | 3.7 |

Footnotes to table 18

(1) 1 person: 10 litres/day
(2) large livestock: 20 litres/day
(3) small livestock: 2 litres/day

In table 19 (p. 76 ) and on the map fig. 24 (p. 77 ) the summarized consumption of the water-supply areas is compared to the available quantity of water during the dry season. Southeast of Mount Kakka the available water quantity is less than the demand and the people have to move to other places during the dry season. In areas south of Mount Kakka & northwest of the Munessa forest, natural water supplies and present demand of water are equal. On the plateau west of Chilalo and round the Munessa - Kakka Mountains there are large areas with a small surplus of water available for consumption within the present walk distances to perennial rivers.

## 4.3 Demand for water in the future

It is, of course, difficult to predict the demand of water in the future. A doubling of the present very small consumption can be expected within some 10 years. There are three resons of this estimate.

With an annual grouth rate of 2.5% the population will increase by more than 50 % during 10 years.
Social development will increase the human consumption of water.
Cross-breed cattle introduced by CADU require twice as much water per head as do the unimported indigneous Arussi cattle.

On the map fig. 25 (p. 78) a presumed doubled water consumption is compared to the available water quantities in perennial rivers and lakes. The rivers as a water supply will not suffice in large parts of the awraja. Those areas which at present have a small surplus of water (the map fig. 24, p. 77), will not have enough water. Only in areas adjacent to large rivers and lakes will the water quantity be sufficient, but the walk distances will often be large (8-15 km). It is evident that the present natural water supplies must be complemented with artificial supplies in a near future.

Table 19 Present total water consumption

| No. of area | River, spring or lake | Present consumption l/s (12 h/day) | Present quantity remaining available l/s |
|---|---|---|---|
| 1 | Geleta | 27.2 | 200 - 111 = 89 |
| 2 | Upper Geleta | 15.5 | 179-90-21 = 68 |
| 3 | Wedesha | 16.0 | 21 |
| 4 | Gonde | 9.8 | 6.0 |
| 5 | Simba | 6.4 | 7.2 |
| 6 | Wolchessa | 2.0 | 0.2 |
| 7 | Anko | 0.9 | 0.1 |
| 8 | Burkito springs | 0.3 | 100 |
| 9 | Kompolcha | 2.3 | 0.5 |
| 10 | Dusha | 3.2 | 0.1 |
| 11 | Ellena | 1.4 | 1.0 |
| 12 | Bilalu | 1.6 | 1.0 |
| 13 | Alaltu | 2.0 | 1.0 |
| 14 | Katjama | 5.3 | 3.0 |
| 15 | Sagure/Alaltu | 5.9 | 3.0 |
| 16 | Ashabaka | 5.5 | 368 |
| 17 | Temala | 5.9 | 204 |
| 18 | Gusha | 2.4 | 140 |
| 19 | Weshe | 2.2 | 70 |
| 20 | Sida | 4.4 | 170 |
| 21 | Sirba | 6.3 | 10 |
| 22 | Upper Katar | 44.0 | 75 |
| 23 | Tarkaro - Kakaoa | 18.4 | 1 |
| 24 | Wabe Shebelle | 9.4 | large |
| 25 | Debara | 11.9 | 2 |
| 26 | Asassa | 6.3 | 1,145 |
| 27 | Wekentra | 11.2 | 1 |
| 28 | Middle Wabe Shebelle | 8.3 | large |
| 29 | Ashoka | 11.8 | 10 |
| 30 | Totalamo | 9.7 | 50 |
| 31 | Upper Wabe Shebelle | 13.8 | large |
| 32-33 | Angelo | 17.0 | 5 |
| 34 | Guracha | 5.4 | 5 |
| 35 | Gadamso | 4.7 | 5 |
| 36 | Lepis | 0.4 | 1 |
| 37 | Rajebo | 2.2 | 8 |
| 38 | Guna | 0.2 | 3 |
| 39 | Makanissa | 0.9 | 1 |
| 40 | Dalali | 1.5 | 1 |
| 41 | Matana | 0.8 | 0.5 |
| 42 | Taji | 2.0 | 0.5 |
| 43 | Karsa | 10.3 | 0 |
| 44 | Middle Katar | 4.3 | 456 |
| 45 | Lake Langano | 2.7 | large |
| 46 | Katar | 25.4 | 1,550-20=1,530 |
| 47 | Lake Zuai | 11.5 | large |
| 48 | " " | 2.6 | " |
| 49 | Koka Dam (Lake Galilea) | 3.2 | " |
| 50 | Wonji irrigation channel | 9.8 | " |
| 51 | Upper Awash | 3.4 | " |
| 52 | Lower Awash | 3.7 | " |

"large" = quantity not measured but large improportion to present consumption


PRESENT WATER RESOURCES
WITHIN WALK DISTANCES
Good
Less good
Poor
Inadequate
Barren or wooded areas
Fig 24
0
10 km
Sept. 1973


WATER RESOURCES AFTER
DOUBLED CONSUMPTION
Good
Less good
Poor
Inadequate
0
10 km
Sept. 1973

Fig. 25

# 5 RESEARCH ON WATER SUPPLIES

## 5.1 General considerations

The rivers commonly are eroded into deep valleys. Thus piped water, supplied by gravity, demands long distances and large costs. As the perennial rivers are few and have limited water quantities, dams for ponds must be constructed. In areas without rivers the ground water or rainwater is the only water resource.

The basis for developing water supplies must be in line with the economic and technical resources of the awraja. All expensive and complicated constructions are therefore excluded. Engines should be avoided, at least in rural areas. From river sources, water supplies by gravity are better than using pumps. At drilled wells hand pumps are preferable. The present ponds, dams and hand dug wells must have better designs. For isolated households, rain-water can be collected on roofs or on the ground.

The following water sources and storage methods have been considered:

| | |
|---|---|
| Ground water | Dug wells |
| | Drilled wells |
| Rainwater | Household wells |
| | Tanks |
| Periodic rivers | Earth dams |
| Periodic or perennial rivers | Ponds, in clay or sealed with plastic sheet |
| Perennial rivers | piped water |

## 5.2 Dug wells

### 5.2.1 Present situation of dug wells as water supply

Dug wells already exist in areas with a high ground water table.

In 1967 I pointed out that ground water would probably be found at a depth of about 30 metres at Abura northeast of Lake Zuai. Since then the people have dug four wells, reaching ground water between 21 and 37 m.

At the village of Djila, southeast of Lake Zuai, there are two wells dug to a depth of 5 m; the water table corresponds to the level of the lake.

At the town of Kofale in the southwestern part of the awraja there are several wells reaching ground water 4-10 m below the surface. Also north and east of Kofale it is possible to find ground water on the plateau in a permeable layer on the bedrock. At and north of Gobe water is available in wells 6-9 m deep; also at Kore 12 m deep.

The dug wells are simple. The diameter is only 80-90 cm. In the Abura and Kofale areas there is often a cover and a four-sided lining of wood in the upper part of the well to prevent erosion and caving in. Sometimes the wells are deepened when they dry up. As there is no lining at the bottom at and below the water table the wells usually cave in at this level after some time.

In some areas the people have employed professional well-diggers in attempts to find ground water down to a depth of 60 m, e.g. on a farm west of Ethaya and at the village of Weraba in the Rift Valley.

### 5.2.2 Improved design

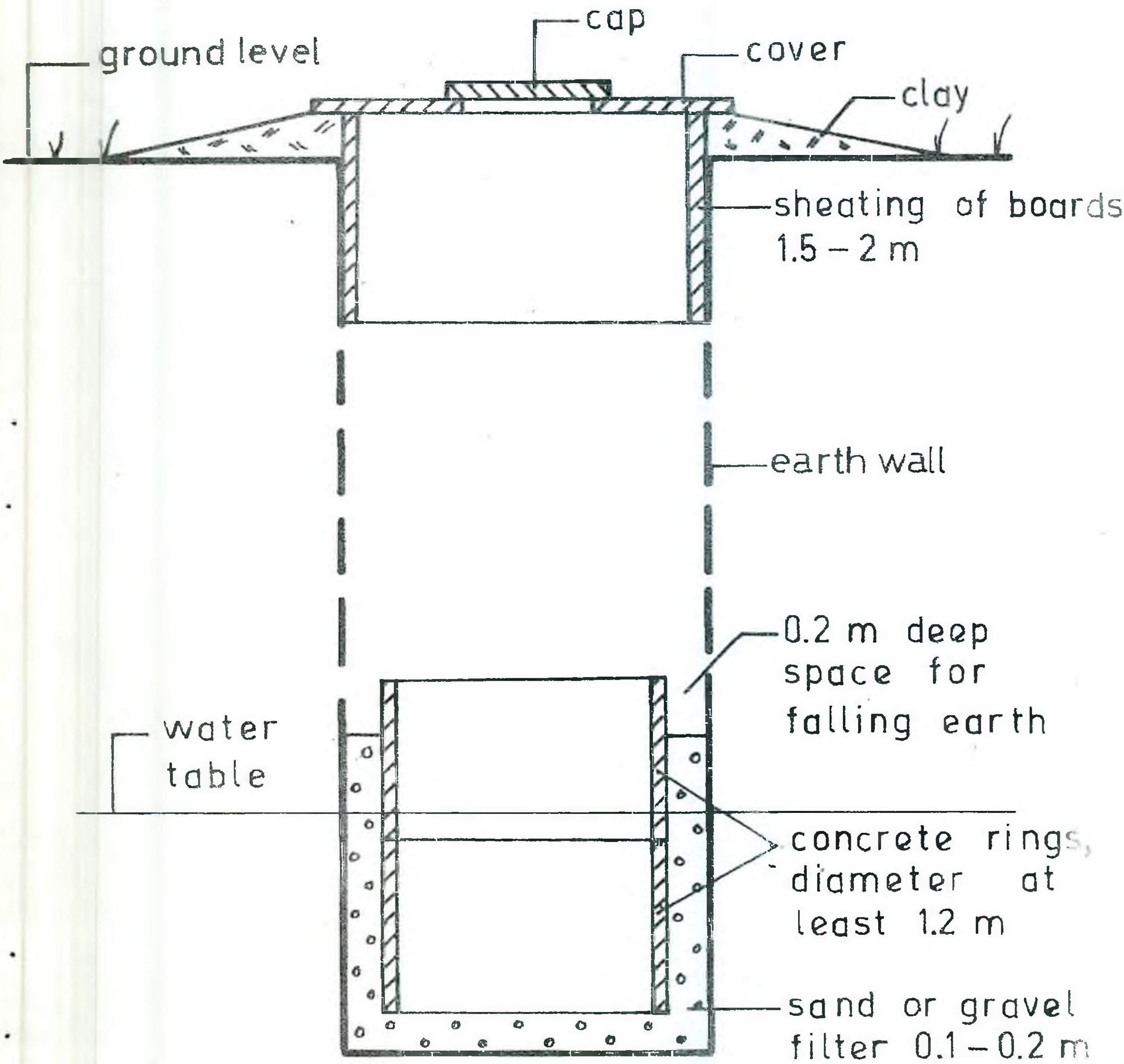
The diameter of the well should be large enough to make a lining, e.g. concrete rings. Inside the fings it is possible to dig below the water table and the darth walls do not cave in. As the yield of the well is proportional to the surface of the well in the aquifer, the diameter ought to be as large as possible.

A design is shown on fig. 26 (p. 81). A conical collar off trampled clay (or clay with sand) is made up on the ground round the well to prevent polluted surface water flowing in. If the earth walls seem stable, it is enough to have a vertical sheathing of boards for the uppermost 1.5-2 m and a built wall from the bottom of the well up to 1-1.5 m above the highest water level in the well. Between the built wall and the dug earth wall of the well, a sand or gravel filter is needed to collect and clean the water. On the bottom of the well a gravel filter is needed, if the bottom is not bedrock.

The concrete rings can be replaced by a brick wall or by stone masonry. If the earth walls of the well are not stable, the well has to be completely lined with a built wall.

Fig.26

# DESIGN OF DUG WELL



### 5.2.3 Yield and quality of water in dug wells

The yield is dependent on the thickness and the permeability of the water-bearing strata. The material of the aquifer is often a fine sand, and the yield will therefore be rather low in a dug well of ordinary size (diameter 1-2 m). Often, However, a dug well has a sufficient yield for a few families and their livestock.

The chemical quality has been assessed of the water from some dug wells at Abura and Djila (table 14, p. 51). The water is acceptable according to international standards for drinking water, but the high fluoride concentration of the Djila water (3.4 ppm) makes it unwise to use only this water for protracted periods.

### 5.2.4 Cost of dug wells

The construction cost of a well at Abura, 37 m deep was Eth. $ 150:-.
The 60 m deep well at Weraba costed Eth. $3:- per metre.
The construction time was 3 months.

CADU has not yet constructed any wells dug by hand. Such wells, however, are to be recommended in areas with a water table of lesser depth than about 20 m.

## 5.3 Drilled wells

### 5.3.1 Drilled wells as water supply

Of 52 boreholes so far dilled (table 13, p. 40-41), 12 boreholes (23%) have very poor or no yield of water. This percentage does not apply to all parts of the awraja. In the low plains of the Rift and Wabe Shebelle valleys no well has failed. On the plateau of Ethaya and the connected low land of Dodota, and on the Luckuche Plain southwest of the Katar River, 100% have failed. In the other parts of the awraja 10% of the boreholes have failed.

The boreholes have an average depth of 111 m, minimum 44 and maximum 266 m. The water-bearing wells have an average depth of 90 m and an average depth to the water table of 67 m. The depth of drilled wells is considerable, if compared to those in other parts of the world with statistics on

wells, e.g. Sweden and USA (fig. 27, p.84), (1).
The yield of drilled wells has been determined by test pumping (table 13, p. 39-40). In rural areas without engine power, however, the raising facilities put a limit on the delivery (see next chapter).

The quality of the water from the drilled wells is good both for consumption and irrigation purposes, but the quantities available for irrigation are probably limited.

5.3.2 Cost of drilled wells

During four years of drilling the costs have been studied in detail, not only to control the drilling work but also to establish the costs of drilling water wells. The detailed tables of the 2-year reports have been partly recalculated and then summarized in table 20 (p. 85).

"Travel and transportation" includes materials, water and crew every day or week, purchase of goods from Addis Ababa, samples, etc. The cost of the pick-up has been $0.30/km that of the lorry $0.45/km.

To find the "personnel" costs for every borehole, the daily cost for all employeds has been multiplied by the number of days, **including transportation**, drilling and test pumping.

The cost of the Swedish foreman (superintendant) has been high, but the low drilling cost per metre has shown the value of a trained drilling foreman. During the two last years he has worked more as a supervisor. As well as supervising the drilling, he has usually carried out other work, such as the construction of a small extra drilling rig for test pumping and inserting pipes for pumps, long-duration tests of yield, contracts with landowners, repairs and maintenance.

The drilling work is run in two shifts. After the introduction of a bonus of Eth. $0.70 per drilled metre to be shared by the crew, the cost per metre for comparable boreholes diminished.

The total cost of consumed cable lines, electrodes, filters, etc, has been distributed between boreholes in proportion to the drilled depths.

(1) regarding Sweden and USA the figures are from P.E. Troften: Utnyttjande av grundvatten i harda formationer, Atlas Copco Tryckluft 3,1972.

Distribution of depths of wells drilled in USA, SWEDEN and ETHIOPIA

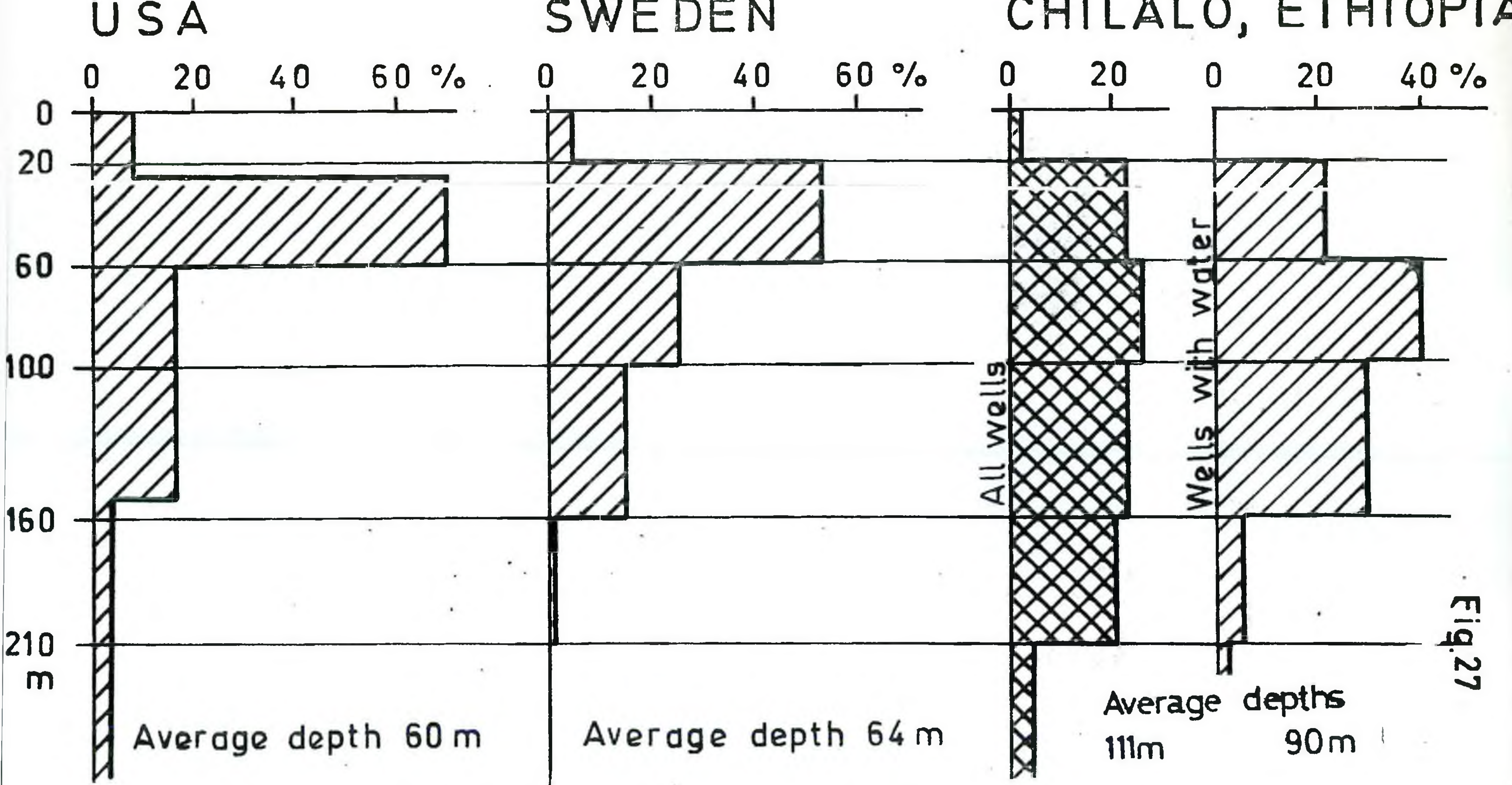



Fig.27

The depreciation cost of a complete cable-tool rig covers everything needed for drilling to a depth of about 300 metres; Eth. $39,000:- in 1968. 'Extra equipment' for which there is a depreciation cost includes a generator set; a welding plant and a grinding machine! 'Camp and boarding' includes 1 tent, 2 plastic sheds, 2 tarpulins, 5 bed sets and 1 kitchen set. The total cost of a cable tool rig with extra equipment and camping gear etc. is Eth. $48,650:-. Depreciation is calculated on the basis of a complete writing-off after 6 years. The depreciation cost every year has been distributed to the different boreholes in relation to the number of days spent drilling. If a drilling spread over two calendar years, the boreholes costs have not been so split: the number of days during the several calendar year added to the first year. A "borehole year" thus can have a little more or alless than 365 days.

The item construction materials' is the casing' this has been left in those boreholes where a ground water capacity is stated.
A cost per metre on a business-like basis ought to include depreciation of the stock, and central administration.

The practice is now to have a stock of drilling equipment for at least one year ahead at a cost of at least Eth. $50,000:- per rig. In table 20 an interest rate calculation at 10% has not always given Eth. $5,000; this is because the interest applies to a number of boreholes performed during periods that are not exactly 365 days. "Administration cost" is 20% of the total costs for drilling plus identifiable administrative costs.

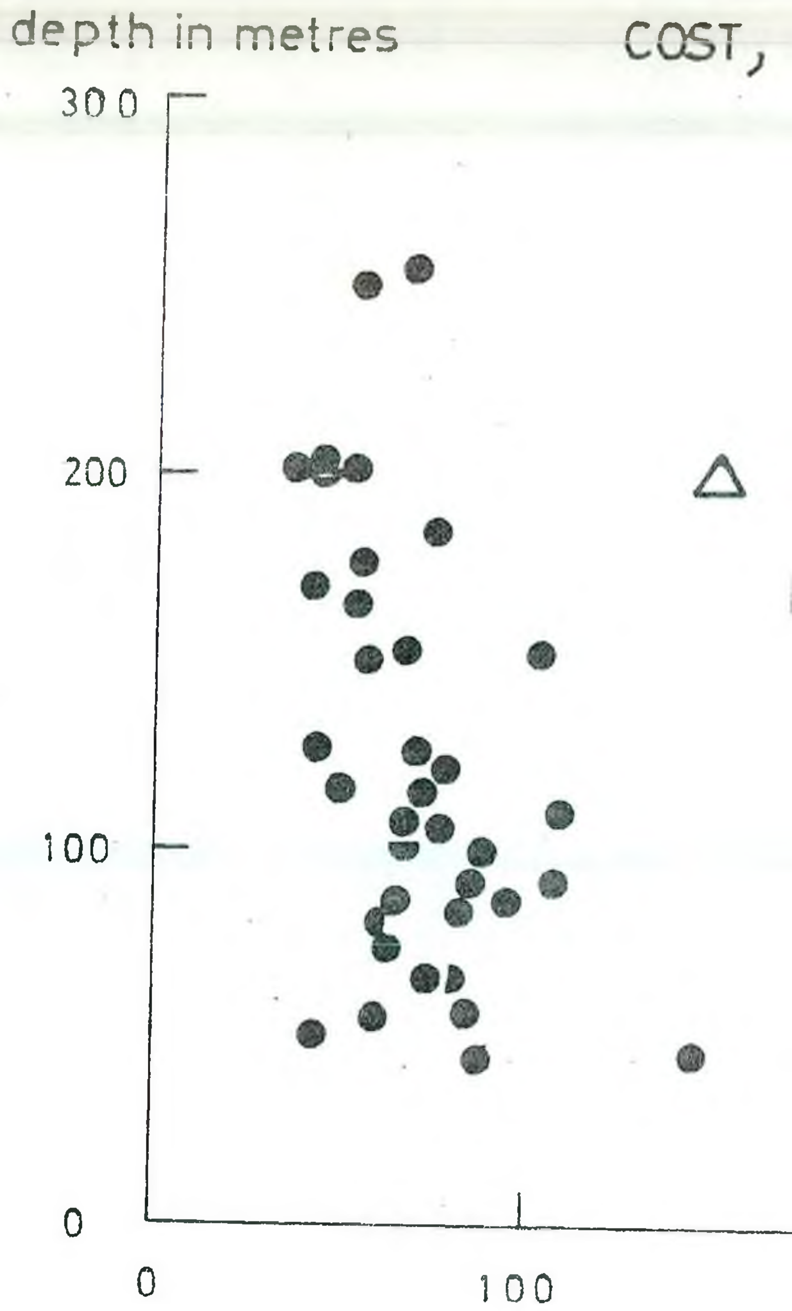
As shown in table 20 (p. 85) the drilling cost of a borehole has been Eth. $48:-/metre; with casing construction for a well included, Eth. $53 per metre; with central administration, etc. included, Eth. $72 per metre.

This cost for drilling wells is low compared to corresponding drilling work offered or carried out in Ethiopia during 1967 (fig. 28). The CADU costs per metre are about 1/3 of the prices of other organizations.

Table 20, Costs of drilling water wells - Eth.$

Annual averages of cost per well

| TRAVEL AND TRANSPORTATION | 1st year | 2nd year | 3rd year | 4th year rig 1 | 4th year rig 2 | Average of 4 years |
|---|---|---|---|---|---|---|
| Pick-up | 1,002 | 1,787 | 726 | 484 | 321 | 877 |
| Lorry | 75 | 131 | 73 | 0 | 23 | 59 |
| Tractor (hire) | 0 | 0 | 94 | 105 | 0 | 49 |
| PERSONNEL | | | | | | |
| Foreman (exp. staff) | 2,243 | 2,257 | 993 | 680 | 1,100 | 1,433 |
| Asst. foreman | 545 | 547 | 487 | 899 | 415 | 480 |
| 3 workers | 322 | 322 | 286 | 227 | 437 | 306 |
| Guard, extra asst. | 176 | 113 | 131 | 89 | 119 | 124 |
| Bonus | 0 | 114 | 190 | 118 | 167 | 112 |
| Allowances | 532 | 63 | 230 | 317 | 245 | 288 |
| CONSUMPTION | | | | | | |
| Diesel | 96 | 138 | 153 | 82 | 90 | 112 |
| Petrol | 45 | 40 | 97 | 34 | 33 | 51 |
| Lubricant oil | 63 | 38 | 72 | 44 | 46 | 53 |
| Cement | 4 | 20 | 13 | 16 | 6 | 12 |
| Drive shoes | 24 | 0 | 0 | 0 | 0 | 5 |
| Cable line | 118 | 81 | 198 | 158 | 297 | 158 |
| Electrodes, filters, etc. | 148 | 167 | 238 | 190 | 356 | 205 |
| DEPRECIATIONS | | | | | | |
| Cable tool rig ($39,000) | 931 | 793 | 846 | 631 | 975 | 810 |
| Extra equipment ($6,000) | 150 | 128 | 137 | 102 | 158 | 131 |
| Camp, boarding, etc($3,350) | 80 | 68 | 73 | 54 | 84 | 70 |
| Interest 10% of ($48,650) | 696 | 594 | 633 | 472 | 730 | 606 |
| Total for drilling | 7,236 | 7,416 | 5,668 | 4,201 | 5,610 | 5,935 |
| Cost per metre borehole | 50 | 45 | 45 | 54 | 50 | 48 |
| CONSTRUCTION MATERIALS | | | | | | |
| Casing 4" | 0 | 0 | 17 | 21 | 0 | 9 |
| Casing 6" | 620 | 306 | 387 | 437 | 233 | 424 |
| Casing 8" | 52 | 77 | 340 | 218 | 205 | 180 |
| Total for drilling & constr. | 7,932 | 7,799 | 6,411 | 4,876 | 6,047 | 6,548 |
| Cost per metre well | 57 | 48 | 51 | 62 | 54 | 53 |
| STOCK-HOLDING AND ADMINISTRATION COSTS PER YEAR | | | | | | |
| Interest 10% of stock value | 718 | 1,535 | 650 | 485 | 300 | 623 |
| Administration 20% | 1,730 | 1,767 | 1,412 | 1,072 | 1,269 | 1,434 |
| Total for drilling, constraction stock-holding & administration | 10,380 | 10,601 | 8,473 | 6,433 | 7,316 | 8,605 |
| Cost per metre well | 72 | 66 | 67 | 82 | 64 | 72 |



depth in metres
COST,
300
200
100
0
0
100

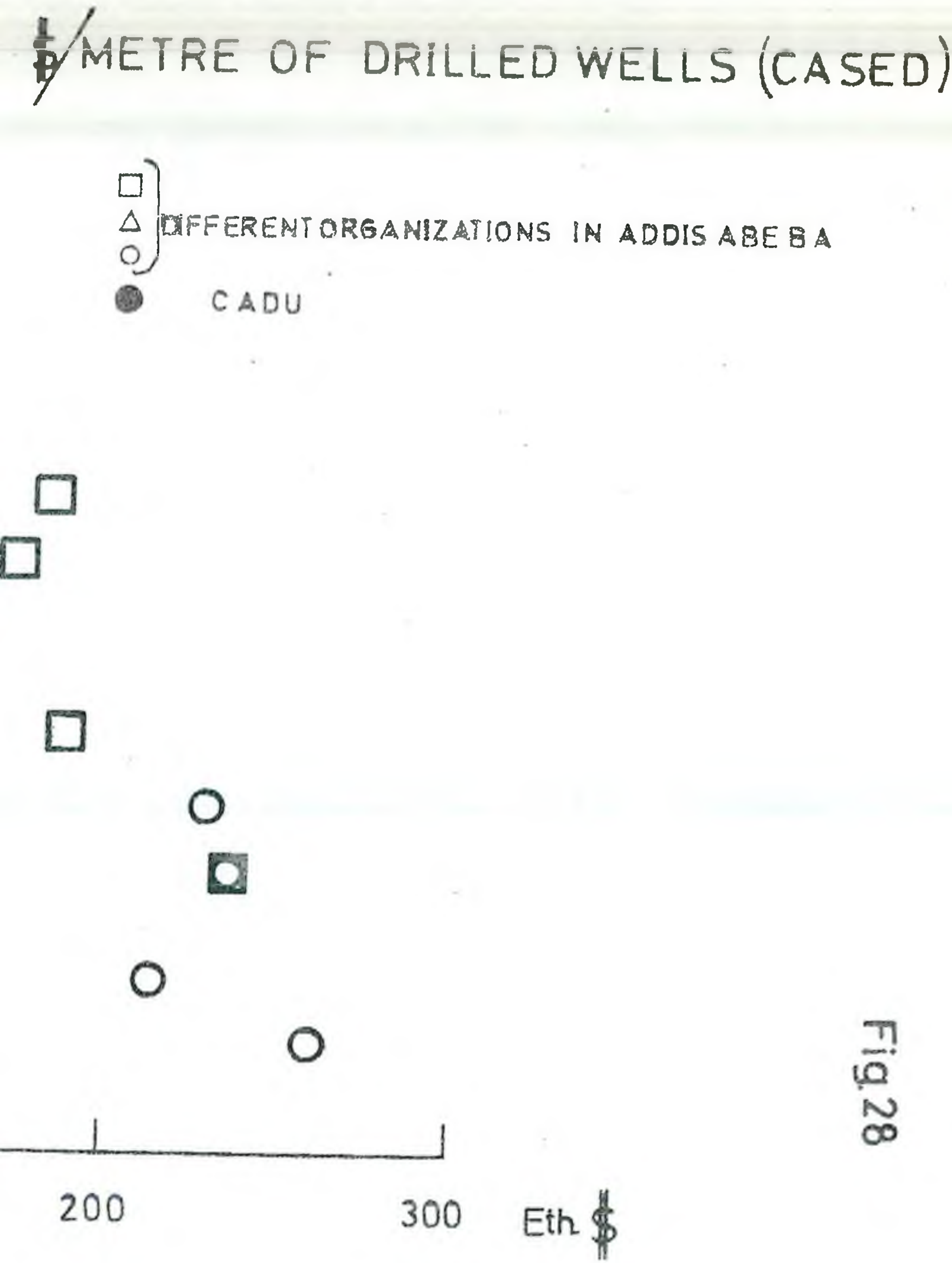

L/D/METRE OF DRILLED WELLS (CASED)
DIFFERENT ORGANIZATIONS IN ADDIS ABEBA
CADU
200
300
Eth. $

Fig. 28

The low borehole costs have several explanations: trained management and good organization; planning of work in advance and with consideration to climatic seasons; work within a restricted area; large stock preventing delays; repairs and maintenance carried out on the drilling site; use of pick-up instead of lorry; bonus system favouring rapid moves to next drilling site and 12 hours daily working time; low costs for administration and no profit element.

5.3.3 Different water raising facilities and their costs. In rural areas piston pumps are preferable, working at depths around or less than 100 m. In 73% of the water-bearing wells the depth is less than 100 m. For raising the water in such wells different means of powering have been tried: by hand, by draught-animal and by wind.

5.3.3.1 Hand pump

5.3.3.1.1. Construction and cost

A heavy model of hand pump with a long level has been used to raise water from large depths (photo 2 in Appendix,p.164). The pump cylinders have been bought, but otherwise the pumps have been manufactured in the section's workshop during times when there has been no repair or maintenance work.

The fixed costs of pump equipment in a cased well have been: 70 cm x 1¾" pump cylinder, $225; hand pump materials, $150; manufacturing work, $25; installation work, $110; concrete and sand to fix the pump in the ground, $25; total Eth. $535:-. Increased by the variable costs that depend on the depth of the pump cylinder and piston, the the prices of a hand pump are:

| depth in metres | fixed costs | 2½"pipe | pump rod ½" | total Eth.$ |
|---|---|---|---|---|
| 10 | 535 | 60 | 10 | 605 |
| 20 | 535 | 120 | 20 | 675 |
| 30 | 535 | 180 | 30 | 745 |
| 40 | 535 | 240 | 40 | 815 |
| 50 | 535 | 300 | 50 | 885 |
| 60 | 535 | 360 | 60 | 955 |
| 70 | 535 | 420 | 70 | 1,025 |
| 80 | 535 | 480 | 80 | 1,095 |
| 90 | 535 | 540 | 90 | 1,165 |
| 100 | 535 | 600 | 100 | 1,235 |

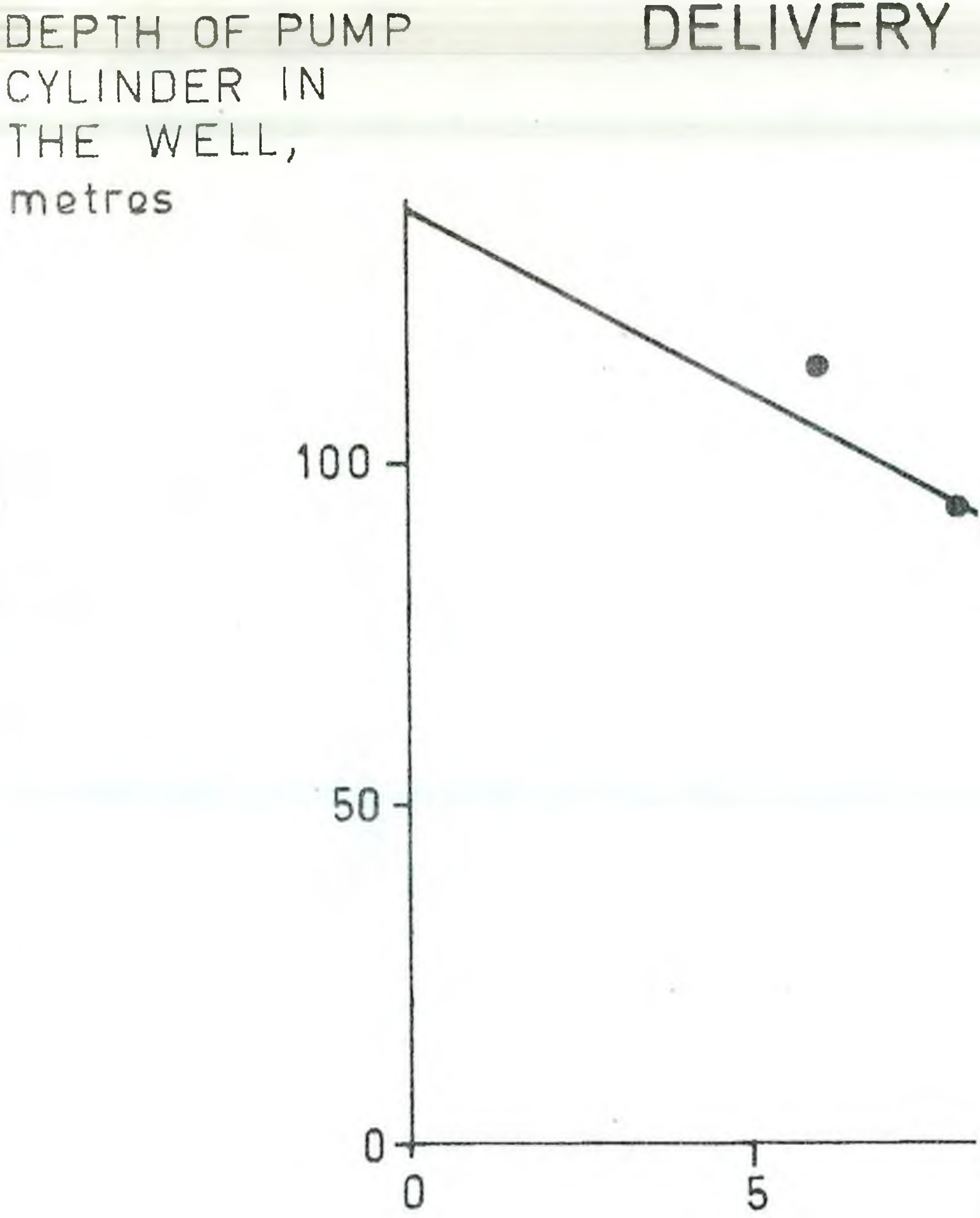
The total price thus shown does not include the transport cost, $0.30/km.

5.3.3.1.2 Water delivery of hand pump

The delivery is dependent on the pumping depth as is shown on fig. 29 (p. 89) showing eight tests. On the test of the deepest borehole 115 m, the delivery was 0.1 l/s.

The water consumption from 14 drilled wells with hand pumps has been measured (fig 21, p. 64). As an average the extraction from the wells has varied between 130 and 200 l/h, but there are local differences depending, among other things, on the size of the area and population supplied by the well. In the Asassa area the maximum consumption was 180 l/h, in the Abura area 450 l/h, corresponding to 0.05 and 0.1 l/s respectively from the wells measured.

# DELIVERY



AS FUNCTION OF DEPTH

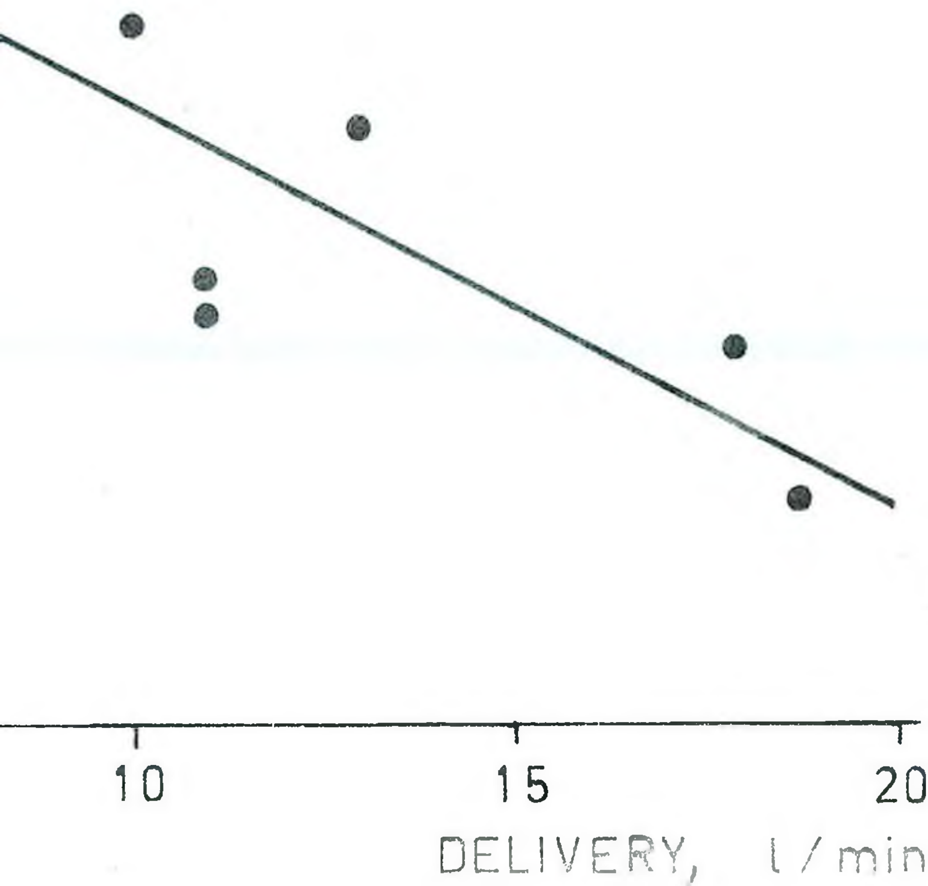



Fig.29

5.3.3.2 Ox-powered pump

For a more continous pumping the hand pump can be replaced by an ox-powered pump. The ordinary 0.7m pump cylinder is unsuitable and has been replaced by a cylinder 2 m long. The driving gear (fig. 30 p. 90 ) has been designed by Mr. T.E. Cobbald at CADU's Agricultural Engineering Section. Regarding details of the design and the costs I refer to his CADU report: "CADU ox-powered water pump".

In the drilled well No. 52, with a water table 53m below the ground, the rotation speed is around 4 revolutions/minute and the delivery 7 l/ stroke, giving almost 0.5 l/s. This is about double that of a hand pump.

The costs of the ox-powered pump, constructed by the Water Development Section, have been: pump cylinder 2½" x 2 m, Eth. $450:-; pump materials, $400; manufacturing work, $200; installation work, $145; concrete, $120; total Eth. $ 1,315. This is Eth. $430 more than the cost of a hand pump (see p. 88 ).

A cattle through has been estimated to cost Eth. $310:-.

5.3.3.3 Wind-powered pump

In practice the windmill requires an extension of the piston rod of the ordinary hand pump (fig. 31, p. 91). The rod is moved by vanes on a shaft on the top of a tower exposed to wind from any direction. To power a pump a minimum wind speed of around 2.5 m/s is required. Such a wind speed extends a flag and keeps the leaves and small twigs of threes in constant motion. Some pumping data of the Australian 'COMET' windmill are given in table 21 (p. 92 ).

## OX-POWERED PUMP

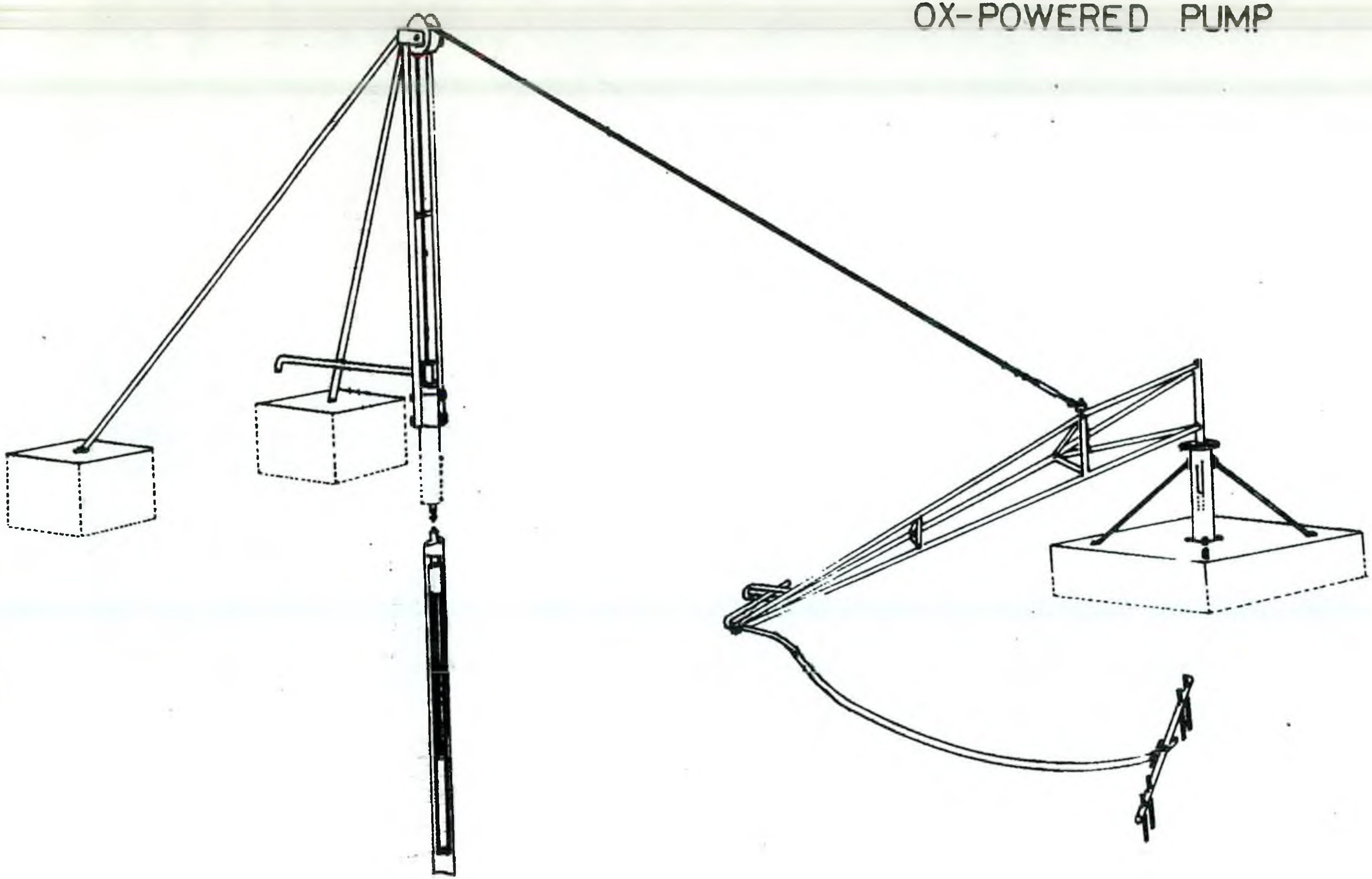
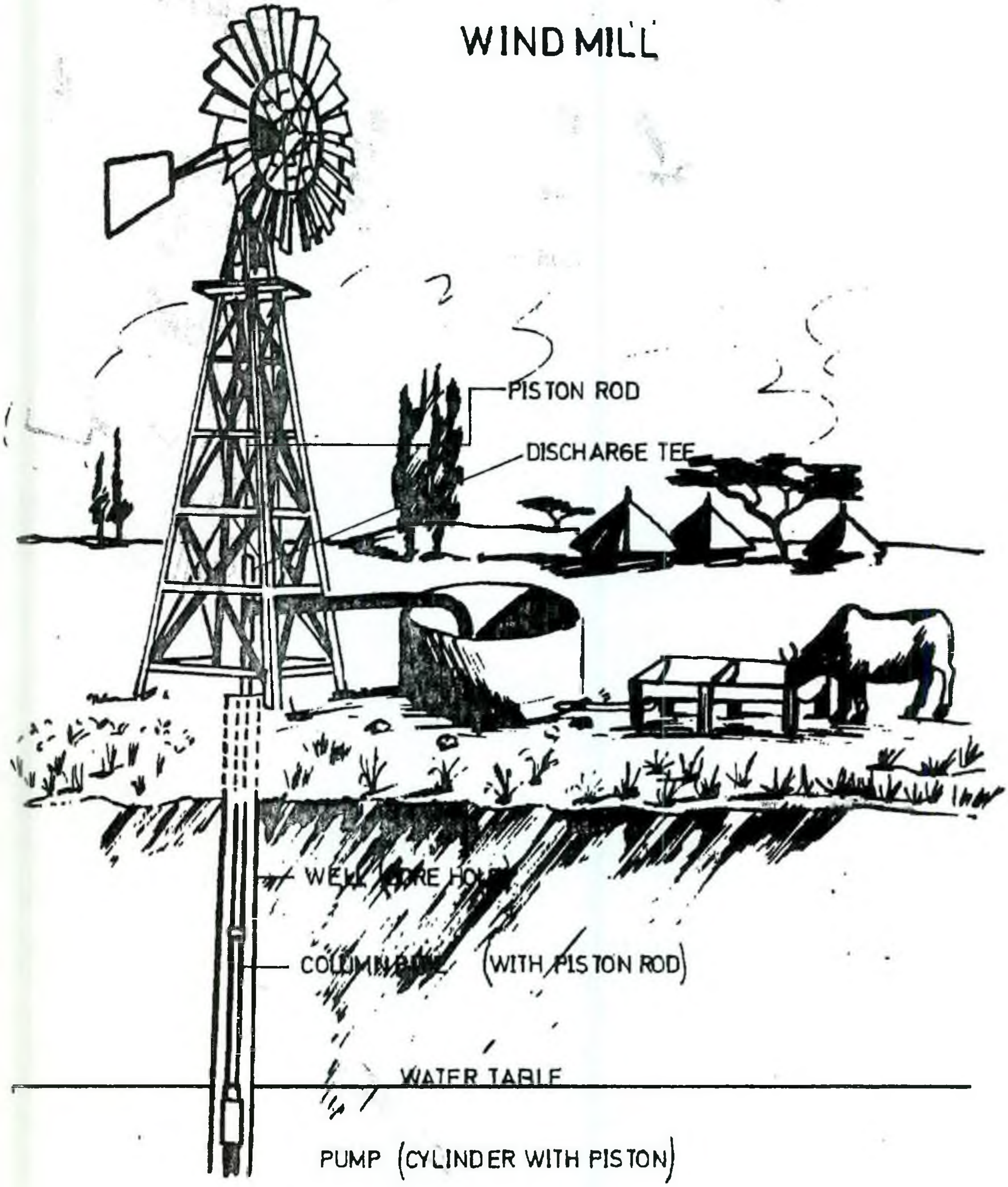


Fig.30

Fig 31

WIND MILL



For experience and demonstration purposes a windmill has been put up at well No. 43, which has the water table at a depth of 75m. It has worked very well and more windmills(of a smaller and cheaper size) have been ordered.

The costs of the windmill, in the Asassa area where:

| | |
|---|---|
| complete windmill (imported, duty-free) | 6,000:- |
| foreman and helper | 1,000:- |
| cattle trough and fence | 600:- |
| transportation and travel costs | 300:- |
| Total Eth. $ | 7,900:- |

This cost could be reduced if some local manufacture were undertaken and only the gear mechanism, etc.. imported.

Table 21 Pumping data for windmill

| Pump cylinder inches | Diameter of windmill m | Wind 3.4 m/s | | | Wind 2.5 m/s | | |
|---|---|---|---|---|---|---|---|
| | | Total head m | l/h | l/s | Total head m | l/h | l/s |
| 2 | 2.4 | 38 | 243 | 0.07 | 22 | 201 | 0.06 |
| | 3.1 | 67 | 250 | 0.07 | 40 | 212 | 0.06 |
| | 3.7 | 85 | 269 | 0.07 | 53 | 214 | 0.06 |
| | 4.3 | 125 | 292 | 0.08 | 76 | 239 | 0.07 |
| | 4.9 | 167 | 398 | 0.11 | 98 | 341 | 0.09 |
| 2½ | 2.4 | 26 | 379 | 0.11 | 16 | 313 | 0.09 |
| | 3.1 | 44 | 390 | 0.11 | 26 | 332 | 0.09 |
| | 3.7 | 59 | 417 | 0.12 | 37 | 335 | 0.09 |
| | 4.3 | 88 | 436 | 0.12 | 52 | 371 | 0.10 |
| | 4.9 | 115 | 625 | 0.17 | 67 | 536 | 0.15 |
| | 5.5 | 159 | 557 | 0.15 | 91 | 483 | 0.13 |
| 3 | 2.4 | 19 | 545 | 0.15 | 12 | 451 | 0.13 |
| | 3.1 | 31 | 559 | 0.16 | 18 | 474 | 0.13 |
| | 3.7 | 42 | 597 | 0.17 | 26 | 483 | 0.13 |
| | 4.3 | 61 | 644 | 0.18 | 37 | 536 | 0.15 |
| | 4.9 | 83 | 909 | 0.25 | 49 | 773 | 0.21 |
| | 5.5 | 111 | 805 | 0.22 | 64 | 697 | 0.19 |
| | 6.1 | 154 | 938 | 0.26 | 93 | 777 | 0.22 |

5.3.4 Maintenance of piston pumps

The piston pumps and the lifting arrangements on the ground are simple to use. A difficulty, however, is that the plunger cups have to be repaired every one or two years. To make this repair the rod and piston have to be lifted up.

The required maintenance is rather expensive as shown by the following figures, which relate to the section's Pump Maintenance Unit:

| Daily running costs | | Total cost/day Eth.$ |
|---|---|---|
| Salaries for 2 persons | Eth. $14,00 | |
| Allowances | " $ 6.10 | |
| Fuel | " $ 8.00 | |
| | | Eth. $28.10 |
| Equipment | | |
| Depreciation of equipment over 4 years | | |
| Pick-up | Eth. $14,000:- | |
| Hoist, etc. | " $14,500:- | |
| Camp,gear, etc. | " $ 4,750:- | |
| Total | Eth. $33,250:- | per day $22.78 |
| Interest 10% of $33,250 | | per day $ 2.28 |
| Interest 10% of stockvalue $10,000 | | per day $27.40 |
| Total cost per day | | $80.56 |

Cost per well

| | |
|---|---|
| 3 days per well at $80 per day | Eth. $241.68 |
| Spare parts for repair approximately | " $ 75.00 |
| Transportation average 50 km at $0.30/km | " $ 15.00 |
| Direct cost per well | Eth. $331.68 |
| Administration 20% | " $ 66.50 |
| Total cost per well | Eth. $398.18 |

At present there are about 25 wells requiring maintenace, taking 33 - 75 days a year. In the near future, with an increased number of wells, a service unit for maintenance will have work all the year round.

5.3.5 Cost of water from drilled wells

A drilled well 70 m deep with a hand pump costs about $6,000:-. To compare this cost with that of reservoirs of water, e.g. ponds and dams, the annually available water quantity must be estimated. If a low amount of 500 l/h (= 0.1 l/s) is assumed to be pumped during 12 hours a day, the annual quantity will be round 2,200 $m^3$ at a cost per $m^3$ of $2.72.

This cost is quite theoretical in respect of rural areas. In reality the walk distance puts a limit to the number of consumers. If the population density is 50 persons/$km^2$, as is usually the case, the well above can supply the $5,650 people living within a radius of 6 km. In more thinly populated areas, say 25 persons/$km^2$, the supplied number of people will be the half, $2,575 (assuming the same maximum walk distance). If a household is assumed to consist of 7 persons, the cost of the water supply per family will be $7.43 in a densly populated area and $16.30 in a thinly populated area.

5.4 Rainwater supplies

5.4.1 Rainwater as water supply

In the extensive dry areas of the awraja rainwater is the only water resource available at reasonable cost. Water can be caught on corrugated iron roofs or on sloping ground. From the catchment area the water has to be collected into watertight reservoirs situated on or below the ground.

The construction must be cheap and simple. As much as possible materials locally available should be used. This has demanded some research work on the design of catchment areas and dug holding wells. An exhaustive report is given by Mr. Olle Schönbeck in CADU publication No. 85: 'Trials with experimental household wells'.

5.4.2 Different designs for rainwater conservation

5.4.2.1 Catchment area

Collection of water from roofs requires galvanized iron cladding with an overhang and gutters and pipes for collecting and conducting the water. If there is no leaking or flooding over, all water from the roof can be collected within measurable limits.

This statement is based on measurements of the run-off from 21 roofs. As the area of a corrugated iron roof often is at least 30 $m^2$, quite a large quantity of water is available from precipitation.

If suitable roofs do not exist or if the roofs are not large enough, water can be collected on a catchment area on sloping ground. Different kinds of ground with an inclination of 5% have been tested during rainy season:

1. natural ground with continuous grass cover,
2. grass and topsoil (15 cm) removed and replaced by puddled clay mixed with gravel and/or sand in a layer 5-10 cm thick, covered by a layer of gravel 5 cm thick (Appendix, photo 1, p. 164).
3. Grass and topsoil (15 cm) removed & replaced by 5-10 cm compacted soil without sharp stones or plants, covered by a plastic PE-sheet with an overcovering of 5 cm gravel.

   The run-off coefficient (i.e. the percentage of the received precipitation collected of the different types of ground catchment) have been:

| Area | type 1 grassy ground" | type 2 clay concrete" | type 3 Plastic lining |
|---|---|---|---|
| On the plateau: | | | |
| Katjama | 20% | 39% | 71% |
| In the lowland: | | | |
| Dodota | - | 29% | 56% |

Type 1 is not usable in the hot and dry lowland, because a continuous grass cover does not exist. The plastic lining of type 3 is very effective. The selection, however, hinges on the question of cost. The ratio of the construction cost per $m^2$ to the run-off coefficient (Eth. \$/$m^2$/coeff. %) gives an indication of most economic type of catchment design:

| Area | type 1 grassy ground | | | type 2 "clay concrete" | | | type 3 plastic lining | | |
|---|---|---|---|---|---|---|---|---|---|
| | $/m² | run-off coeff. % | ratio | $/m² | run-off coeff. % | ratio | $/m² | run-off coeff. % | ratio |
| Katjama | 0.81 | 20 | 0.04 | 3.74 | 39 | 0.10 | 5.81 | 71 | 0.08 |
| Dodota | - | - | - | 3.02 | 29 | 0.10 | 5.05 | 56 | 0.09 |

5.4.2.2 Storage reservoir

5.4.2.2.1 Storage in household wells

5.4.2.2.1.1 Soil properties

There are three main types of soil: the red and the black clays of the plateau and the silty clay of the lowlands. The red clay is dominating on the slopes from the tree limit (about 3,000 metres above sea level) down to the plateau, where it often is overlain by 1-2m of black clay (vertisol or "back cotton soil"), e.g. as on the Ethaya-Kulumsa plateau. This black clay can swell or shrink enormously with a change in the moisture content. The silty clay of the lowlands often has a great permeability, to a depth of several metres, on account of holes made by animals or roots.

Experimental household wells sealed by puddled clay, have succeeded in the red clay (Bekoji, Katjama, Egu, Karsa and Munessa) but failed in the black clay (Ethaya) and in the silty lowland clay (Sire, Dodota and Lole).

Clay samples from different depths have been tested. According to these tests the following limits appear to determine the suitability of clays for house hold wells.

| depth, metres | minimum degree of saturation % | minimum volume weight, g/cm |
|---|---|---|
| 1.0 | 65 | (1.60) |
| 2.0 | 70 | 1.40 |
| 3.0 | 75 | 1.45 |
| 4.0 | 80 | 1.50 |

The degree of saturation changes during the year down to a depth of about 2 metres. The analyses show that the degree of water saturation of a soil during the dry season is an indication if the soil is suitable for the construction of household wells or not (fig. 32, p. 98).

The volume weights in natural state are: 1.1-1.9 $g/cm^3$ and are especially low at Ethaya, Sire & Lole. Compacted in the laboratory the maximum weights are 1.5-1.8 and especially high at Ethaya, Sire and Lole (1.7-1.8). This means that the ground of the low-land and the black clay of the plateau are not as suitable for household wells and ponds as is the red clay of the plateau.

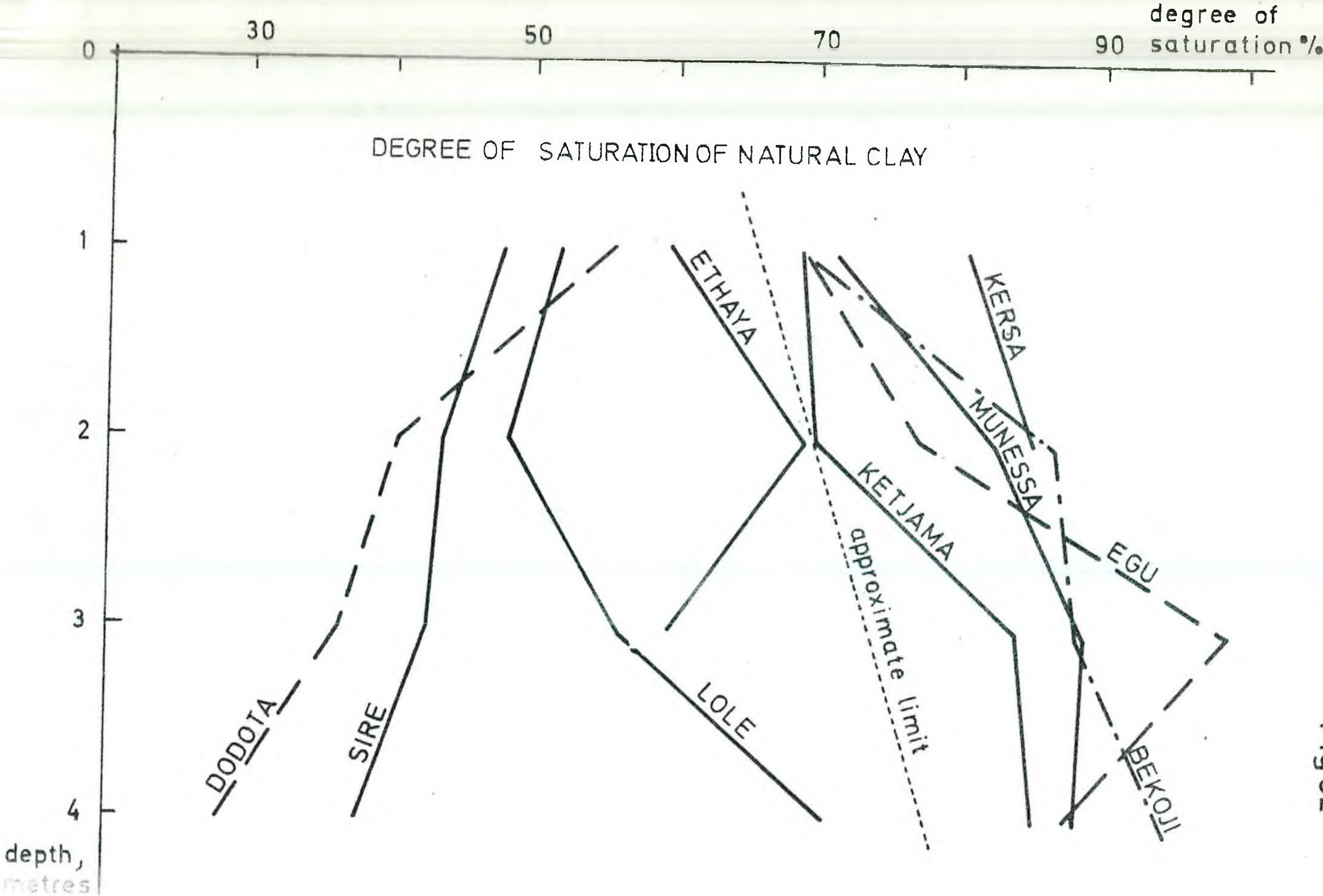

degree of saturation %
0
30
50
70
90
DEGREE OF SATURATION OF NATURAL CLAY
1
2
3
4
depth, metres
ETHAYA
KERSA
MUNESSA
KETJAMA
EGU
approximate limit
LOLE
SIRE
DODOTA
BEKOJI

Fig 32

5.4.2.2.1.2. Design of household wells

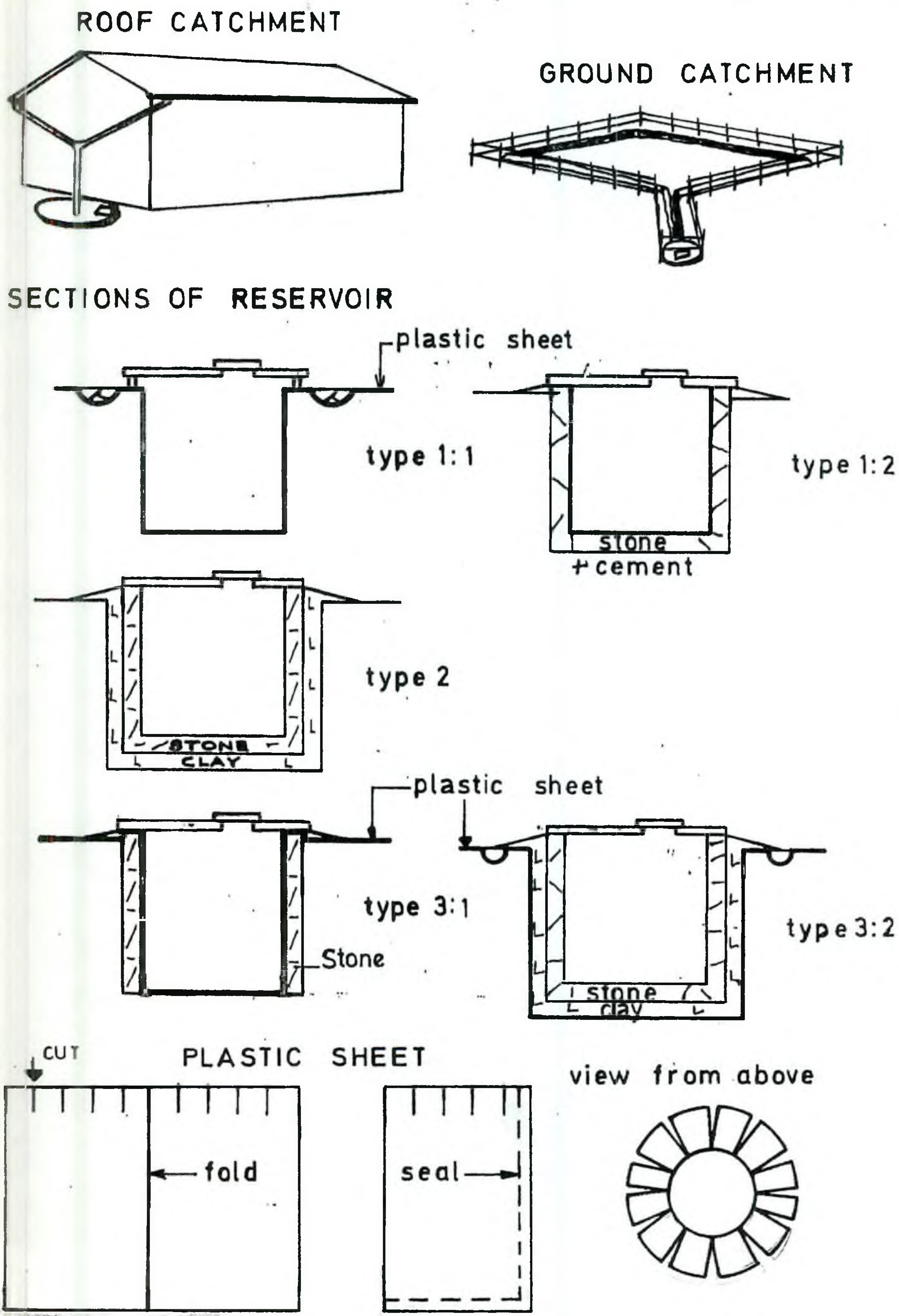
The design of a reservoir, dug in the ground, should be adapted to the stability and the permeability of the excavated strata. In case of strata with low permeability (approximately $10^{-3}$ cm/min or lower) the clay can be refilled on the walls after puddling to make it homogenous. If the strata are permeable, the excavation can be lined with a plastic PE-sheet (0.30 mm thick) or a built impermeable wall. There are thus three types of storage reservoirs:

| Type No. | soil | wall stability | inherent soil water tightness | design | geographic area |
|---|---|---|---|---|---|
| 1. | Silty clay | Wall construction not needed | Bad | Plastic liner or impermeable wall | Dodota and other lowlands |
| 2. | Red clay | Wall construction needed | Good | Wall design without plastic liner | Lukuche Plain and upper parts of plateau |
| 3. | Black clay | Wall construction needed | Bad | Wall design with plastic liner | Ethaya - Kulumsa plateau & lower parts of other plateau |

Type 1. In the silty clay of the Dodota lowland the vertical wall of pits 1,2 and 3 m deep have remained stable for three years without any support . In such cases there are two alternative methods of lining; either a plastic sheet liner or masonry. With the first alternative the plastic sheet liner is inserted and anchored on the ground with aid of a circular ditch, refilled with earth (fig. 33, p.100).

## HOUSEHOLD WELLS

Fig 33



With the second alternative a masonry wall, bonded with cement mortar, is substituted for the plastic liner, This has been tried by Mr. Stefan Grönberg at Dodota in 1973. Time will show which is the better alternative; in practice the plastic sheet is susceptible to accidental damage, while the cement/masonary alternative may be susceptible to attack by agressive elements in the rainwater.

Type 2. If the clay strata do not permit stable vertical walls, these latter can be supported with stone masonry, bricks, concrete rings, etc. Commonly masonry is cheapest. Between the dug surfaces and the masonry clay has to be puddled. If in practice this construction fails to be watertight a plastic liner can be put down. Thus a household well need never fail.

Type 3. Alternative 1. Masonry walls can be built directly from the bottom of the excavation, located against the dug walls. A plastic liner is then inserted as in type 1. Alternative 2. The plastic liner is inserted in the excavated pit, after removing stones with sharp edges and sharp roots from the earth walls. To be on the safe side a layer of clay can be applied to the bottom of the pit. Also, on the bottom of the plastic liner, a layer of 10 - 20 cm uncompacted clay can be applied and above that 10 cm of clay compacted by trampling. On this base of clay the stone floor and the circular masonry wall are built; clay is puddled between the masonry and the earth wall with its plastic lining as in type 2.

The experimental household wells commonly have had a pit diameter of 3.6 m, a stone masonry thickness of 0.3 m with the width between the masonry and the pit wall 0.5 m. Here the puddled clay has been applied and compacted in layers 5-10 cm thick. The depth of the well depends on the water quantity needed (p.107).

Any type of household well needs a cover and, if possible, a fence with a gate. The cover has been made of thin tree stems, planks and/or corrugated iron sheet.

In theory the roof water can be filtered through a barrel with sand, placed on the cover of the household well. This arrangement, however, has not worked very well in practice; the barrel has sometimes flooded and the filtration has not been very effective.

5.4.2.2.2 Above-ground tanks

At the instigation of Ato Ibrahim Ahmado, Head of CADU's Infrastructure Department, experimental iron tanks have been built by Mr. Stefan Gronberg. Such tanks can be used for roof catchment. Two different types have been fabricated so as to compare the costs: a cylindrical galvanized iron tank is reinforced by flat iron and a square black iron tank reinforced by angle iron (figs. 35 and 36, p. 103-104). The cylindrical tank is soldered, the square one welded. Because of the acidity of rain water, the tanks need anticorrosive paint inside. The outlet pipe should be placed above the bottom of the tanks, so as to leave undisturbed the sediment on the bottom. Another type of tank has been constructed in Uganda (N. Harris: 'Roof catchment supplies , Domestic water supplies in rural areas, Geol. Survey of Uganda, 1957). A single cylindrical piece of corrugated galvanized iron has around its top a reinforcing angle iron ring. It is recommended that the roof is made cone-shaped, removable or with a manhole. These cylindrical tanks have to be fabricated by local metal workers. The sheet thicknesses used are different for different capacities, viz:

Fig 34

CYLINDRICAL TANK 3.3 $m^3$
SOLDERED GALVANIZED IRON

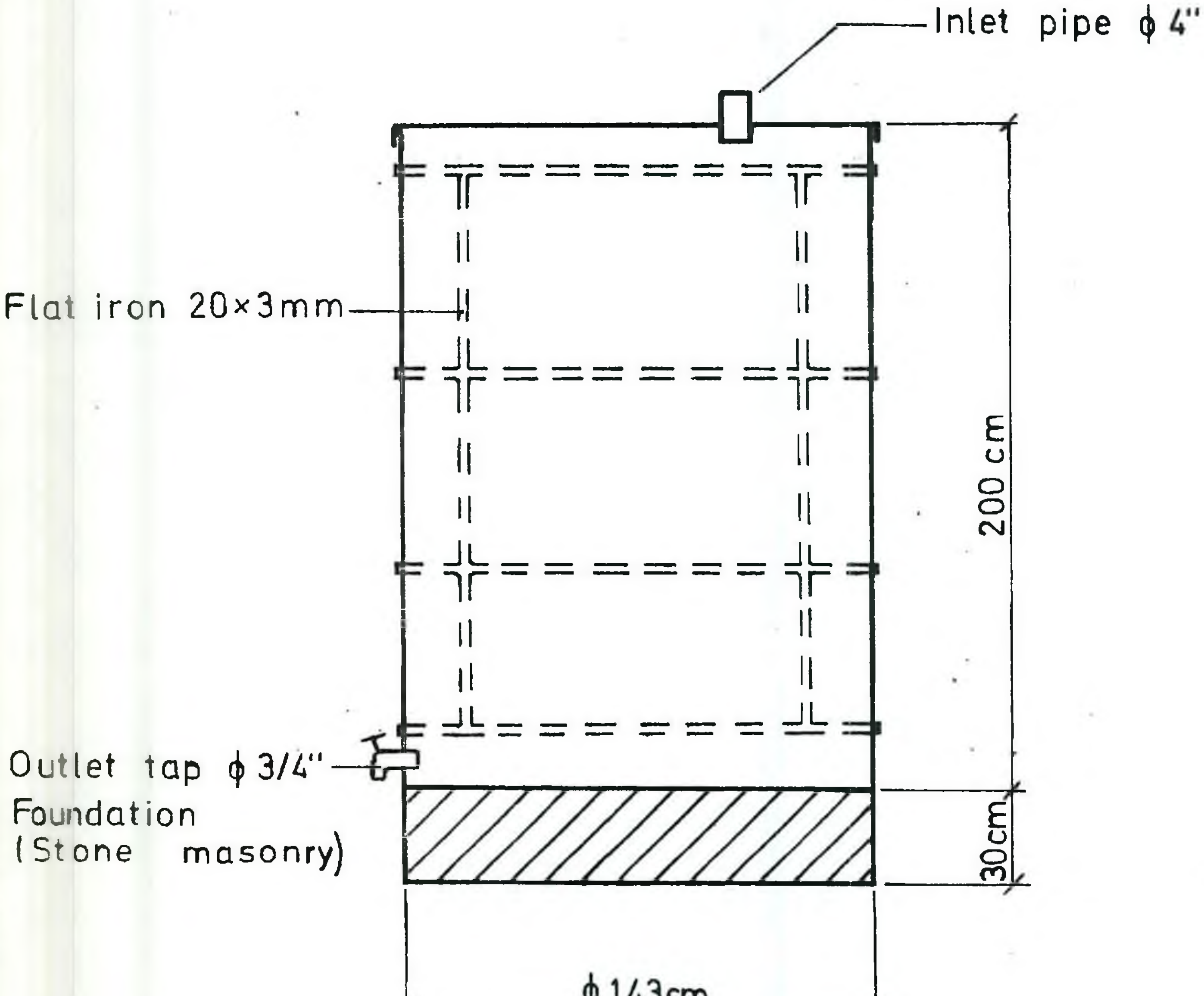
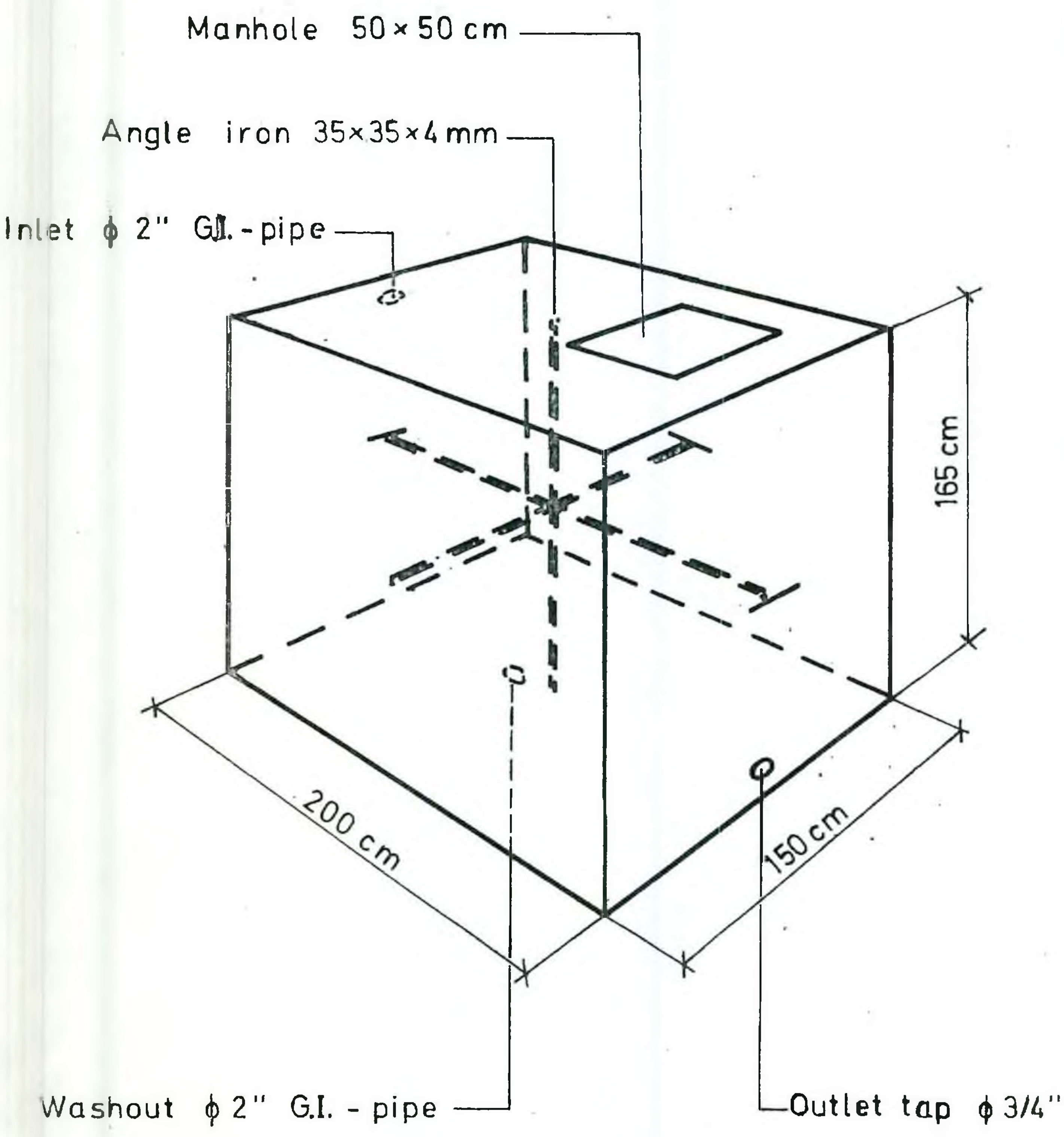


Fig. 35

SQUARE TANK 5.0 $m^3$
WELDED BLACKIRON SHEET



| size in litres | gauge for wells | gauge for bottom |
|---|---|---|
| less than 9,090 | No! 24 | No. 22 |
| 9.090 - 22,750 | No. 22 | No. 20 |
| greater than 22,750 | No. 20 | No. 20 |

As to dimensions and costs the following figures are given:

| size in litres | height in m | diameter in m | costs in shs. | costs in Eth.$ |
|---|---|---|---|---|
| 2,275 | 1.83 | 1.35 | 265 | [illegible]5 |
| 4,545 | 1.83 | 1.77 | 475 | 152 |
| 6,820 | 2.44 | 1.88 | 650 | 208 |
| 9,090 | 2.44 | 2.16 | 750 | 240 |

5.4.2.2.3 Conclusions on rainwater collecting

The soils of the different parts of the awraja and the properties of these soils are not accurately known yet. It seems probable that the people of the dry Lukuche Plain can be supplied with household wells collecting water from corrugated iron roofs or sloping grassy ground. In the silty clay of the lowlands without vegetation cover, e.g. at Dodota, plastic sheet is needed both for collecting and storage of water. In areas with black soil, the walls of the storage reservoirs need reinforcement and plastic sheet. Probably a plastic sheet is to be recommended also for catchment area on the ground. For the storage of water from corrugated iron roofs above ground tanks are an alternative.

5.4.3 Available water quantity and desired volume of household wells.

Observations on precipitation are shown in table 22 (p. 106). Because the year 1972/73 was very dry, the available precipitation data for this year are given in the table.

Table 22 Precipitation at 13 observation stations during 12 months of one dry year starting July 31st, 1972. Data received from CADU's Crop and Pasture Section (millimetres).

| Observation station | J | F | M | A | M | J | J | A | S | O | N | D | Total for year |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Abura (Ogelcho) | 0.0 | 0.0 | 0.0 | 5.2 | 98.1 | 48.8 | 120.1 | 168.5 | 48.4 | 22.2 | 0.0 | 0.0 | 511.3 |
| Asassa | 0.0 | 26.7 | 0.0 | 0.4 | 74.1 | 87.2 | 142.4 | 79.0 | 54.2 | 6.3 | 0.9 | 1.4 | 472.6 |
| Asella | 2.0 | 0.0 | 1.0 | 33.8 | 188.7 | 172.3 | 155.5 | 341.0 | 117.0 | 2.0 | 6.5 | 0.0 | 1019.8 |
| Bekoji | 0.0 | 7.9 | 0.0 | 69.1 | 90.7 | 98.7 | 181.8 | 139.6 | 60.5 | 19.3 | 21.5 | 0.0 | 689.1 |
| Dighelu | 0.0 | 2.0 | 0.0 | 16.2 | 91.8 | 95.0 | - | 241.0 | 39.2 | 0.4 | 28.0 | 11.5 | - |
| Dugda (Arata) | 0.0 | 0.0 | 0.0 | 16.0 | 119.0 | 48.5 | 143.4 | 172.7 | 62.6 | 7.5 | 1.0 | 0.0 | 570.7 |
| Egu | 6.5 | 0.0 | 0.0 | 57.3 | 127.8 | 88.5 | 61.1 | 101.0 | 134.0 | 12.5 | 1.5 | 5.0 | 595.2 |
| Ethaya | 4.0 | 0.0 | 0.0 | 3.0 | 187.0 | 108.0 | 131.2 | 125.4 | 134.3 | 30.8 | 0.0 | 0.0 | 723.7 |
| Gobe | 23.0 | - | 0.0 | 48.0 | 231.5 | 192.0 | 247.3 | 124.0 | 162.0 | 25.0 | 31.0 | 10.5 | (1094.3) |
| Huruta | 0.0 | 0.0 | 0.0 | 13.4 | 184.4 | 88.8 | 109.6 | 158.7 | 90.4 | 28.6 | 0.0 | 0.0 | 673.9 |
| Katar Genet (Golja) | 0.0 | 0.0 | 0.0 | 5.2 | 98.1 | 48.8 | - | 59.4 | 46.8 | 26.0 | 1.3 | 0.0 | - |
| Kulumsa | 0.0 | 0.0 | 0.0 | 24.4 | 52.6 | 95.6 | 107.2 | 186.7 | 107.2 | 11.7 | 8.9 | 0.0 | 594.3 |
| Sire | 0.0 | 0.0 | 0.0 | 10.9 | 86.8 | 86.4 | 78.5 | 159.6 | 115.8 | 18.5 | 0.0 | 0.0 | 556.5 |

The evaporation from three household wells has been measured.

| place | altitude, metres above sea level | evaporation mm/day |
|---|---|---|
| Lole | 2,440 | 0.17 |
| Ethaya | 2,140 | 0.63 |
| Dodota | 1,770 | 1.53 |

On the plateaux the evaporation is so small that it can be disregarded, at least in the case of household wells.

In the household wells constructed with puddled clay only (type 2, p. 101), a consumption of 50 l/day demands the following depths in different places:

| | |
|---|---|
| Egu, Karsa, Munessa | 5 m |
| Bekoji | 5 - 6 m |
| Katjama | 5,5 m |

A larger consumption than 50 l/day is made available by greater depths or diameters (p.107 and p. 112).

5.4.4 Quality of household well water

5.4.4.1 Suspended matter

After the dry season water collected by the gutter of the CADU office during heavy rain contained 3 ml of dust per litre. Later the water was cleaner. Thus it is wise to prevent the first heavy rain after the dry season washing down, into the household well or tank, matter accumulated during the dry season.

5.4.4.2 Chemical quality

The rainwater has a low pH value and low salt content (table 23, p. 108). The elements detected have been dissolved by the rainwater in the atmosphere. Rainwater is corrosive.

5.4.4.3 Sanitary quality

The bacteriological quality of the water in the first household well, constructed at Asella 1970, has been tested at three times (table 24, p.109).

Table 23 Chemical quality of rainwater and of water supplies. All concentrations in mg/1

| | Sampling date | PH | TDS | TH as Ca $CO_3$ | Bicarb alkalinity as $CaCO_3$ | $NH_4$ | $NO_2$ | Ca | Mg | Na | K | $HCO_3$ | Cl | $SO_4$ | $NO_3$ | $SiO_2$ | F | $Fe^{II}$ | Mn | Z |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Rainwater | | | | | | | | | | | | | | | | | | | | |
| Kulumsa rain gauge | 30.7.73 | 6.7 | 45 | 6 | 15 | 0.90 | 0.10 | 0.8 | 1.0 | 9.0 | 1.0 | 18.3 | 6.6 | 0 | 2.46 | 1 | 0.3 | 0 | 0 | 0.[illegible] |
| Water from roof (G.I) | 16.7.73 | 6.6 | 50 | 12 | 20 | 0.71 | 0.08 | 2.8 | 0 | 8.9 | 1.2 | 24.4 | 6.6 | 0 | 0.18 | 1 | 0 | 0 | 0 | 0.0[illegible] |
| Household Wells | | | | | | | | | | | | | | | | | | | | |
| Dodota (a) | 16.7.73 | 7.3 | 248 | 61 | 100 | 0.58 | 0.25 | 20.8 | 2.4 | 27.6 | 8.5 | 122.0 | 13.2 | 0 | 2.29 | 32 | 1.0 | 0 | 0 | 0.0[illegible] |
| Ethaya (b) | 16.7.73 | 7.4 | 353 | 84 | 134 | 0.32 | 0.05 | 33.7 | 4.9 | 23.3 | 5.2 | 162.9 | 13.2 | 0 | 5.02 | 29 | 2.0 | 0 | 0 | 0.0[illegible] |
| Egu (b) | 17.7.73 | 6.8 | 175 | 40 | 40 | 1.35 | 0.46 | 12.0 | 2.4 | 13.6 | 6.1 | 48.8 | 19.8 | 0 | 12.30 | 32 | 0.4 | 0 | 0 | 0.0[illegible] |
| Asella | Apr. 1971 | 6.6 | 60 | - | - | - | - | 4.8 | 0.2 | 14.0 | 2.4 | 36.6 | 10.6 | - | tr. | 5 | 1.0 | 0 | 0 | 0.0[illegible] |
| Ponds | | | | | | | | | | | | | | | | | | | | |
| Dodota | 16.7.73 | 7.6 | 218 | 66 | 80 | 1.68 | 0.28 | 22.4 | 2.4 | 8.8 | 8.6 | 97.6 | 6.6 | 0 | 5.46 | 35 | 0.8 | | | |
| Egu | 8.12.72 | 7.3 | 230 | | | | | 4.8 | 0.2 | 14.0 | 2.4 | 36.6 | 10.6 | 0 | 3.20 | 83 | 0.3 | | | |
| " | 1.5.73 | 8.0 | 394 | | | | | 24.8 | 5.8 | 12.8 | 17.2 | 128.0 | 20.0 | 0 | 0 | 107 | 0.7 | | | |
| Dams | | | | | | | | | | | | | | | | | | | | |
| Egu | 17.7.73 | 7.1 | 283 | 60 | 86 | 2.26 | 0.10 | 16.8 | 4.6 | 13.8 | 12.0 | 104.7 | 13.2 | | 0.70 | 45 | 0.5 | 0 | 0 | 0.06 |

(a) ground catchment and well construction with masonry and PE lining

(b) roof catchment and well construction with p ddled clay and masonry

Table 24 Bacteriological quality of and suspended matter in different supplies with surface water, bacteriological analyses by the Central Laboratory

| Water supply | Place | Sampling date | Total plate count at 37° C after 48 hours (organisms/ml) | Presumtive coliform count (organisms/100 ml) | Esherichia coli | Suspended matter ml/l |
|---|---|---|---|---|---|---|
| Household wells | Asella | 16/7 1970 | 2,240 | 17 | 0 | - |
| | | 11/2 1971 | 310 | 50 | 0 | - |
| | | 25/11 1971 | 140 | 13 | 0 | - |
| Ponds | Dodota No.1 | 5/12/1969 | 2,400 | 180 | present | - |
| | 2 | " | 2,460 | 90 | " | 0.3 |
| | 3 | " | 1,280 | 14 | " | 0.1 |
| | 4 | " | 1,860 | 14 | " | 0.2 |
| | 5 | " | 3,480 | 180 | " | 0.2 0.4 |
| | Egu | " | > 1,000 | - | - | - |
| Perennial rivers | average | | 10,250 | - | present | - |
| | variations | | 420 - 40,000 | | | |
| Boreholes | Kulumsa No.7 | 5/7 1968 | 640 | 0 | 0 | 0 |

The quality is better than that of rivers and ponds. The faecal pollution probably derives from the cover. People do not always understand that the cover must be clean and cattle not permitted to foul the cover.

Later, water has been tested from three household wells and one storage tank (table 25, p. 111). According to international standards, the water is not drinkable without treatment.

However, in contradistinction to the situation with river water, the pollution of household wells is of local origin, i.e. probably from the consumers. There is thus little likelihood of the introduction to them of fresh pathogens.

5.4.5 Costs of collecting and storage of rainwater in household wells and tanks

5.4.5.1 Collecting costs

For an average roof area of 49 $m^2$ the costs have been estimated to be:

| | | Eth. $ |
|---|---|---|
| materials: | corrugated iron sheet cladding | 147:- |
| | gutters and down pipe | 30 |
| labour | | 35 |
| transportation | | 20 |
| | Total cost Eth. $ | 232 |
| | cost per $m^2$ Eth. $ | 4.73 |

As the roof of corrugated iron is often in existence the cost of installing roof catchment will often be much less, about Eth. $65:-

For ground catchment the costs in Eth. $ can be estimated in the following way for different places and design.

(a) = with a plastic lining

(b) = without a plastic lining

Table 25 Bacteriological quality of different supplies, surface water, analyses by CADU (Mr. P.O. Nilsson)

| Water supply | Place | Sampling date | Total plate count agar 22 °C 48 hours organisms/ml | Presumptive coliform count lactose broth 35 °C 48 hours organisms/100 ml | 44 °C 48 hours |
|---|---|---|---|---|---|
| **Rain gauge** | Kulumsa | 17/7 1973 | **greater than 1,000** | 2 | 2 |
| Storage tank | Ethaya | 16/7 1973 | " " 1,000 | Greater than 2,400 | Greater than 2,400 |
| Household wells | Dodota | 16/7 1973 | " " 1,000 | " " 2,400 | " " 2,400 |
| | Ethaya | 16/7 1973 | " " 1,000 | " " 2,400 | " " 2,400 |
| | Egu | 17/7 1973 | " " 1,000 | 600 | - |
| Ponds | Dodota | 16/7 1973 | " " 1,000 | Greater than 2,400 | Greater than 2,400 |
| | Egu | 15/5 1973 | " " 1,000 | " " 2,400 | " " 2,400 |
| | | 17/7 1973 | " " 1,000 | 600 | - |
| Dam | Egu | 17/7 1973 | " " 1,000 | Greater than 2,400 | Greater than 2,400 |
| Lakes | Zuai | 18/4 1973 | " " 1,000 | 1,300 | 60 |
| | Langano | 18/4 1973 | " " 1,000 | 542 | 70 |

| Item of cost | Katjama (a) | Katjama (b) | Dodota (a) | Dodota (b) |
|---|---|---|---|---|
| Plastic sheet | 120 | - | 122 | - |
| Gravel | 51.5 | 51.5 | 63 | 73.5 |
| Fence | 37 | 37 | 41 | 42 |
| Labour | 5 | 25 | 5 | 30 |
| Transport | 70 | 70 | 72 | 90 |
| Total cost Eth.$ | 283.5 | 183.5 | 303 | 235.5 |
| Catchment area $m^2$ | 49 | 49 | 60 | 70 |
| Cost Eth. $/$m^2$ | 5.78 | 3.75 | 5.05 | 3.36 |

5.4.5.2 Storage costs

The real costs of experimental household wells (clay and/or plastic), and also estimated reduced costs when the owner himself takes part in the work, are shown in table 26 (p. 113). **The costs are based on the ordinary size of wells** (depth 3.8 m, diameter 3.6 m) and an ordinary family consumption (50 l/day). As so calculated to table 26 the costs of a household well vary between $10:- and $30:-/$m^3$ of water.

An increased demand for water requires other dimensions of the household well, costing as follows:

| diameter, m | depths 4 m (l/d) | 4 m Eth. $ | 5m (l/d) | 5m Eth. $ | 6m (l/d) | 6m Eth.$ |
|---|---|---|---|---|---|---|
| 4 | ( 50) | 200:- | ( 75) | 240:- | (100) | 280 |
| 5 | (100) | 285:- | (150) | 335:- | (200) | 390 |
| 6 | (180) | 390:- | (250) | 460:- | (320) | 530 |

The cost account for seven household wells at Dodota (masonry with cement mortar bonding). gives a cost of Eth. $ 273 per well and $30/$m^3$ of water (table 27, p. 114).). The costs of constructed tanks are high (table 28, p. 115).).
The cost of the cylindrical tank is $376.60 for 3.3 $m^3$ = Eth. $114.12/$m^3$ of capacity; in the square tank $560.45 for 4.95$m^3$ = Eth. $113.23/$m^3$.

Table 26 Costs of household wells(clay or PE-sheet) providing 50 l/day. Eth. $

| Type of household well (a) | Number of wells (b) | Duration time days (c) | Total cost Eth. $ experi-mental wells (d) | Total cost Eth. $ example of reduced cost (e) | Costs Eth. $/m³ of water: experimental wells, during duration time only basis | experimental wells, all the year basis | reduced costs, during duration time only basis | reduced costs, all the year basis |
|---|---|---|---|---|---|---|---|---|
| Plastic bag | 0 | 160 | - | 187.5(f) | - | - | 23.4 | 10.3 |
| Plastic bag+ puddled clay | 4 | 178 | 412 | 264.5 | 46.3 | 22.6 | 29.7 | 14.5 |
| Intensively puddled clay | 4 | 161 | 401 | 202.5 | 49.8 | 22.0 | 25.2 | 11.1 |
| Puddled clay (Karsa) | 1 | 160 | 314 | 182.5 | 39.3 | 17.2 | 22.8 | 10.0 |

(a) Different designs (see p. 99). In the Karsa area there is a soil with very high content of clay and thus with low permeability

(b) The costs of experimental wells in columns showing costs, are averages of wells in this column

(c) Duration time is the period a well lasts from the date of filling up

(d) Common material costs for all experimental wells: beams 13.05, cover 76.13, barrel 17.00, gravel sand 1.57, poles 2.40, barbed wire 16.00, labour 2.50 and transport 10.00, total Eth. $128.65.

(e) Reduced cost if the owner does some work himself:

| Own work | Plastic bag + puddled clay Eth. $ | Intensively puddled clay Eth. $ |
|---|---|---|
| well pit | 30 | 38 |
| water | 10 | 10 |
| masonry assistant | 25 | 60 |
| beams | 3 | 3 |
| fence | 4 | 4 |
| sundry labour | 2.5 | 2.5 |
| transport | 6 | 6 |
| sub-total | 80.5 | sub-total 123.5 |
| **Constracted work** | | |
| stone | 12 | 12 |
| plastic bag | 115 | - |
| mason | 30 | 40 |
| cover | 15 | 15 |
| barrel | 10 | 10 |
| grave sand | 2 | 2 |
| sub-total | 184 | sub-total 79 |
| total | 264.5 | total 202.5 |

(f) calculated with aid of figures above (e)

Table 27 Total costs fof seven household wells at Dodota. Lining with masonry with cement mortar joints. Catchment on roof or ground.

| | | |
|---|---|---|
| A | **Material** | Eth. $ |
| | Stone | 144.00 |
| | Aggregate (gravel) | 40.00 |
| | Sand | 40.00 |
| | Cement | 231.00 |
| | PE-sheet for one ground catchment | 50.00 |
| | Total | 505.00 |
| B | **Labour** | |
| | Excavation of pits by the landowners themselves | 72.00 |
| | Quarryman | 72.00 |
| | Mason | 391.25 |
| | Mason helper | 188.10 |
| | labourers for ground catchment construction | 8.80 |
| | Total | 660.15 |
| C | **Installation. (material and labour)** | |
| | Gutters and wire for six roof catchments | 280.50 |
| | Plank covers | 350.00 |
| | Total | 630:50 |
| D | **Transportation** | |
| | Loading and unloading of stone for masonry | 67.80 |
| | Loading and unloading of sand | 8.40 |
| | Water by donkey | 37.00 |
| | Total | 113.20 |
| | Total costs for seven wells | 1,908.85 |

Average cost per household well, catchment included, Eth. $273:-

Table 28 Cost of storage tanks

| Cylindrical flat galvanized iron tank | Unit | Quantity | Unit cost Eth. $ | Total cost Eth. $ |
|---|---|---|---|---|
| A Material | | | | |
| Galvanized iron sheet 26 gauge | pc | 9 | 0.90 | 62.10 |
| Flat iron | m | 24 | 0.50 | 12.00 |
| Solder | pce | 35 | 2.00 | 70.00 |
| Red oxide paint | litre | 2 | 4.00 | 8.00 |
| Tap ¾" and plain socket ¾" | pce | 1 | 4.50 | 4.50 |
| Total | | | | 156.60 |
| B Labour | | | | |
| Welder | $/day | 20days | 3.50 | 70.00 |
| Helper | $/day | 20days | 1.25 | 25.00 |
| Total | | | | 95.00 |
| C Installation (material and labour) | | | | |
| Stone masonry | | | | 35.00 |
| Gutter | m | 16 | 3.75 | 60.00 |
| Total | | | | 95.00 |
| D Transportation of the tank | | | | |
| Assumed distance | $/km | 100 | 0.30 | 30.00 |
| | | | Total/tank | $ 376.60 |
| Square steel tank | | | | |
| A Material | | | | |
| Flat black iron 2 mm | $m^2$ | 17 | 19.20 | 325.40 |
| Angle iron 40 x 40 x 4 | m | 6 | 1.25 | 7.50 |
| Electrodes | kg | 16.5 | 2.75 | 45.40 |
| Abrasive cutting wheel | pce | 2 | 2.00 | 4.00 |
| Red oxide paint | litre | 4 | 3.25 | 13.00 |
| Tap ¾" and plain socket ¾" | pce | 1 | 4.50 | 4.50 |
| G.I. pipe 2" | m | 0.6 | 4.00 | 2.40 |
| Total | | | | 402.20 |
| B Labour | | | | |
| Welder | $/day | 7 | 3.50 | 24.50 |
| Helper | $/day | 7 | 1.25 | 8.75 |
| Total | | | | 33,25 |
| C Installation (material and labour) | | | | |
| As above | | | | 95,000 |
| D Transportation | | | | |
| As above | | | | 30,00 |
| | | | Total per tank | $560,45 |

It is thought that the Uganda type of tank could (see p.105) be constructed rather more cheaply.

A small semi-rotary hand pump can lift the water from the well to the ground level or into the kitchen. Such a pump costs $50 and plastic tube from the well to the kitchen $ 1/m.

## 5.5 Ponds

### 5.5.1 Existing ponds

By pond is meant a large earth excavation supplied with water, which is diverted from a river or which is collected from overland flow after a heavy rain. People understand by experience that a pond must never be excavated in the stream bed of a periodical river but should be on the side of this so as to avoid filling up with sediments during times of flood.

Ponds have been excavated by the people in the driest parts of the awraja, e.g. the Awash River valley between Dodota and Dhera and Rift Valley north and southeast of Lake Zuai. Commonly the ponds are more or less circular with a volume of 1,000 - 5,000 $m^3$ and a depth of 1.5 - 3.5 metres. The ponds usually dry up during the middle or latter part of the dry season. Therefore, improvements are needed.

At one place in the Dodota area there is a very large natural pond. As the water depth at the beginning of the dry season is only 1.2 m, the pond dries up in February. It has been said that the pond is used by 1,330 families paying $1/year per family plus 15 cents for each head of cattles(with an average of 6 cattle, each family will thus pay $1.90 per year). Thus the total payments are around $2,500 per year.

### 5.5.2 Improved design

#### 5.5.2.1 Background of two experimental ponds

In the watertight clay of Egu a pond was designed and constructed by Mr. Olle Schönbeck. This is the subject of a short report dated July 16th, 1973.

In areas without good clay a watertight lining is necessary for the storage of water in excavated basins. When starting the research work I proposed linings with 1) puddled clay, 2) asphalt and 3) plastic sheet.

Puddling of clay on permeable strata in the excavated basin has not worked well. A trial was made at Dodota. The American Asphalt Institute has reported several interesting and sucessful designs of ponds. The asphalt qualities required are not available in Ethiopia and they demand special equipment, which cannot be afforded by the present CADU project.

Lining with plastic sheet, however, has been tried at Dodota. A short report was made by Mr. Stefan Grönberg in September 1973.

5.5.2.2 Pond at Egu

The place is situated approximately 5 km northwest of the village of Egu in an area known as Yodola. The site is a broad, grass covered valley with short periodical flood at the end of the rainy season.

The D-6 bulldozer of CADU's Road Section excavated a rectangular pond with several small basins for sedimentation before the inlet to the pond. The volume of the pond is 2,400 $m^3$, but if the sedimentation basins are also filled , a volume of [illegible],500 $m^3$ can be stored. So much was filled up by one single flood on September 9th, 1972. After that there was no further rain until April. No water collecting of the people was permitted during observations of the water level 17/1 - 5/3 1973. During this time there was a fairly constant sinking of the water level from a height of 1.85 m to 1.52 m above the bottom, i.e. 33 cm in 47 days or 7 mm/day.

This corresponds roughly to the estimated evaporation. Thus the leakage to the ground is very small. If evapora ion is considered to be neglible during the three months of the rainy season, 1,200 $m^3$ should be available in the pond (2,400 $m^3$ if the entire pond area is flooded, the sedimentation basins not being so used.) The pond was paid for by the people. So far as can be judged at present, the people are going to use the flooded pond area with 5,500/$m^3$ water available after filling up.

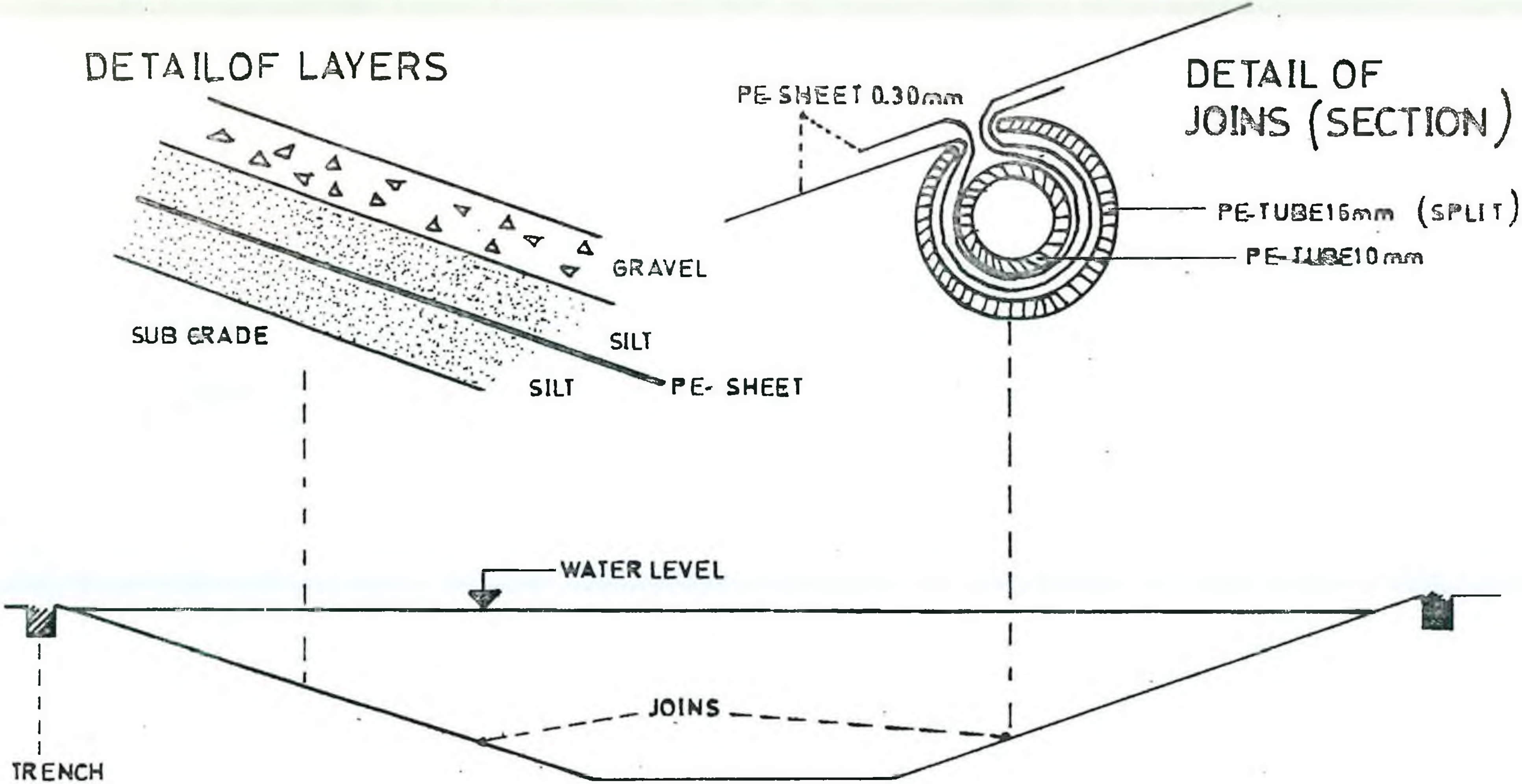
5.5.2.3 Pond at Dodota

A pond was excavated east of the road at Dodota. The size was 23 x 36 m. with a depth of 3 m, giving a volume of 1,390 $m^3$ The pond is fed by a river of which the flow is periodically torrential.

Originally this pond was excavated with a view to sealing with clay or asphalt. The lining with puddled clay did not work because of contraction cracks, and no equipment was available for asphalt work. If this had been the case, the cost would have been about Eth. $8,000:- for an asphalt lining. This is much more than for a lining with plastic sheet. Therefore, the original excavation work was changed.

The slopes were changed through filling to be 1 vertical metre to 3 horizontal metres. Sharp projections, such as roots and sticks, were removed from the bottom of the pond basin, which was covered with a cushion layer of 5-10 cm silt. Later this subgrade was covered with a black polyethylene sheet 0.30 mm thick in strips 40 x 9 m. The strips were bonded with overlapping joins, fastened by using PE-tubes, d = 10 mm, forced into slotted PE-tubes, d = 16 mm. The sheet was anchored in a trench at the top of the slope (fig, 36, p. 119). and photo 3 in Appendix p, 165).

It remains to cover at least the slopes with 10-15cm silt topped with 10-15 cm layer of gravel or aggregate. The area covered with PE-sheet is 1,080 $m^2$ and the volume is now 850 $m^3$.




SECTION OF POND LINED WITH PE-SHEET

SCALE 1:100

Fig. 36

5.5.3 Available water quantities

5.5.3.1 Feed of water

If a pond is filled up by diverting a part of a periodical river flowing every year, the available quantity is commonly large enough. But if the idea is to use the overland flow of some catchment basin, this flow has to be estimated. The ratio between total precipitation and overland flow has been studied only in two small discharge areas of red clay in a trial area between Kulumsa and Asella (Mr. Göran Hanson: 'Water budget and erosion in two small catchment areas', 1972). On ground with 15-20% slope and consisting of 60-70% grass land, the monthly run-off increased during the rainy season from 0 to 10-20% of the monthly precipitation. At least 5% of the annual precipitation can be collected in a reservoir fed by overland flow.

5.5.3.2 Loss of water

If a pond is excavated in clay which is not itself watertight it has to be sealed with plastic sheet. In both cases the water volume available for consumption is roughly the pond volume, less evaporation losses plus the precipitation (table 22, p. 106) and table 29, p. 121 ). According to these tables the annual water deficit is:

| Place | Precipitation mm | Evaporation mm | Deficit mm |
|---|---|---|---|
| Gobe | 1,094(?) | 1,151 | 57 |
| Asassa | 473 | 2,456 | 1,073 |
| Bekoji | 689 | 1,915 | 1,226 |
| Ethaya | 724 | 2,689 | 1,965 |
| Kulumsa | 594(?) | 2,574 | 1,980 |
| Dugda | 571 | 2,728 | 2,157 |

These figures represent a very dry year when there was not a small rainy season. These observations have been made with the Andersson evaporimeter; check observations were also made with a pan above the ground.

able 29 Evaporation at 6 obbservation stations during 12 monthis of one dry year from July 4th, 1972 - June 1973. Data from CADU's Crop and Pasture Section (millimetres).

| YEAR | 1972 | | | | | | 1973 | | | | | | Total for year |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| MONTH | J | A | S | O | N | D | J | F | M | A | M | J | |
| Asassa | 84.82 | 103.08 | 149.40 | 187.10 | 228.10 | 242.00 | 265.05 | 233.44 | 363.95 | 331.50 | 188.77 | 168.80 | 2,546.01 |
| Bekoji | (28.75) | 72.07 | 94.52 | 117.69 | 132.30 | 164 (a) | 196.27 | 204.08 | 333.75 | 243.58 | 190.11 | 137.51 | (1,914.63) |
| Dugda (Arata) | 103.80 | 102.30 | 124.90 | 262.10 | 270.30 | 270.20 | 247.40 | 302.90 | 354.70 | 330.10 | 189.80 | 169.30 | 2,727.80 |
| Ethaya | 122.90 | 117.60 | 119.80 | 210.20 | 281.50 | 278.00 | 226.60 | 268.00 | 316.00 | 323.00 | 202.80 | 223.00 | 2,689.40 |
| Gobe | 30.10 | 42.80 | 62.60 | 108.30 | 99.20 | 114.20 | 139.20 | 168. (a) | 196.80 | 162.90 | 71.80 | 55.20 | (1,151.10) |
| Kulumsa | 92.15 | 166.36 | 121.14 | 232.96 | 221.15 | 210.60 | 288.89 | 298.94 | 269.20 | 291.04 | 222.84 | 159.17 | 2,574.44 |

(a) estimated value

As the meteorological observations in the Chilalo Awraja have not been analysed and are not yet sufficient regarding low altitudes, I present some data from the 'Report on survey of the Awash River basin' (FAO).

| Altitude, metres above sea level | Annual precipitation, mm | Annual evaporation: large area, mm | sunken pan, mm |
|---|---|---|---|
| 3,000 | 1,995 - 1,350 | | |
| 2,700 | 1,760 - 1,215 | | |
| 2,400 | 1,525 - 1,080 | 1,410 | 1,740 |
| 2,100 | 1,290 - 950 | | |
| 1,800 | 1,050 - 815 | | |
| 1,600 | - | 1,750 | 2,130 |
| 1,500 | 820 - 685 | | |

In Chilalo the wet subtropical area is situated between the Erica heaths on the mountains commencing at about 3,000 m a.s. and the escarpments towards the Rift Valley at about 2,000 m a.s. The dry subtropical area is Rift Valley, including the Awash River valley, 1,800 - 1,500 m a.s. Because of large differences between different years and different localities and because of the difficulties of determining the true evaporation for different sites, I prefer to state the following provisional values for estimating of the needed storage capacity of ponds and dam reservoirs:

| | Annual precipitation m | Annual evaporation m | Difference m |
|---|---|---|---|
| above Rift Valley | 0.7 | 2.0 | 1.3 |
| in Rift Valley | 0.5 | 2.5 | 2.0 |

The water deficit can be considered to be 1.3 m in the wet zone and 2.0 m in the dry zone.

### 5.5.4 Quality of pond water

#### 5.5.4.1 Sediment load

The amount of suspended matter in water from periodical rivers, flowing for the most part of the year, is probably similar to that in perennial rivers. Only the suspended matter in water that has been diverted to fill up a pond will deposit in the pond.

Regarding small catchment areas, the best pond water derives from overland flow in grass covered catchment basins, where there is no or little bare ground for erosion and where the water is filtered by the grass. Assessments of the soil denudation of the land, in the upper and lower parts of two small basins in the trial area between Asella and Kulumsa, have been made using the sediment load data.

| Basin | Gauge No. | Denudation $m^3/km^2$ in the year of 1970 |
|---|---|---|
| Upper | 1 | 80 |
| part | 5 | 85 |
| Lower | 2 | 140 |
| part | 3 | 150 |

In the lower part of the basins there is a more pronounced stream channel and some gully erosion. In the nearby discharge area of the Simba River the degnudation in another year was as much as 480 $m^3/km^2$ (table 5, p. 17).

The worst pond water appears in dry areas with a thin sporadic vegetation cover. In the Dodota area the suspended matter in five ponds on December 5th, 1969 varied between 0.1 and 0.4 ml/l (table 24, p. 109). These figures often represent the maximum amount of suspended matter in most rivers (table 3, p. 15). The annual silting up of a pond in the Dodota area has been estimated at about 10 cm/year, judging by test pits.

Every annual deposition is represented by a number of thin strata, very similar to annual glacial varves, every stratum representing firstly a flow to the pond (c.f. silty part of varve) and then a period of settling of the clay particles (c.f. clayey part of 'varve'). I counted 40 'varves' or flows in a deposition 15 years old.

A sedimentation basin between the inflow and a utilized pond can settle at least the bottom load of the water flow. In the future the sedimentation basin might be used for chemical flocculation of suspended particles.

5.5.4.2 Chemical quality

The chemical quality of small overland flows has been tested in the trial area between Kulumsa and Asella. The cation content, especially iron, is higher than in the rivers.

The chemical quality has also been tested in the Egu pond. To start with the pond had the same quality as the supplying flood, but the evaporation increases the salt concentration. Samples taken 3 and 8 months after the filling up show an increase in the salt concentration (table 23, p.108) but the water is still drinkable at the end of the dry season.

5.5.4.3 Sanitary quality

Because of self-purification ponds contain lower bacterial pollution than most perennial rivers during the dry season (table 24, p.109). The faecal pollution derives partly from livestock, especially sheep, entering into the pond in spite of a fence of thorny branches. With a good fence the pond water is expected to be improved during storage because of self-purification (Egu pond, table 24, p. 109).

In the subtropical lowlands of Rift Valley and the Awash River valley the use of ponds can increase the incidence of some diseases, including bilharzia and malaria.

5.5.4.4 Biological pollution

To the people the most important quality demanded of drinking water is that it should be odourless. On some occasions the C DU extensions agents have reported that pond water has a smell. Also water samples have shown a green colour. These characteristics derive from the reproduction of green algae, which, after death, settle and decay. In the Asella dam the algae during the dry season in 1973 was Palmella, which could be removed by spreading powdered copper sulphate over the water, giving a concentration of 2 ppm or 2 g salt per $m^3$ of water.

5.5.5 Cost of ponds

The costs in Eth. $ for the Egu pond were (table 30, p. 126).

| | | | |
|---|---|---|---|
| salaries: | for administration | Eth. | $1,520:- |
| | for labourers | " | $1,880:- |
| hire of bulldozer | | " | $1,700:- |
| material | | " | $ 400:- |
| transport: | of personnel | " | $1,000:- |
| | of bulldozer | " | $ 280:- |
| | Total | Eth. | $6,780:- |

The volume utilized by the people is 2,400 $m^3$ costing Eth. $6,780:-. This means a construction cost of Eth.$2.83/$m^3$ of water capacity.

The pond can supply with water 650 persons or, alternatively, 150 persons, 250 large livestock and 2000 small livestock. The former alternative (without livestock) means about 120 households, the latter (livestock included) 30 households. Depending upon whether or not livestock are watered, the cost per family will be either Eth. $56:- or Eth. $226:-.

A cost account of the Dodota pond is shown in table 31 (p. 126). The cost of plastic lining is Eth. $1.08/$m^2$. The total construction cost is estimated at Eth. $4,415:- or Eth. $5.19/$m^3$ of water capacity. This cost can certainly be reduced.

Table 30 Cost of the construction of the Egu pond. Eth. $

| | Labourers | Material | Services | Totals |
|---|---|---|---|---|
| Excavation: | | | | |
| of pond | | | 1,700 | 1,700 |
| of settling basins | 360 | | | 360 |
| of spillway channel | 275 | | | 275 |
| Wet-packing of slopes in settling basins | 320 | | | 320 |
| Stone facing: | | | | |
| in pond | 175 | 100 | | 275 |
| in settling basins | 230 | 90 | | 310 |
| Grass sods on slopes: | | | | |
| of pond | 320 | | | 320 |
| of settling basins | 110 | | | 110 |
| Inlet pipe | | 120 | | 120 |
| Fence | 90 | 90 | | 180 |
| T Totals | $1,870 | $400 | 1,700 | 3,970 (Total cost |

Table 31 Cost of the construction of the Dodota pond. Eth.$

| | | | |
|---|---|---|---|
| Excavation of pond, labour cost | Eth. | $ | 695:- |
| Inlet structure, estimated costs for: | | | |
| excavation work | " | $ | 175:- |
| masonry work | " | $ | 172:- |
| material | " | $ | 311:- |
| Sub-total | Eth. | $ | 658:- |
| Plastic lining including anchor trench: | | | |
| labour | Eth. | $ | 54:- |
| PE-sheet | " | $ | 1,026:- |
| joins of sheeting (PE-tubes) | " | $ | 88:- |
| sub-total | Eth. | $ | 1,168:- |
| (Cost per $m^2$ of plastic lining: = | Eth. | $ | 1.08) |
| Fence: | | | |
| labour | Eth. | $ | 40:- |
| barbed wire | " | $ | 210:- |
| poles | " | $ | 75:- |
| staples | " | " | 10:- |
| Sub total | Eth. | $ | 335:- |
| Transportation | Eth. | $ | 957:- |
| Ethiopian ML and locally employed staff | " | $ | 602:- |
| Total cost of construction | " | $ | 4,415:- |

It was not possible to make this pond wider and deeper, because it was not possible to buy connected land. Thus this PE-lined pond should be regarded as an experimental pond to gain experience of construction and to make observations regarding water storage.

## 5.6 Dams

### 5.6.1 Present situation

By dam is here meant an earth embankment damming up a water basin in a valley. The excavation of a pond will give a water reservoir of volume corresponding to the excavated mass. The same amount of moved mass, however, when used in a dam construction, can create a much larger water reservoir.

Small earth embankments, 1-2 metres high, have been made by the people in periodic rivers of the dry areas. Because of the shallow water, and the leakage of water through the earth embankment, these dam reservoirs dry up early during the dry season. As no spillway is dug, floods damage the embankments every year. Therefore, improvements are needed.

### 5.6.2 Improved design

#### 5.6.2.1 General considerations

As always the principle must be a simple and cheap design, with materials available locally and the people able to make the construction themselves. These conditions demand an earth dam.

The first condition for a dam project is that the annual flow is large enough to fill up a dam reservoir. The ground for a good dam reservoir should consist of clay or silty clay, at least 1-2 thick. Bare rock should be avoided. Underneath the dam construction the soil must not be sandy or consist of fissured bedrock or stones, because of the risks of piping and under-mining. Water must in no circumstances flow over the crest of an earth dam. The overflow water, which is sometimes of considerable volume, has to be drained by a broad spillway on one or both sides of the dam.

The channel of a spillway must be separated from the dam construction and have the minimum possible gradient in order to prevent erosion damage. If the spillway is dug in soil, its threshold should be covered by a stone facing. The threshold should not reach higher than 1-1.5 m below the crest of the earth dam. For the construction of the dam a suitable clay or silty clay must be available on one or both sides of the dam site or on the bottom of the water reservoir. The earth material should be spread in thin layers 10-15 cm thick, and every layer compacted. On the crest, and the downstream slope of the dam, grass should be planted or a turf facing made. The upstream slope of the dam should be covered with stones or gravel.

5.6.2.2 Dam at Egu

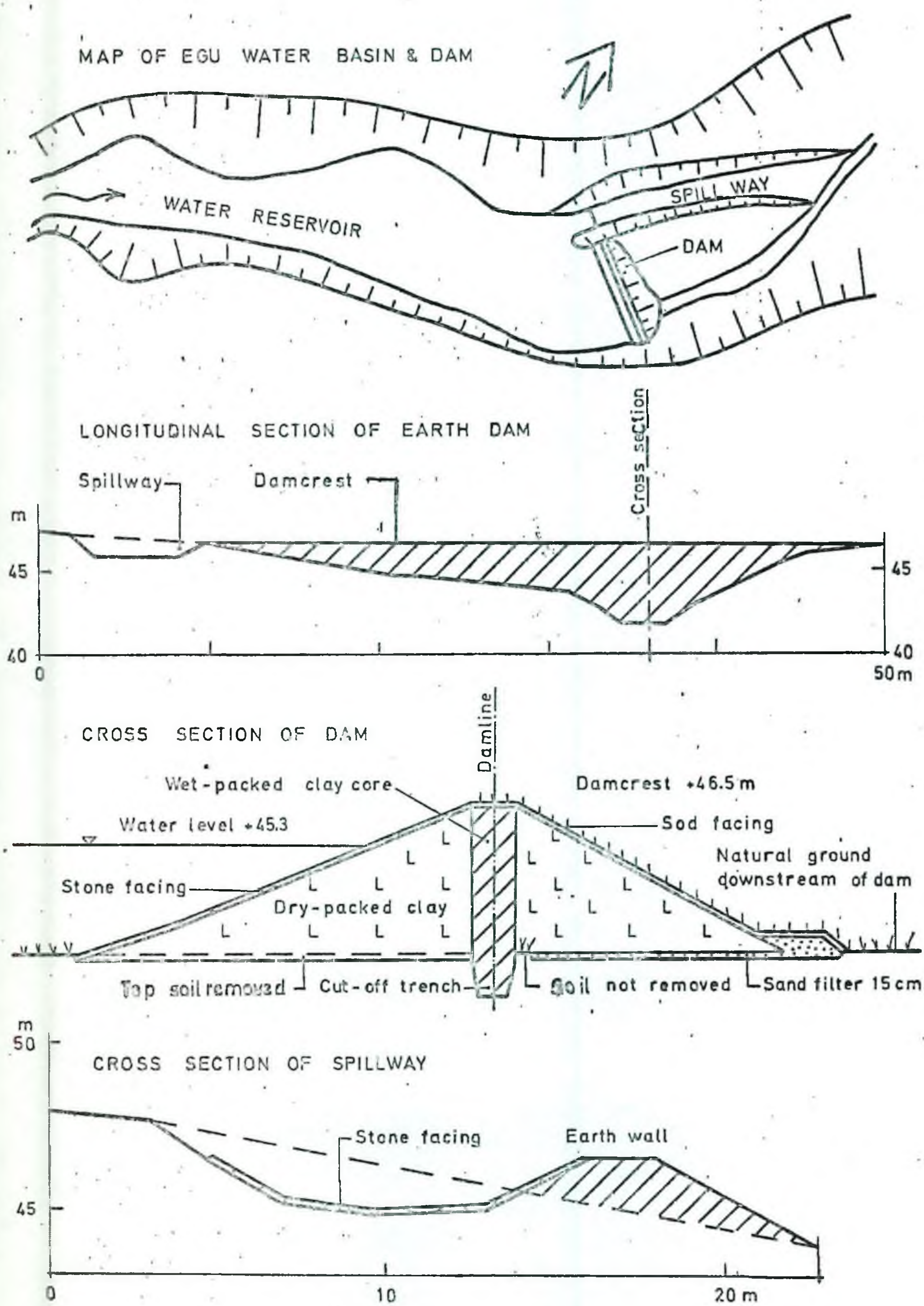
For demonstration purposes and cost studies I designed and constructed an earth dam in the Lagadena Valley at the village of Egu. This place is situated in the middle of the vast dry area southwest of the Katar River. The nearst water supply during the dry season is the Karsa River, 11 km from Egu.

There is a wet-packed core of yellow clay with dry packed black or silty clay on both sides of the core (fig. 37, p. 129 and photo 4 in Appendix p.165) The downstream slope of the dam has a grass covering and an inclination of 1:2. The slope of the reservoir side has a stone facing and an inclination of 1:3. The spillway threshold is 1.25 m below the crest of the dam and has a bottom width of 4.5 m with transverse slopes of 1:1.5. This size of spillway permits a water-filled section at least 50% larger than the section area of the largest flood observed in the natural stream channel.

The top of the dam is 4.7 m above the lowest point of the natural stream bed. The dam construction is 760 $m^3$ and the reservoir holds 9,000 $m^3$ of water. All constructions were made by hand; the earth being transported with wheelbarrows,

Fig.37

# EGU DAM



Quantities and prices of different work operations are shown in table 32 (p. 131). Further details are available in a CADU publication: 'Construction of earth dam at Egu' April 1973.

5.6.3 Available water quantities

5.6.3.1 General conditions

The available water quantity depends on the site. A good dam site has a narrow transverse section, widening upstream to a basin with a flat longitudinal section. As the rivers commonly have steep fall profiles and narrow valleys, it is usually difficult to find good dam sites. Sometimes it may be necessary to combine a dam and a pond;i.e. the dammed basin may have to be excavated to provide sufficient storage capacity.

As in a pond reservoir there are water losses in a dammed reservoir, caused by evaporation and seepage. The evaporation can be calculated in the same way as for a pond. The seepage is often more difficult to estimate in a dammed reservoir, because of the variability of the underlying strata. A permeable bottom will lose water during some years, but the bottom of the water basin can be expected to eventually seal itself with clay, deposited by the stored water.

5.6.3.2 Dam at Egu

The water deficit is estimated at approximately 1.3 m/year; a volume of 3,000 $m^3$. The measured permeability of the Egu clay is $10^{-5}$ cm/min, but probably layers with larger permeability exist. The seepage is estimated at 2,000 $m^3$ yearly.

5.6.4 Quality of dam water

5.6.4.1 Sediment load

Only the water quantity necessary for filling up is led into a pond. In a dam reservoir, on the other hand, all the periodic flow is passing through the reservoir. Most of the suspended load does not settle but is carried by the overflow water through the spillway.

Table 32
Quantities and unit prices of the work operations of the Egu dam

| Work Operation | Quantity | Costs in Eth. $. for: Labour only | | Materials included | | Transport also included | |
|---|---|---|---|---|---|---|---|
| | | Total Cost | Unit Price | Total Cost | Unit Price | Total Cost | Unit Price |
| Removing top soil of dam area | 100 $m^2$ | 6.60 | 0.07/$m^2$ | | | | |
| Digging of axial trench | 40 $m^3$ | 6.60 | 0.17/$m^3$ | | | | |
| Sand filter with clay cover | 54 $m^2$ | 1.10 | 0.04/$m^2$ | 121.10 | 2.06/$m^2$ | 196.70 | 3.64/$m^2$ |
| Excavation of spillway | 865 $m^3$ | 440.00 | 0.51/$m^3$ | | | | |
| Wet-packing of clay core | 230 $m^3$ | 58.30 | 0.25/$m^3$ | | | 243.10 | 1.06/$m^3$ |
| Dry-packing of dam | 530 $m^3$ | 86.90 | 0.16/$m^3$ | | | | |
| Stone facing: | | | | | | | |
| on dam | 290 $m^2$ | 30.80 | 0.11/$m^2$ | 95.90 | 0.33/$m^2$ | 109.23 | 0.38/$m^2$ |
| in spillway | 370 $m^2$ | 70.40 | 0.19/$m^2$ | 154.40 | 0.42/$m^2$ | 181.84 | 0.49/$m^2$ |
| Grass sods: | | | | | | | |
| on dam | 220 $m^2$ | 14.30 | 0.07/$m^2$ | | | | |
| on earth wall | 15 $m^2$ | 1.10 | 0.07/$m^2$ | | | | |
| Stone wall (silt trap) | 31 $m^3$ | 33.00 | 1.06/$m^3$ | 98.10 | 3.16/$m^3$ | 113.14 | 3.65/$m^3$ |
| Fence and gate | 760 m | 22.00 | 0.03 | 485.00 | 0.64/m | | |

The bottom load of sand and silt, however, is deposited in the dam reservoir. To concentrate this deposition in shallow water, where it can be removed at lower water levels, a stone wall should be constructed across the narrow upstream part of the water reservoir.

Algae and other plant life increase the proportion of organic substances in the suspended matter, as is evidenced by the fact that determinations in the Dusha River showed 5.2-8.6% of carbon in the suspended matter, whereas in the Asella dam reservoir the amount was 6.6 - 11.7%.

5.6.4.2 Chemical quality

The chemical quality of periodic rivers is thought to be the same as that of perennial rivers. Further, analyses of the perennial Dusha River and the Asella dam reservoir show the same chemical character, but in this particular dam the large depth of 13 m has resulted in a stagnant bottom water with decay processes going on and a reduction of the trivalent iron into soluble divalent iron (table 33, p. 133).

5.6.4.3 Sanitary quality

Judging also from the Asella dam the bacteriological quality is better in the dam reservoir than in the inflowing river (table 34, p. 133).

## 5.6.5 Cost of dams

### 5.6.5.1 Dam at Egu

The costs in Eth. $ for the Egu dam were:

| | | |
|---|---|---|
| salaries: for administration | Eth. | $1,003.00 |
| for labourers | " | $ 771.10 |
| material | " | $ 904.40 |
| transport: of material | " | $ 393.10 |
| of administrative person | | $ 823.20 |
| Total | Eth. | $3,894.80 |

Table 33 Analyses of iron and calcium (concentrations in ppm) in Asella water system

| Sampling date | Dusha River | | Asella dam | | Before filter | | After filter | | Public tap | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Fe | Ca | Fe | Ca | Fe | Ca | Fe | Ca | Fe | Ca |
| April 1971 | 0.10 | 10.5 | 0.61 | 6.6 | 0.30 | 10.1 | 0.18 | 27.3 | 0.04 | 17.5 |
| August 1971 | 0.12 | 7.7 | 0.66 | 6.6 | 0.50 | 6.0 | 0.23 | 20.0 | 0.23 | 20.4 |
| October 1972 | - | - | 1.63 | 3.6 | 1.90 | 4.0 | 0.60 | 12.3 | 1.64 | 15.0 |
| February 1973 | 0.23 | 6.5 | 1.46 | 5.0 | 1.59 | 5.1 | 1.80 | 13.9 | 1.73 | 14.0 |

Table 34 Bacteriological tests in the Iusha River and in the Asella dam reservoir

| Sampling date | Total plate count at 37°C after 48 hours (organisms/ml) | Presumptive coliform count (organisms/100 ml) | Presence of Escherichia coli |
|---|---|---|---|
| Dusha River | | | |
| 28/11 1969 | greater than 5,000 | 160 | + |
| 6/4 1970 | 3,200 | greater than 180 | + |
| 28/8 1970 | 1,040 | 35 | - |
| Asella dam reservoir | | | |
| 28/11 1969 | 450 | 14 | - |
| 29/3 1971 | 240 | 24 | - |
| | 49 | 8 | - |

Starting with the dam reservoir filled up, the available water volume after evaporation and seepage losses has been estimated at 4,000 $m^3$. Thus the cost to create this water reservoir has been Eth. $0.81 per $m^3$ of available water capacity.

Assuming the consumption quantities per person and per animal used in this report, the Egu dam reservoir can supply more than 1,000 persons with water; alternatively around 200 persons, 300 large livestock and 200 small livestock. If the needs of livestock are disregarded the dam reservoir seems to have the possibility of supplying the village of Egu with water. On this basis the construction cost works out at $19 per family; if only 200 people and their livestock are catered for then the cost per family is $102:-.

5.6.5.2 Comparison of pond and dam

For a comparison of pond and dam I have summed up the excavation and transportation works of the experimental projects:

| place | project | moved earth $m^3$ | available water $m^3$ | excavation cost, Eth. $ | price per $m^3$ moved earth | per $m^3$ available water capacit |
|---|---|---|---|---|---|---|
| Egu | pond | 2,400 | 1,200 | 1,700 | 0.71 | 1.42 |
| flooded | pond | 5,500 | 2,400 | 2,060 | 0.37 | 0.86 |
| Egu | dam | 1,075 | 4,000 | 793 | 0.74 | 0.20 |

It is interesting that bulldozer power and manpower cost about the same in terms of output. If there is a dam site that gives a good ratio between dam volume and the water reservoir, the obtainable water volume is cheaper in a dam project than in a pond project.

# 6 CONSUMPTION WATER PROGRAMME

## 6.1 Water consumption

### 6.1.1 Consumption now and in the future

The total water consumption in the Chilalo Awraja has been calculated to be 387 l/s during 12 hours every day:

| | Persons | Large Livestock | Small Livestock | Total |
|---|---|---|---|---|
| Total number | 396,137 | 599,600 | 381,681 | - |
| Consumption: | | | | |
| l/day/capita | 10 | 20 | 2 | - |
| l/day | 3,961,370 | 11,992,000 | 763,362 | 16,716,732 |
| l/s during 12 hours | 91.7 | 277.6 | 17.7 | 387.0 |
| Relative total consumption | 5.2 : | 15.7 : | 1 | - |

How the demand of water will develop in the future is difficult to predict. According to experience in other countries an increased availability of water does not increase the consumption much. Instead an increase of the water demand depends on social and cultural development. When the rural population has been more educated in schools, the demand is expected to increase regarding both quantity and quality of water.

In the future a doubled population and a doubled consumption per capita will give a demand of 367 l/s for human consumption. As to the livestock, the water consumption is higher than in my table above in most more-developed countries; cattle and horses 38-45 l/d, sheep and goats 3-4 l/d. Thus the livestock consumption could be doubled to 591 l/s. More intensified gardening will also increase the demand of water. It is quite obvious that only in areas where there are large natural supplies will water from this source be sufficient in the future.

### 6.1.2 Geographical distribution of consumption

The large perennial rivers, two large springs and two large lakes are now the most important natural water resources and will also be so in the future. The map fig. 38 (p. 137) shows areas with walk distances of 2 km, 4 km, 6 km and more than 6 km from the large water resources. According to an investigation in Tanzania the "critical" distance is between 1½ and 2 hours walking (a distance from supply to house of 4.5-6 km). This is also valid in Chilalo. In any case, 6-8 km is regarded as a long walk distance here.

The wide areas where water supplies are poor have been divided into five geographically different areas, and the number of persons per sq. km calculated (fig. 39, p. 138 and table 35, p. 139). In the table 36 the number of persons per sq. km has been calculated for those parts of the five areas which are outside a walk distance of 6 km. It is interesting to find that there are small differences in population density between the total areas and those situated more than 6 km from the water supplies. In three areas (2a, 3a and 5b) the population is denser in the areas more than 6 km from water supplies. The availability of good land for agriculture has been more important than the availability of consumption water.

## 6.2 Different types of water supply

### 6.2.1 Selection of water supply

The water quantities of perennial rivers are limited. Gravity flow from perennial rivers is difficult to arrange in Chilalo because of the deep valleys. The incised nature of the river valleys necessitate lengthy water channels, and in many cases the valleys of tributaries make ditch or pipeline construction difficult.

Especially in the lowlands there is an increased risk of bilharzia and malaria when open ponds or dams are the source of water for human consumption. Therefore, where possible, household wells for human consumption should be provided with the cattle needs being met by ponds or dams somewhat remote from the centres of habitation. Simple ground storage of water demands good soil conditions regarding permeability. Good clays - as far as is known - are available in areas 3a, parts of 3b, 4a and 4b, and the southern part of 5a. In other areas a waterproof lining is necessary.

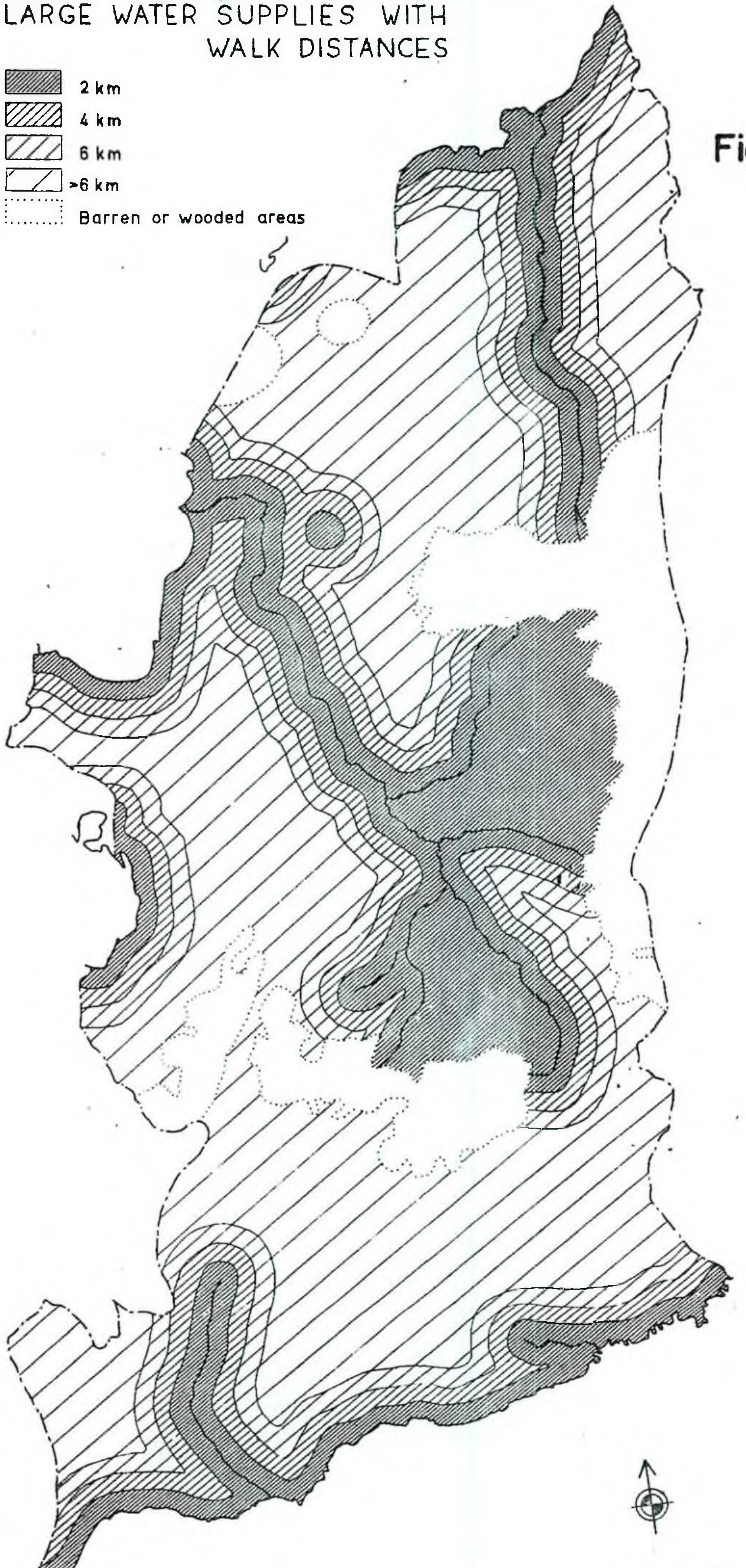

LARGE WATER SUPPLIES WITH WALK DISTANCES
2 km
4 km
6 km
>6 km
Barren or wooded areas
Sept. 1973
0
10 km
Fig. 38

Table 35 Calculation of population density within the five areas of fig 38, p. [illegible]3
(from census of consumption units)

| Area | $km^2$ | Number of Consumption units | Consumption units per $km^2$ | Persons per consumption unit | Persons per $km^2$ |
|---|---|---|---|---|---|
| 1 Awash Valley | 202 | 276 | 1.37 | 25 | 34 |
| 2 Rift Valley | 1,207 | 1,531 | 1.27 | 31 | 39 |
| 3 Wabe Shebelle Valley | 2,277 | 3,695 | 1.62 | 28 | 45 |
| 4 Lukuche Plain | 1,172 | 2,280 | 1.94 | 24 | 47 |
| 5 Chilalo Plateau | 1,958 | 5,486 | 2.80 | 27 | 76 |

Table 36 Calculation of population density in areas more than 6 km from large water supplies

| | Area | $km^2$ | Number of consumption units | Consumption units per $km^2$ | Persons per consumption unit | Persons per $km^2$ |
|---|---|---|---|---|---|---|
| 1 a+b | Awash Valley | 15 | 20 | 1.33 | 24 | 32 |
| 2a | Rift Valley | 250 | 410 | 1.64 | 31 | 51 |
| 2b | | 271 | 256 | 0.94 | 27 | 26 |
| 2a | Wabe Shebelle Valley | 194 | 385 | 1.99 | 29 | 58 |
| 2b | | 1,034 | 1,875 | 1.81 | 27 | 49 |
| 4a | Lukuche Plain | 373 | 700 | 1.88 | 22 | 41 |
| 4b | | 60 | 107 | 1.78 | 24 | 43 |
| 5a | Chilalo Plateau | 544 | 1,536 | 2.82 | 27 | 76 |
| 5b | | 256 | 949 | 3.71 | 24 | 89 |

If ground water is available, this is preferable because of its better quality.

6.2.2 Sequence of providing water supply facilities

The construction of a water supply includes three steps:

1) creating a water supply
2) purification of water and
3) distribution of water in pipes.

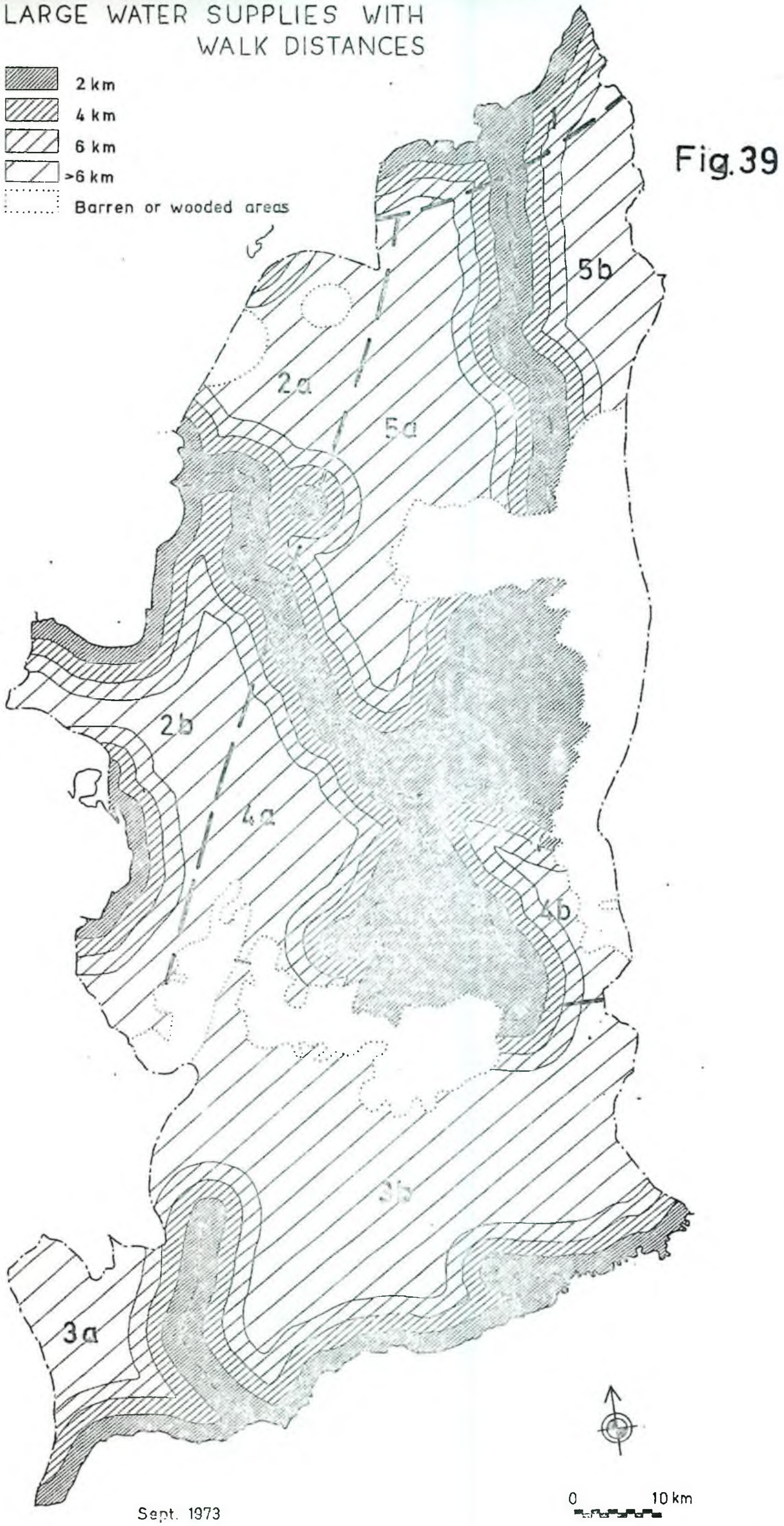
At present only the first step can commonly be of interest in rural areas. Chemicals are expensive and the purification troublesome. People do not always appreciate the importance of unpolluted water. For example a water well at Egu was regarded good when it contained four dead frogs and four alive ones. Even if the water should be purificated in the water supply, the water often is contaminated during the storage in the houses because of unhygienic domestic containers.

Especially when river or lake water is used, there are sometimes risks of diseases such as typhoid, infectious hepatitis and cholera. Human drinking water should be boiled, filtered or treated with, for example, chloride tablets in the households.

6.3 Comparison of costs of water from different supplies (table next page)

The experience so far is limited, and it is possible that the costs of the experimental water supplies can be reduced. In the following table, however, the real costs according to previous chapters are presented, together with some prices for water sold in Chilalo. Column 'a' is the construction cost obtained by dividing the total cost by the available water volume. In columns 'b' and 'c' an amortization has been made over 5 or 10 years respectively at the rate of 10%.

A dam reservoir on a good site gives cheaper water than a pond. A drilled well is not more expensive than a pond. Wells are to be prefered as they give cleaner water. The water of household wells and tanks is expensive. Water transported by lorry is cheaper. The sizes of the experimental iron tanks are so small that they will last only 3-6 months or permit a consumption of only 10-24 l/d all the year round.


LARGE WATER SUPPLIES WITH WALK DISTANCES
2 km
4 km
6 km
>6 km
Barren or wooded areas
Fig.39
5b
2a
5a
2b
4a
4b
3b
3a
0
10 km
Sept. 1973

| Water supply | Cost Eth. $/m³ of water a | b | c | Sales price Eth.$/m³ |
|---|---|---|---|---|
| Transport by lorry from Gonde River to Ethaya | - | - | - | 2.50 |
| Piped water from: | | | | |
| dam reservoir (Asella) | - | - | - | 0.50 |
| Awash River (Dhera) | - | - | - | 0.65 |
| spring (Bekoji) | - | - | - | 0.50 |
| Periodic rivers collected in: | | | | |
| natural pond (Dodota) | - | - | - | 0.15 |
| clay pond (Egu) | 2.83 | 0.75 | 0.46 | - |
| lined pond (Dodota) | 5.19 (a) | 1.37 | 0.85 | - |
| dam reservoir (Egu) | 0.81 | 0.21 | 0.13 | - |
| Ground water: | | | | |
| drilled well (70 m with a handpump) | 2.72 | 0.72 | 0.44 | - |
| Rainwater cellected in: | | | | |
| A. household wells (50 l/day consumption) | | | | |
| a. with puddled clay (Katjama) and catchment: on roof | 25.61 | 6.76 | 4.17 | - |
| on grassy ground | 25.00 | 6.59 | 4.07 | - |
| b. with plastic liner (Dodota) and catchment: on roof | 19.72 | 5.20 | 3.21 | - |
| on plastic sheet | 32.11 | 8.47 | 5.23 | - |
| c. with cement + cement mortar and catchment on roof | 30.00 | 7.91 | 4.88 | - |
| B. iron tanks with roof catchment | | | | |
| a. circular galvanized iron | 103.18 | 27.22 | 16.79 | - |
| (10-50 l/day consumption)(b) | 20.67 | 5.44 | 3.36 | - |
| b. square black iron | 61.42 | 16.20 | 10.00 | - |
| (25-50 l/day consumption)(b) | 30.71 | 8.10 | 5.00 | |

(a) can be reduced

(b) 10 and 25 l/day represent an extended dry season.

6.4 Implementation of the water supply programme to ate

Built-up areas, including village with some hundred inhabitants, have 45,780 persons, i.e. 12% of the population of the Chilalo Awraja. Their needs are met by different types of supplies according to table 37 (p. 143-144).

In Africa the definition of a rural area varies, including built-up areas, with from 2,000 to 5,000 inhabitants. If 2,000 is taken as a limit, there are only six towns in Chilalo (Asella, Bekoji, Dhera, Huruta, Kofale and Sire), with 30,650 inhabitants or 7% of the population of the Chilalo Awraja. Of these approximately 50% are supplied by piped water. Of those not using piped water, about 30% take water from perennial rivers, 10% from springs and 10% from dug wells.

In the rural areas, including built-up areas with populations not more than 2,000 persons, there is piped water only at Sagure. Only 4% of the rural population are supplied by drilled wells (see table 38, p. 145) and 4% by springs, dams or dug wells. Thus by 92% of the rural population use ordinary river water.

If all the Awraja is considered, 91% of the people use rivers and lakes; 4% drilled wells; 3% dams and 2% springs. Only 10% of the population use a water which is "safe" from a sanitary point of view. Only 8% of the population use constructed water supplies, which is a low number compared to other developing countries. During the implementation period around 30 water supplies have been constructed so far, not counting household wells. See map fig. 40 (p. 146 ). A further half a dozen are under construction. More effort is needed to provide safe water supplies; the number of constructed supplies will have to be increased.

Which groups of people have been able to afford water supplies? Most important have been the concentrations of people in towns and other built-up areas. These areas have had economic and administrative capability to order water supplies. Then, in some areas private interests have combined with the demand of people, to make possible the construction of a water supply. Sometimes a rich landowner or a mission have paid for the whole of of a water supply, not only for themselves but also for the labourers, schools, clinics, etc. Then there is a third category, people with walk distances to water more than 8 km during the dry season, who have been able to make some contribution towards the cost of a water supply.

Table 37 Number of people using different types of water supplies in built-up areas

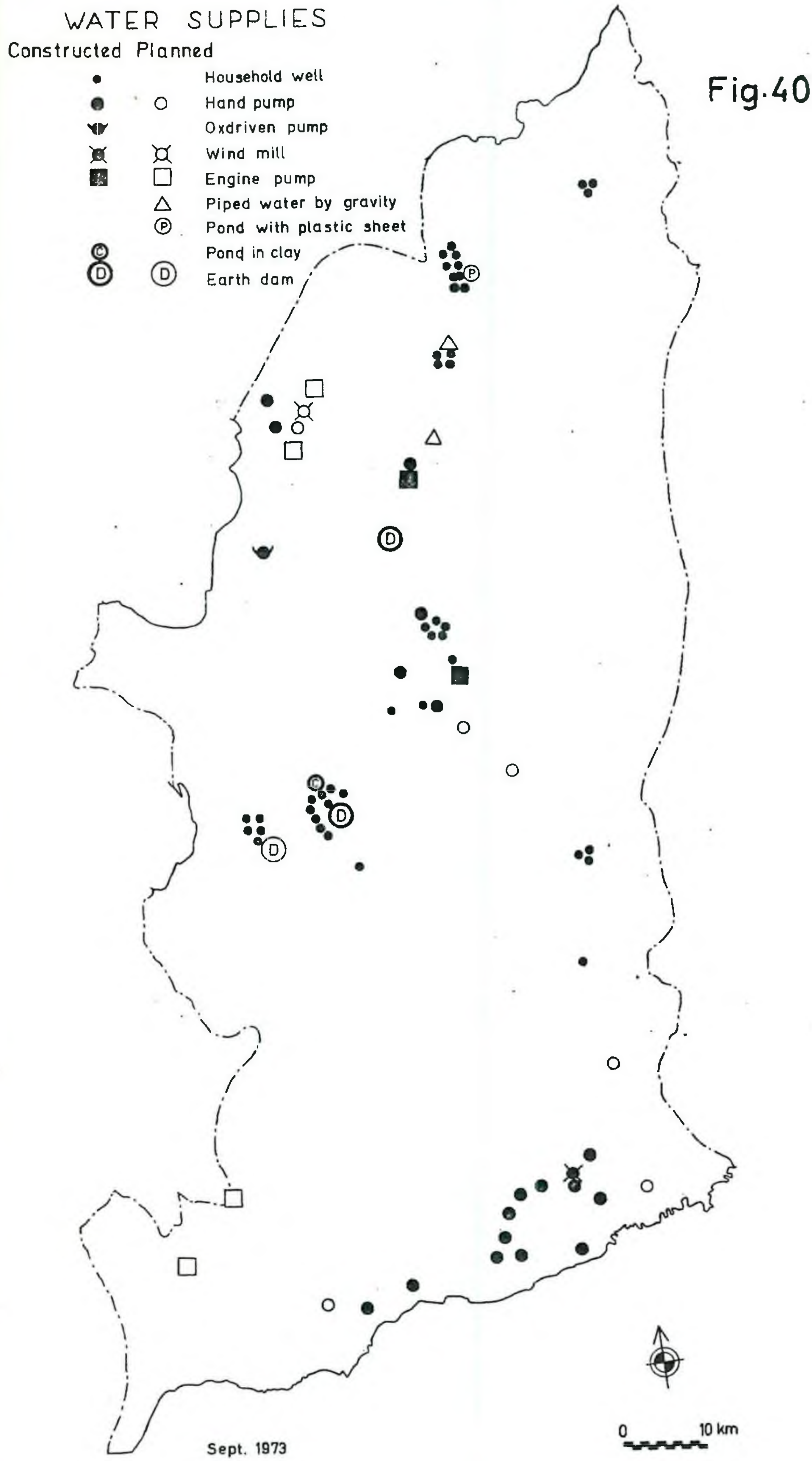
| Built up areas | Population | Source of water supply | | | | | Piped water |
|---|---|---|---|---|---|---|---|
| | | Rivers | Dams | Springs | Dfilled wells | dug wells | |
| Abura | 1,100 | 1,000 | - | - | - | 100 | - |
| Asassa | 1,100 | - | - | 1,100 | - | - | - |
| Asella | 12,400 | 2,400 | 10,000 | - | - | - | 10,000 |
| Bekoji | 2,400 | - | - | 2,400 | - | - | 2,400 |
| Change | 700 | - | - | 700 | - | - | - |
| Degaga | 300 | 300 | - | - | - | - | - |
| Dhera | 3,000 | 3,000 | - | - | - | - | 3,000 |
| Dighelu | 300 | - | - | 300 | - | - | - |
| Egu | 300 | - | 300 | - | - | - | - |
| Ethaya | 1,300 | 1,300 | - | - | - | - | - |
| Gimbite | 200 | 200 | - | - | - | - | - |
| Gonde | 800 | 800 | - | - | - | - | - |
| Gumguma | 400 | 400 | - | - | - | - | - |
| Huruta | 6,000 | 6,000 | - | - | - | - | - |
| Karsa | 1,000 | 1,000 | - | - | - | - | - |
| Katar Genet | 800 | 800 | - | - | - | - | - |

Table 37 contd.

| Built up areas | Population | Source of water supply | | | | | Piped water |
|---|---|---|---|---|---|---|---|
| | | Rivers | Dams | Springs | Drilled wells | Dug wells | |
| Kofale | 3,100 | - | - | - | - | 3,100 | - |
| Kore | 500 | 450 | - | - | - | 50 | - |
| Kulumsa | 600 | - | - | - | 600 | - | - |
| Lemu | 300 | 300 | - | - | - | - | - |
| Lole | 260 | 260 | - | - | - | - | - |
| Meraro | 1,100 | 1,100 | - | - | - | - | - |
| Munessa | 500 | 500 | - | - | - | - | - |
| Sagure | 2,000 | 1,000 | - | - | 1,000 | - | 1,000 |
| Shire | 470 | 470 | - | - | - | - | - |
| Sire | 3,750 | - | - | 3,750 | - | - | - |
| Tijo | 500 | 500 | - | - | - | - | - |
| Welenkome | 300 | 300 | - | - | - | - | - |
| Wocentra | 300 | 300 | - | - | - | - | - |
| Total | 45,780 | 22,300 | 10,300 | 8,250 | 1,600 | 3,250 | 16,400 |

Table 38 Number of people using drilled wells outside built-up areas

| No. of wells | Number of people |
|---|---|
| 7 | 360 |
| 14 | 560 |
| 22 | 560 |
| 23 | 560 |
| 43 (windmill) | 560 |
| 32 | 450 |
| 38 | 810 |
| 45 | 300 |
| 37 | 400 |
| 46 | 360 |
| 39 | 500 |
| 40 | 470 |
| 47 | 560 |
| 33 | 900 |
| 34 | 650 |
| 50 | 900 |
| 51 | 1,230 |
| 56 | 950 |
| 35 | 250 |
| Total | 11,330 |



WATER SUPPLIES
Constructed Planned
Household well
Hand pump
Oxdriven pump
Wind mill
Engine pump
Piped water by gravity
Pond with plastic sheet
Pond in clay
Earth dam
Fig.40
0 10 km
Sept. 1973

## 6.5 Proposals of further supplies

### 6.5.1 Built-up areas

Priority should be given to supplying the built-up areas with water. There are three reasons of this:

1) the needs of the built-up areas are more critical than the country side from a sanitary point of view,

2) the economic feasibility is better because of the concentration of richer people and,

3) there is better appreciation of the value of clean water.

The following built-up areas are already supplied with "safe" water: Asella (14,000 inhabitants), Bekoji (2,400), Dhera (3,000), Kulumsa (600) and Sagure (2,000). The town of Huruta is due to be supplied by other foreign aid.

I have visited the built-up areas of the Chilalo Awraja, both towns and villages, and made a rough estimate of the cost of supplying 22 built-up areas with water (table 39, p. 148-149 and fig. 41).

In most cases the natural water resource is "safe" ground water from drilled wells or springs. Only in 4 - 6 exceptional cases are the water resources either a river or a dam. In one case household wells are an alternative to a dam, in another to a pipeline.

The idea is that every built-up area should have sufficient water for the people and animals within the built-up area. Pipelines should conduct the water to the built-up area, if the water is not available there. If water by gravity is int available. I have proposed a "pump unit", either a windmill or, exceptionally, an engine. In small villages, however, I think a hand pump or an ox-powered pump is to be prefered, e.g. at Dighelu and Shire. This will reduce the cost by Eth. $6,000 and will be safe and economical in operation. In one place with a small population, Munessa, I have proposed household wells, which will be cheaper than a water supply common to all. At Wekentra with 300 people, however, CADU's Road Section is also interested in a well.

Table 39 Preliminary proposals of water supplies in the built-up areas of the Chilalo Awraja

| Place | Approximate size population | Type of water resource | Type of water supply | Approximate costs in Eth. $ construction work | $ | Total |
|---|---|---|---|---|---|---|
| Abura(a) | 1,100 | well | pipeline | drilling | 2,000 | |
| | | | | pump and pipeline | 18,000 | 20,000 |
| Asassa | 1,000 | well | wellhead | drilling | 3,000 | |
| | | | | pump unit | 6,000 | |
| | | | | tank etc. | 1,000 | 10,000 |
| Change | 700 | spring | pipeline | intake | 400 | |
| | | | | pump unit | 6,000 | |
| | | | | pump house | 1,000 | |
| | | | | pipe | 6,300 | |
| | | | | tank, etc. | 1,000 | 14,700 |
| Degaga | 400 | spring or river | pipeline | intake | 500 | |
| | | | | pipe | 14,000 | |
| | | | | tank etc. | 1,000 | 15,500 |
| Dighelu | 300 | well | wellhead | drilling | 3,600 | |
| | | | | pump unit | 6,000 (d) | |
| | | | | pump house | 1,000 | |
| | | | | tank etc. | 1,500 | 12,100 |
| Egu (b) | 300 | dam | pipeline | pump unit | 6,000 | |
| | | | | pump house | 1,000 | |
| | | | | pipe | 3,500 | |
| | | | | tank etc. | 1,500 | 12,000 |
| Ethaya(c) | 1,300 | well or river | pipeline | | | |
| Gimbite | 250 | spring | pipeline | intake | 500 | |
| | | | | pipe | 10,000 | |
| | | | | tank etc. | 1,000 | 11,500 |
| Gonde | 800 | spring | pipeline | intake | 500 | |
| | | | | pump unit | 6,000 (d) | |
| | | | | pump house | 1,000 | |
| | | | | pipe | 14,000 | |
| | | | | tank etc. | 1,500 | 23,000 |
| Gumguma | 400 | well | pipeline | drilling | 5,000 | |
| | | | | pump unit | 6,000 | |
| | | | | pump house | 1,000 | |
| | | | | pipe | 7,000 | |
| | | | | tank etc. | 1,500 | 20,500 |
| Karsa | 1,000 | well | wellhead | drilling | 7,500 | |
| | | | | pump unit | 6,000 | |
| | | | | pump house | 1,000 | |
| | | | | tank etc. | 1,000 | 15,500 |

(a) already drilled and designed people expected to collect money for a distribution system

(b) dam already constructed (c) a large and expensive project already under survey

(d) or hand pump $1,000

Table 39 contd.

| Place | Approximate size population | Type of water resource | Type of water supply | Approximate costs in Eth. $ construction work | $ | Total |
|---|---|---|---|---|---|---|
| Katar Genet (= Golja) | 800 | river | pipeline | pump unit | 6,000 | |
| | | | | pump house | 1,000 | |
| | | | | pipe | 14,000 | |
| | | | | tank etc. | 1,500 | 22,500 |
| Kofele | 3,100 | well | wellhead | drilling | 3,600 | |
| | | | | pump unit | 6,000 | |
| | | | | pump house | 1,000 | |
| | | | | tank etc. | 1,500 | 12,100 |
| Kore | 500 | well | wellhead | drilling | 3,600 | |
| | | | | pump unit | 6,000(g) | |
| | | | | pump house | 1,000 | |
| | | | | tank etc. | 1,500 | 12,100 |
| Lole | 260 | river | pipeline | intake | 1,000 | |
| | | | | pump unit | 6,000 | |
| | | | | pump house | 1,000 | |
| | | | | pipe | 14,000 | |
| | | | | tank etc. | 1,500 | 23,500(e) |
| Meraro | 1,100 | river or spring | pipeline | intake | 500 | |
| | | | | pipe | 14,000 | |
| | | | | tank etc. | 1,500 | 16,000 |
| Munessa | 500 | dam | pipeline | dam | 7,000 | |
| | | | | pump unit | 6,000 | |
| | | | | pump house | 1,000 | |
| | | | | pipe | 21,000 | |
| | | | | tank etc. | 3,000 | 38,000(f) |
| Shire | 470 | well | wellhead | drilling | 3,600 | |
| | | | | pump unit | 6,000 (g) | |
| | | | | pump house | 1,000 | |
| | | | | tank etc. | 1,500 | 12,100 |
| Sire | 3,750 | well | | drilling | 10,000 (h) | |
| Tijo | 500 | well | wellhead | drilling | 4,200 | |
| | | | | pump unit | 6,000(g) | |
| | | | | pump house | 1,000 | |
| | | | | tank etc. | 1,500 | 12,700 |
| Welencome | 300 | river | pipeline | intake | 500 | |
| | | | | pump unit | 6,000 | |
| | | | | pump house | 1,000 | |
| | | | | pipe | 7,000 | |
| | | | | tank etc. | 1,500 | 16,000 |
| Wekentra | 300 | well | wellhead | drilling | 9,000 | |
| | | | | pump unit | 6,000 | |
| | | | | pump house | 1,000 | |
| | | | | tank etc. | 1,500 | 17,500 |
| Total | 21,730 | people rounded to 20,000 | | Total | | 338,300 |

(e) or household wells Eth. $15,000
(f) or household wells Eth. $ 30,000
(g) or hand pump Eth. $1,000

(h) This drilling will be paid for by the town; if water is struck further survey has to be done

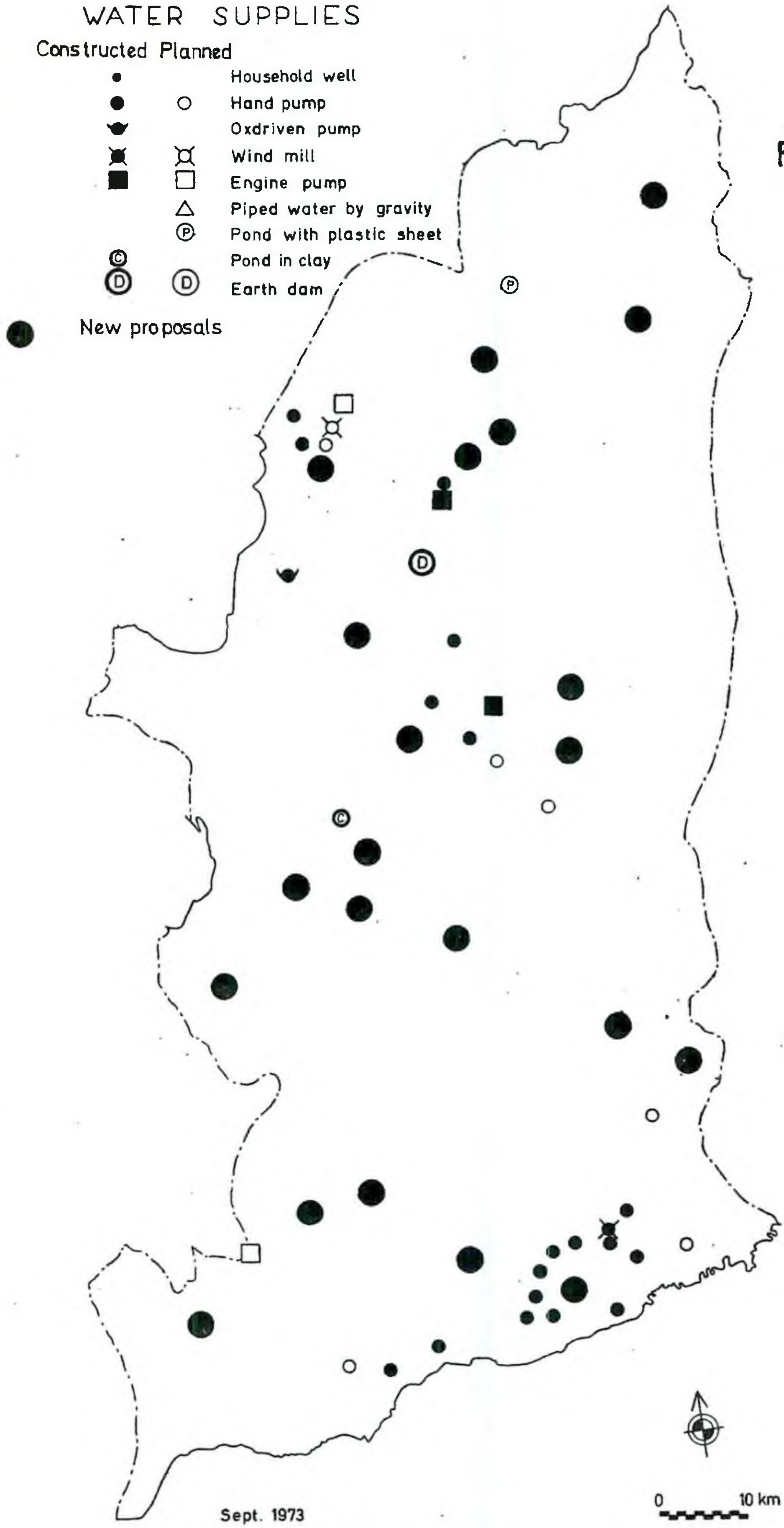

WATER SUPPLIES
Constructed Planned
Household well
Hand pump
Oxdriven pump
Wind mill
Engine pump
Piped water by gravity
Pond with plastic sheet
Pond in clay
Earth dam
New proposals
0
10 km
Sept. 1973

Fig.41

For a cost of Eth. $350,000 around 20,000 people in most of the built-up areas can be supplied with water. In the reality people living round the built-up areas will also be supplied with water, e.g. as at Kulumsa where people walk 5 km to the hand pump. In such a case about 1,200 people will be supplied instead of only the 600 people of the built-up area.

I am sure that for a construction cost of $350,000 at least 50,000 will probably be supplied with water. The actual cost per capita will be $7 if this potential usage is realised, not the $17 that a calculation solely on the number of urban beneficiaries would indicate.

Some of the proposed supplies (rivers and dams) need purification regarding suspended load and bacteria. I do not think the populations of all areas are yet prepared to pay for such treatment. Individuals who are not satisfied by a common water supply without treatment, can construct household wells and/or clean the drinking water in their homes.

A third step is distribution of the common water to the different households and other consumers of water. At present this step can be taken only by large communities, e.g. some of the towns.

The question often is, however, whether the people can afford the cost of even a simple water supply. I think several of the water supply proposals can be simplified; in small villages the pump units can be replaced by hand pumps as proposed alternatively. Regarding springs and rivers with water supply by gravity a start could be made with an intake and a cheaper pipeline. In four places, with the water supply in a deep river valley, it is difficult to simplify the proposed water supply system.

### 6.5.2 Rural areas

The criteria for priority of new water supplies should be:

1) large distance to present water supplies,
2) interest and request of the people,
3) lack of natural water resources in a near future,
4) resources of good quality available,
5) the area has general economic potential and
6) the area is accessible at present.

On the map fig. 42 (p. 153 ) areas with longer walk distances than 2 km have been transfered from fig. 38. Small springs and small perennial rivers have been disregarded. Of course the central parts of the vast areas between the large rivers and lakes have the most urgent need, because the walk distances to water at present are more than 10 km.

It is noteworthy that the requests for aid come mainly from areas with large walk distances:

1) the Dodota area west of the Geleta River,
2) the Rift Valley northeast of Lake Zuai,
3) the Egu area southwest of the Katar River and
4) the areas north of the Wabe Shebelle River.

From fig. 25 to fig. 42 (p. 153 ) I have transfered areas which will have a lack of water in the near future, i.e. within 10 - 20 years.

As river water by gravity is difficult to obtain, and as the river water is always bacteriologically polluted and often dirty because of the suspended load, ground water is to be prefered. Another reason to look for ground water in the first instance is that drilling equipment is now available through CADU at low costs. To the map fig. 42 I have transfered areas, where ground water resources are regularly available within 100 metres depth at least in carefully selected sites.

Regarding the potential for agriculture no survey data covering all Chilalo exists, but Mr. Olle Hammar, Head of the Crop and Pasture Section, has agreed that potentials exist on the plateaux round Chilalo and Kakka Mountains, in parts of the Rift Valley and in the Wabe Shebelle valley. These areas have ground water resources available in some parts.

At present some areas are not accessible because of lack of roads, e.g. the Rift Valley east and northeast of Lake Langano and most slopes of the Chilalo and Kakka Mountains. These areas are thought not to have good ground water resources.

RURAL AREAS, PRIORITY FOR WATER SUPPLIES

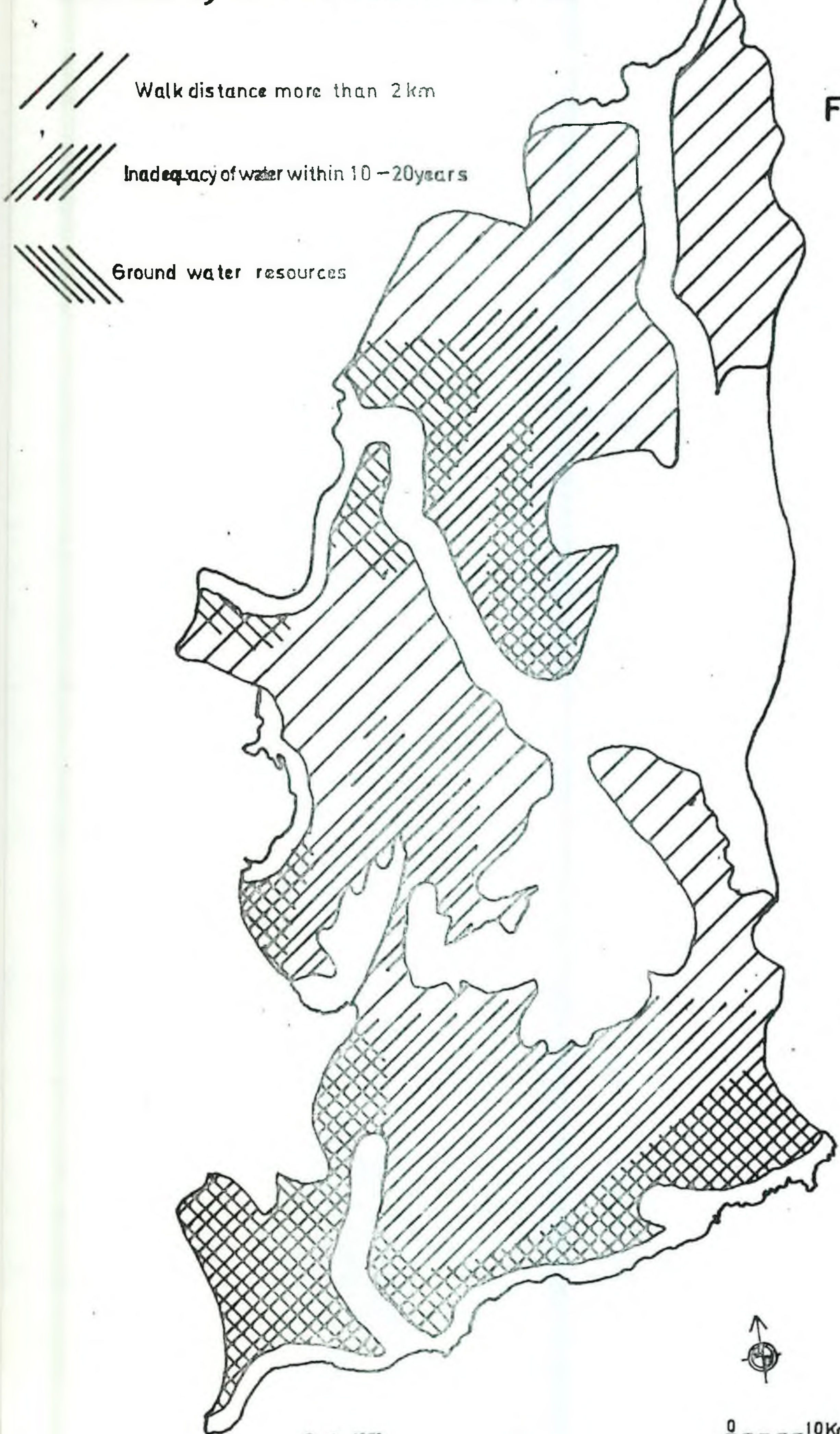



Fig. 42

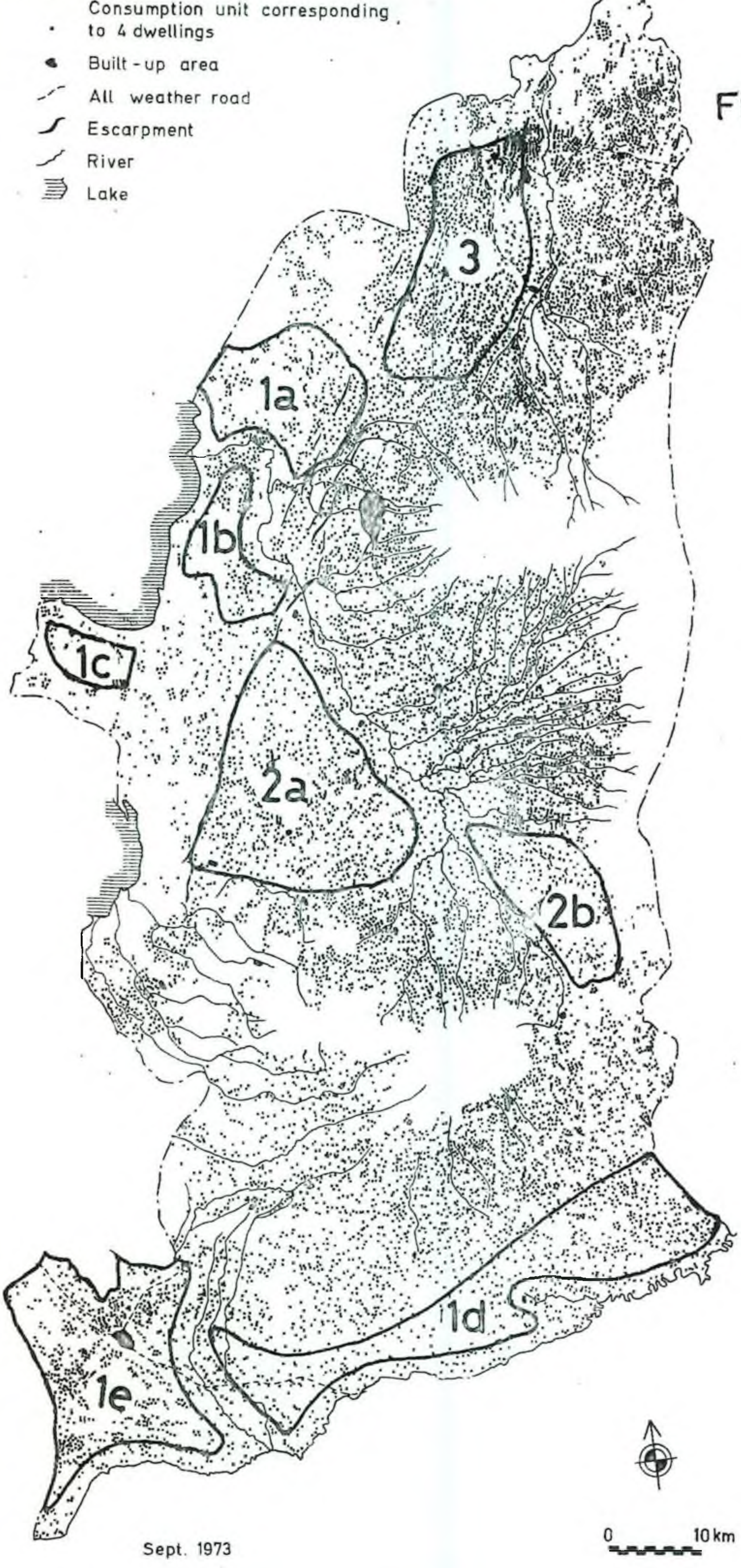
In the areas satisfying the criteria of need for water supplies ground water is not available everywhere. Therefore, the type of water supply has to conform to the hydrogeological conditions. I propose activities in the following areas:

| | | |
|---|---|---|
| 1 a. | accessible parts of the Rift Valley northeast of Lake Zuai, called the Abura area | dug or drilled wells |
| 1 b. | The Rift Valley between Lake Zuai and the Katar River, called the Chefe Djila area | drilled wells |
| 1 c. | the Rift Valley south of Lake Zuai, called the Djila area | dug or drilled wells |
| 1 d. | the area north of the Wabe Shebelle River | drilled wells |
| 1 e. | the Kofale district | mainly dug & drilled wells |
| 2 a. | the area between the Katar River and the Munessa Mountain, called the Egu area | earth dams |
| 2 b. | the area round Bekoji | earth dams and possibly drilled wells |
| 3. | the area west of the Geleta River, called the Dodota area | lined ponds |

The areas mentioned above have been marked on the map fig. 43 (p. 155 ), showing proposed water supply activity in rural areas. People cannot yet understand or take interest in the provision of water supplies needed 10-20 years hence; I have therefore excluded areas with many small rivers from the activity areas: i.e. round the Chilalo and Kakka Mountains. Areas which are not accessible at present, have also been excluded: the area east of the Geleta River, the area east and northeast of Lake Langano and the northern slopes of the Wabe Shebelle Valley.

## AREAS PROPOSED FOR RURAL WATER SUPPLY ACTIVITIES

Fig. 43



With the aid of the figures in chapter 4.2 the numbers of households and people have been calculated within the activity areas:

| | areas | households | people | already supplied | remaining to supply |
|---|---|---|---|---|---|
| 1 a. | Asassa | 1,100 | 9,900 | 5,000 | 4,900 |
| 1 b. | Chefe Djila | 600 | 5,400 | 1,000 | 4,400 |
| 1 c. | Djila | 200 | 1,800 | 0 | 1,800 |
| 1 d. | Wabe Shebelle | 2,300 | 15,900 | 1,500 | 14,400 |
| 1 e. | Kofale | 2,650 | 19,350 | 0 | 19,350 |
| 2 a. | Egu | 2,550 | 14,000 | 0 | 14,000 |
| 2 b. | Bekoji | 1,350 | 8,100 | 0 | 8,100 |
| 3 | Dodota | 3,100 | 18,750 | 0 | 18,750 |
| | Totals | 13,700 | 93,200 | 7,500 | 85,700 |

If we take $6,000 as a mean cost of a water supply for 500 persons, the total cost would be round Eth. $1,000,000 or $12 per capita. For different reasons, however, all the people of the activity areas cannot be supplied with water. Often topographical and geological conditions prevent any economic execution of a communal water supply scheme.

It will not be possible to provide all individual households with common water supplies in a near future, if ever. Therefore, household wells have to the considered to large extent. Different designs have been tested; they are appliable to different conditions regarding houses, soil and climate.

No ecological disadvantages are to be expected by new common water supplies, as e.g. in East-Africa, where the Masai tribes concentrate their cattle herds round drilled wells. The private landowners in Chilalo do not permit other people to graze their cattle around the wells, but only permit them to use already existing paths.

# 7 IRRIGATION POSSIBILITIES

## 7.1 Present irrigation

At present two modern farms are irrigated from the Simba River and one large farm from the Anko River.

Irrigation at a smaller scale is used by the people in a few places, especially below the southern part of the Munessa forest, where the topographical conditions for conducting water by gravity are good.

## 7.2 Natural conditions regarding increased irrigation

### 7.2.1 Tests of water quality

Two criteria are especially important for irrigation water: the salinity and the sodium adsorption ratio.

The salinity can be expressed as total amount of dissolved solids (TDS) in mg/l. The TDS value can be translated into conductivity in micromhos/cm at 25°C with aid of the graph on fig. 44 (p.158 ). The permissible limits regarding TDS and conductivity are given in a table below fig. 44 (p.158 ).

The relation between sodium on one hand, and calcium and magnesium on the other also has to be considered. The latter ions must be adsorbed on the clay particles, to maintain good tilth and permeability properties. This will not happen if the sodium is too dominant. The sodium adsorption ratio (SAR)

$$= \frac{\text{sodium}}{\sqrt{(\text{calcium} + \text{magnesium})/2}}$$

has been calculated for perennial rivers, lakes and drilled wells. The SAR values are given in the last column of the tables showing chemical quality (tables 7 and 14, p. 21 and 51 - 52). The permissible limits are demonstrated in the diagram (fig. 45, p. 159).

The Katar River has in its lower part a TDS value of 80 (corresponding to a conductivity less than 150 micromhos). The SAR value is only 0.5. Both the TDS and the SAR values are far below the permissible upper limits for irrigation water.

7.2.2 Available water quantities

Irrigated agriculture requires water in a quantity of 0.5 - 1 l/s per hectare. Thus large quantities are needed for irrigation schemes. As the water of the Awash River with its tributary Geleta River and the Wabe Shebelle River are needed for other development projects, only the Katar River remains for irrigation in the Chilalo Awraja, if large dams are not constructed.

In 1971 the minimum flows of the Katar River during the months of January-April were 1,550 - 1,660 l/s. As the smallest values were constant over some months, the method of measuring is perhaps suspect. In January 1967 I measured 1,200 l/s in the Katar River below the old stone bridge between Dugda and Laki.

The available water quantity in the Katar River, however, cannot be 1,200 l/s. The water consumption of people and cattle will be at least doubled in a near future. This demand of water will be approximately 200 l/s in those parts of the Katar River basin when water is supplied by the river.

Wehhave to consider also the water balance of Lake Zuai. During the dry season the lake receives surface water mainly by the Katar River. The outlet of Lake Zuai is the Bul Bula River, entering into Lake Abiata. If the discharge of this river is smaller than the discharge of the Katar River, the quantity available for irrigation (assuming no effect on the level of Lake Zuai) is not the quantity of the Katar River but that of the Bul Bula River. I have not measured the Bul Bula River, but passing this river on February 2nd, 1967 I made a note, that the flow was small. As the distance between Lake Zuai and Lake Abiata is about 25 km, the Bul Bula River probably is the water supply for many thousands of persons and cattle. Of course such a water supply cannot be allowed to disappear.

7.2.3 Land suitable for irrigation

Like most other rivers, the Katar River is deeply incised in the plateau, which makes irrigation difficult there. Also the climate on the plateau does not suit real irrigation all the year.

Regarding the Katar River in the Rift Valley there are flat areas upstream and downstream of Abura. The downstream area along the right bank of the Katar River is large and flat. Possibly water can be brought from the upstream area to the downstream area by gravity flow.

## 7.3 Water regulations required for irrigation

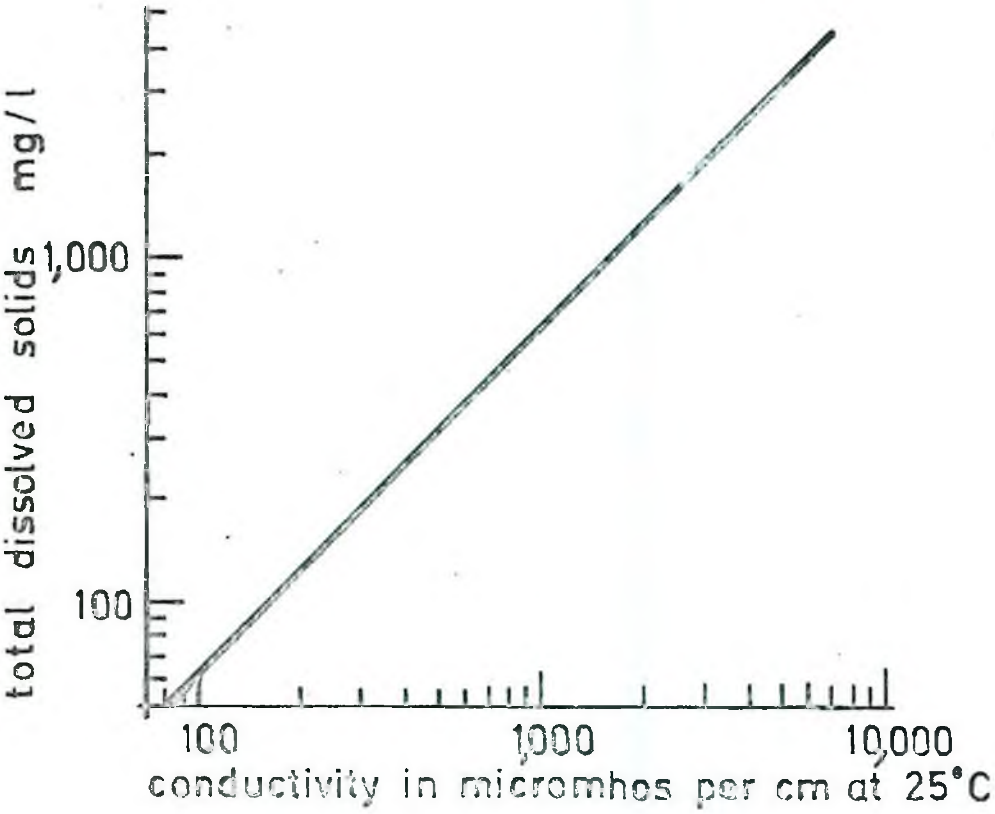
An irrigation project downstream of Abura would demand the construction of a dam in the Katar River upstream of Abura or in the Bil-Bula River.

A dam in the outlet of Lake Zuai would make possible irrigation round Lake Zuai by pumping water from the lake.

I think irrigation plans should start with a consideration of the possibilities of dam constructions. This does not only concern the Katar River and Lake Zuai but also other water resources. In the future the valleys on the plateaux above the Rift Valley might be surveyed regarding possibilities for dam constructions; these could supply people in the Rift Valley with consumption and irrigation water.

Fig.44

## RELATION BETWEEN TOTAL DISSOLVED SOLIDS AND ELECTRICAL CONDUCTIVITY 1)




Suggested guidelines for salinity in irrigation water 2)

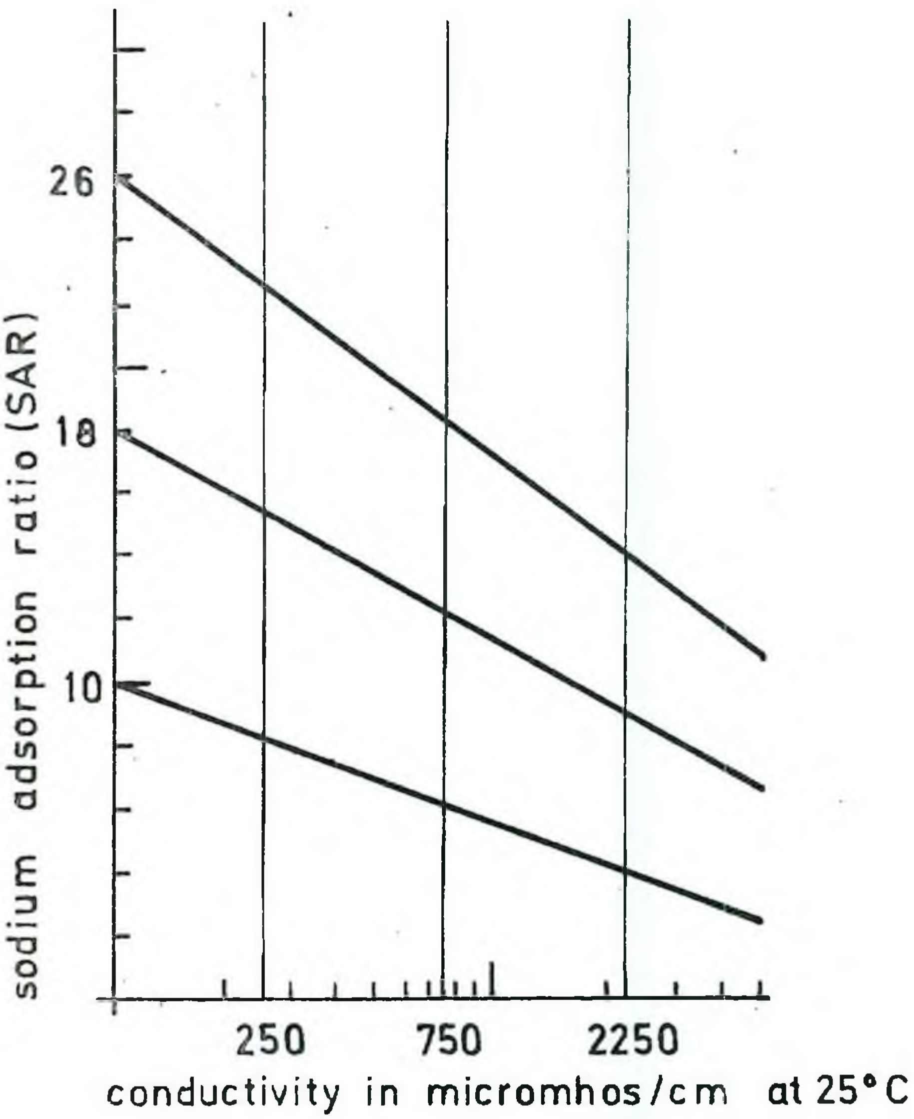
| Crop response | TDS mg/l | Electrical conductivity micromhos/cm |
|---|---|---|
| Water for which no detrimental effects will usually be noticed | <500 | <750 |
| Water which can have detrimental effects on sensitive crops | 500–1,000 | 750–1,500 |
| Water which may have adverse effects on many crops and requiring careful management practices | 1,000–2,000 | 1,500–3,000 |
| Water which can be used for salttolerant plants on permeable soils with careful management practices | 2,000–5,000 | 3000–7500 |

1 From Thomas R. Camps, Water and its impurities, 1968

2 From Water Quality Criteria, Federal Water Pollution Control Administration, Washington 1968

Fig. 45

RELATION BETWEEN SODIUM ADSORPTION RATIO (SAR) AND ELECTRICAL CONDUCTIVITY




Adapted from U.S. Salinity Lab. Staff, Diagnosis and improvment of saline and alkali soils, 1954.
U.S. Dept. of Agr. Handbook 60, p.80.

## 8 SUMMARY AND CONCLUSIONS

The 5-year plan of operations has been executed regarding both goals and budget.

The natural water resources of the Chilalo Awraja have been explored, in the light of the demand of water now and in the near future. Different types of simple and cheap water supplies have been designed and constructed, for demonstration purposes and for cost studies. Already during the 4-years of invdstigations and research on water supplies, and especially during the 5th year, implementation of water supply projects has started. During this work the reactions of the people to water facilities have been observed.

The total water dewelopment project has costed around Eth. $1.2 million, administration and foreign personnel costs included. Altogether around 30 water supplies have been constructed (40 supplies for single families being disregarded).

Water supplies ordered by the people have been paid for in advance before the construction work started. For two reasons the payment of 100% in advance cannot continue indefinitely. Only a limited number of rural communities can pay, say, Eth. $5,000 in advance. The poorest people, those who suffer most of lack of water, cannot be helped, if this condition of prepayment is imposed.

Experience has shown that it is very difficult for the rural people to contribute more than Eth. $1,000 in one year for a water supply. Costs of water supplies amounting Eth. $5,000 - 10,000 are not possible in the countryside of Chilalo, which has a low density of population, compared to other cultivated subtropical areas.

In the 5-year plan of operations, funds were proposed for helping the people to have water facilities. Hirtherto such funds have not been available. Some months ago, however, SIDA agreed to contribute a limited amount of money for the implementation of water suppy proposals on the basis of 50% aid.

I hope that the specific proposals in this publication can be a basis for futher consideration and actual activities regarding construction of rural water supplies. The cost to supply all the village centres of Chilalo with water has been estimated at Eth. $350,000. In addition there is a need of water in the country area away from the villages; to meet this would cost an estimated Eth. $1,000,000. At present it is not possible, I think, to execute these programmes except to a limited extent. The reasons are that in many places the costs and potential benefits are too large in relation to the number and economic status of people, and the present stage of development.

The idea is that the technical advice and the economic aid should be given to the people, in close cooperation directly with CADU. As hirtherto, the construction of water supplies should be contracted between CADU's Water Development Section on one hand, and the local authorities or the elected representatives of rural co-operatives on the other. In this way the work on water supplies will be integrated in the provincial development, and will involve the people themselves in decisions and development.

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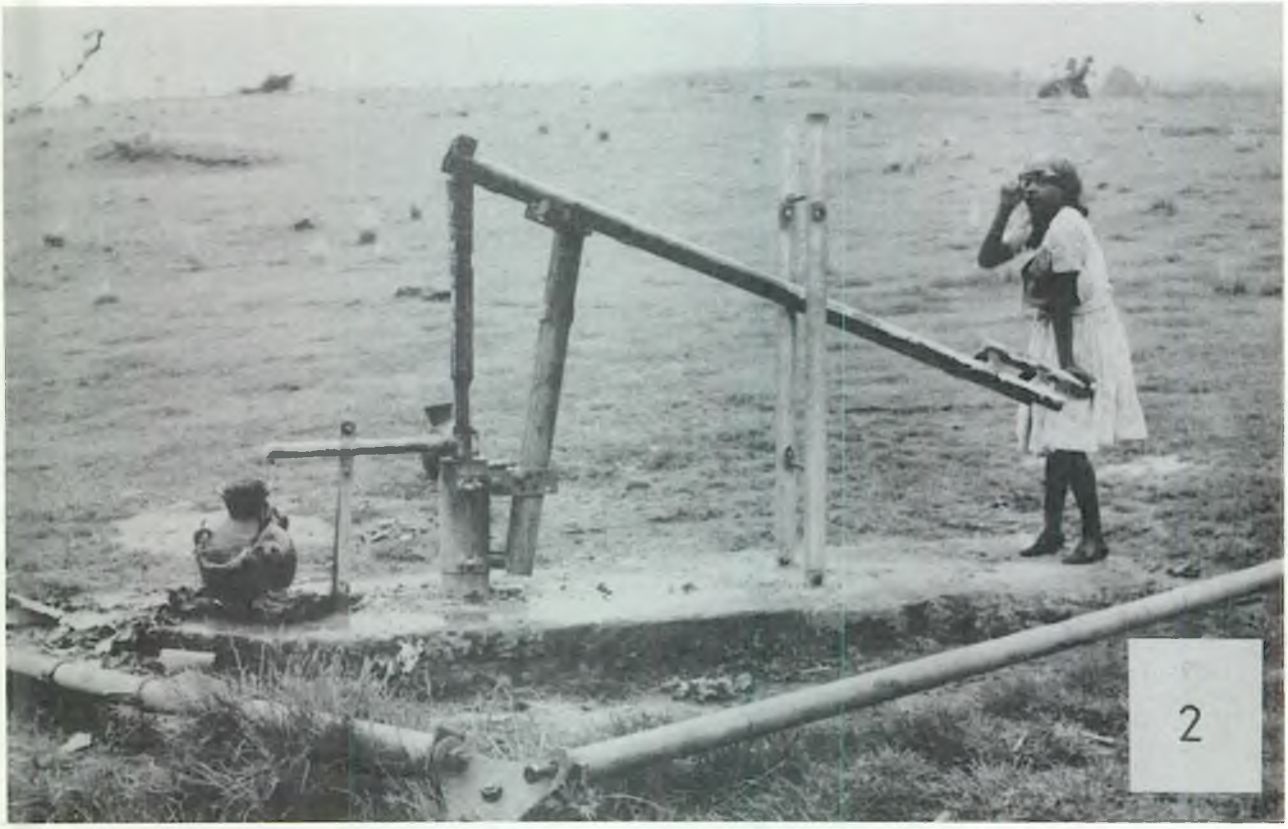
## 10 PLATES

Photo 1. A household well at Dodota whith ground catchment, lined with PE-sheet and being covered with gravel.

Photo 2. Hand pump at Kulumsa (the tripode in the foreground is not part of the hand pump).

Photo 3. Pond at Dodota lined with PE-sheet. On the top of the slope it is anchored in a trench with refilled earth (the slopes have not yet been covered with earth topped with gravel).

Photo 4. Dam and spillway at Egu under construction. Earth is being brought by wheelbarrow from the spillway to the dam, where it is compacted. The stone facing is on the upstream slope of the dam.

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### A. Project Preparation Period

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   Part I — General Background

   Part II — Project Outline

   Part III — Appendices

   (A reprint of the Summary is also available)

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