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Rehabilitation of Hand-Dug Wells and Protected Springs in Kisii, Kenya

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REHABILITATION OF HAND-DUG WELLS AND PROTECTED SPRINGS IN KISII, KENYA

by

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REHABILITATION OF HAND-DUG WELLS AND PROTECTED SPRINGS IN KISII, KENYA

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ABSTRACT

The study area covers 24 km² of Magwagwa I sub-location of North Mugirango/ Chache Location in Kisii District of Nyanza Province in Kenya. The area of study was limited in order to have a thorough and compherensive field inventory of the existing traditional hand-dug wells and protected springs within the available time of thesis writing.

The present population density of 332 persons per square kilometre is experienced. The area is of high agricultural potential with deep and fertile soils. The primary agricultural outputs are tea, coffee, pyrethrum, bananas, maize, pineapples, together with limited dairy farming.

Three main water resources which offer good opportunities in the provision of potable water are surface water (rivers), groundwater (hand-dug wells) and rainwater harvesting. River Sondu within the vicinity of the study area gives 96 % reliable yield of 51 000 m³/day. The area has also 220 existing traditional hand-dug wells privately owned and 39 permanent springs which are in communal use. This gives an indication of groundwater potential for exploitation. The area experiences an average annual rainfall of 1500 mm which means that roof catchment is possible.

The bacteriological water analysis results of the water sources revealed the extent of water pollution. Only 3 % of the water sources investigated had no faecal coliform organisms in 100 ml of water sample. Applying the current WHO guidelines, 97 % of the all traditional water sources investigated were unacceptable. No hand-dug well had faecal coliforms within the acceptable range by WHO guidelines. Due to the scarcity of water and high production costs for new water schemes the goals have by necessity to be set realistic.

The rehabilitation methods recommended for hand-dug wells and protected springs are based on economic factors, availability of local materials and labour with no complicated and expensive maintenance infrastructure. The methods have been selected after an evaluation of the sources of water pollution and thus trying to eliminate the pollution for future water use. Different rehabilitation alternatives are selected for suitability and not prestige, but convenience and aesthetic are not overlooked. No features that exhaust the technical, economic or social resources of the community have been selected.

The rehabilitation of these sources provides the community with safe and abundant water from a reliable, accessible and socially acceptable sources at the lowest cost. The rehabilitation costs per capita for different rehabilitation alternatives for hand-dug wells range between 215 KES and 419 KES. The rehabilitation costs per capita for protected springs range between 7 KES and 44 KES. To reduce the rehabilitation cost per capita for the hand-dug wells, five families per well are recommended contributing a maximum of 2000 KES for the rehabilitation. The contribution is within the affordable level of the average families in the area.

I INTRODUCTION

To attain the goal of the Water Decade, Water for all by 1990, the most feasible strategy would be to emphasize the least-cost technologies, such as shallow wells and handpumps, spring protection and rehabilitation of traditional water sources. To rehabilitate the water supplies for all members of the community, a more appropriate strategy must take the traditional water sources as a starting point in some rural areas. Only in this manner there is a possibility for ensuring an improved level of supply for most consumers in a community, and thus for ensuring the greatest possible impact. In developing countries, water consumers in rural areas have abandoned improved water supplies and turned into their traditional polluted water sources. This is due to the fact that in most rural areas, improved water supplies cannot compete with traditional water sources in terms of accessibility, reliability and affordability.

The advantages of a rehabilitation programme of traditional had-dug wells and protected springs are: the economic requirements are relatively modest, the traditional water sources can be improved by quite simple means, local materials and know-how can be utilized to a greater extent, all stages of the rehabilitation are within the capabilities of the villages and operation and maintenance can be entrusted to the village level. Such rehabilitation leads to self-help methods where community participation is much easier to implement. The women's links with traditional sources are already established and thus their participation in rehabilitation, operation and maintenance could be facilitated. The women can, in a very natural manner, be involved in expressing their felt needs, and in indicating the limitations of existing sources and the possible rehabilitation.

The present population density of 332 persons per a square kilometre in the study area and an average of 9 hand-dug wells per a square kilometre lead to 36 persons per a hand-dug well. This directly reveals the importance of hand-dug wells to the villagers as a source of water supply. As well springs were protected as far back as 1955 and left without any maintenance.

In this aspect, the study was concentrated on the investigation of the bacteriological water quality of these traditional water sources in view of establishing the sources of pollution. From the bacteriological water quality results obtained and the conditions of the hand-dug wells and springs noted during a field inventory, an evaluation of sources of pollution was investigated. Based on the findings, appropriate rehabilitation alternatives are proposed to eliminate the pollution. The proposed alternatives take into account the financial affordability of the villagers, different site conditions, norms and habits existing at the sources.

2 DESCRIPTION OF THE STUDY AREA

2.1 Physical Features

The area of study covers 24 km² in the northeastern part of Kisii District, Nyanza Province. A location map showing the study area in relation to district boundaries and other divisional boundaries in the district is shown in Figure 1. The study area is mainly covering Magwagwa I sub-location of North Mugirango/Chache Location.

The area lies between 1540 m and 1780 m above sea level. The area is comprised largely of rolling hills. The prevailing drainage direction of the area is towards the Sondu river in the eastern boundary of the study area. The western side of the area drains towards the Awach river. Considered broadly, the majority of the area slopes northerly and easterly.

The climate of the study area is directly influenced by its elevation and proximity to Lake Victoria. The annual rainfall range of 1400 - 1600 mm is experienced (Figure 2). The daily maximum temperature variation of 22 °C - 26 °C and minimum of 14 °C - 18 °C occurs (Figure 2).

The soils in the study area are well-drained, deep reddish brown to dark reddish brown, friable, silty, clay loam. The rainfall has encouraged vigorous grass growth thereby reducing erosion even on steep slopes where overgrazing occurs. Forestry continues to assume increasing importance in the area and thus arresting soil erosion.

2.2 Economic Characteristics

The study area can be classified as a high potential agricultural land with deep and fertile soils and high rainfall.

The 1979 census estimate in the study area was 6.672 and 1985 the population estimate was 7.980 with the annual growth rate of 3,03 %. The present density of 332 people per km² is high in comparison with other rural areas of Kenya. Over 55 % of the population of the area is made up of children under 15 and people over 60 years old. Thus, a high proportion of the population consists of dependants. Table 1 shows the population projections and the growth rates upto the year 2005 in the study area.

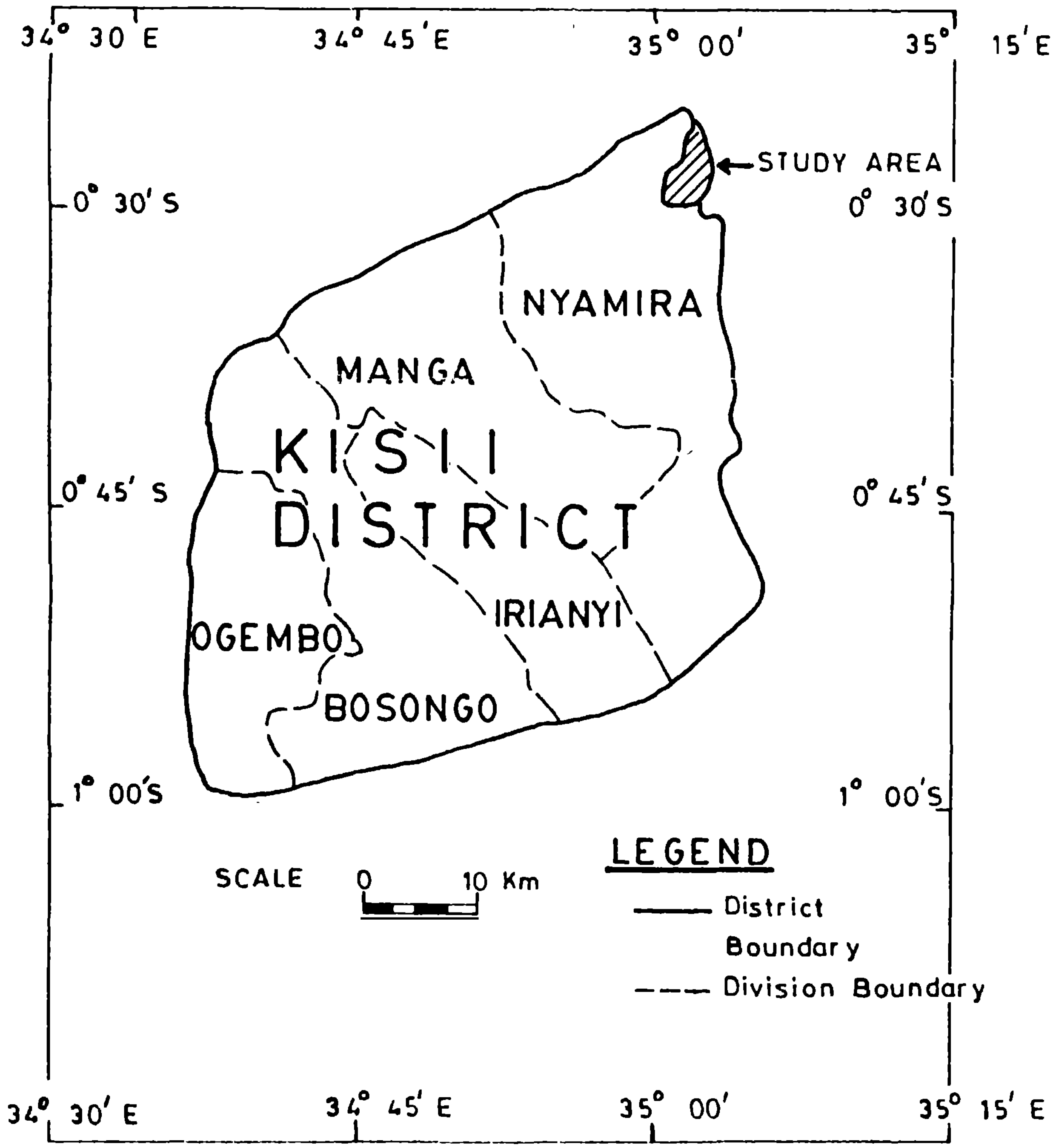


Figure 1. Location map of the study area (DHV 1982).

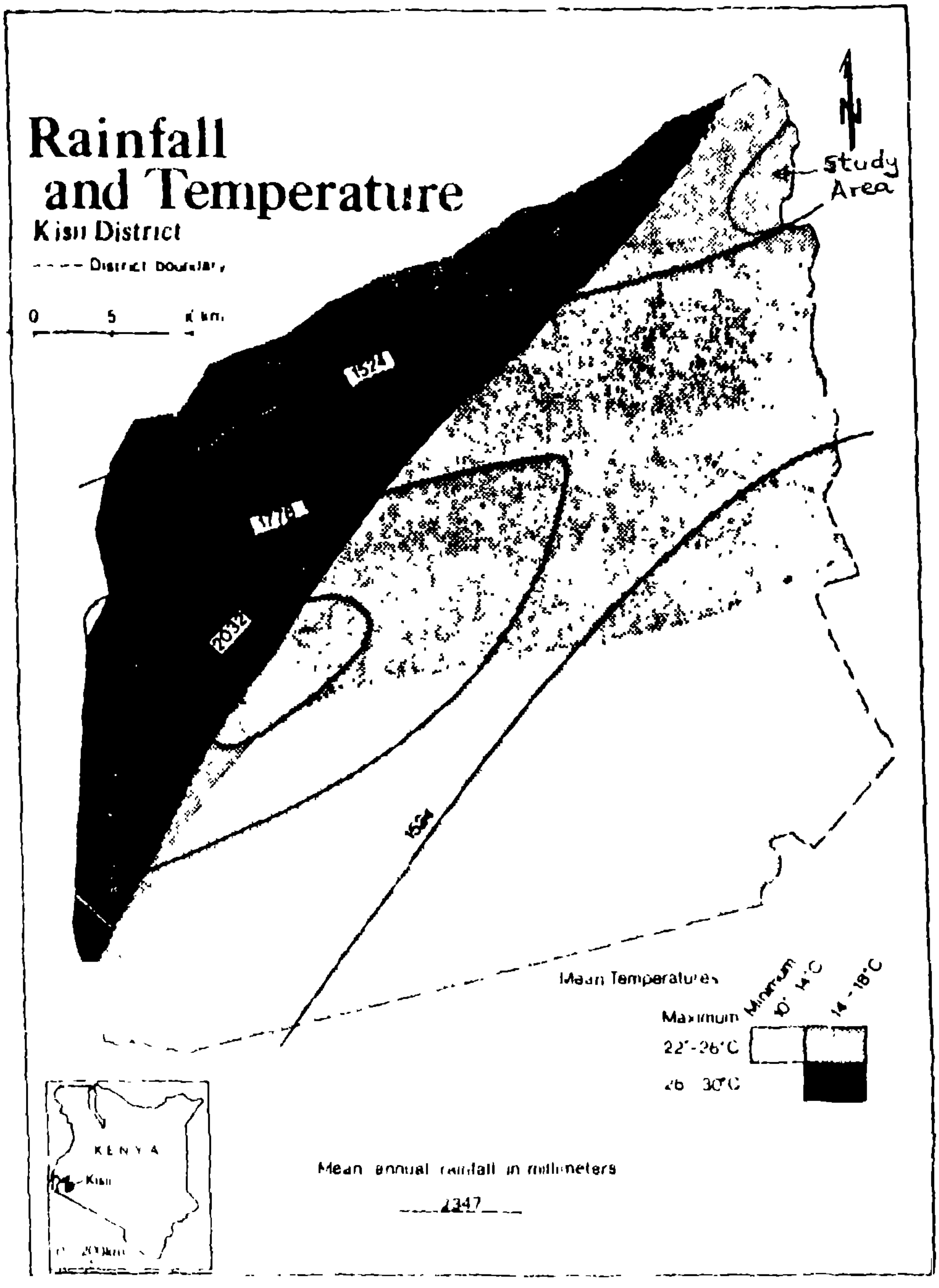


Figure 2. Rainfall and temperature distribution in Kisii District (National Environment Secretariat DP-3 August 1981).

Table 1. Population projections and growth rates 1985 to 2005 (Rofe Kennard and Lapworth 1982).

	1979	1985	1995	2005
Population	6.672	7.980	11.090	14.870
Density head/km²	278	332	462	620
Growth rate %	← 3,03	→	← 3,04 →	← 2,95 →
Period	1978	1988	1998	2005

Farming is the backbone of the economy of the study area. It is estimated that 75 % of the total income of the study area comes from agriculture, while 80 % of all the people directly derive their livelihood from this sector. 20 % of the population is believed to be landless (Rofe Kennard and Lapworth 1982).

Land available to individual farmers is, in most cases, uneconomic in terms of size because it does not allow farmers to adopt mechanised farming methods. However, introducing more technical methods in agricultural production would mean replacing human labour with machinery. Since land and not labour is the scarce resource in the study area, the objective should be to aim at economic rather than technical efficiency. This can be achieved by using improved labour-intensive methods of farming. These include proper spacing of crops, plant protection (i.e. spraying and physical control), regular weeding and fertilizer application.

Accordingly, subsistence farming is still a distinct feature of the study area's agricultural sector. Farmers are, however, becoming more cash crop oriented, though investment is still conservative.

The land carrying capacity in the study area will approach saturation in 1995 with 462 people per km² compared with MoWD (Ministry of Water Development) recommendations of 465 people per km². Demand for land is a growing problem due to fertile and deep soils with high and reliable rainfall. Most farmers are multicropped with both cash and food crops. A small number of traditional cattle is reared in the area.

Coffee is extensively grown in the area. Coffee was first planted on a commercial scale in the area in 1935. There is only one coffee processing factory in the study area and five other coffee processing factories within 5 km radius from the area.

Tea production is increasing in the area despite its recent introduction. There is great enthusiasm in planting tea by farmers. The nearest tea processing factory is 15 km away from the study area.

Pyrethrum production in the study area has dropped steeply and it has been replaced by other crops.

Banana production is increasing but there is still scope for development of this cash crop through improved methods of agriculture. The yield is in average some 12 tonnes per hectare (Rofe Kennard and Lapworth 1982).

Subsistence farming in the area concentrates mainly in growing maize, onions and beans. Production of crops like carrots, cabbages, potatoes, pineapples, tomatoes and millet is increasing due to high demand from urban centres.

Lack of land for all crops is one of the major limitations to the efforts of increasing food production. Farmers are, however, encouraged to use more advanced and intensive methods of growing these food crops to develop from subsistence into cash crop farming.

About two thirds of the maize produced is sold outside the area especially places where maize is in short supply.

The role of livestock in the study area is less important than that of crop farming, as land is a limited resource and of high potential for crop farming. There are no large ranches in the area.

The livestock activities in the area include the rearing of sheep and goats. The demand for dairy produce has been rising faster than the supply and for this reason there is a need to promote the production of dairy products.

Livestock populations are difficult to estimate with any degree of confidence because of inaccuracy of past censuses and the uncertainty of the growth patterns caused by drought, disease and market values of animal produce. Table 2 shows the livestock population projections 1985 - 2005 in the study area.

Table 2. Livestock population projection 1985 - 2005 (Rofe Kennard and Lapworth 1982).

	1985	1995	2005
Grade cattle	1.335	3.207	7.331
Traditional cattle	7.478	6.614	4.214
Small stock (goats and sheep)	4.156	4.156	4.156

Rofe Kennard and Lapworth (1982) estimated that 80 % of all homes are built of traditional materials, with mud-walls and thatched roofs. Small proportions of the rural population have managed to build permanent homes for themselves from personal savings or loans from commercial banks or from the National Housing Corporation. The proportion of houses with galvanized corrugated iron roofs has increased considerably over the last fifteen years, denoting a move towards more permanent dwellings.

There are no designated urban centres within the study area except one market centre (Magwagwa). Kisii town is approximately 75 km away from Magwagwa market.

Two major tarmac roads run in the northern and southern parts of the study area. The two roads are joined by a murram road through the rural trading centre Magwagwa. The northern road serves Kisumu and Kisii towns whilst the southern road serves Kericho and Kisii towns.

The Kenya Posts and Telecommunications Corporation has drawn up plans to extend postal communication services in the study area. Presently, the telephone services are 5 km (Matongo) away from Magwagwa trading centre. There is a line intended to run from Ikonge to Magwagwa trading centre which is also 5 km away.

Kenya Power and Lighting Company is laying a power line from Kericho District through Magwagwa market to Sondu market. This line will serve as a source of power in the study area after completion. The coffee processing factory which is presently using diesel will also benefit from this power project.

2.3 Geology

The study area is covered by geological mapping prepared by Geological Survey of Kenya (report No. 50).

The study area consists of rocks of the Bukoban system (Figure 3) which is an extension of the Kisii hills. The order of succession and the character of the rocks in the area according to Binge (1962) have the sequence of

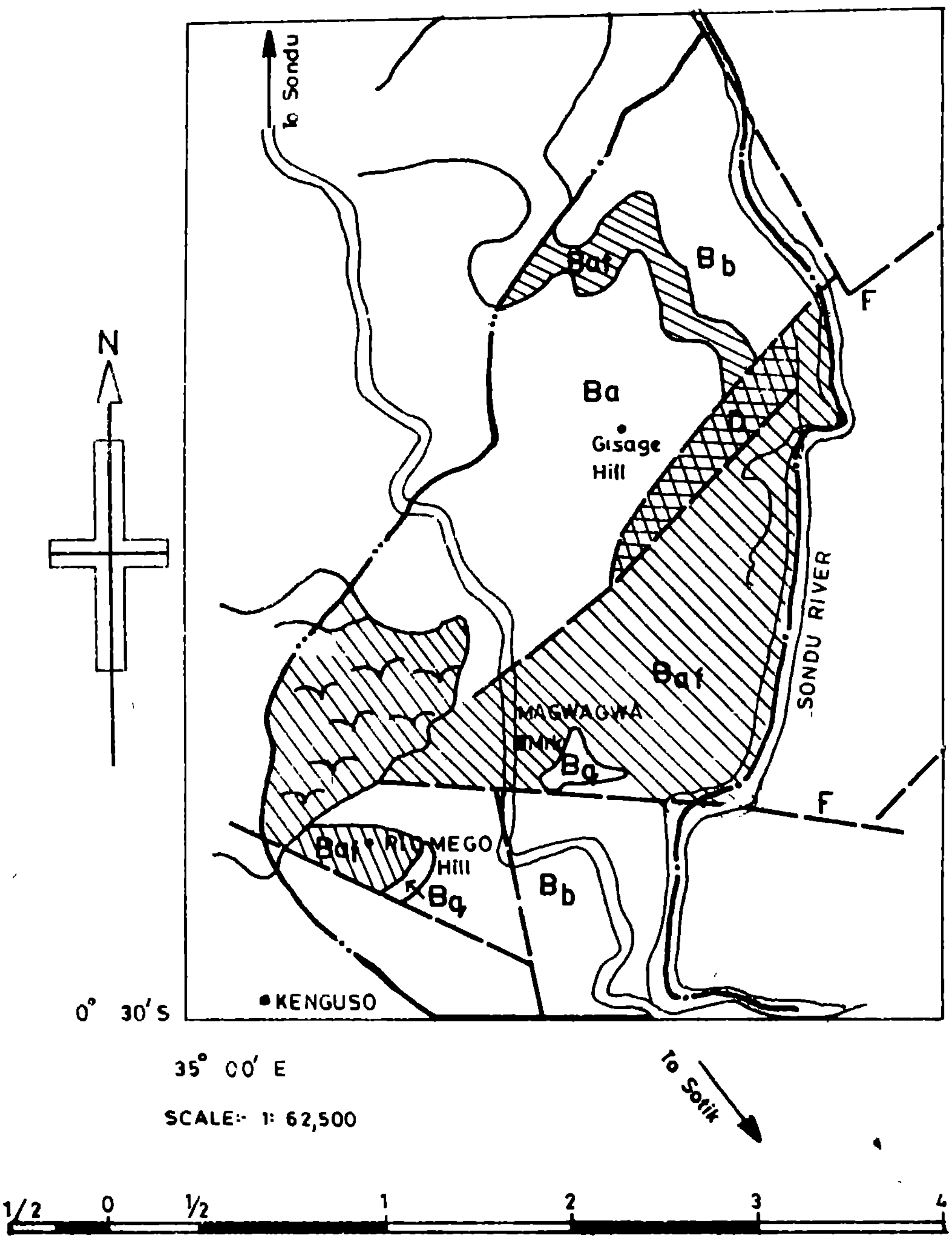
1) porphyritic basalts,
2) quartzite,
3) porphyritic felsites,
4) quartz, andesites and dacites.

The porphyritic variety occurs southwest of Magwagwa between Sotik road and the river. Between Kenguso and Riomego hills, episodites occur. The normal sequence with quartzite underlain by basalts is well developed.

The quartzite is well developed on the east flank of Riomego hill and is cut off to the south by a fault into which a "bull" quartz vein has been emplaced. To the east of Magwagwa the quartzite horizon dips to the southeast and east towards the Sondu river.

The porphyritic felsites occupy the southern part of Sondu of relatively level uplands at 1700 m, and underlie the dacites to the north, below which they again outcrop around Gisage hill.

The quartz, andesites and dacites overlie the felsites on the highest ground south of Sondu and outcrop as low as 1615 m elevation.



Geological pattern	Age	Rock system	Genetic group	Description
Quaternary		Alluvium	Fluvial deposits	Clays
Pre-Cambrian	B	Bukoban	Volcanic rocks	B_a - Andesites B_b - Basalts B_{af} - Felsites B_q - Quartzites
Post-Nyanzan	D	Dolerites	Intrusive rocks	Dolerites

Figure 3. Geological map of the study area (Binge 1962).

3 GROUNDWATER UTILIZATION

Areas of natural groundwater discharge are indicated by springs and groundwater seepage. The occurrence of these phenomena is governed by geological and geomorphological features. The location and magnitude of springs give a good indication of general hydrological conditions in the area. Abundant small springs on valley sides and slopes of hills generally indicate a shallow groundwater table with a shallow circulation of subsurface water in aquifers of low permeability (Ker-Priestman 1980, Vol. I).

The Kisii District is characterised by an abundance of spring flow. Top soils overlying Bukoban strata are generally clays and likely to impede infiltration from the generally higher rainfall. Above average stream flows tend to confirm this (Ker-Priestman 1980, Vol. I).

The advantages of groundwater are:
1) it is likely to be free of pathogenic bacteria,
2) it may be used without further treatment,
3) it may be found in close vicinity of rural communities,
4) it is often most practical and economical to obtain and distribute, and
5) the water bearing stratum from which it is drawn usually provides a natural storage at the point of intake.

The disadvantages of groundwater are:
1) it is often high in mineral content, and
2) it usually requires pumping.

There are a few hundreds of privately owned hand-dug wells with different levels of protection in the study area as shown in Table 3. The condition and the level of contamination of each well is different. From Table 3, most of the wells are likely to be bacteriologically contaminated. Therefore it was necessary to investigate the bacteriological water quality of the wells and springs. A field survey was also undertaken to determine the nature of water held in the shallow groundwater environment and that issuing as springs.

3.1 Hand-Dug Wells

A total estimate of 220 privately owned hand-dug wells have been dug within the 24 km² of the study area. The skill of well digging in the study area can be traced back to 1947 when the first well of depth 13,7 m was dug. Out of the estimated 220 hand-dug wells, 110 were visited to give a field inventory of the existing wells and their general conditions. The visited wells were given numbers for convenience of bacteriological water quality result identification as tabulated in Table 3. Even though the wells are privately owned, some wells are shared with the neighbouring families. Well data were obtained under the following headings:

a) well owner and the year of construction,
b) depth, diameter and the type of well construction,
c) well water extractions with seasons,
d) water quality (bacteriological).

3.2 Boreholes

Only six boreholes have been drilled into the Bukoban system of Kisii highlands (Table 4). Groundwater is typically confined and encountered at either 20 or 55 - 60 m below the ground level. The groundwater potential throughout Kisii District is regarded as poor (yields generally less than 50 m³/day). The potential has been based mainly on borehole yields and hydraulic parameters. Table 5 gives the hydrogeological parameters of aquifers in Kisii District. The recharge potential is low in the district (Ker-Priestman 1980, Vol. I).

Table 3. Field inventory of existing hand-dug wells.

Well No	Well owner	Date dug (year)	Well diameter (m)	Well depth (m)	Concrete slab available	Type of lining	Depth of lining (m)	Type of cover	Lifting device
5	Osoro D.	1960	0,9	5,5	Yes	Brick	0,9	No	Rope/bucket
13A	Mogere N.	1966	0,9	7,0	Yes	Stone	0,3	Timber	Rope/bucket
13B	Mogere N.	1976	0,9	6,7	Yes	Stone	0,6	Timber	Rope/bucket
13C	Mogere N.		0,9		No	No		No	Rope/bucket
13D	Mogere N.		0,9		No	No		No	Rope/bucket
14A	Oange A.	1971	0,9	7,0	Yes	Block	0,9	Steel	Rope/bucket
14B	Oange A.	1963	0,9	20,4	Yes	Block	0,6	Steel	Rope/bucket
15	Oange A.	1981	0,9	7,0	Yes	Block	0,9	Steel	Rope/bucket
16	Tabiga	1973	0,9	4,6	No	No		Timber	Rope/bucket
17	Mokua R.	1962	0,9	6,1	No	No		Timber	Rope/bucket
18	Nyamanga		0,9		No	No		No	Rope/bucket
20	Arasa S.	1974	0,9	5,5	Yes	Stone	0,9	Steel	Rope/bucket
21	Ongaki A.	1969	0,9	6,1	Yes	Stone	1,5	Steel	Rope/bucket
22A	Ndubi J.	1970	0,9	4,6	Yes	Stone	0,9	No	Rope/bucket
23	Ndege A.		0,9		No	No		Timber	Rope/bucket
24	Nyaribo S.	1958	0,9	7,6	Yes	Stone	0,9	Steel	Rope/bucket
26	Kwega N.	1984	0,9	8,5	No	No		No	Rope/bucket
27	Ombusuro N.	1966	0,9	9,5	No	No		Timber	Rope/bucket
28A	Nyachieo N.	1950	0,9	12,2	No	No		No	Rope/bucket
28B	Nyachieo N.		0,9		No	No		No	Rope/bucket
29	Nyamasege S.	1981	0,9	6,1	No	No		No	Rope/bucket
30	Nyaribo N.	1960	0,9	19,8	Yes	Stone	0,6	Steel	Rope/bucket
31	Ondoro E.	1964	0,9	4,6	No	No		No	Rope/bucket

Table 3. Cont'd.

Well No	Well owner	Date dug (year)	Well diameter (m)	Well depth (m)	Concrete slab available	Type of lining	Depth of lining (m)	Type of cover	Lifting device
32	Mokua M.		0,9	9,1	No	No		Timber	Rope/bucket
33	Nyakundi S.	1948	0,9	12,2	No	No		No	Rope/bucket
34	Miregwa B.	1981	0,9	9,1	No	No		Timber	Rope/bucket
35	Moikobu S.	1981	0,9	4,6	No	No		Timber	Rope/bucket
36	Masisa O.		0,9		No	No		No	Rope/bucket
37	Nyangau K.		0,9		No	No		Timber	Rope/bucket
38A	Omare O.	1947	0,9	13,7	No	No		No	Rope/bucket
38B	Omare O.	1985	0,9	9,5	No	No		Timber	Rope/bucket
39	Onyinge O.		0,9	7,6	Yes	No		No	Rope/bucket
40	Arimba		0,9	13,7	No	No		Timber	Rope/bucket
41 A	Ndubi M.	1957	0,9	9,1	Yes	Stone	0,9	No	Rope/bucket
42	Mokua R.	1963	0,9	8,5	No	No		Timber	Rope/bucket
43	Ngweso N.	1968	0,9	6,7	No	No		No	Rope/bucket
44	Ogendi	1975	0,9	9,1	No	No		No	Rope/bucket
45	Nyagetari M.		0,9		No	No		Timber	Rope/bucket
46	Gisore P.	1961	0,9	8,5	No	No		Timber	Rope/bucket
47	Mongiti	1979	0,9	9,1	No	No		No	Rope/bucket
48	Simon O.	1955	0,9	9,1	No	No		No	Rope/bucket
50	Ombasa J.		0,9		No	No		No	Rope/bucket
51	Ondari E.	1973	0,9	7,0	No	No		No	Rope/bucket
52	Mogere N.	1953	0,9	15,8	Yes	Stone	0,6	Timber	Rope/bucket
53	Mochengo J.		0,9		No	No		Timber	Rope/bucket
54	Osumo P.	1975	0,9	9,1	No	No		No	Rope/bucket

Table 3. Cont'd.

Well No	Well owner	Date dug (year)	Well diameter (m)	Well depth (m)	Concrete slab available	Type of lining	Depth of lining (m)	Type of cover	Lifting device
55	Mokoro O.		0,9		No	No		Timber	Rope/bucket
56	Mwambi		0,9		No	No		No	Rope/bucket
57	Nyakawa M.		0,9		No	No		No	Rope/bucket
58	Tinega B.		0,9	11,3	Yes	Stone	0,9	Timber	Rope/bucket
59	Ongworu		0,9		No	No		No	Rope/bucket
60	Kengere		0,9		No	No		No	Rope/bucket
61	Nyaore O.		0,9		No	No		No	Rope/bucket
62	Omoti O.		0,9		No	No		No	Rope/bucket
63	Kamanda A.		0,9		No	No		No	Rope/bucket
64	Misuko		0,9		No	No		Timber	Rope/bucket
68	Sobera O.		0,9	7,3	No	No		No	Rope/bucket
69	Isoe O.	1968	0,9	8,5	No	No		No	Rope/bucket
70	Kimwami K.	1983	0,9	7,6	No	No		No	Rope/bucket
71	Saboke N.	1964	0,9	6,1	Yes	Stone	0,3	Timber	Rope/bucket
72	Saboke K.	1984	0,9	9,1	No	No		Timber	Rope/bucket
73	Kimwomi M.	1974	0,9	3,7	No	No		No	Rope/bucket
74	Osiago S.	1972	0,9	6,7	No	No		No	Rope/bucket
75	Ndege H.	1981	0,9	7,9	Yes	Stone	0,3	No	Rope/bucket
76	Monanti S.	1972	0,9	12,2	No	No		No	Rope/bucket
77	Nyangau S.	1975	0,9	8,8	No	No		No	Rope/bucket
78	Osiago N.	1975	0,9	12,2	No	No		Timber	Rope/bucket
79	Nyasani N.	1982	0,9	10,1	No	No		Timber	Rope/bucket
80	Nyangau O.		0,9		No	No		No	Rope/bucket

Table 3. Cont'd.

Well No	Well owner	Date dug (year)	Well diameter (m)	Well depth (m)	Concrete slab available	Type of lining	Depth of lining (m)	Type of cover	Lifting device
81	Botomere N.		0,9		No	No		Timber	Rope/bucket
82	Morumbwa J.	1983	0,9	11,6	No	No		Timber	Rope/bucket
83	Kionga A.	1980	0,9	7,6	No	No		Timber	Rope/bucket
84	Bundi N.	1969	0,9	4,6	No	No		Timber	Rope/bucket
85	Kionga J.	1968	0,9	11,0	No	No		No	Rope/bucket
86	Areba N.		0,9		No	No		Timber	Rope/bucket
87	Nyangau D.	1979	0,9	6,7	No	No		Timber	Rope/bucket
88	Kionga N.	1975	0,9	10,1	No	No		Timber	Rope/bucket
89	Mosota A.	1973	0,9	10,7	No	No		No	Rope/bucket
90	Basweti M.	1960	0,9	7,0	No	No		Timber	Rope/bucket
91	Marko B.	1960	0,9	12,2	No	No		No	Rope/bucket
92	Momigi M.		0,9		No	No		No	Rope/bucket
93	Obanyi M.	1985	0,9	12,2	No	No		Timber	Rope/bucket
94	Onchonga T.	1983	0,9	12,2	No	No		Timber	Rope/bucket
95	Machuka M.	1982	0,9	14,6	No	No		No	Rope/bucket
96	Osero M.	1973	0,9	13,4	No	No		No	Rope/bucket
97	Omwanza	1984	0,9	7,3	No	No		Timber	Rope/bucket
98	Mobira N.	1969	0,9	9,8	No	No		Timber	Rope/bucket
99	Omwanza	1985	0,9	10,7	No	No		Timber	Rope/bucket
100	Tinega M.		0,9	13,4	No	No		No	Rope/bucket
101	Momanyi S.		0,9	22,8	No	No		No	Rope/bucket
102	Agwata M.	1983	0,9	10,7	No	No		Timber	Rope/bucket
103	Nyaugo	1963	0,9	9,1	No	No		No	Rope/bucket

Table 3. Cont'd.

Well No	Well owner	Date dug (year)	Well diameter (m)	Well depth (m)	Concrete slab available	Type of lining	Depth of lining (m)	Type of cover	Lifting device
104	Daniel T.	1973	0,9	5,8	Yes	Stone	0,6	Steel	Rope/bucket
105	Ondengi O.	1985	0,9	20,7	Yes	Brick	0,6	No	Rope/bucket
106	Moraa M.	1959	0,9	10,4	No	No		Timber	Rope/bucket
107	Maraga B.	1960	0,9	11,0	No	No		No	Rope/bucket
108	Nyaroche N.	1965	0,9	7,6	No	No		Timber	Rope/bucket
109	Nyaroche S.	1965	0,9	8,5	No	No		Timber	Rope/bucket
110	Guto O.	1985	0,9	9,1	No	No		No	Rope/bucket
111	Mose O.	1968	0,9	7,6	No	No		No	Rope/bucket
112	Mungei O.	1980	0,9	9,1	No	No		No	Rope/bucket
113	Morema O.	1983	0,9	9,1	No	No		No	Rope/bucket
114	Semboi M.	1981	0,9	9,1	No	No		Timber	Rope/bucket
115	Morema M.	1959	0,9	16,8	No	No		No	Rope/bucket
116	Ndoka M.	1983	0,9	9,1	No	No		Timber	Rope/bucket
117	Nyamweya B.	1982	0,9	10,7	No	No		Timber	Rope/bucket
118	Nyasani B.	1984	0,9	13,7	No	No		Timber	Rope/bucket
119	Tanga N.	1976	0,9	10,7	No	No		No	Rope/bucket
120	Omache M.	1972	0,9	9,1	No	No		No	Rope/bucket
121	Bundi K.	1968	0,9	9,1	No	No		No	Rope/bucket

Table 4. Schedule of boreholes in Kisii District (Ker-Priestman 1980, Vol. II).

No.	Location	Lat./Long.	Use*	Date drilled	Depth (m)	Diameter (mm)	Water struck (m)	SWL (m)	Aquifer	Test yield (m^3/d)	Hours pumped	Specific capacity Q/S (m^2/d)
C 2989	Nyanturago	00°47', 34°51'	N	1960	61	150	57	33,5	Bukoban	9,2	12	0,37
C 3125	Kisii town	00°42', 34°47'	N	1961	122	250	21,9	4,3	Bukoban	6,5	5	0,06
C 3126	Kisii town	00°42', 34°47'	P	1961	122	300	18,3	6,1	Bukoban	283,9	96	2,6
C 3248	Kamagambo	00°45', 34°39'	D	1963	76,2	150	55,2	6,4	Bukoban	21,8	7	0,33
C 4303	Kiamokama	00°50', 34°53'	C	1977	138,1	200	56,5	22,9	Bukoban	294,0	24	41,9
C 4490	Musa Nyandusi	00°43', 34°50'	D	1977	66	150	12...49	7,3	Bukoban	20,7	12	5,3

Latitudes are south, longitudes are east, SWL = static water level

* D = domestic, C = commercial, P = public supply, N = none (includes abandoned)

Table 5. Hydrogeological parameters of aquifers in Kisii District (Ker-Priestman 1980, Vol. I).

Aquifer	
Lithology	Bukoban
Type	Confined
Boreholes	
Number	6
Mean depth (m)	98
% abandoned	16
Water level	
Struck (m)	10 ... 60
Static (BGL)	5 ... 30
Mean (m^3/d)	106
Yield	
s.d. (m^3/d)	142
c.v. (%)	133
Hydraulic parameters	
Specific capacity 24 h (m^2/d)	5 ... 38
Transmissivity (m^2/d)	8 ... 58
Aquifer potential	Poor

3.3 Springs

There are 39 communally used springs in the study area. During the field survey 23 springs were visited. A total of 11 springs were protected by the Ministry of Health between 1955 and 1963. The remaining 28 springs still remain unprotected. Out of the 11 initially protected springs, only 4 remain in good condition with headwall and outlet pipe still strong (Table 6). 7 springs can be used as gravity supply systems for people living downstream of the spring due to the good topography. In some cases, hydraulic rams can be used to supply people in the higher elevations.

The protected springs are discharging from a 50 mm galvanized iron pipe. Figure 4 shows the locations of the springs whose bacteriological water quality was analysed. Other springs have been omitted for reasons of clarity. Spring data was obtained under the following headings:

a) location, elevation, site conditions and year of construction,
b) flow variations,
c) water quality (bacteriological),
d) number of users (people and cattle).

Table 6. Field inventory of protected springs.

Spring No.	Name of spring	Elev-ation (m)	Date protected (year)	Spring conditions						Number of users/day	
				Head wall	Discharge pipe	Backfill cover	Drainage	Washing basin	Cattle trough	People	Cattle
SP 1	Nyakenyomisia	1660	1955	Fair	Good	No	No	No	No	60	15
SP 2	Nyakemwate	1660	1963	Good	Good	No	No	No	No	300	40
SP 3	Teya/Moturi	1640	1955	Good	Good	No	No	No	No	250	10
SP 4	James Buyeke	1640	1960	Good	Good	No	No	No	No	150	10
SP 9	Nyabigena/Nyaribo	1640	1960	Bad	No	No	No	No	No	300	-
SP 10	Mokarate (I)	1645		No	No	No	No	No	No	500	50
SP 10	Mokarate (II)	1645		No	No	No	No	No	No	500	50
SP 11	Nursery	1655		No	No	No	No	No	No	520	20
*	Ensoko/Makori	1635		No	No	No	No	No	No	400	30
SP 12	Nyabigena/Raini	1640	1960	No	No	No	No	No	No	200	30
*	Rianyansumora	1680		No	No	No	No	No	No	80	-

* No bacteriological tests carried out

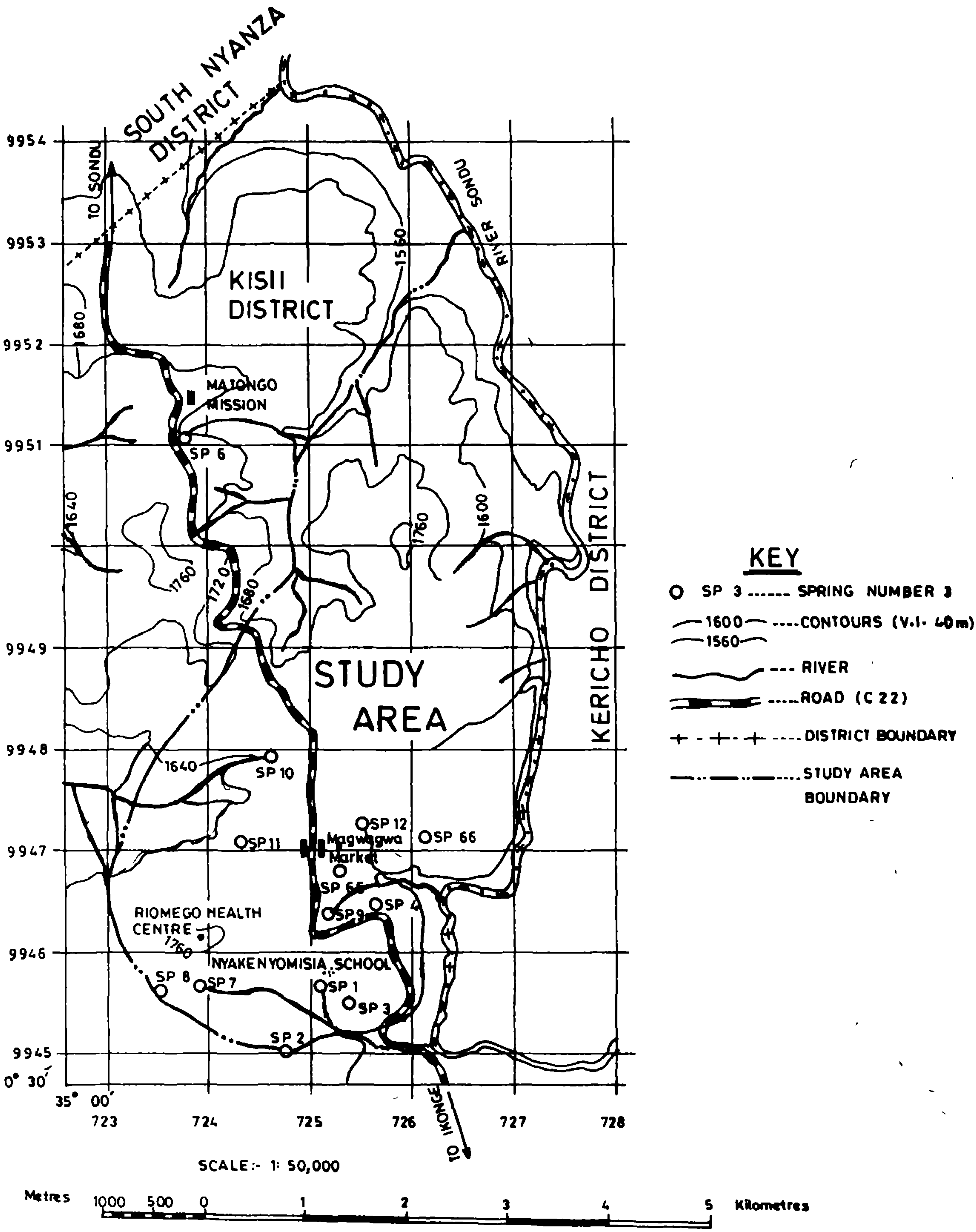


Figure 4. Locations of springs.

3.4 Groundwater Quality

3.4.1 pH of Groundwater

The pH value gives information about the acidity of the water and thereby, indirectly, the risk of corrosion. A value of 6 or below in water with a high carbon dioxide content ($\geq$ 20 mg/l) indicates that acid attack and direct hydrogen evolution are likely to occur, if the water contacts iron or steel. Higher pH values (above 8) are usually associated with waters that cause localized pitting instead of general corrosion, particularly if dissolved oxygen is present, and such waters may also encrust well parts with carbonate deposits (Clarke 1980). The groundwater pH for the different wells and springs in the area was measured. The purpose was to see pH variations in the area and obtain a general value for planning. Tables 7 and 8 show the pH of hand-dug well water and spring water respectively.

Table 7. The pH of hand-dug well water.

Well No.	Date tested	Source	pH
5	4.11.85	Osoro	6,0
13	5.11.85	Mogere A	6,0
		Mogere B	5,6
15	5.11.85	Oange	5,6
16	5.11.85	Tabiga	5,4
17	5.11.85	Mokua R.	5,2
18	5.11.85	Nyamanga	5,4
20	5.11.85	Arasa S.	5,4
21	5.11.85	Ongaki A.	5,4
22	5.11.85	Ndubi J.	5,4
24	5.11.85	Nyaribo S.	5,6
26	6.11.85	Kwega N.	6,0
27	6.11.85	Ombusuro N.	6,0
28	6.11.85	Nyachieo A	5,6
		Nyachieo B	5,6
29	6.11.85	Nyamasege	6,0
30	6.11.85	Nyaribo N.	5,6
31	6.11.85	Ondoro E.	6,0
32	6.11.85	Mokua M.	5,8
33	6.11.85	Nyakundi S.	6,0

Table 7. Cont'd.

Well No.	Date tested	Source	pH
34	6.11.85	Miregwa B.	5,4
23	6.11.85	Ndege A.	5,8
36	6.11.85	Masisa O.	5,6
40	6.11.85	Arimba	5,4
41	6.11.85	Ndubi M.	7,0
		Average	5,7

Table 8. The pH of spring water.

Spring No.	Date tested	Source	pH
SP 1	4.11.85	Nyakenyomisia spring	6,4
SP 2	4.11.85	Nyakemwate spring	7,0
SP 3	4.11.85	Teya/Moturi spring	6,6
SP 4	4.11.85	James Buyeke spring	6,4
SP 7	5.11.85	Nyagoanchaga spring	5,6
SP 8	5.11.85	Omoba spring	5,6
SP 9	5.11.85	Nyabigena/Nyaribo spring	5,6
SP 10	5.11.85	Mokarate spring	5,6
SP 11	5.11.85	Nursery spring	5,4
SP 12	5.11.85	Nyabigena/Raini spring	5,4
		Average	5,9

The variation of the groundwater pH in the study area is shown in Table 9.

Table 9. Variation of the groundwater pH values in the area.

Water source	pH range < 6,5 No	%	6,5 - 8,5 No	%
Springs (N = 11)	8	73	3	27
Hand-dug wells (N = 25)	24	96	1	4
Total (N = 36)	32	89	4	11

From Table 9 it can be seen that 89 % of the water sources are acidic and thus when iron pipes are used without the adjustment of pH, corrosion can take place. On the average, hand-dug wells and springs in the study area have a low pH value.

3.4.2 Physical and Chemical Water Quality

Water from well No. 5 was used as a random sample for the physical and chemical groundwater quality testing in the study area. The results obtained from the water sample are shown in Table 10.

Table 10. Physical and chemical groundwater quality for well No. 5.

Constituent	Unit	Well water values	WHO guideline values (1984)
Colour	mg Pt/l	25	15
Turbidity		9,5 FTU	5 NTU
Conductivity	μs/cm	40	-
Iron	mg/l	0,25	0,3
Manganese	mg/l	0,2	0,1
pH		6,0	6,5 - 8,5
Total hardness	mg $CaCO_3$/l	4	500
Chloride	mg/l	8	250
Fluoride	mg/l	0,12	1,5
Nitrite	mg/l	0,02	-
Nitrate	mg/l	6,2	10
Ammonia	mg/l	0,43	-

3.5 Discussion

Ker-Priestman (1980) regarded the groundwater potential in the whole of Kisii District as poor. The high concentration of hand-dug wells and the abundance of spring in the area indicates the potential of groundwater in shallow aquifer. Even though there has been no outside influence on the hand-dug well knowledge to the community, some people have tried to improve their well conditions by partial lining, construction of concrete slab and provision of strong covers (steel) to reduce water pollution. This shows that some people have realised that seepage water and surface runoff can pollute well water. The well protection know-how was observed in some elite groups and the people whose income is above the average income in the area.

From the 11 springs initially protected, only 4 springs qualify for rehabilitation. The remaining 7 initially protected springs and 28 unprotected springs need new spring protection. But before any new protection is carried out, one year flow measurements from the springs need to be done. After the flow measurements, the pipe sizes required can be established and the viability of the use of hydraulic rams can be evaluated where the flow and topograph permit.

The colour and turbidity of the well water tested is higher than the WHO guideline values. This could be due to surface runoff as the well is uncovered (Table 3). Iron and manganese content in the water is within the acceptable value. The fluoride content is below the allowable value. Generally, the groundwater quality in the study area can be regarded as soft and acidic.

4 WATER EXTRACTION

4.1 Water Resources

River Sondu is the only major surface water source in the study area. At the river gauging station (1JG1) in the vicinity of Sondu market, the 96 % reliable yield of the Sondu river is estimated to be 52 700 m^3/day based upon some 36 years of daily flow records. A major water supply, namely North Mugirango Water Supply Project under preliminary design stage at the moment is intended to have an intake at Sondu river near Magwagwa market. The study area is within the supply area of the project. The equivalent 96 % reliable yield at the Sondu intake site near Magwagwa market in connection with the present proposed project is 51 000 m^3/day. The Sondu river is therefore capable to meet the demands of the study area (Rofe Kennard and Lapworth 1982).

However, the water for this project will be boosted several times before the distribution. A raw water booster will raise water 30 m to the treatment works. A booster in the treatment works will lift water 110 m high to an intermediate tank. The last booster at the intermediate tank will lift water another 110 m to the last tank for distribution. A full conventional water treatment (coagulation, flocculation, sedimentation and filtration) is recommended due to the raw water quality (Rofe Kennard and Lapworth 1982).

With the water treatment costs, large and long pipelines plus high pumping heads, the use of surface water might, to some extent, deny most of the beneficiaries the opportunity of using the water due to the high water rates. Hence, there is a likelihood of the people going back to their free traditional point sources.

From the high concentration of privately owned hand-dug wells (Figure 5) and approximately two permanent springs per a square kilometre indicate the potentiality of the shallow groundwater aquifer. Zone E does not have hand-dug wells. Several hand-dug wells have been dug in the area but they have collapsed during the rainy season.

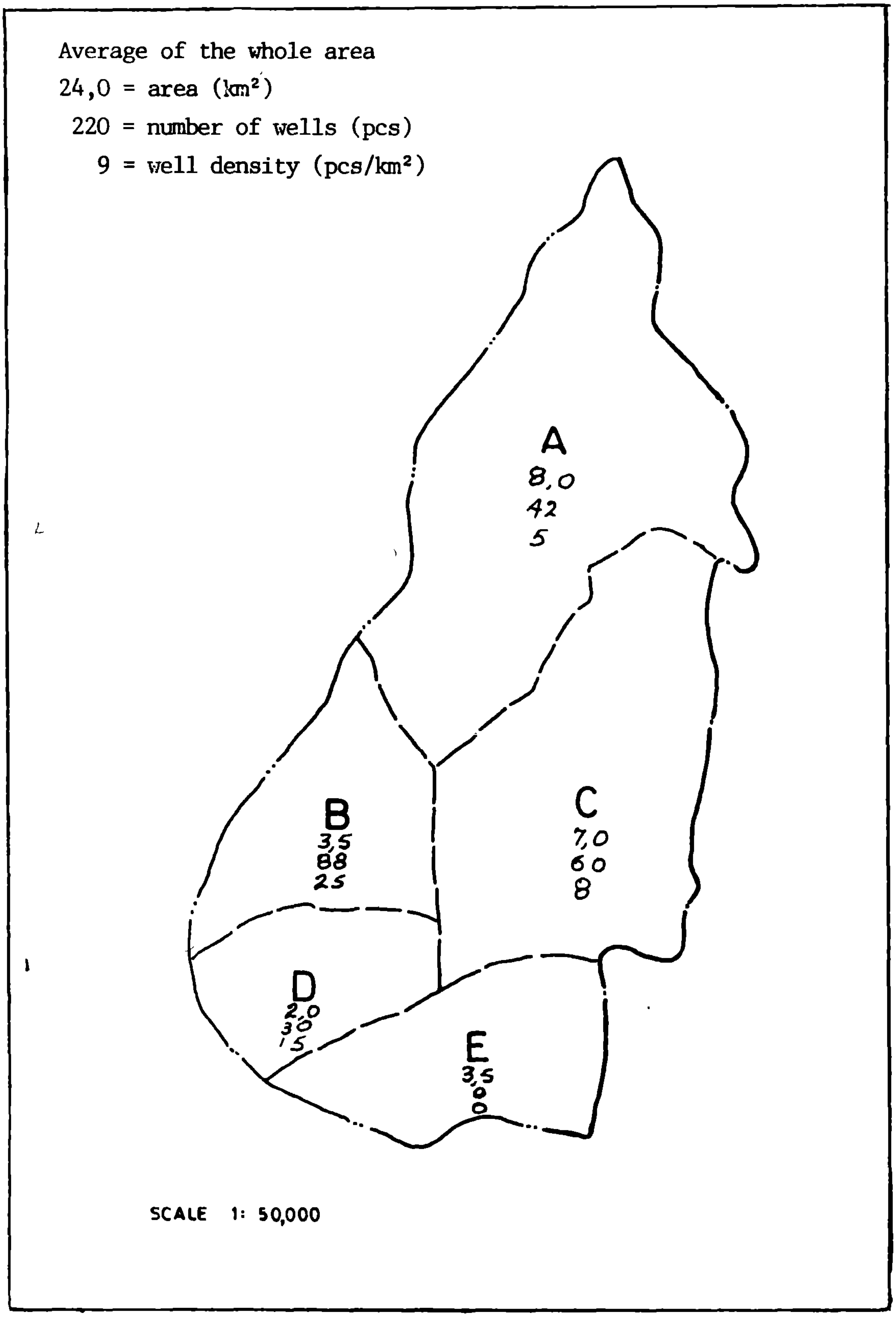


Figure 5. Hand-dug wells distribution.

Basically, there are two types of rainwater catchments: roof catchments and ground catchments. The two types of rainfall catchments will provide water in areas where it is uneconomical or unsafe to use other sources of water for drinking. Roof catchments are practical in areas where rainfall is abundant and fairly evenly distributed throughout the year. They have the following advantages:

- they can be used in most places,
- materials for catchments are readily available,
- their design is simple,
- they are relatively inexpensive to develop,
- they are efficient collectors of rainwater, and
- they are easy to maintain.

Ground catchments are more expensive than roof catchments because of material and labour costs. They should be considered in areas where rainfall is very scarce and other sources are not available. Ground catchments are best suited for providing water for several families or for small community supplies, rather than individual families. Design of ground catchments is more difficult and greater skill is needed for construction. Ground catchments do, however, have the following advantages:

- large quantities of water can be collected for a community supply,
- they provide large quantities of water with little rainfall, and
- if properly designed, they are very efficient collectors.

The study area has abundant rainfall and thus, the roof catchment is considered in the rainwater harvesting resources. Roof catchments collect rainfall from a roof and channel it through a gutter into storage for use by individual households. The amount of water available for use depends on three factors: the amount of annual rainfall, the size of the catchment area and the capacity of the storage tank. The roof of the house is the catchment area for the rainfall. The effective roof area for collecting water is not the roof area itself but the ground area covered by the roof. In the study area there are two types of roofs. Thatched roofs are common in the area. Families get water from these roofs even though the water is coloured and unattractive. They can, however, be improved by using plastic sheeting which provides a good catchment surface for water harvesting. The corrugated galvanized iron roofs have been used to harvest rainwater in schools, churches and individual houses when gutters are installed. There are few cases in the area where water from the roof is collected to the tank. This is mainly due to the financial incapabilities of the people and priorities attached to limited financial resources.

With the high rainfall (average 1500 mm per year), rainwater harvesting can be a supplementary source of water supply in the family. The average dimensions of the ground area for houses in the study area are 7 m x 10 m. Assuming 80 % of the total volume of rainfall is available for use because of evaporation and other losses, the amount of available rainfall is:

$$1500 \text{ mm} \times 70 \text{ m}^2 \times 0{,}80 = 84.000 \text{ l/year}$$

$$\text{average monthly rainfall} = \frac{84.000}{12} \text{ l} = 7.000 \text{ l}$$

$$\text{average daily rainfall} = \frac{7.000}{30} \text{ l} = 233 \text{ l}$$

Taking the average daily water consumption of 25 l per person, the number of people to be served is:

$$\frac{233}{25} = 9 \text{ persons.}$$

Thus, the roof cathcment of the above dimensions is capable of serving a family of nine persons for the whole year if all the collected water can be stored. The size of the cistern will depend on a) the amount of water needed, b) the amount and frequency of rainfall available, c) the size of the collecting surface, and d) cost. Since rainfall is not evenly distributed throughout the year, the size of the cistern can be increased to store water during the wet season for use in the dry period normally of maximum three months. The cistern required for this period of three months storage is large and would be very expensive to build and thus impossible for most individual families.

One alternative is to use collected rainwater for drinking and cooking only and find another source for washing and bathing. In this way, water use from the cistern can be reduced and thus a smaller, less expensive cistern can be built.

4.2 Water Consumption

The rural villagers in the study area need water mainly for domestic purposes comprising of

- drinking,
- cooking,
- washing,
- livestock watering,
- local brewing,
- small irrigation (vegetable),
- tree nurseries,
- coffee and tea nurseries.

The urban market centre in the study area needs water mainly for

- hotels,
- shops,
- bars,
- butcheries,
- slaughtering units,
- cooling grinding mills.

A field survey was carried out to show the household water sources with their seasonal variation. In the study area, the long rains come between April and June and the short rains between August and September. The dry season falls between January and March.

There are some parts within the study area where the distribution of hand-dug wells is low. The survey covered only the areas with high density distribution of shallow wells. Water from springs is regarded by the users as clean for drinking and thus needed no boiling or any form of treatment. Water from the hand-dug wells is regarded unclean for drinking unless boiled or chlorinated. Water from the hand-dug wells is mainly used for all domestic purposes except drinking.

Table 11. Household water sources used.

Source	Dry season Respondents No.	Dry season Percentage %	Wet season Respondents No.	Wet season Percentage %
River	5	7	0	0
Spring	21	29	21	27
Well	47	64	53	69
Rain	0	0	3	4
Total	73	100	77	100

Table 11 shows the household water sources with seasonal variations. The table indicates that more than two thirds of the respondents in the study area use well water throughout the year. An average of 28 % of the respondents use spring water for drinking all the seasons. Table 11 clearly shows that during the dry period, more people use springs. People use wells more in the wet season than during the dry season. With this type of pattern of water use, the demand is likely to be varying with seasons.

A field inventory of the water extraction from shallow wells and its seasonal variation was done. The wet season and the dry season were considered with respect to the amount of water extracted. Out of the 110 wells visited, 69 had adequate and reliable water extraction data for analysis. Table 12 shows water extraction from hand-dug wells during the wet and dry seasons of the year. From Table 12, 19 % of the wells supply more than 1,5 m^3/day throughout the year. The maximum noted extraction from a single well was 5,0 m^3/day. This well serves 10 families with domestic consumption, waters 30 heads of traditional cattle and supplies water for spraying a coffee nursery.

Table 12. Water extraction from hand-dug wells (m^3/day).

Amount of water extracted (m^3/day)	Wet season Number of wells (N = 69)	%	Dry season Number of wells (N = 69)	%
≤ 0,2	8	11	24	35
0,2 - 0,5	16	23	9	13
0,5 - 1,0	24	35	16	23
1,0 - 1,5	8	12	7	10
1,5 - 2,0	4	6	4	6
2,0 - 3,0	6	9	6	9
3,0 - 5,0	3	4	3	4

The use of spring water is higher than the utilization of water from hand-dug wells (Table 13). All springs are communal, whereas the hand-dug wells are privately owned. Thus the number of people using one hand-dug well is limited. With the normal belief of the people that spring water is clean, the consumption from springs is thus increased.

Table 14 shows the unit consumption rates recommended by the Ministry of Water Development Design Manual. The actual consumption rates in Magwagwa market were surveyed and results are shown in Table 15.

Table 13. Water extraction from springs.

Source	Population served per day: Number of people	Population served per day: Number of cattle	Estimated total consumption (m^3/d): Domestic demand	Estimated total consumption (m^3/d): Livestock demand	Total extraction (m^3/d)
Nyabigena/Nyaribo	300	-	7,5	-	7,5
Omoba	200	-	5,0	6,0 *	11,0
Nyakenyomisia	60	12	1,5	0,6	2,1
Nyabigena/Raini	200	100	5,0	5,0	10,0
Nyakemwate	400	40	10,0	2,0	12,0
Egetiongo	600	-	15,0	-	15,0
Teya/Moturi	250	5	6,3	0,3	6,6
Ekioma	150	30	3,8	1,5	5,3
Aori	100	-	2,5	-	2,5
Rianyansumora	80	-	2,0	-	2,0
Riomouria (I)	200	-	5,0	-	5,0
Ekioma/Buranda	230	40	5,8	2,0	7,8
Riomouria (II)	200	-	5,0	-	5,0
James Buyeke	120	10	3,0	0,5	3,5
Moora	150	-	3,8	-	3,8
Engoto	300	90	7,5	4,5	12,0
Mokarate	1000	200	25,0	10,0	35,0
Nursery	740	200	18,5	10,0	28,5
Ensoko/Makori	400	-	10,0	-	10,0

* No livestock using the water except for the cattle dip once in 4 months.

Table 14. Unit water consumption rates (Rofe Kennard and Lapworth 1982).

Nature of demand	Consumption
- Schools	
secondary day	10 l/head
secondary boarding	50 l/head
primary and nursery	10 l/head
- Health centres	5.000 l/day
- Shops	50 l/day
- Coffee factory	12.000 l/day
- Bars and hotels	300 l/day
- Livestock	
grade cattle	75 l/day
traditional cattle	25 l/day
small stock	5 l/day

Table 15. Field inventory of average water consumption rates.

Nature of demand	Consumption
- Shops	200 l/day
- Hotels and bars	500 l/day
- Grade cattle	80 l/day
- Traditional cattle	50 l/day
- Slaughtering unit	150 l/day

4.3 Discussion

From the three water resources (surface water, groundwater and rainwater), it was observed during the field survey that groundwater utilization in the study area is high. The groundwater utilization is mainly from the hand-dug wells. The average of 9 hand-dug wells per square kilometre in the study area serving 36 persons per well per day (1985 population estimate) is high when compared with the normal recommendations of low-cost well distribution of one well for a population of 250 persons per day.

Areas where caving of hand-dug wells takes place, well lining with bricks or concrete rings can be the only solution. This is a new knowledge to the people in the area. The introduction of the idea of well lining will be appreciated in areas where the people have suffered financial losses due to well collapses. Simple and cheaply made ring mould designs from locally available materials can make the production of concrete rings cheap for the hand-dug well lining.

Even though most people use hand-dug well water throughout the year, the pattern shows that the amount of people using spring water increases during the dry season. This indicates that either some wells dry up or do not provide enough water during the dry period. Table 13 shows that springs play an important role in supplying water to the people in the area. The investigation of water quality for both hand-dug wells and springs can be of vital value to the community as these are the major sources of water supply in the area. Any recommendation for the improvement of these water sources will be based on the findings of the water quality analysis.

The average unit water consumption rates recommended by the Ministry of Water Development as the basis for the design of water supply schemes need revision in order to meet the actual field water requirements. It was observed during the survey that the actual average water consumption is higher than the recommended values.

5 BACTERIOLOGICAL WATER QUALITY IN THE STUDY AREA

The main purpose of bacteriological examination of water quality is the detection of recent, and therefore potentially dangerous, faecal pollution. Contamination of drinking water by human or animal excrement, or by sewage, is dangerous if among the contributing population there are cases of carriers of infectious enteric diseases which may be waterborne.

The faecal coliform organisms retain the ability to ferment lactose at a temperature of 44,5 °C. The primary purpose of bacteriological analysis is to detect faecal pollution. Incubations at 44 °C or 44,5 °C provide the most direct route to detecting faecal coliform organisms (WHO 1984, Vol. III).

Sample — Incubate with lactose at 44 °C or 44,5 °C

→ Positive: Faecal coliform organisms present faecal pollution

→ Negative: No evidence of faecal pollution

5.1 Detection of Coliform Organisms

There are two basic methods of detecting coliform bacteria (Analyzing a Water... 1982).

a) "The multiple tube method" in which measured volumes of water are added to sets of tubes containing a suitable liquid medium. The sample tubes are incubated and the nutrient broth supports the multiplication of the bacteria. After 48 hours in incubation, the most probable number (MPN) of bacteria in the water sample is estimated based on the number of tubes which produce gas, the sign of bacterial growth. Field kits are available for the multiple tube method but this test is most effectively performed in a well equipped laboratory.

b) "The membrane filter technique", in which measured volumes of sample are filtered through a membrane which retains any bacteria present in the water. The filter is then placed on a growth medium and incubated. The bacteria multiply forming visible colonies. The colonies are counted directly by eye or with the aid of a binocular wide-field microscope.

The accuracy of both these methods of coliform detection is highly dependent on the water sample being properly collected from the water source under investigation.

The advanteges of the multiple tube method over the membrane filter method are as follows (Analyzing a Water... 1982).

1. The equipment and supplies necessary for the multiple tube test are common to well equipped laboratories. They are more readily available in most countries than equipment and supplies for the membrane filter method. Membrane filter portable kits must be imported from the manufacturer which involves high expenditure of foreign exchange for aquisition and replacement parts. Because costs are high, availability and distribution may also present problems.

2. The equipment for the multiple tube method can be reused. The membrane filter portable kits are disposable and cannot be used more than once.

Advantages of the membrane filter method over the multiple tube method for field analysis are as follows (Analyzing a Water... 1982).

1. The number of coliform bacteria colonies grown in a filter can be visually identified and counted. The multiple tube method estimates the number of coliform bacteria statistically. The membrane filter results can be preserved for future reference unlike the multiple tube results.

2. The membrane filter method requires less equipment preparation and clean-up. Disposable equipment and pre-prepared supplies are standard parts of membrane filter field kits. The membrane filter test also takes less time to perform than the multiple tube method. The membrane filter method requires 24 hours from sample collection to interpretation of results. The multiple tube method requires 48 hours for incubation alone, and can take up to 96 hours for complete procedures. Therefore, where labour costs are high, the membrane filter method may be less expensive to use.

3. The membrane filter technique is better adapted to field work and emergencies than the multiple tube method. Preparation for, performance of and clean-up after the membrane filter test are less complicated and quicker than for the multiple tube method. Membrane filter test equipment and supplies take up less space than those for multiple tube tests. More equipment especially adapted for field conditions is available for the membrane filter tests than for the multiple tube tests.

The membrane filter method is appropriate when reliable laboratory service is not available within six hours of water sample collection and when the kits are available cheaply.

5.2 Field Methodology

5.2.1 Sampling Procedure

Samples for bacteriological analysis were collected in sterilized glass bottles with stoppers prepared by heating for two hours at the temperature of 120 ^{o}C with a thin aluminium foil paper hood over the stopper and bottle neck. The aluminium foil covering was kept in place after sampling. Slightly over 200 ml of each sample was collected in order to perform all tests required for bacteriological contamination.

With the stopper in place, a string was tied to the bottle. A stone was tied to the bottom to weight the bottle down. The cap was removed carefully without touching the inside of the stopper or bottle and the bottle was lowered into the well until it was about 1 m below the water surface. The bottle was then raised out of the well and the cap and hood carefully replaced. The sample was labelled the time of collection and number (Figure 6). For the protected springs with outlet pipes, a sample was collected directly from the pipe. For the unprotected springs, the sampling method used depended on the water collection procedure at the spring. There were springs with water from the spring outcrop coming to a collection pool before outflowing. Water from these springs was sampled from midspring facing upstream. The bottle cap was removed and bottle plunged downwards into the spring pool while facing the direction of the current. Then the cap was carefully replaced and the sample was labelled with the time of collection and number. Some springs had the spring outcrop level between 0,5 m and 2,0 m above the outflow ground level, because of the erosion on the drain channel and people digging into the eye of the spring to avoid stagnation. Water from these springs was collected by putting a sisal leaf or a banana cover into the eye of the spring. The water flows along the banana cover and falls down to drain. Water samples were collected directly as the water falls from the banana cover.

Normally collecting buckets are placed on the ground and water is collected like a piped spring. Normally the users do not disturb the spring outcrop unless when replacing the water conveyance mechanism.

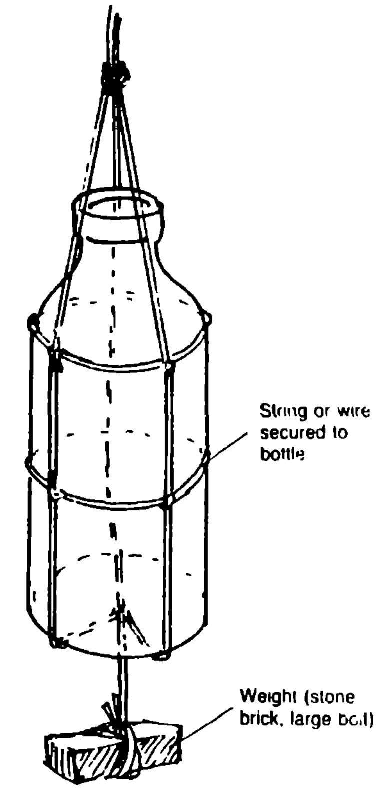


Figure 6. Weighted bottle for well samples (Analyzing a Water... 1982).

5.2.2 Handling of Samples

Changes occur in the bacteriological quality of water when it is stored. The samples were put in the sampling box while collection continued. Ideally the temperature of samples during storage should remain as close as possible to the temperature of the source from which they were drawn. This ideal cannot be guaranteed in the field. The samples were transported to the laboratory for incubation within six hours of collection (Guidelines for... Vol. I, WHO 1984).

5.2.3 Analysing Procedure

For the bacteriological analysis the membrane filter technique of coliform bacteria detection was used in the study area. A water sample of 100 ml was drawn from a funnel by a vacuum pump through a flat filter. The wet filter was removed from the filter holder and placed in a petri dish over a pad saturated with growth medium (Figure 7). The petri dish was then placed in an incubator of controlled temperature at 44,5 ^{O}C for a period of 22 - 24 hours. Any coliform bacteria present grew in distinctly coloured colonies on the filter. Only developed and sharply contoured, dark red colonies with a greenish metallic sheen and a dark red point on the underside of the membrane filter were counted.

Some results of 13 hours incubation period have been included. The incubation period was short due to failure of the generator during the incubation time. Nevertheless, the results were easily visible with the naked eye.

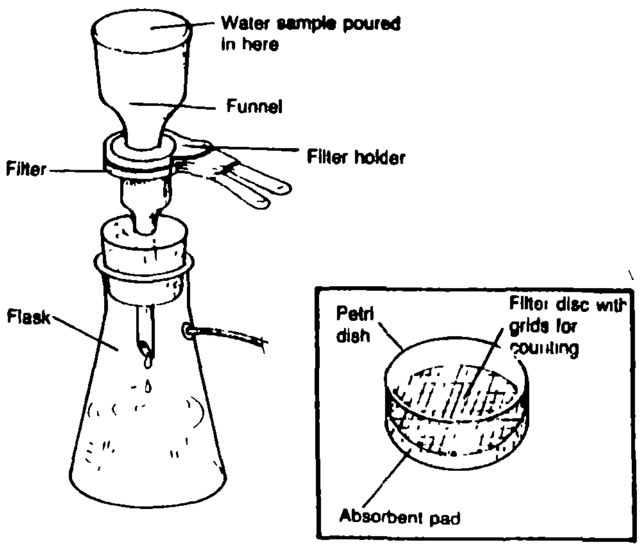


Figure 7. Membrane filter method of coliform detection (Analyzing a Water... 1982).

5.3 Results of Bacteriological Water Analysis

Bacteriological water analysis of 59 samples from hand-dug wells and 21 samples from springs were tested. The results of the analyses are shown in tables 16 and 20 respectively.

5.3.1 Hand-Dug Wells

The hand-dug wells were registered numbers during the sampling period for the identification of the sample results after incubation. Table 16 shows the bacteriological water analysis for hand-dug wells investigated.

Table 16. Bacteriological water analysis for hand-dug wells.

Well No.	Well owner	Date tested	Incubation period (hrs)	Number of faecal coliforms (/100 ml)
5	Osoro D	4.11.85	23	45
13	Mogere A	5.11.85	24	> 100
	Mogere B	5.11.85	24	> 100
15	Oange	5.11.85	24	> 100
16	Tabiga	5.11.85	24	> 100
17	Mokua R.	5.11.85	24	94
18	Nyamanga	5.11.85	24	> 100
20	Arasa S.	5.11.85	24	> 100
21	Ongaki A.	5.11.85	24	> 100
22	Ndubi J.	5.11.85	24	confluent growth
24	Nyaribo S.	5.11.85	24	> 100
26	Kwega N.	6.11.85	23,5	70
27	Ombusuro N.	6.11.85	23,5	> 100
28	Nyachieo N. A	6.11.85	23,5	confluent growth
	Nyachieo N. B	6.11.85	23,5	65
29	Nyamasege S.	6.11.85	23,5	confluent growth
30	Nyaribo N.	6.11.85	23,5	37
31	Ondoro E.	6.11.85	23,5	76
32	Mokua M.	6.11.85	23,5	96
33	Nyakundi	6.11.85	23,5	> 100
34	Miregwa B.	6.11.85	23,5	> 100
23	Ndege A.	6.11.85	23,5	> 100
36	Masisa O.	6.11.85	23,5	confluent growth

Table 16. Cont'd.

Well No.	Well owner	Date tested	Incubation period (hrs)	Number of faecal coliforms (/100 ml)
40	Arimba	6.11.85	23,5	> 100
41	Ndubi M.	6.11.85	23,5	15
5	Osoro	12.11.85	23,5	> 100
13	Mogere B	12.11.85	23,5	confluent growth
21	Ongaki A.	12.11.85	23,5	confluent growth
24	Nyaribo S.	12.11.85	23,5	confluent growth
37	Nyangau K.	12.11.85	23,5	confluent growth
14	Oange A	13.11.85	24	89
	Oange B	13.11.85	24	> 100
35	Moikobu	13.11.85	24	76
51	Ondari E	13.11.85	24	> 100
52	Mogere N.	13.11.85	24	32
53	Mochengo	13.11.85	24	> 100
48	Simon O.	14.11.85	22	80
50	Ombasa J.	14.11.85	22	> 100
54	Osumo P.	14.11.85	22	> 100
55	Mokoro O.	14.11.85	22	confluent growth
56	Mwambi	14.11.85	22	66
57	Nyakawa M.	14.11.85	22	> 100
59	Ongworu	14.11.85	22	58
60	Kengere	14.11.85	22	> 100
61	Nyaore O.	14.11.85	22	> 100
62	Omoti O.	14.11.85	22	47
63	Kamanda A.	14.11.85	22	> 100
64	Misuko	14.11.85	22	> 100
80	Nyangau O.	14.11.85	22	> 100
81	Nduko B.	14.11.85	22	82
26	Kwega	19.11.85	13	14
28	Nyachieo B	19.11.85	13	130
31	Ondoro E.	19.11.85	13	> 100
35	Moikobu	19.11.85	13	108
41	Ndubi	19.11.85	13	41
39	Onyinge	19.11.85	13	145
38	Omare B	19.11.85	13	> 100
13	Mogere C	19.11.85	13	> 100
	Mogere D	19.11.85	13	> 100

The investigated hand-dug wells had different conditions of well protection. Some wells were lined and had a cover whereas other wells were unlined but with a cover. Some wells were lined but had no cover whereas other wells were unlined and without a cover. Table 17 shows the number of faecal coliform bacteria in hand-dug wells according to the kind of well protection.

Table 17. Number of faecal coliform bacteria in hand-dug wells.

Well protection	Number of faecal coliform/100 ml							
	0		1 - 10		11 - 100		> 100	
	No	%	No	%	No	%	No	%
Well with lining and cover (N = 13)	0	0	0	0	3	23	10	77
No lining but with cover (N = 15)	0	0	0	0	4	27	11	73
Lining but no cover (N = 5)	0	0	0	0	3	60	2	40
No lining and no cover (N = 26)	0	0	0	0	9	35	17	65
Total (N = 59)	0	0	0	0	19	32	40	68

Even though the hand-dug wells in the study area are privately owned, some wells are in communal use by the neighbouring families. The common use of the well by neighbours is on friendly terms and existing neighbourhood relations. Each family using the well had its own rope and bucket system for lifting the water. Table 18 shows the number of families per well per day versus the number of faecal coliform bacteria range for each set of hand-dug well.

5.3.2 Springs

Water samples were collected from both protected and unprotected springs. The spring water bacteriological analysis for the springs investigated is shown in Table 19.

Table 18. Number of families per well versus the number of faecal coliform bacteria in hand-dug wells.

Number of families per well per day	Number of faecal coliforms/100 ml							
	0		1 - 10		11 - 100		> 100	
	No	%	No	%	No	%	No	%
1* (N = 20)	0	0	0	0	14	70	6	30
2 (N = 7)	0	0	0	0	0	0	7	100
3 (N = 8)	0	0	0	0	3	37	5	63
4 (N = 4)	0	0	0	0	0	0	4	100
5 (N = 7)	0	0	0	0	1	14	6	86
Total (N = 46)	0	0	0	0	18	39	28	61

* Average family size is 12 persons.

Table 19. Springwater bacteriological analysis.

Spring No.	Date tested	Source	Incubation period (hrs)	Number of faecal coliforms (/100 ml)
Sp 1	4.11.85	Nyakenyomisia Spring	23	3
Sp 2	4.11.85	Nyakemwate Spring	23	confluent growth
Sp 3	4.11.85	Teya/Moturi Spring	23	confluent growth
Sp 4	4.11.85	James Buyeke Spring	23	12
Sp 6	4.11.85	Matongo Intake Spring	23	0
Sp 7	5.11.85	Nyagoanchaga Spring	24	47
Sp 8	5.11.85	Omoba Spring	24	44
Sp 9	5.11.85	Nyabigena/Nyaribo Spring	24	67
Sp 10	5.11.85	Mokarate Spring	24	0
Sp 11	5.11.85	Nursery Spring	24	15
Sp 12	5.11.85	Nyabigena/Raini Spring	24	> 100
Sp 4	12.11.85	James Buyeke Spring	23,5	17
Sp 9	13.11.85	Nyabigena/Nyaribo Spring	24	127
Sp 11	13.11.85	Nursery Spring	24	34
Sp 4	19.11.85	James Buyeke Spring	13	22
Sp 8	19.11.85	Omoba Spring	13	2
Sp 9	19.11.85	Nyabigena/Nyaribo Spring	13	12
Sp 10	19.11.85	Mokarate Spring	13	20
Sp 11	19.11.85	Nursery Spring	13	8
Sp 65	19.11.85	Rianyatindi Spring	13	42
Sp 66	19.11.85	Egetiongo Spring	13	3

The springs which were investigated are categorized into two groups. Group one contains protected springs and group two unprotected springs. In group one, one spring was fully protected with a spring box at Matongo and it was used as a sample of well protected springs. Other protected springs had only the headwall and outlet pipe but no backfill cover. Water at the backfill is exposed to the surface. The top of the headwall in all the springs is used as a washing platform. Unprotected springs are separated into two sets according to the water collection conditions existing on the site. Set one includes springs, where water is collected from a pool and set two includes springs, where water is collected from the banana cover outflow. The bacteriological water quality for these springs is shown in Table 20.

Table 20. Number of faecal coliform bacteria in springs.

Spring condition	Number of faecal coliforms/100 ml							
	0		1 - 10		11 - 100		> 100	
	No	%	No	%	No	%	No	%
Protected (N = 7)	1	14	1	14	3	43	2	29
with box cover (N = 1)	1	100	0	0	0	0	0	0
without box cover (N = 6)	0	0	1	17	3	50	2	33
Unprotected (N = 14)	1	7	3	21	8	57	2	14
pool collection (N = 11)	0	0	2	18	7	64	2	18
banana collection (N = 3)	1	33	1	33	1	34	0	0
Total (N = 21)	2	10	4	19	11	52	4	19

Table 21 gives the summary of the bacteriological water analysis of the traditional sources used in the study area. These results can be compared with results from similar protected sources (Table 22) in Western Kenya.

Table 21. Summary of faecal coliform bacteria in the hand-dug wells and springs.

Water source	Number of faecal coliforms/100 ml							
	0		1 - 10		11 - 100		> 100	
	No	%	No	%	No	%	No	%
Hand-dug wells (N = 59)	0	0	0	0	20	34	39	66
Springs (N = 21)	2	10	4	19	11	52	4	19
Total (N = 80)	2	3	4	5	31	38	43	54

Table 22. Bacteriological analyses of protected point source water supplies (Kefinco 1985).

Waterpoint type	% in range, faecal coliforms/100 ml			
	0	1 - 10	11 - 100	> 100
Protected springs (N = 133)	87	5	5	3
Hand-dug wells (N = 119)	65	19	13	3

5.4 Discussion

Well protection plays an important role in keeping well water free from external pollution. With partial well protection practised in the study area, some well users are convinced that well water is clean for any use. The analysis shown in Table 17 clearly shows that lining and providing a cover for the well do not eliminate well pollution. The results show that wells without lining and cover have less faecal coliform organisms than wells with lining and cover. From Table 17, it is evident enough that there is an external pollutant with greater effect in well pollution outweighing the well protection.

78 % of the lined wells with cover are used by three or more families per day. From Table 18, it can be seen that as more families use one well, the number of faecal coliforms increases. Since each family uses its own rope and bucket lifting device for drawing water, the bucket can definitely pollute the water. Normally, the buckets are left lying on the wet ground (Figure 16). Animals put their waste on the ground as the wells are not fenced. The bucket gets in contact with the waste on the ground. Spilling water returns to the well

hence polluting the water. As more families use the well, the amount of spilling water increases. The pollution from the bucket and dirt spilling water increases the pollution as more families use unprotected hand-dug wells.

The results of the bacteriological water analysis for protected springs without a box cover clearly show that the water is polluted. The open backfill area is subject to pollution from surface runoff and dirt water from the washing taking place on the headwall. Unprotected springs show that the mode of water collection determines the extent of spring pollution. The banana collection system is better than the pool collection system. Water from the spring outcrop is conveyed by the banana cover to the container. Water from the spring is clean otherwise the only contaminant can be the banana cover. Pool water is subject to contamination all the time as the water is stagnant. The outflow is controlled depending on the spring flow. Surface runoff contaminates the water collected in the pool.

When the summary results of the bacteriological water quality in the study area are compared with results from similar protected sources, it can be inferred that protection of hand-dug wells and springs can improve the bacteriological water quality. Applying the WHO guidelines of not more than three coliform organisms and no faecal coliforms it means that 97 % of the samples should be unacceptable. This indicates that all traditional water sources are badly contaminated. It was suggested that it is better to have standards based on hygienic, technical and economic reasons that can meet and lead to improvements in protection of the sources, combating the sources of pollution. For small community water supplies a maximum of 10 faecal coliform organisms in 100 ml of water sample is recommended by Botswana... (1983). Apply this recommended value, 92 % of the tested samples should be unacceptable. It should however be born in mind that no systems are chlorinated. Due to the scarcity of water and high production costs for new water schemes the goals have to be set low by necessity.

6 SPRING PROTECTION

Due to the large number of unprotected springs in the study area, the selection of springs for protection has to be based on the following facts:

- discharge during the dry season,
- construction possibilities,
- availability of local construction materials (stones, sand),
- number of users and distance to the users,
- sources of contamination.

Using the cheapest technique, the spring site must be protected to prevent pollution.

The advantages of a spring as a water source compared with wells are:

- short construction time,
- no need for a pump and pumping,
- it can serve in favourable conditions as a source for a small piped scheme,
- almost maintenance free,
- community participation easy to organize.

The only disadvantage is the relatively long distance to carry water.

6.1 Designing Structures for Springs

A properly designed protective structure ensures an increased flow from the spring. The silt, clay and sand deposited at the spring outlet and other material washed down from the slope by surface run-off, must be cleared away.

The design chosen for a particular spring will depend on local conditions, materials available and spring yield.

6.1.1 Spring Box Design

Spring boxes serve as collectors for spring water. They can be used as storage tanks when a small number of people is being served and the source is located near the users. When a larger number of people is being served, the water collected in the spring box flows to larger storage tanks.

To protect a spring, it should be dug back into the hillside to the water bearing layer where the water is flowing from the "eye" of the spring, and build "a spring box" around the eye as shown in Figure 8.

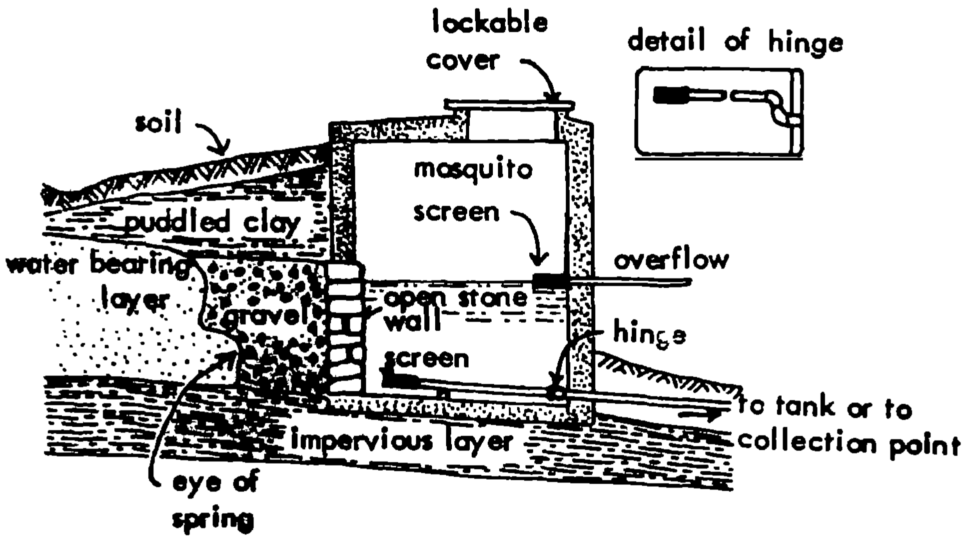


Figure 8. Protected spring (Cairncross and Feachem 1978).

Digging should not exceed the impervious layer otherwise water may seep downwards so that the spring disappears or moves down the hill.

Before constructing the spring box, loose stones should be piled against the eye of the spring. This is partly to make a foundation for the box and also to prevent the springwater washing soil away from the eye. The loose stones also filter suspended solids. The gravel filled area should be between 0,5 - 1 m wide depending on the size of the spring collection area. To ensure that no contamination reaches the water, the gravel pack should be at least 1 m below the ground surface (Designing structures... 1982). This is done either by locating the spring catchment in the hillside or by raising the ground level with backfill. Caution must be taken not to disturb ground formations when digging out around the spring. In cases where the box does not reach impermeable material, puddled clay should be used to seal the area around the sides of the spring box.

The outlet pipe should be at least 100 mm above the bottom of the spring box, but below the eye of the spring if possible. If the water level in the spring box is too high, silt may settle over the eye and block it up. The end of the outlet pipe inside the box should be covered with a screen to prevent stones, rubbish and frogs from blocking the pipes. Table 23 shows the recommended outlet galvanized iron pipe sizes that can be used at different spring flows upto 1 m in length set in a spring retaining wall. Two or more smaller pipes can be used in place of one larger pipe.

Table 23. Recommended galvanized iron pipe sizes to be used in springs (Gormley et al 1984).

Maximum spring flow (1/s)	Pipe diameter (mm)
up to 1,0	30
1,1 to 3,0	50
3,0 to 7,0	60

There should be an overflow pipe big enough to carry the maximum flow of the spring in the wet season. This pipe should be below the eye of the spring if possible. The end of the overflow pipe inside the spring box should be covered with screen fine enough to keep out the mosquitoes, but strong enough to hold back frogs which may block the pipe.

The top of the spring box should be at least 300 mm above the ground to prevent surface water running into it. The box should be covered with a concrete slab which has an access hole to facilitate cleaning. The hole should have a raised edge to prevent surface water running into the box. The cover should be lockable or so heavy that it can only be opened with a lever or a man-hole key, to stop anyone from interfering with it. A third pipe for cleaning out silt from the bottom of the spring box is also useful. This pipe should have a cap fixed on the end firmly enough to stop children from removing it.

Where it is not possible to dig deep enough for the bottom of the spring box to be at least 100 mm below the outlet pipe, then the outlet pipe should be at least 50 mm in diameter and lead the water to "a silt trap" not more than 50 m away as shown in Figure 9 (Cairncross and Feachem 1978).

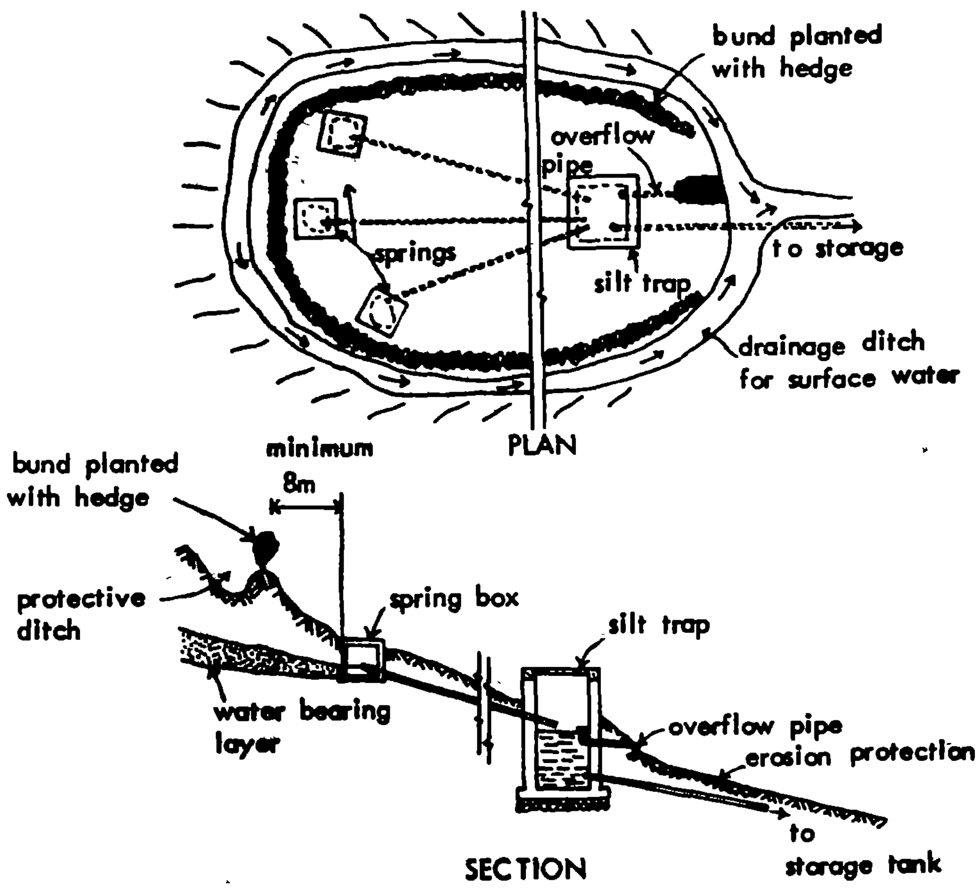


Figure 9. Three protected springs connected to a silt trap (Cairncross and Feachem 1978).

This box also needs a manhole cover, a mosquito proof overflow, an outlet pipe at least 100 mm above its bottom and a strainer on the outlet pipe. Water from several small springs may be collected to one silt trap as shown in Figure 9.

One point to watch when piping water by gravity from several springs is the danger of the pressure from one spring stopping up another. The pipelines from separate springs should only come together as separate inlets above the water level, to a reservoir or silt trap.

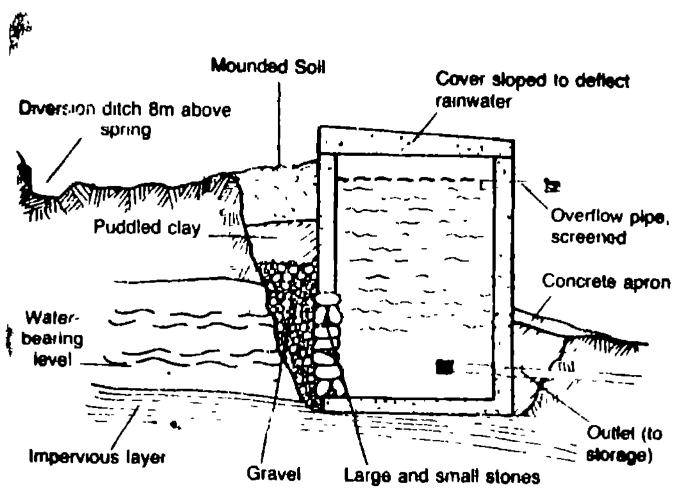
When the spring box is complete, the space behind it should be filled with soil. At the bottom, level with the eye, this space should be filled with gravel or sand at least as coarse as the water bearing layer. Further up it should be made watertight to prevent surface water running down the outside wall and into the box. This can be made with cement or with puddled clay. New spring boxes and silt traps should be sterilized by scrubbing on the inside with bleach solution (Cairncross and Feachem 1978).

A drain should be dug at least 8 m uphill and around on each side of the spring box to take surface water away from it and prevent pollution of the springwater (Cairncross and Feachem 1978). A fence around the area will keep animals from getting near the spring box and help in preventing contamination and destruction of the area. The fence should have a radius of 7 - 8 m (Designing Structures... 1982).

6.1.2 Spring Box with Open Side

A spring box with a pervious side is needed to protect springs flowing from hillsides. The area around the spring must be dug out so that all available flow is captured and channelled into the spring box.

A collection box is built around the spring outlet as shown in Figure 10. The dug-out area should be lined with gravel. The gravel placed against the spring opening serves as a foundation for the box and prevents the springwater from washing soil away from the area. The gravel pack also filters suspended solids (Designing Structures... 1982).



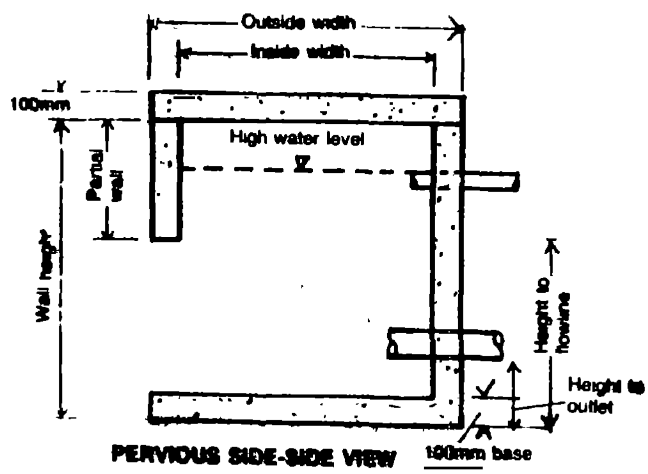


Figure 10. Spring box with open side (Designing Structures... 1982).

6.1.3 Spring Box with Open Bottom

If a spring flows through a fissure and emerges at one point on level ground a spring box with an open bottom can be developed as shown in Figure 11. The area around the spring is dug out until an impermeable layer is reached. This area is then levelled and lined with gravel. The spring box is placed over the spring and gravel to collect the flow. Clay or concrete is packed around the box to prevent seepage between the ground and the box.

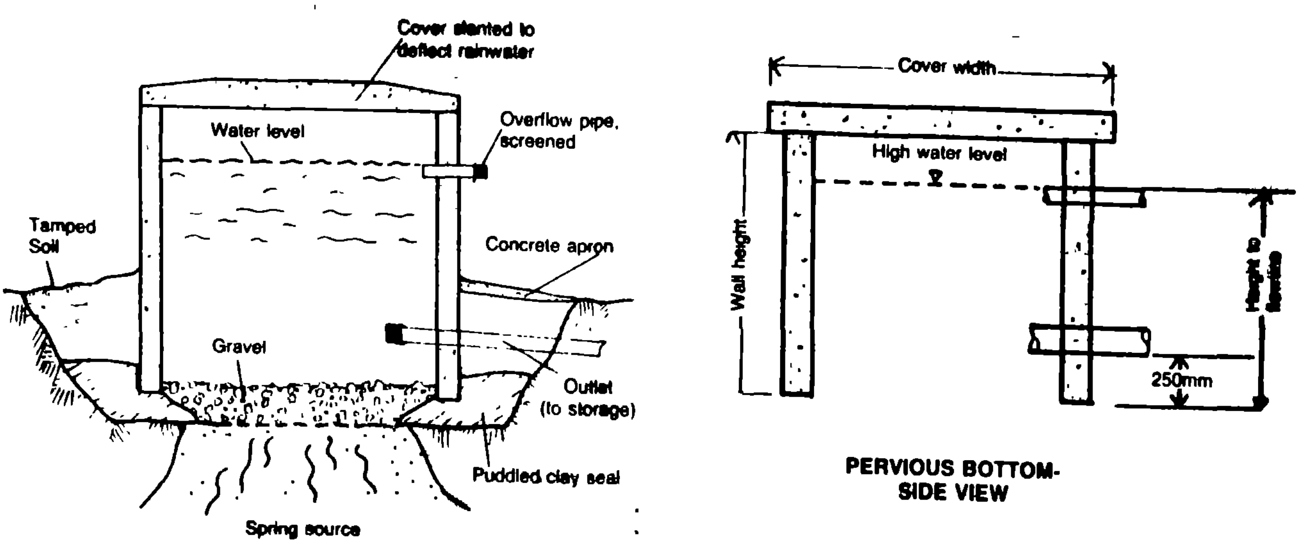


Figure 11. Spring box with open bottom (Designing structures... 1982).

6.1.4 Spring Box Capacity

The capacity of the spring box will depend on whether it is being used for storage or pre-storage. When used as a storage, it should be large enough to hold a volume of water equal to the needs of the users over a 12-hour period. For example: if 100 people each use 25 l of water per day, the amount of water consumed in 12 hours is $(100 \times \frac{12}{24} \times 25)l = 1250\ l$ (Designing Structures... 1982).

Therefore the volume of the spring box should be 1,25 m^3 (volume = length x width x height). If the collection box is used only for pre-storage and water flows on to another storage tank, the collection box can be smaller.

6.2 Seep Design

Designs for seep systems are similar to those for spring boxes. Intakes (collectors) are very important features of seep development (Figures 12 and 13). The collector system consists of small channels containing 100 mm clay open joint or 50 mm plastic perforated pipe packed in gravel. The collectors are installed in the deepest part of the aquifer. They take advantage of the saturated ground above them for storage during times when the groundwater table is low. The perforations in the pipes must be about 5 mm in diameter or larger enough to collect sufficient water but small enough to prevent suspended matter from entering the pipes. In fine and medium sized sand, perforated pipe should be packed in gravel but suspended material often will enter the pipe in spite of the gravel. To prevent clogging, the collectors should be sized so that the velocity of water flow in them is between 0,5 m per second and 1 m per second (Design Structures... 1982).

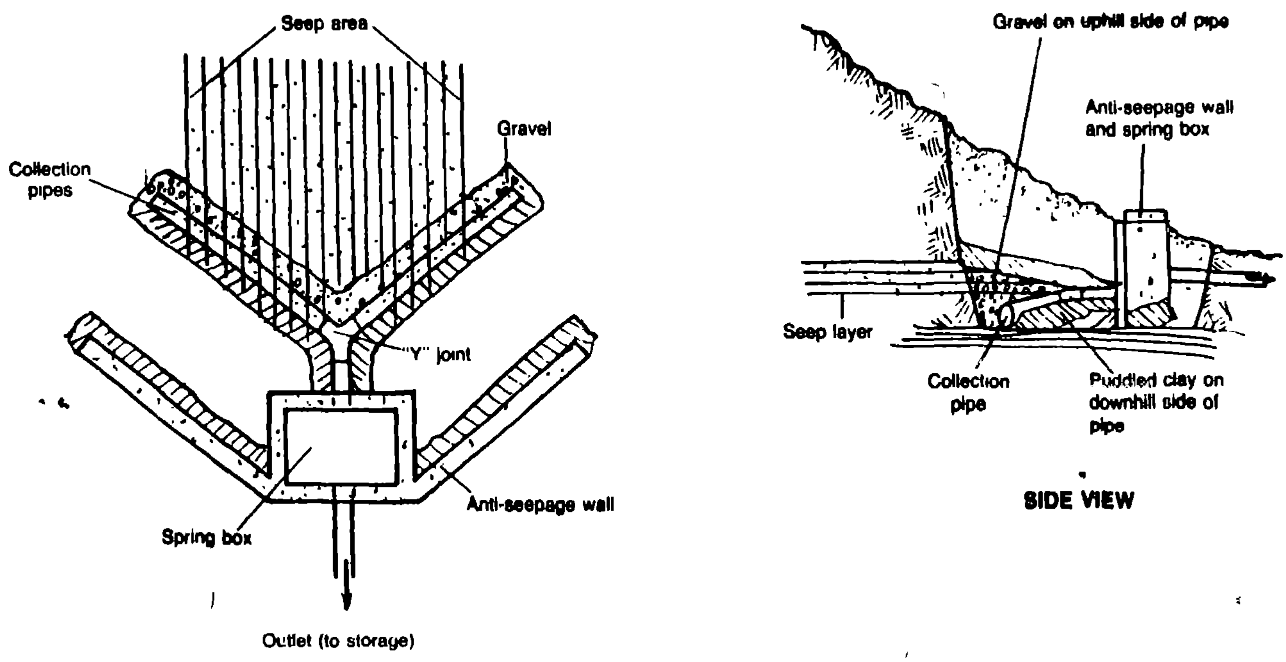


Figure 12. Seepage collection system (Designing Structures... 1982).

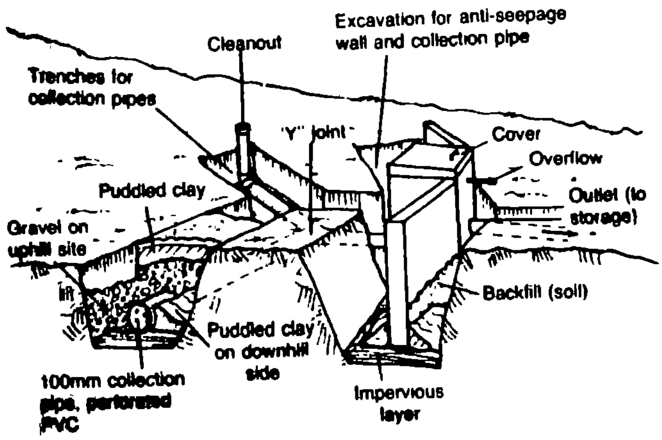


Figure 13. Basic design feature of a seep collection system (Designing Structures... 1982).

Water collected by the pipes is channelled to the spring box through a gravel pack. The collectors must extend across the entire width and length of the water-bearing zone and should be perpendicular to the flow of the aquifer. These intakes should extend below the water-bearing zones to collect the maximum amount of water and permit free flow into the collector. The advantage of a collector system is that water seeping over a large area can be channelled into a central storage basin.

Clean-out pipes to flush sediment from the collection pipes should be attached to the collection pipes. To install clean-out pipes, add a length of pipe to the far end of the collection pipe. At the end of this length, place an elbow joint facing upwards and attach a vertical length of pipe. The pipe should extend a little above the ground and be capped.

For seep development, a cut-off wall of clay, concrete or other impervious material should be constructed. The cut-off is usually constructed as a large "V" pointing downhill with wingwalls extending into the hill to prevent water from escaping. The cut-off should extend down into impervious material to force the flowing water to move to the collection point and to prevent loss of water due to underflow.

An outlet pipe is installed to move water from the collection point to the storage. A watertight connection should be made where the pipe leaves the spring box or goes through the cut-off wall.

6.3 Discussion

Since most of the initially protected springs have been damaged and there exist several unprotected springs, it was thought worthwhile to include spring protection in this paper. Due to varying site conditions in each spring, several design alternatives have been discussed. These design alternatives are based on the conditions seen during the field inventory of the springs. All the alternatives have been chosen on simplicity purpose, availability of local material and easy operation and maintenance by the villagers.

7 REHABILITATION OF HAND-DUG WELLS AND PROTECTED SPRINGS

7.1 Objectives of Rehabilitation

The main objectives of the rehabilitation of wells and protected springs are:
- to improve the water quality and
- to raise water production to the demand level.

Five steps have been identified to be carried out within the framework of the rehabilitation programme:

1) identification and correction of faults in the existing wells and protected springs to meet the present demand,
2) carrying out engineering studies to prepare a revised design including expansion of full spring protection and any major rehabilitation work of the wells and springs,
3) establish user groups to take care and pay for operation and maintenance costs of wells and springs,
4) plan for the organisation and management of the operation and maintenance activities of the rehabilitated wells and springs at a satisfactory level in the future,
5) train well and spring operators to carry out the necessary tasks of operations and maintenance.

These five steps are to provide for improvement of the existing water sources as rapidly as possible, to establish the basis for insuring that the sources will function properly in the future (better operation and maintenance), and to provide for continuity in the rehabilitation programme.

7.2 Issues Related to a Water Supply Rehabilitation Programme

Implementation of a rehabilitation programme is usually more difficult than a programme for the construction of new water supplies. Planning, design and construction activities for new schemes can be relatively simply managed by specific project groups, or almost independently by consultants and contractors, with only limited interaction with the potential beneficiaries or with other parts of the organization responsible for providing water. A rehabilitation programme, on the other hand, has to be much more comprehensive in nature. Reconstruction of existing facilities is only one component. Renovation of many aspects of the systems for operation and maintenance is even more important. Those activities must be carried out mainly by management and staff within the water supply sector (Grover 1977).

A rehabilitation programme is also more complex than a construction programme because of the social climate which prevails. Before a water supply is built the various interest groups, particularly the consumers, lack experience and are generally willing to accept whatever proposals are made by the management of the water authority. After a water supply has been built and has failed to provide reliable service, however, the climate is quite different. The consumers are disgruntled and sceptical. Those who were previously responsible for the supply are sometimes unwilling to understand or accept the responsibility of its failure. Rational analysis of past problems can be difficult in this atmosphere and modifications, either to the physical or the administrative systems, are not easy to implement.

7.3 Rehabilitation of Hand-Dug Wells

Figures 14, 15 and 16 show the existing hand-dug well conditions. It is evident enough that most if not all the wells are contaminated. The bacteriological water analyses from the 59 wells tested showed that 34 % of the wells had between 11 and 100 faecal coliforms per 100 ml of sample. The remaining wells (66 %) had more than 100 faecal coliforms in 100 ml of water sample. Of the 110 wells visited in the study area, 57 wells had no covers, 91 wells had no superstructure or lining. All the 110 wells had no sanitary arrangements for drawing water. The rehabilitation of these hand-dug wells is necessary in order to provide water of good quality to the users and a reliable supply in all seasons.

In rural areas and villages, the most serious threat to groundwater quality is contamination by human and animal wastes. For the case of shallow wells, pollution occurs mainly from privies, cesspools and seepage pits, septic tanks and farmyard manure. Pollution from these sources results in increased levels of inorganic chemical constituents and micro-organisms, including pathogens. The spread of pathogens via polluted groundwater sources is related to sanitation practices, the hydrogeology of the region, well location and construction and education of the villagers.

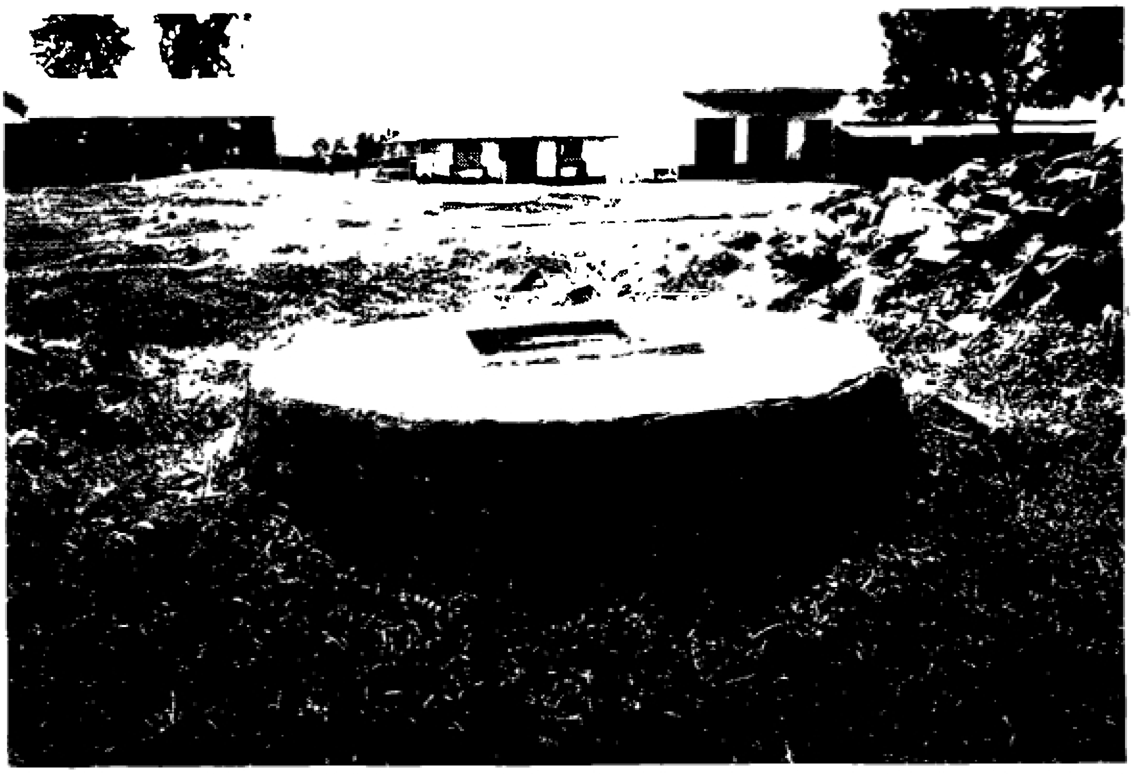


Figure 14. Hand-dug well No. 20.

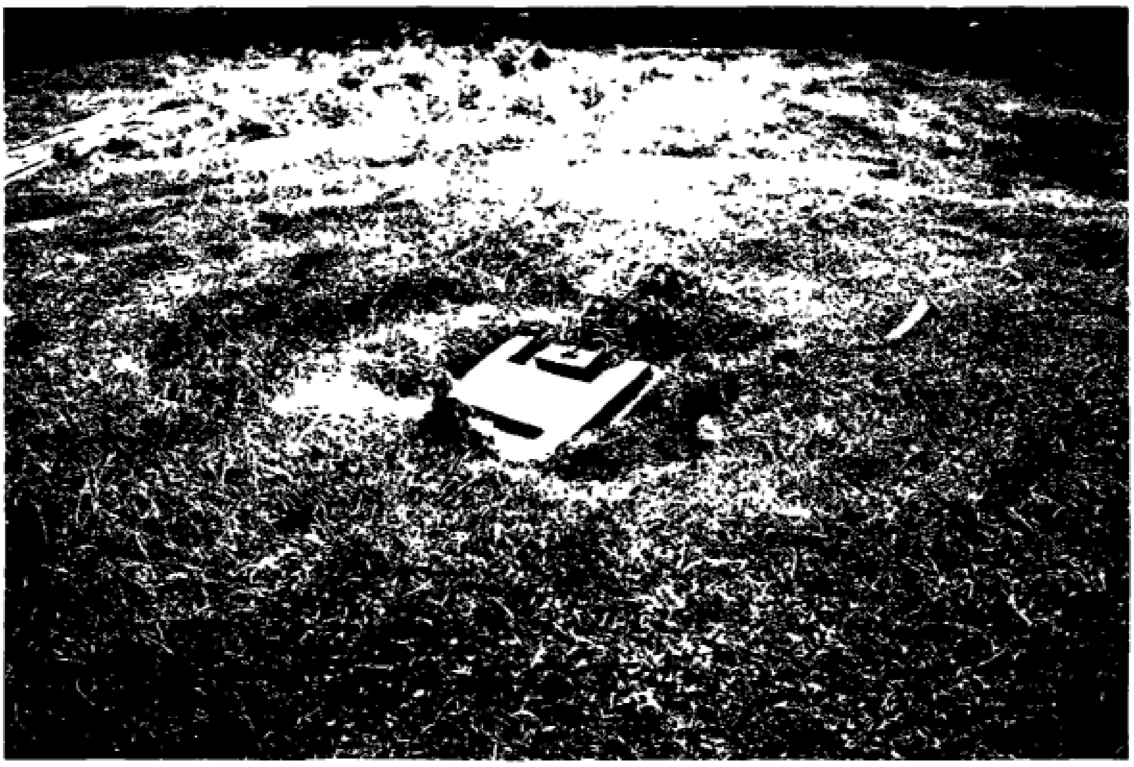


Figure 15. Hand-dug well No. 17.

Figure 16. Hand-dug well No. 18.

The sources of well pollution are:

- surface water washed straight down the hole if the ground surface around the well is sunk;
- spilt water for wells with no headwall or if people stand on the headwall to draw water from the well; water which has splashed against their feet may fall back into the well;
- seepage water from the surface through the top few metres of the well lining;
- the vessel used for drawing water can pollute the well: when the vessel is put on the ground, it becomes contaminated by the animal and human wastes on the ground surface;
- polluted groundwater resulting from the location of the well too close to pit latrines, soakaways of refuse dumps; and
- rubbish thrown down the well where there is no permanent cover: children playing near the well can throw rubbish into the well; when trees are planted near the well, leaves can fall into the well.

It is essential that any well should be located, designed and constructed in such a way that it protects the groundwater source from contamination. Also it must be used and maintained in a hygienic manner. Failure to ensure adequate protection will turn the well into a potential source of the very disease it was designed to prevent.

Table 11 shows that the number of households using wells in the dry season is lower by 5 % than in the wet season. This indicates that some wells dry up or do not provide enough water during the dry period.

The simplest, but the most important single improvement to an existing hand-dug well is the construction of a well head consisting of a headwall, drainage apron and approximately 2 m depth of brick lining. The well lining should be extended at least 0,5 m above the ground to form a headwall as shown in Figure 17. This improvement can be done on good solid ground where there is no danger of the shaft collapsing. If the ground is unstable, complete lining with either brick (Figure 18) or concrete rings (Figure 19) can be done before the headwall and pump installation.

The drainage apron should slope down away from the well, so that spilt water will drain away to a soakaway (Figure 20). The concrete apron seals any fissures between the well lining and the walls of the excavated hole and so prevents polluted water from seeping into the well.

A satisfactory safeguarding of the bacteriological safety of the water from a well can only be obtained if the well top is completely sealed with a watertight slab on which a pump is mounted to draw the water. This point is supported by comparison of the bacteriological analyses (Tables 21 and 22) of wells with half lined but without a hand pump in the study area and the fully protected wells in Western Kenya (Kefinco) respectively.

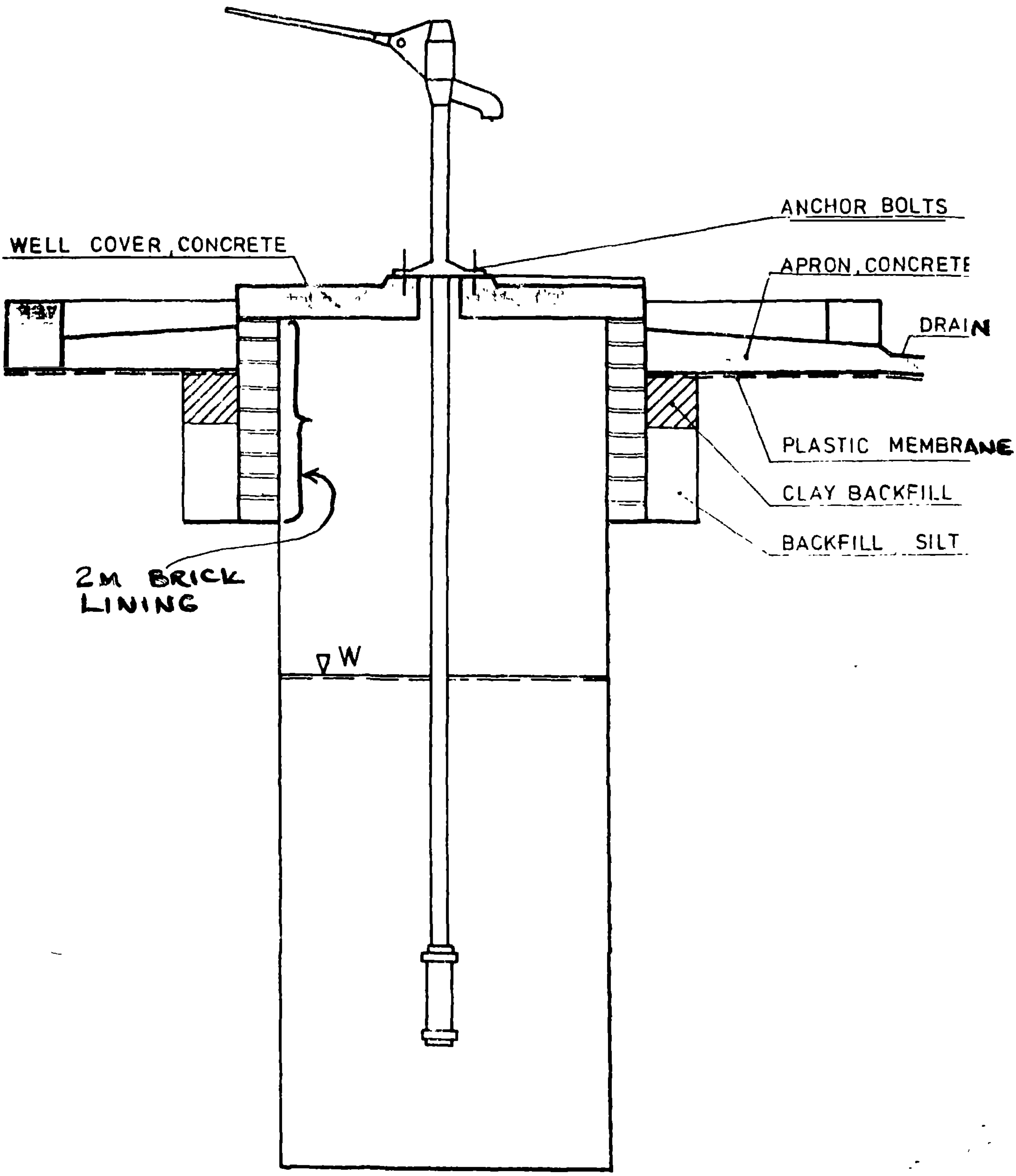


Figure 17. Hand-dug well partly lined with bricks.

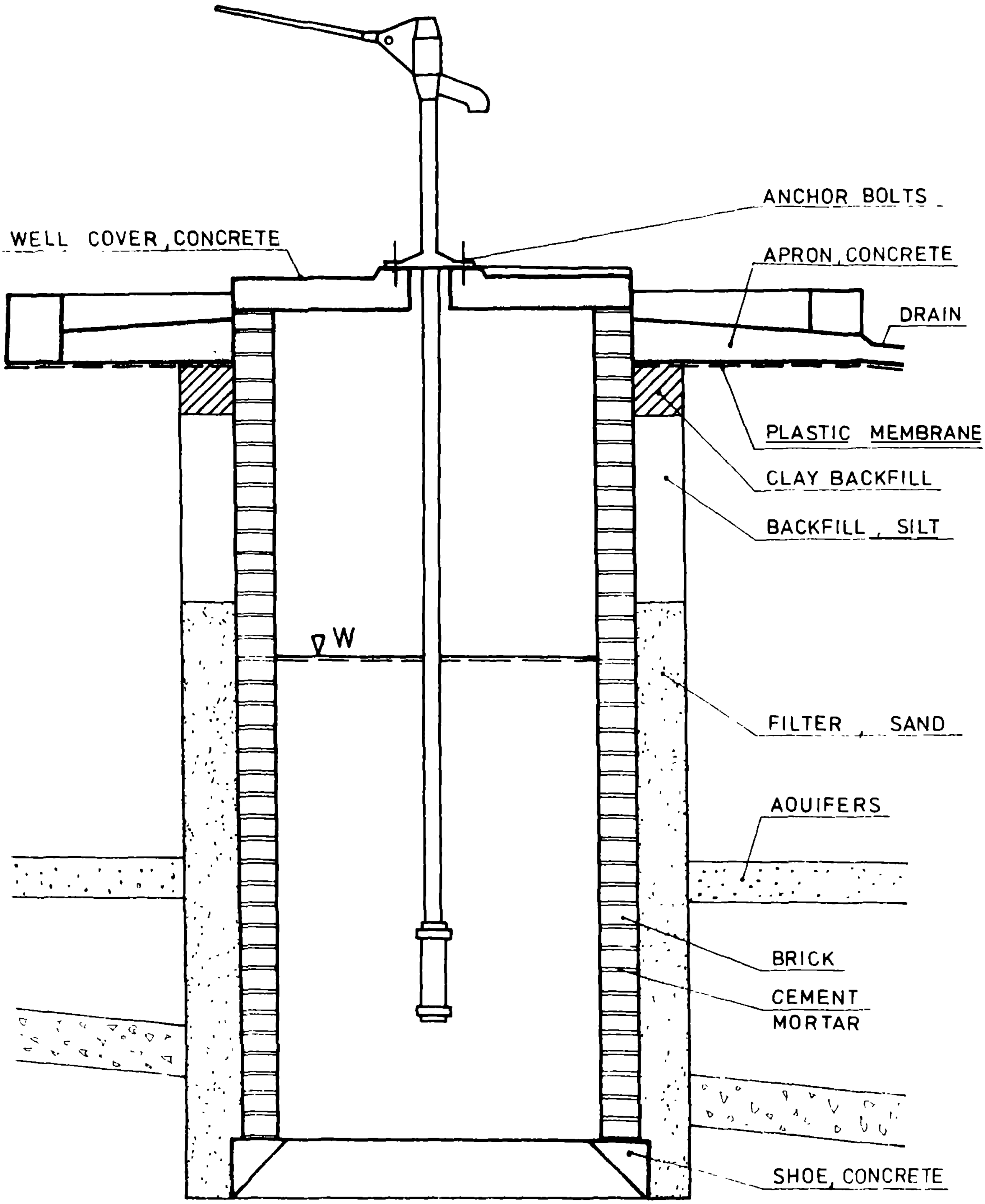


Figure 18. Hand-dug well lined with bricks (Kefinco 1983).

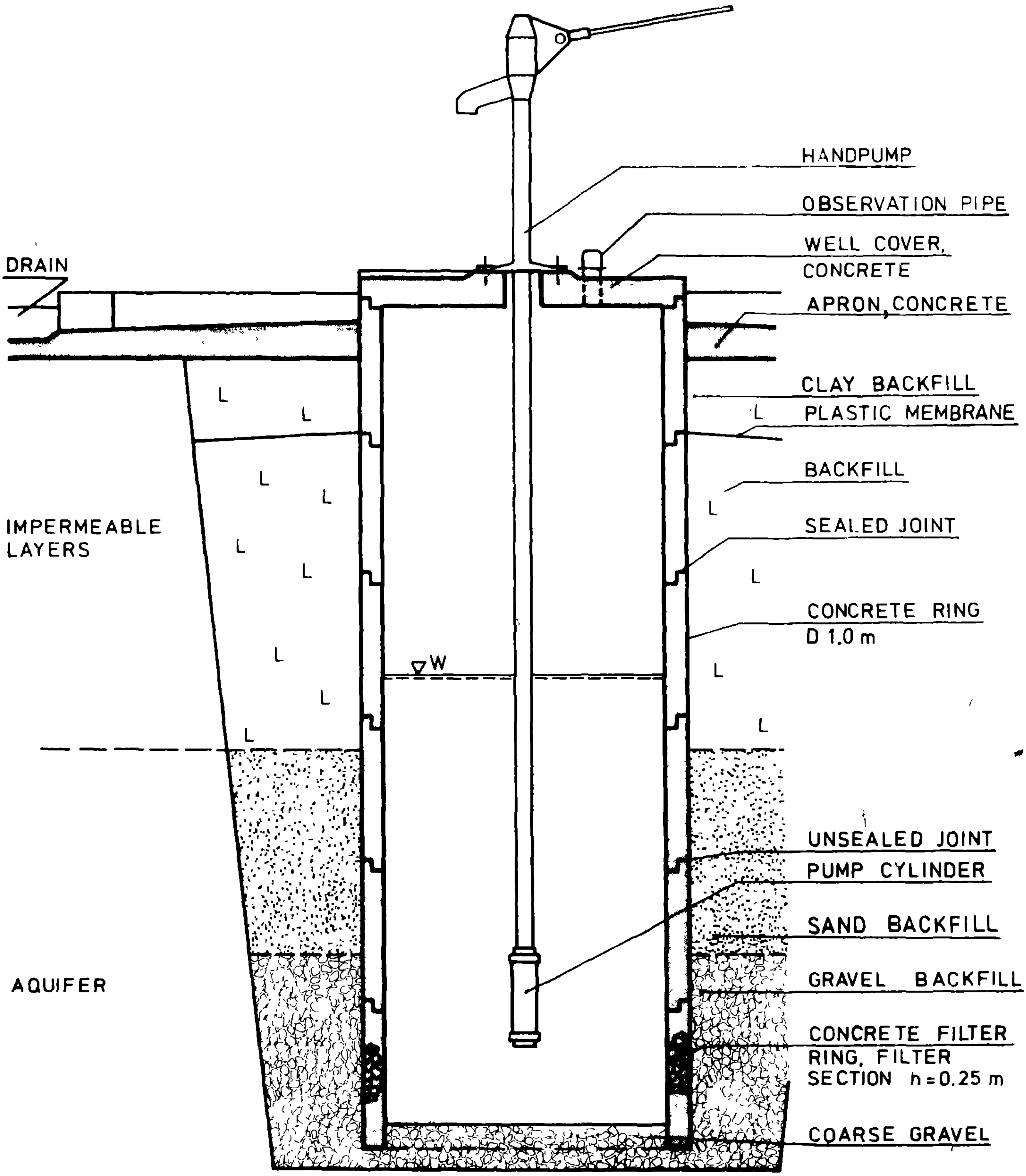


Figure 19. Hand-dug well lined with concrete rings (Kefinco 1983).

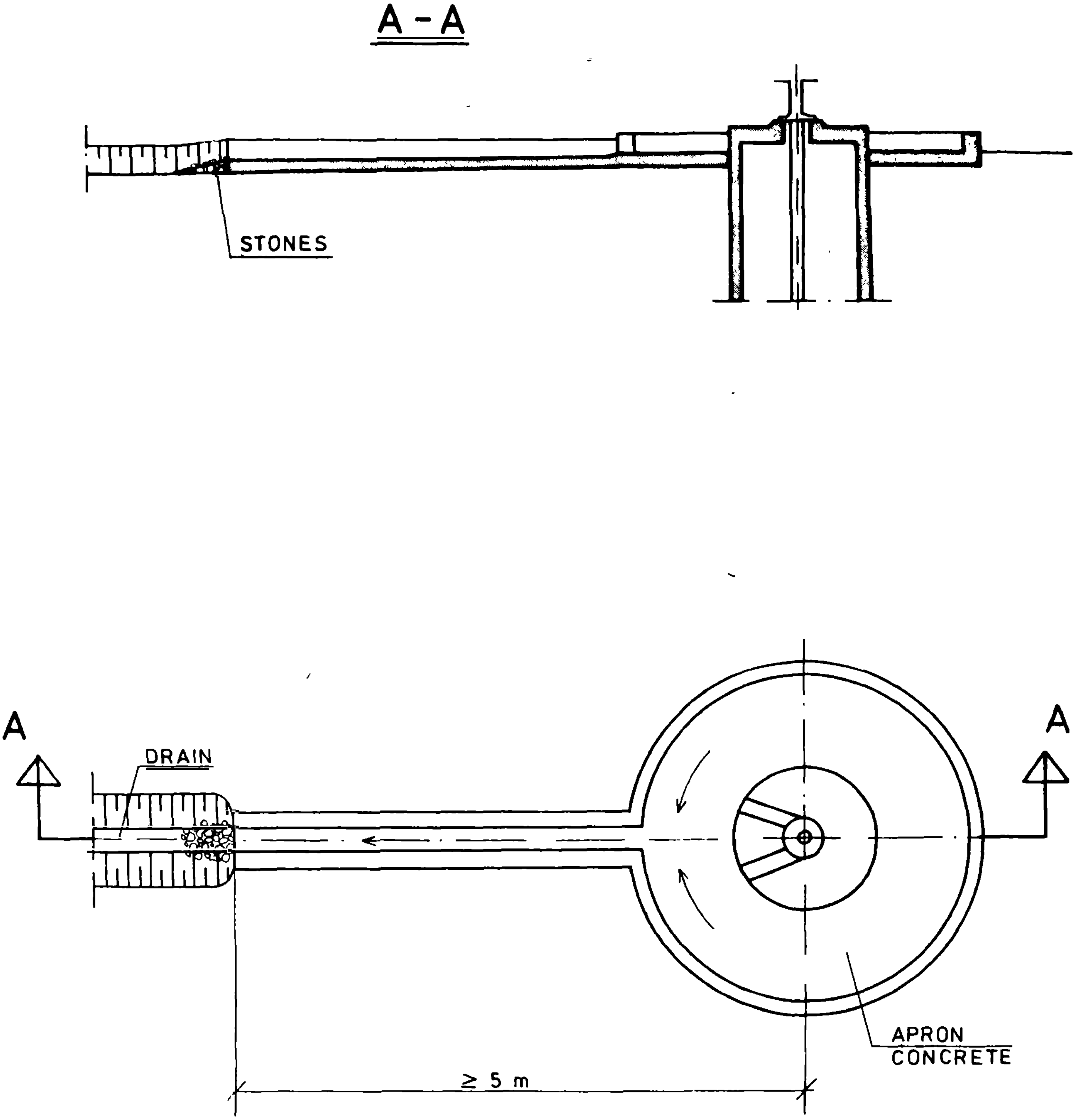


Figure 20. Drainage apron for wells (Kefinco 1983).

Some of the hand-dug wells can be rehabilitated through conversion into tube wells by filling the bottom part with gravel and the top with clay or other soil as shown in Figure 21, leaving a tube in the middle for a hand pump.

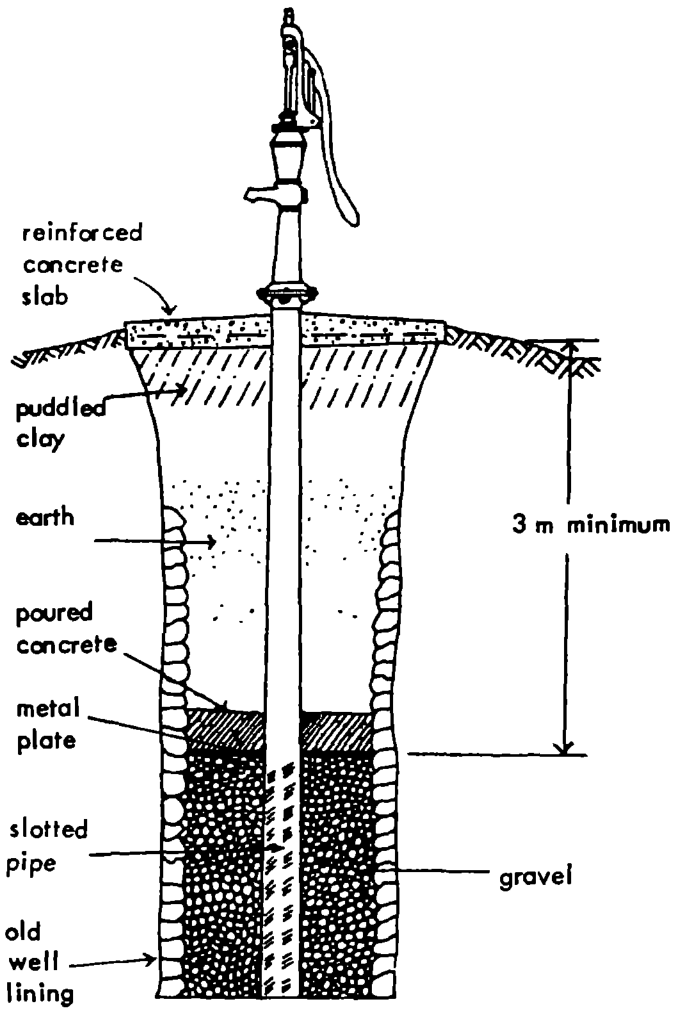


Figure 21. A hand-dug well converted into a tube well (Cairncross and Feachem 1978).

Those wells which run dry or do not give enough water can be rehabilitated by sinking a tube well into the bottom of the well and then backfilling the original well with puddled clay. By this method it is possible to reach much further down into the water bearing layers and thus improve the well yield (Figure 22).

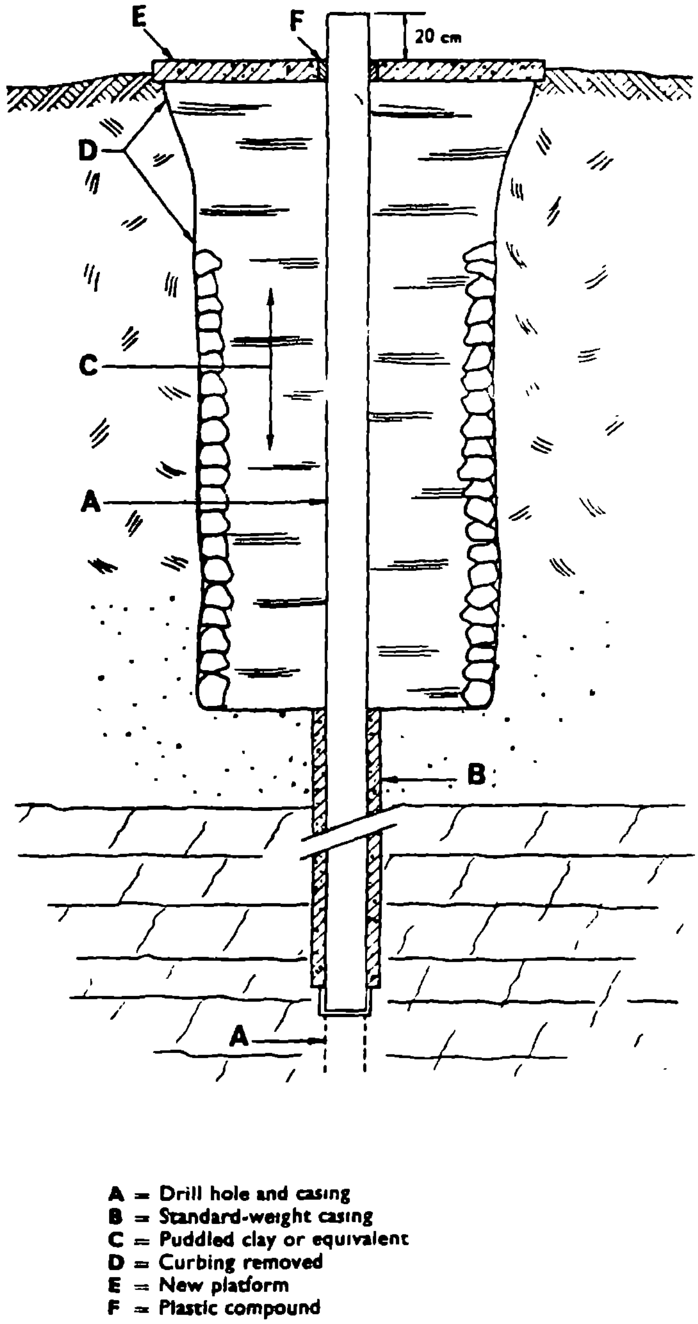


Figure 22. Hand-dug well converted into a tube well (Wagner and Lanoix 1959).

The major cost component in the rehabilitation of hand-dug wells is the installation of the hand pump to improve the sanitary conditions of the lifting method. Alternative sanitary methods of lifting the water from the well such as the shaduf (Figure 23) or windlass (Figure 24) can be used.

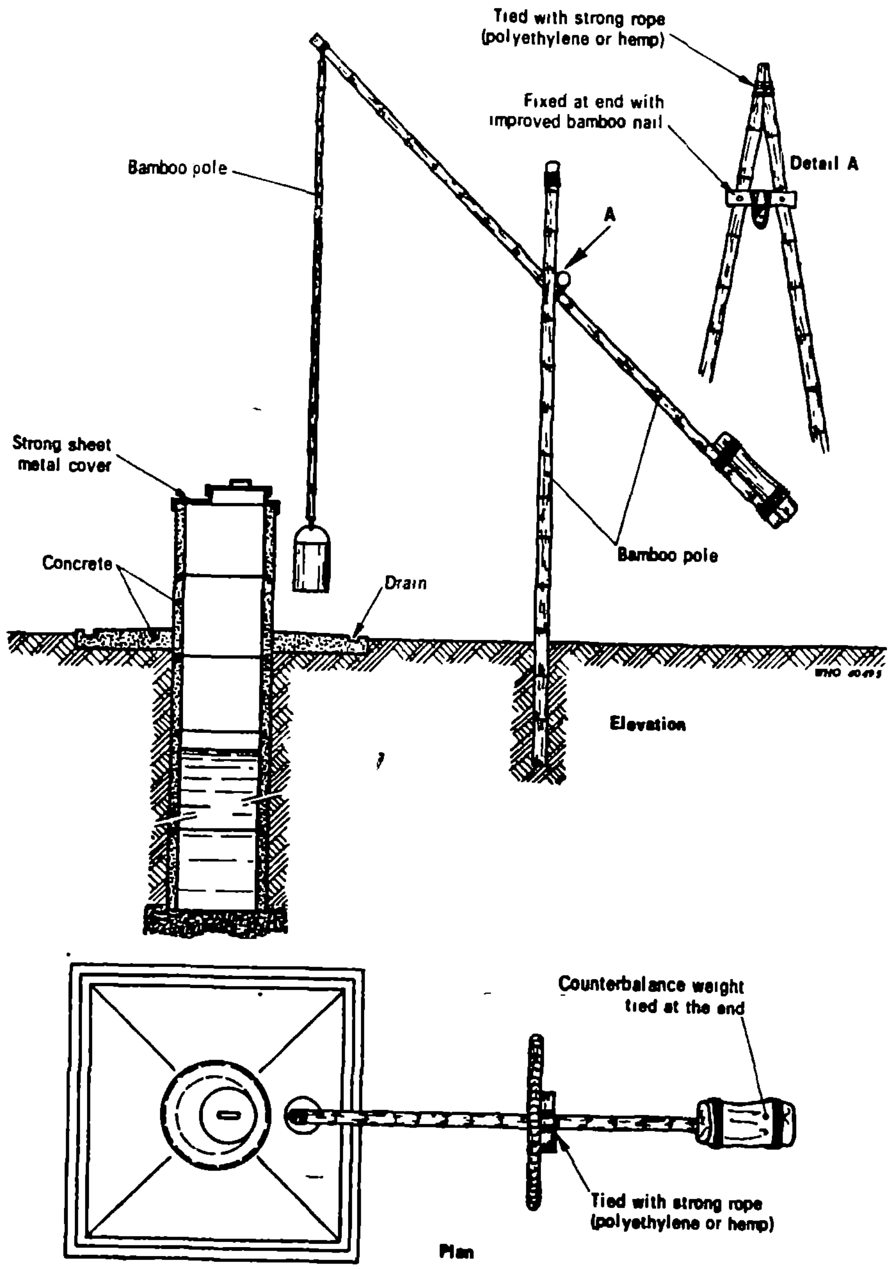


Figure 23. A shaduf used over a hand-dug well (Cairncross and Feachem 1978).

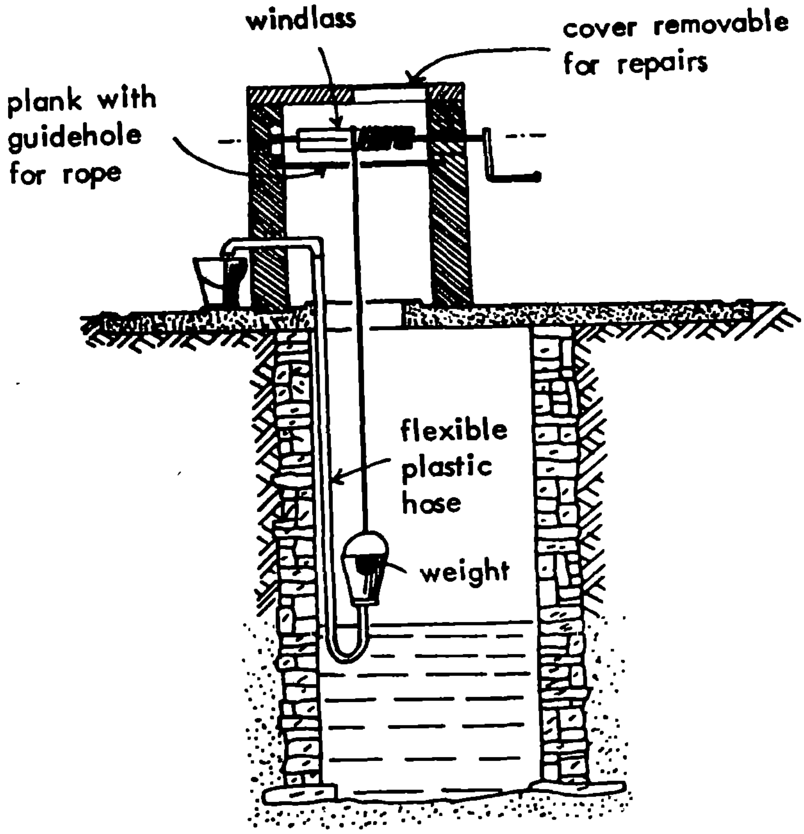


Figure 24. One method of protecting a well from pollution (Cairncross and Feachem 1978).

Another alternative is keeping of the rope and bucket away from the ground by hanging the bucket on a tree when not in use. The well should be lined, provided with a raised headwall, cover and concrete apron with good drainage. Animals should be watered at some distance from the well and a fence provided to keep off animals.

The suitability of different well construction methods and materials have been studied. The advantages and disadvantages of both concrete rings and brick-lined wells are (Kefinco 1983):

Advantages	Disadvantages
Concrete ring wells	
+ short construction time	- need of efficient transportation
+ fewer risks of fracturing	- higher consumption of cement
+ suitable method for all dug wells	- need of a tripod and a pulley for construction
+ possibility to mould the rings "in situ"	- need of factory made concrete ring moulds
Brick lined wells	
+ more suitable for self-help construction and community participation	- takes a longer time to construct
+ existing brick factories can be utilized	- vulnerable to a break down when sinking
	- quality of bricks varies/percentage of loss varies
	- distance to transport bricks often long
	- not advisable in the area of collapsing soil

Hand pumps to be used in wells should meet the following requirements:

- The pump should be as simple as possible, hardly requiring any maintenance.
- Costs per pump should be as low as possible.
- The pump should be made, as far as possible, from locally available materials so that it can be repaired and preferably manufactured locally.

An introduction of a simple, cheap and easily assembled hand pumps is a focal part of a community protected wells programme in general.

The pump chosen should have its components below the ground simplified in such a way that replacement of worn or broken parts will be easy and cheap. Attention should be focused on maximum use of different kinds of plastic for the underground components and a way be found to drain the column of water when pulling out the pump. Use of injection-moulded plastic for the replaceable parts of hand pump mechanisms could have a significant impact on costs of spareparts. Stocks of regularly needed parts could be held in villages, and thus routine maintenance can be managed (Guyumba 1984). India Mark II and the Malawi hand pump are best suited to Kenya. Both pumps are manufactured locally by "Nile Investments" and "Kenya Steel" respectively. India Mark II is also manufactured by WECO (Western College of Arts and Applied Science). The locally manufactured India Mark II can lift water upto a depth of 30 m and yields 1 000 l/h sufficient for 250 families. Malawi hand pump manufactured by WECO is under test. This is very encouraging as far as village level operation and maintenance pumps are concerned (Guyumba 1984).

7.3.1 Hand-Dug Well Disinfection

Chlorine kills bacteria, schistosome larvae, some viruses and, in higher doses, amoebic cysts. There is little danger to health from excessive dosing, but if too much chlorine is added, the unpleasant taste may drive people to use other sources of water which may be polluted. Dirty or cloudy water is not suitable for chlorination because the dirt in the water will absorb the chlorine (Cairncross and Feachem 1978).

The disinfection unit can be built using local materials and local labour. The simplest type of chlorinator is a pot containing a mixture of coarse sand and bleaching powder which is hung under water in a well (Figure 25). Figure 26 shows two types of pot chlorinators. The double pot is suitable for a well serving up to 20 people and needs to be refilled with 1 kg of bleaching powder and 2 kg of coarse sand every 3 weeks. The single pot will serve up to 60 people if it holds 50 % more bleach and sand, but it requires replenishing every 2 weeks. For wells serving larger communities, more pots would be required (Cairncross and Feachem 1978).

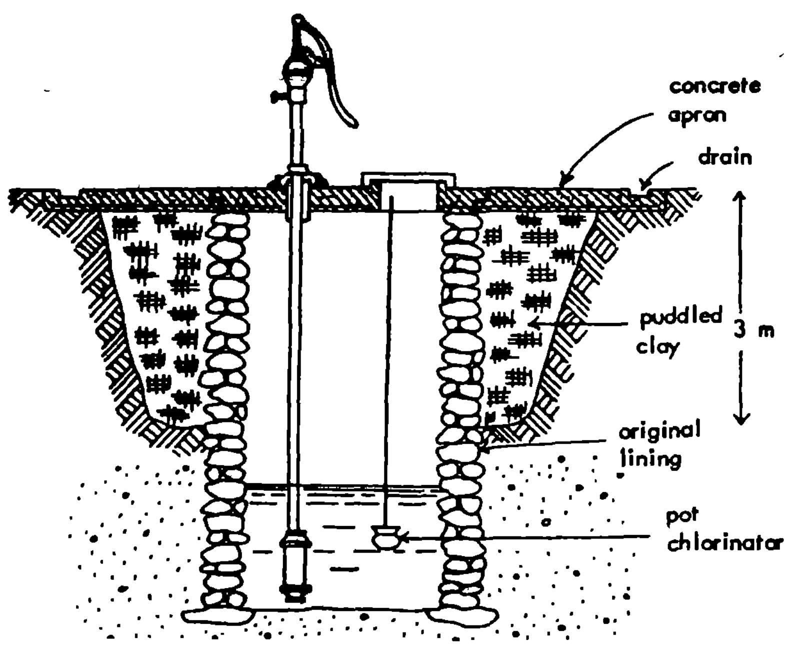


Figure 25. Chlorination of well water (Cairncross and Feachem 1978).

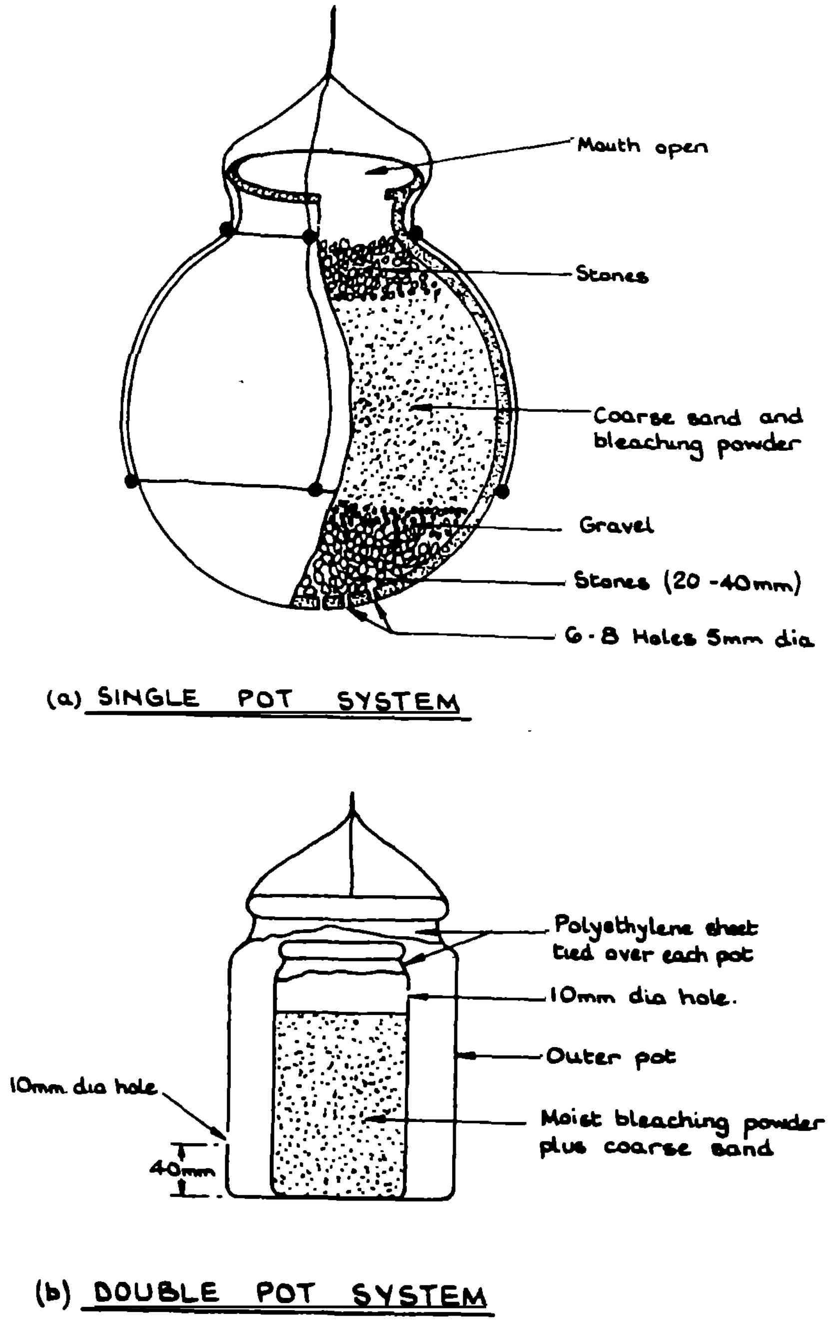


Figure 26 . Pot chlorinators, two alternative designs (Cairncross and Feachem 1978).

Figure 27 shows another simple type of chlorinator which can be adjusted to feed chlorine solution at a slow constant rate to water in a tank or even in a pipe if the pressure is low. The tank can be painted inside with bitumen paint, because chlorine will rust metal and even attack rubber and wood. The tank should have a drain for cleaning out and a cover over the top to keep out light although it should not be airtight.

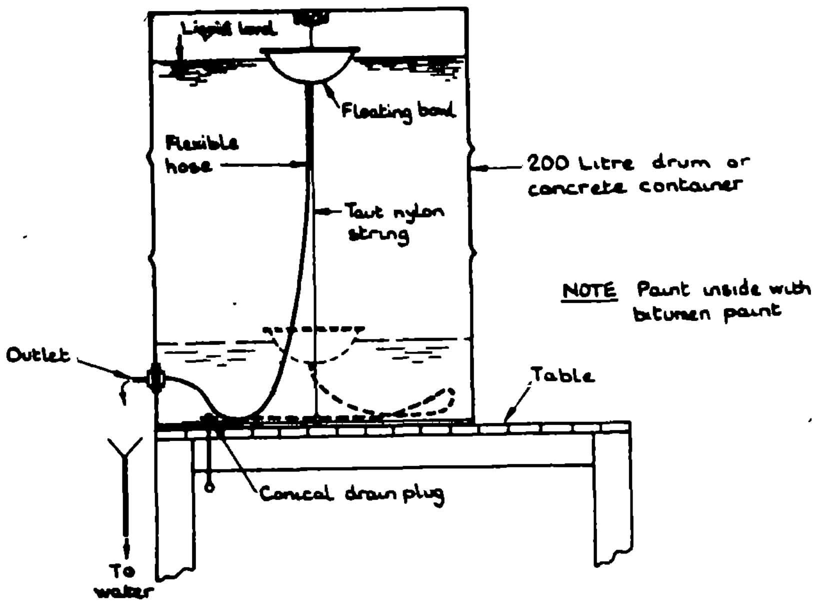


Figure 27. Floating bowl chlorinator, to feed chlorine solution at a constant rate (Cairncross and Feachem 1978).

After completion of the well it should be disinfected due to the possible pollution during construction. The contamination can be caused by equipment, materials or surface drainage during construction or repairs. A chlorine compound can be used as a disinfectant. Disinfecting a well involves calculating the required amount of chlorine compound, mixing a chlorine solution, and applying the solution to the well.

To disinfect a well the following items are needed:
- chlorine compound such as calcium hypochlorite, bleaching powder or liquid bleach;
- mixing container rubber lined or made from crockery or glass;
- stiff broom with a long handle;
- length of perforated pipe, 0,5 - 1,0 m long.

The other method of disinfecting a well is by first calculating the amount of chlorine solution needed to disinfect the well. The prepared solution is then poured through the access hole in the cover into the well. The chlorine solution is mixed with water in the well by using a rope tied to a large, clean rock (Figure 28). The rock is moved up and down in the water to ensure even mixing of the chlorine solution.

The chlorine solution is allowed to stand in the well for 24 hours, after which the water is pumped from the well until chlorine can no longer be smelt or tasted. The discharge should be disposed in a soakaway pit.

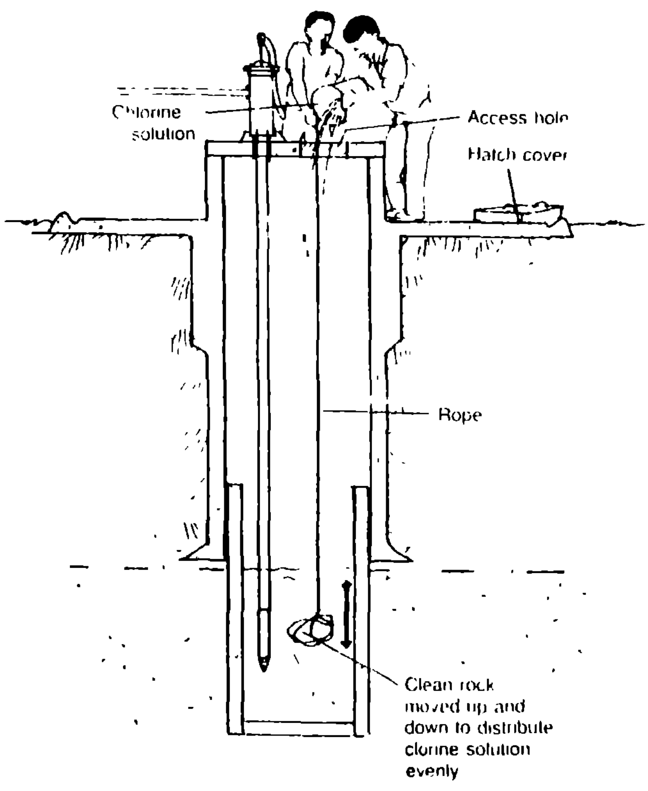


Figure 28. Pouring chlorine solution into a well (Disinfecting Wells 1982).

7.4 Rehabilitation of Protected Springs

Out of the 11 initially protected springs in the study area, 4 springs can be rehabilitated whereas 7 springs need new protection. Most of the 7 springs to be newly protected have changed their course while others have two or three springs outcroping at different places.

The 4 springs recommended for rehabilitation have been considered case to case due to variations in their damages, uses and site conditions. The existing conditions in each spring are described first to give a clear picture of the spring before any recommendations for the rehabilitation.

1) Nyakenyomisia Spring (SP 1)

The spring was visited on 20.9.1985. It is a permanent source protected around 1955. The structure is composed of a brick-made headwall without a top slab. The headwall is not properly anchored to the sides. A loosely fixed 50 mm diameter galvanized iron outlet pipe is in place and still strong for future use. No overflow and drain pipes are provided.

No proper drainage is available. The difference in level between the outlet pipe and the downstream flow water level is less than 100 mm. The base slab of the outflow water is in good condition. The spring is surrounded by banana palms and maize plantations. Surface runoff from the gardens flow into the spring prior to the outlet pipe.

The spring serves approximately 60 people in the vicinity and 15 heads of traditional cattle. Washing clothes is done at the spring. Drinking water from the spring is not boiled normally. No cattle trough is provided for watering and the animals use the stagnant water.

2) Nyakemwate Spring (SP 2)

The spring was visited on 20.9.1985. It is a permanent spring protected on 13.9.1963. The structure is composed of a concrete headwall in an excellent condition with a 75 mm diameter galvanized iron outlet pipe. No overflow or drain pipes are provided. The base slab is in good condition but no washing basin is provided so the top of the headwall is used as a washing place.

Drainage is not provided but water runs down easily because of the topography. Clearance between the outlet pipe and outflow drain water level is about 350 mm. The spring catchment area is composed of small scale farms. There is no cover behind the headwall. Surface runoff from the gardens floods the spring reservoir behind the headwall.

The spring serves approximately 300 people and 40 animals in the area. No cattle trough is provided.

3) Teya/Moturi Spring (SP 3)

The spring was visited on 20.9.1985. It is a permanent spring protected around 1955. The spring structure consists of a brick headwall in good condition but without a cover at the backfill. Water behind the headwall is exposed to the surface. The headwall is not properly anchored to the sides. A 50 mm diameter galvanized iron outlet pipe is provided and is still in good condition. The clearance between the outlet pipe and outflow drain water level is about 350 mm.

There is no proper drainage of the outflow water. No washing basin and cattle trough are provided. The headwall is presently used for washing clothes.

About 250 people and 10 animals use the spring. These animals started using the spring a year ago, otherwise most people take their animals to the river about 200 m away.

4) James Buyeke Spring (SP 4)

The spring was visited on 16.9.1985. It is a permanent spring protected about 1960. The spring structure is composed of a brick headwall with a 50 mm diameter galvanized iron outlet pipe. The headwall is in good condition with a firm anchorage to the sides and foundation.

The outflow water is not properly drained. The clearance between the outlet pipe and the outflow drain water is about 400 mm. The splash base slab is not in a good condition. Thus, there is a pool of stagnant water due to the poor drainage (Figure 29).

Figure 29. James Buyeke Spring (SP 4).

In the upper part of the spring catchment there are banana palms and small coffee farms. The water behind the headwall is exposed and thus the surface runoff floods the outcrop of the spring.

The spring serves about 150 people and 10 heads of traditional cattle. No cattle trough is provided.

The general parts to be rehabilitated for all the springs are:

- cleaning the backfill,
- placing the backfill with boulders, gravel, sand, plastic sheeting and then clay,
- repair of drainage channel and construction of washing basin,
- construction of cattle trough,
- installation of a pipe to the cattle trough,
- construction of drain ditch for surface runoff diversion,
- fencing the spring site.

Figure 30 shows the technical rehabilitation plan of springs SP 1, SP 3 and SP 4. The specific rehabilitation for each spring is considered case by case.

1) Nyakenyomisia Spring (SP 1)

- repair of the headwall and anchorage to the sides,
- fixing the outlet pipe firmly to the headwall.

2) Nyakemwate Spring (SP 2)

- construction of a small storage tank of similar height as the headwall with dimensions 2 m width, 2 m length and 1,5 m height (6 m^3),
- possibility of utilizing a hydraulic ram about 20 m away from the storage tank with a head of 5 m and a high level storage tank,
- installation of an interconnecting pipework as shown in Figure 31.

3) Teya/Moturi Spring (SP 3)

- anchorage of the headwall firmly to the sides.

4) James Buyeke Spring (SP 4)

- no specific rehabilitation is needed for this spring.

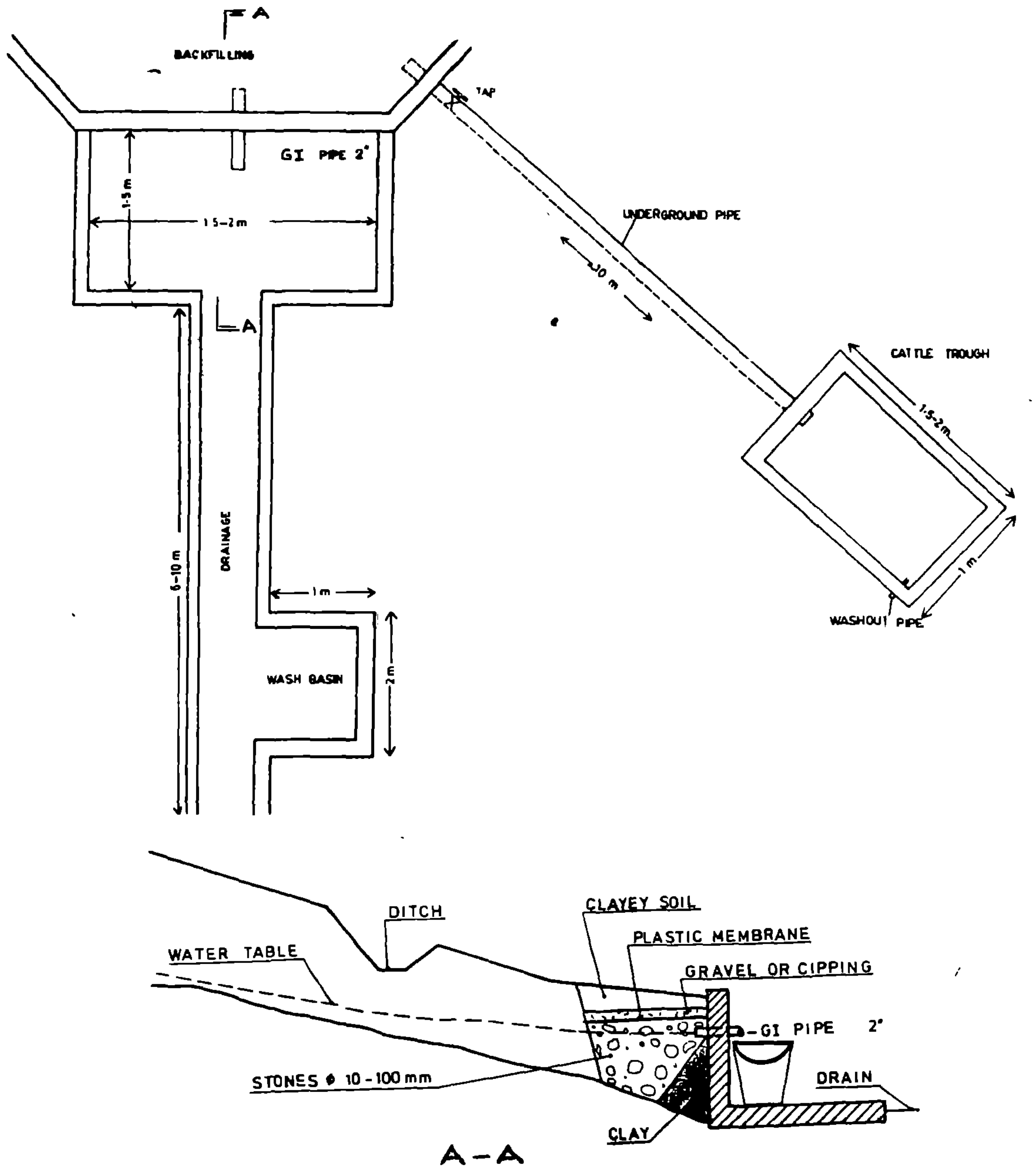


Figure 30. Proposed rehabilitation plan for springs SP 1, SP 3 and SP 4 (Kefinco 1983).

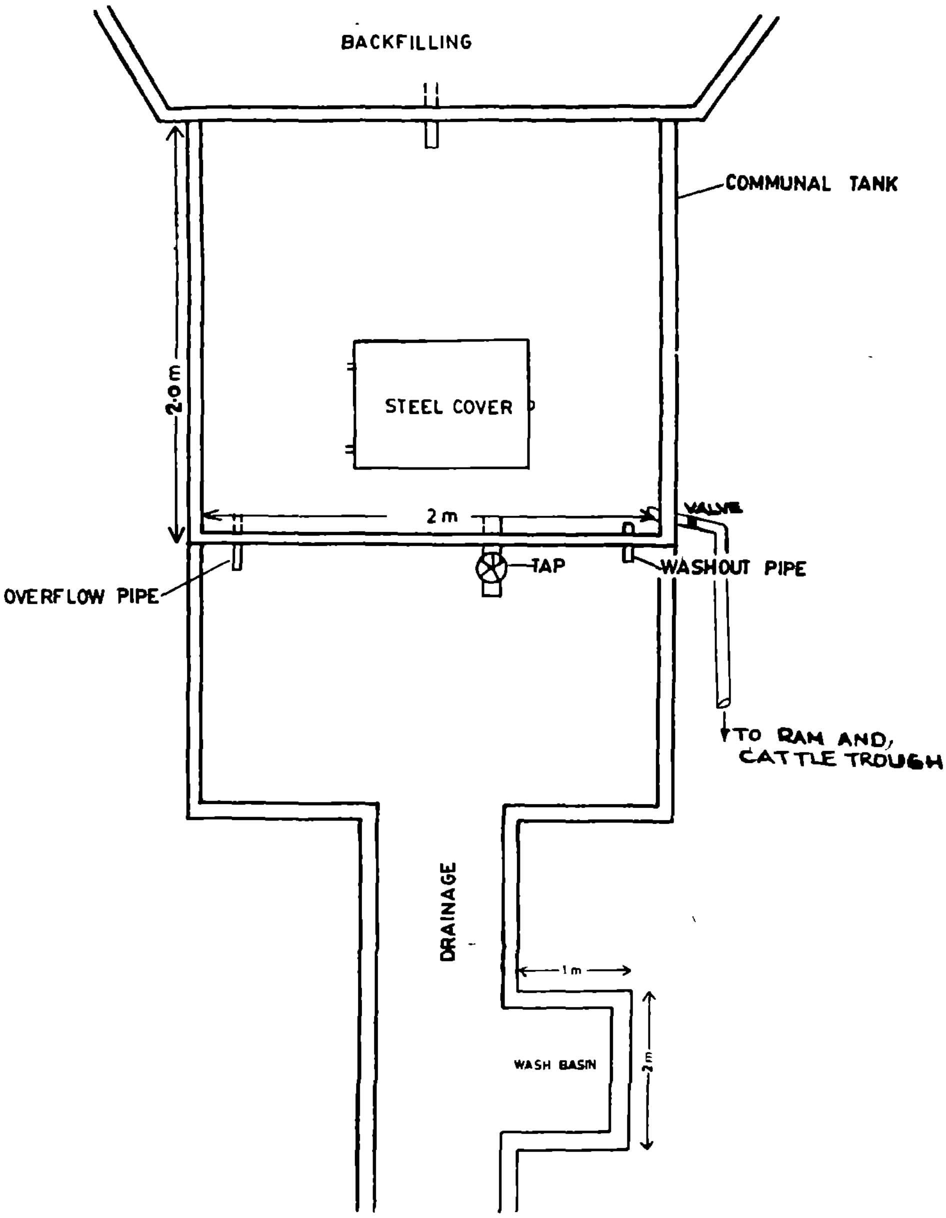


Figure 31. Proposed rehabilitation plan for Nyakemwate Spring (SP 2).

7.5 Discussion

A number of interrelated benefits can be expected from a properly implemented rehabilitation programme.The most obvious benefit would be the restoration of water services which have ceased to operate reliably. The proposed rehabilitation alternatives are intended to eliminate the sources of water pollution and to ensure the reliability of the sources.

Non-quantifiable benefits include improved health, increased time for productive work and increased social welfare. Although it is difficult to demonstrate a direct link between the improved health of a community and the economic output, it is reasonable to suggest that a healthier population would have a higher labour productivity which, in turn, would result in increased local production output, earnings and income. From the field survey of the water sources in the study area, it can be inferred that the standards of general hygiene are low. The provision of a potable regular water is an essential component to the overall improvement of the public health and personal hygiene.

The provision of convenient potable water releases women and children from the time-consuming queueing in water collection. A protected spring lessens the fetching time and hence the queueing time.

Provision of safe and reliable water sources in the study area can improve livestock standards and thus a reduction in mortality. The earnings per hectare will increase to the benefit of the population. Access to safe and reliable water supply in sufficient quantities is a direct socio-economic benefit for which consumers are willing to pay, at the right price. A potable water supply system in the rural area is an integral part of a community's infrastructure.

The rehabilitation methods recommended for hand-dug wells and protected springs are chosen for suitability and not prestige, but convenience and aesthetic are not overlooked. No features that exhaust the technical, economic or social resources of the community and hence invite the system failure have been selected. The rehabilitation of these sources provides the community with safe and abundant water from reliable, accessible and socially acceptable sources.

8 OPERATION AND MAINTENANCE OF HAND-DUG WELLS AND PROTECTED SPRINGS

The problem of operation and maintenance for rural water supplies is extremely complex. A more subtle view of this problem is needed or the rehabilitation programme will soon be followed by another rehabilitation programme. It is necessary to establish a reasonable funding and manpower level needed to support the traditional point sources. A serious thought needs to be given to an organizational approach that will create incentive to support good performance of rural water supplies.

The operation and maintenance problem can be divided into:
- the overall system level and
- the scheme level.

On the first level it is important to provide a detailed operation and maintenance plan, equipment procurement and training of water supply staff to implement the plan during rehabilitation. As the rehabilitation proceeds the scheme level operation and maintenance can be steadily improved provided the necessary budget and manpower are available. Successful rehabilitation requires continued satisfactory operation and maintenance.

The customs, habits, norms and values which exist around the water source should form the basis of a set of similar rules and water by-laws at the springs and wells. Positive socially accepted agreements on water collection protocol should form the basis of the maintenance of well sites and the protected springs, their cleanliness and the prevention of disastrous contamination. Similarly, the accepted structure of power and leadership in the community should be the foundation on which the organisation of well or protected spring management is to be built. The maintenance of the site must be an all-community affair. By means of health education people should be thoroughly aware of the importance of absolute cleanliness of the well or protected spring. The pump attendant, or protected spring attendant, as a representative of the community, should see to it that the hygienic condition prevails at the well or protected spring.

The day to day supervision of the water collection procedures should rest with the attendants. The water by-laws should be formally laid down and given wide publicity in the target communities.

8.1 Remedial and Preventive Measures

In essence it is necessary to identify and determine the reasons for poor water quality and correct or eliminate the causes and where necessary take emergency precautions.

Remedial measures are direct consequences of the evaluation of the bacteriological tests and of the sanitary inspections. The remedial measures to be carried out according to WHO are (Guidelines for... Vol. III, WHO 1984):

a) selection of safe adequate sources,
b) constant vigilance,
c) disinfection checked through residual chlorine tests,
d) community education and primary health care programmes,
e) bacteriological analysis after remedial measures have been implemented,
f) messages such as "boil your water" or "add disinfectant to your water" passed to the community wherever a serious problem occurs, and
g) sanitary checks to ensure that certain remedial measures have been carried out properly.

8.1.1 Immediate Remedial Measures

Remedial measures to be carried out immediately are (Guidelines for... Vol. III, WHO 1984):

a) dug well cleaning and disinfection,
b) "boil water" measures,
c) self-disinfection of collected drinking water by the community,
d) confirmation that remedial measures have been implemented and that they are effective, by means of bacteriological analysis and/or residual chlorine testing, and
e) the introduction of further sanitary checks.

8.1.2 Long-Term Preventive Measures

Some remedial measures are less urgent than others and these can be introduced in the longer term, providing what may be called preventive measures. The necessary feedback by the surveillance agencies to the community for improving the technology and ensuring that codes of practice are strictly followed should be done. Table 24 summarizes the remedial and preventive measures (Guidelines for... Vol. III, WHO 1984).

8.2 Operation and Maintenance of Wells and Hand Pumps

A wise pump design may prevent many difficulties, but regular and proper maintenance is the key to a reliable pump performance.

Every completed hand pump installation will eventually require some form of maintenance. Ideally a pump and well, once installed, should continuously provide water for a lifetime, without need for any repair or inspection. However, such pumps have never been built and probably never will be. A certain amount of regular inspection and maintenance will always be required to ensure the proper functioning of a pump. Whether the funds for new construction come from national or external sources, the relationship between construction and maintenance exists, and should be considered from the start. Otherwise, the investment is likely to be completely wasted. There are several reasons why maintenance requirements and costs are frequently not provided for (Hofkes 1982).

1) The organisation responsible for the construction of water wells and installation of pumps may not be the one that is responsible for the maintenance of the pumps.

2) Too often, without any real justification, it is assumed that the local community will somehow maintain the water supply.

3) International and bilateral agencies frequently offer funds for new construction but are not so readily prepared to finance maintenance, considering this to be a responsibility of the recipient country.

Table 24. Remedial and preventive measures (Guidelines for... Vol. III, WHO 1984).

Source and mode of supply	Evidence of information available	Immediate remedial measures	Preventive action for avoiding recurrence
Open dug wells	Pollution expected to occur	a) Clean well if necessary and shock chlorinate followed by continuous chlorination afterwards b) Boiling of drinking water, use of disinfectants and/or filters at home	Convert to a protected, covered well with hand pump or device for raising water isolated from the users, discourage construction of new open dug wells Promote community education and participation
Covered wells	Findings of sanitary inspection unsatisfactory	Confirm bacterial quality and if necessary boiling or use of disinfectant and/or filters at home	Eliminate pollution sources and/or repair well

4) For their part, the countries receiving assistance have a legitimate need for additional water supplies but also find it difficult to make adequate provision for the maintenance of the existing ones. It happens therefore that a new hand pump installation is sometimes used to replace existing pumps which could have been rehabilitated at much less cost.

Attention should be focused on the maintenance and on finding ways to finance the maintenance cost by using contributions from groups able and prepared to pay.

Most hand pumps have come out of use due to carelessness, improper operation and poor maintenance. The possible causes of frequent breakdown of hand pumps in Kenya have been due to (Guyumba 1984):

1) Poor quality of hand pump design and manufacture, much of hand pump procurement has an inherent bias towards low initial capital cost and ignores life cycle cost.

2) The technology in use makes frequent lubrication mandatory. Iron and steel journals and bearings, poor fits and large clearances, lack of lubricant reservoirs and exposure to weather.

3) Underestimates or lack of appreciation of the structural and bearing loads in deep well pumps.

4) Large variety of hand pumps is used with accompanying need for many different spares. Little parts interchangeability, sometimes even between the same models of the same manufacture. Even fasterners, e.g. bolts and nuts cannot be interchanged.

5) Lack of feedback from maintenance to engineering and procurement personnel. Little analysis, for example, of the most common failures. Inadequate record keeping.

6) Poor maintenance skills, lack of training, inadequate tools (for example, few village maintenance men have a clevis for pulling up pump rod, drop pipe and cylinder), lack of transport, and lack of supervision are characteristics of many programmes.

7) Invisibility of maintenance and lack of urgency. Users return to their pre hand pump source. Maintenance supervisors are far removed from scene or need.

8) Lack of appreciation of preventive maintenance. Maintenance too often seems as a repair function.

Promotion of community participation, especially participation of women in identification of needs and solutions, planning and implementation of the project is to be encouraged. The management, operation and upkeep of facilities, establishment of repair and replacement systems and full or partial contribution to the costs, and training activities on the proper usage and upkeep of the well and the pump are to be strictly adhered to.

8.3 Maintaining Structures for Springs

No structure is completely maintenance-free. Even the most simply designed spring structure needs periodic maintenance to ensure that it provides good quality water in sufficient quantities.

8.3.1 Maintenance of Spring Boxes

The maintenance of spring boxes requires that a check is made to ensure that the structure adequately protects the water source and that all available water is being collected. The spring box has to be examined periodically to ensure that there is no silt build-up and that water quality is good. The following conditions should be studied at the site to ensure that the spring is well protected and free from any operating problems (Maintenance Structures... 1982).

a) Determine whether the diversion drainage ditch above the spring is doing an adequate job of removing surface water from the area. Grass can be planted in the trench to prevent erosion, but it needs regular cutting.

b) The fence above the spring has to be in good repair and should effectively keep animals away from the spring.

c) The upslope wall has to be solid so that erosion is not wearing it away. If there are signs of heavy erosion or settling, an additional clay or gravel backfill of top soil is needed. The fill can be built up with stones and grass planted to help in the control of erosion around the spring box.

d) The water has to be checked. If there is an increase in turbidity or flow after a rainstorm, surface run-off is reaching the source and contaminating it. The source of the run-off has to be identified and the protection of the spring improved.

e) Regular water samples must be taken and analyzed to check for evidence of faecal contamination.

f) The cover has to be checked to be sure that the box is watertight. A watertight cover ensures that users do not contaminate the water by dropping buckets and other utensils into the spring box.

g) It has to be determined that all available water is being collected by the system. If water seeps out, the leak has to be sealed with clay or concrete so that all flow is diverted into the spring box.

h) The system has to be cleaned adequately. It can be disinfected once a year and the sediment has to be cleaned out of the spring box. Sediment removal will prevent clogging and build-up which causes the tank to fill up more quickly. After cleaning, the spring box must be disinfected.

i) The screening on the pipes has to be checked to see if cleaning is necessary. If the screens are clogged or very dirty, they should be either cleaned or changed. Copper or plastic screening has to be used always to prevent rust.

8.3.2 Maintenance of Seep Collection Systems

Operating and maintaining seep collection systems is similar to spring boxes except that extra care must be taken in the maintenance of the collection pipes. If water flow decreases, it has to be suspected that the collection system is clogged. To clean the clogged pipes, the cap from the clean-out pipe is removed and water poured into it. Either a hose or a bucket can be used so that sufficient force is available to break up the sediment as shown in Figure 32.

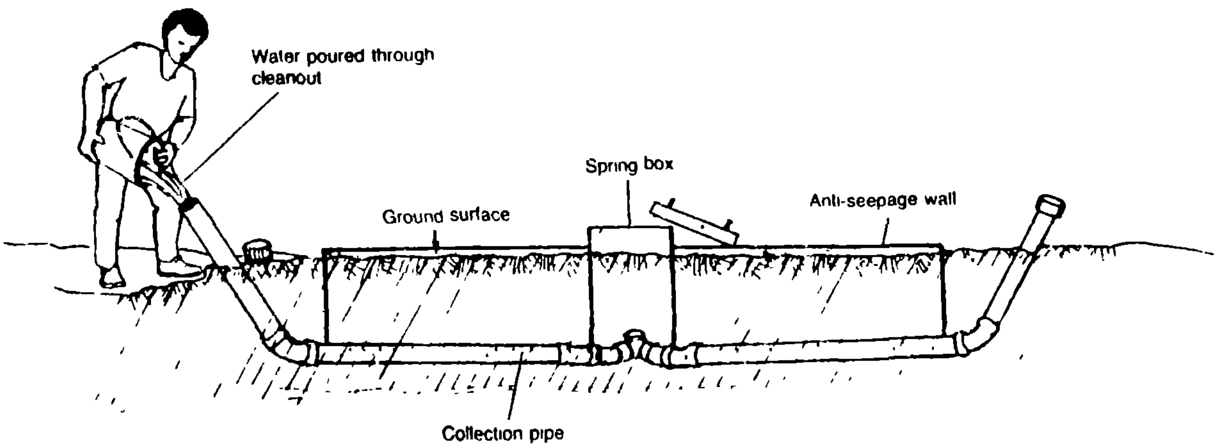


Figure 32. Flushing out seep collection system (Maintaining structures... 1982).

8.4 Community Education and Involvement

The goal of a water supply programme is to ensure that all people have convenient, year-round access to adequate quantities of good quality water. To many people the quality of water can only be assessed in terms of its aesthetic characteristics, i.e. clarity, colour, turbidity, taste and odour. Water may meet requirements for aesthetics yet still be unsafe in terms of its bacteriological and/or chemical quality. Thus, in addition to the installation of hardware, water supply programmes need to contain a component of consumer information and education. This component should aim at creating an awareness of water quality and its relationship to health among those served by the water supply system. Such awareness should lead to an improved behaviour and thus prevent the contamination of water sources, the cleanliness of public water outlets, the sanitary storage of drinking water at home and possibly the prevention of vandalism or other damage to vulnerable parts of the water supply system. The information and education programme should create an appreciation of not only the people's right to a safe water supply but also of their responsibility to use and maintain it wisely and well.

Local awareness and understanding of the advantages of water supply improvements increase the probability of community participation in developing appropriate water facilities. The success of a water project depends on users wanting, understanding and accepting the system. Community education serves several purposes (Community Participation in Planning... 1982):

- it explains to the community the economic advantages of improved water systems,
- it familiarizes the community with the technologies available so that people will select one which they can operate and maintain with a minimum of outside involvement,
- it informs the community about those personal and communal water practices that are harmful to good health so that behavioural changes can take place.

The community education campaign should use all the appropriate cultural channels in reaching all social levels. The educational effort can be coordinated with other development projects, such as hospital construction or primary health care, as well as with local institutions such as schools, and organizations such as women's groups. Community leaders should understand problems and solutions at an early stage so they can help to explain the future changes. Leaders can motivate villagers through their own actions and through approved community sanctions for misuse of facilities. When community leaders, the village committee, the action agency and the villagers all have a similar understanding, they can work toward a common goal.

Surveillance of water quality has the objective of protecting drinking water supplies from contamination to the greatest extent possible. When contamination is detected or suspected, effective surveillance will provide an early warning which permits the introduction of an intervention to reduce or eliminate a condition dangerous to human health. The remoteness from laboratories, small size and large numbers of traditional water sources make it difficult to carry out anything more than periodic surveillance. The solution to these problems is found in the approaches contained in primary health care. The primary health care programmes have three elements which are equally applicable to water quality surveillance (Guidelines for... Vol. III, WHO 1984):

1) health education related to the provision of information designed to arouse the desires of people to have safe water supplies,
2) provision of whatever technical assistance is necessary to help people to achieve their identified desires for safe water,
3) the use by the people in the community of their own skills and resources for actions aimed at improving their health, in this case by actions which keep water supplies safe.

The entry point in community health education is to compile a community profile which describes the local perception of health problems and needs. It is not intended that the profile should be used by government technocrats for the formulation of solutions to the community's problems. Instead, the profile is used as a basis for a dialogue with the community, a dialogue which results in the community devising and deciding on actions that will overcome or circumvent the identified problems and satisfy the perceived needs. It is far better to provide guidance and to lead the community to its own recognition of the problem. In due course the community will come to realize the need for ensuring that the water supply is safe.

Health education concerning water quality must recognize that the use of water for personal and domestic hygiene also can have an impact on health. Thus, educational interventions concerning water must avoid the danger of "overselling" the importance of any aspect of water supply (Guidelines for... Vol. III, WHO 1984).

The improvement of health status resulting from safe water may first be reflected by a reduction in the incidence of infant and early childhood diarrhoea. Meanwhile the health workers must be observant of water supply practices in the community. The water supply, its potential for being contaminated and the way it is used need to be noted and any shortcomings should be discussed with the community leaders. Simultaneously the basis of primary health care, cultural sensitivity, community self-help and appropriate technology must be kept in mind. Once people are able to understand the relationships between water quality and disease, the introduction of surveillance and control measures becomes increasingly possible. Simple measures, such as fencing of water collection points to keep out cattle, or simple protection of springs to exclude surface drainage, may be planned and implemented by the people of the community with guidance from health workers. More complex tasks, such as the construction of a spring box or the installation of a sanitary water storage tank, may require technical and material assistance from the refellar level of the health care system or from the Ministry of Water Development. The concept that must remain at the forefront of a surveillance and rehabilitation programme is that the major responsibility rests with the community, the government can only help the community in the achievement of its objectives (Guidelines for... Vol. III, WHO 1984).

8.4.1 Training Rural Water Workers

As understanding of the water/disease relationship grows and people recognise a need for surveillance in order to maintain the good quality of the water supply, the community should be encouraged to increase its surveillance activities and improve the water system. These activities can be implemented in several ways (Guidelines for... Vol. III, WHO 1984).

- School health education is particularly important and often requires that teachers are given refresher training supported by appropriate teaching materials and visual aids. Health education in schools is an effective and continuing reinforcement of the more intermittent delivery of health information that is possible by other means.

- The central health education unit in the ministry is usually staffed to prepare visual aid material for use by other health workers. Materials that are useful to community health workers include flip charts, flannelgraphs, posters and brochures. The health education unit must ensure that the community health workers understand the information messages to be transmitted and also understand how to use the visual aid material provided to them.

The objective should therefore be to create a desire among the people in the community to be involved in surveillance and control activities which they recognise as a method of improving their health.

8.5 Personnel for Operation and Maintenance

Choosing operation and maintenance personnel should use the rehabilitation period to select and begin training those who perform well. During the rehabilitation phase, the selected personnel will learn what the system is made of, how it is put together and how it works. With this experience they can understand and perform the work that will be expected from them later. The operation and maintenance personnel should be from the village. The future of the system will depend on their responsibilities and on their dedication to their assignment. A community enthusiastic about water rehabilitation may view a breakdown as an evidence that their contributions to the system were wasted. Their further cooperation may be difficult to obtain. An adequate provision must be made for proper operation and maintenance of the facilities at the local level and through an action agency back-up located conveniently to the village (Community Participation in Implementing... 1982).

System operators should live in the village so that they are available to run the system regularly. They should be accepted by, if not chosen or approved by, the village water committee and the community as a whole. They must have an ability to perform technical operations and have an interest in improving the water conditions in the village. Women are the primary water users in the villages, so equal access to training in system operations should be ensured for them. If women are involved in the rehabilitation tasks, they are primary candidates for operation and maintenance tasks. In addition, children will soon learn that operation and maintenance are very important aspects of the water system and grow up with a positive attitude toward maintaining a system. Introducing these new attitudes and approaches to children will make introducing ideas and systems in new generations much easier. Other good prospective system operators are skilled mechanics in the village, water collectors, water vendors, traditional well diggers and primary health workers (Methods of Operation... 1982).

8.6 Women Groups

There are 10 women's groups in the study area. They are registered by the Ministry of Culture and Social Services. Table 25 shows the registered women groups in the study area with their members. The women's groups in Table 25 have their bank accounts in Kisii town. Even though the money in the women's accounts is not related to water supply, it is an indication of the role the women can play in revenue collection and the banking knowledge they have. The groups have democratically elected committee members for running the activities.

Table 25. Registered women groups in the study area.

Group name	Number of members
Gitwebe Ekona	25
Gesoko	27
Bombere	32
Kiamanyomba	21
Morema Ritoke	30
Ikamu Mogondo	60
Riomego	23
Nyakenyomisia	22
Bisembe	30
Esereti	40
Total members	310

8.7 Discussion

All the hand-dug wells in the study area are privately owned despite the use of most wells by the community in the vicinity of the wells. This is by mutual understanding between the well owner and his neighbours. These types of wells which are communally used are recommended for rehabilitation subject to public ownership so as to guarantee the universal accessibility. On completion of the rehabilitation of the wells, appropriate legal documents ought to be prepared describing in detail the legal ownership of the wells (land and the pump). These should be formulated within the context of legal ownership structures defensible in modern courts of law. No oral agreements of ownership are made which do not have legal force in the modern law. All the communal wells must have maximum accessibility. Private wells in schools and church compounds should not be among the wells converted to communal use through legal agreements due to the difficult problems arising from exclusion, restriction and interference in the regular activities of schools. These types of wells should remain privately owned but the communal use of the well should be left to the discretion of the well owner.

Democratically elected, highly motivated well managed committees should be established before any well is rehabilitated. The committee should fully participate in mobilising local involvement, appreciation and willingness to participate in the rehabilitation and maintenance of the wells. The rehabilitated wells owned privately by institutions and individuals should be maintained by the owner. All costs for depreciation and maintenance will be paid by the owner. Generally the privately owned wells are used and maintained more carefully than the community wells. But strictly speaking, communal wells have a wide ranging effect through water education, health improvement and appreciation of clean and safe water.

In order to guarantee that the key roles of women at the local level are recognized, promoted and supported, commitments should be undertaken to facilitate active participation by women. On project preparation and initiation, practical recommendations include:

- identify community needs and especially needs of women,
- organize meetings at suitable times and places for women to attend them,
- help women to express their views through special training or to raise points of concern to women in meetings,
- orient policy makers, planners and executing staff to women's potential and actual roles in water supply through workshops and field exposure,
- build on existing structures or organization at village level and not impose leaders on the community from outside,
- identify and plan for necessary motivational, technical, maintenance and administrative training.

Women should be appointed as caretakers or operators since they are more likely to remain in the community. Women are also more likely to remain interested in this type of part-time work. Logistic support to communities is indispensable, for instance to ensure the provision of spareparts.

The women's groups should be responsible for the financial management and revenue collection for the operation and maintenance costs. Thus, appropriate training in bookkeeping and accounting should be made available to them.

9 COSTS

The cost estimates have been worked under two categories: construction costs of protecting springs and rehabilitation costs of hand-dug wells and protected springs. The labour and material costs are valued as per the rates of construction in the study area in early 1986. The conversion rate of the Kenya shilling to the US dollar is 1 USD = 16,3 KES.

If the financial value of local labour, materials and services can be rendered by the community, the estimated costs can be low. Nevertheless, these costs have been included because there is no absolute guarantee for that provision.

9.1 Construction Costs of Spring Protection

The spring protection is divided into two categories:
a) minor protection involving the provision of headwall and backfill materials,
b) major protection involving the construction of headwall, spring box and the backfill materials.

Most springs fall in the minor protection category. Springs with a spring box in some cases can be used as gravity supplies but the cost estimates do not include this consideration. In some springs, installation of a hydraulic ram is feasible but no provisions in the cost estimates have been included.

Tables 26 and 27 show new construction costs of minor and major spring protection respectively.

Table 26. New construction costs of minor spring protection.

Item	Estimated costs KES
Capital costs (equipment and vehicles)	300
Service and repair of equipment and vehicles	100
Transportation	200
Labour	200
Construction materials	
- sand	300
- ballast	300
- cement	672
- blocks	320
- plastic membrane	35
- pipes	126
- round bars	288
- fencing	210
Total	3 051

Table 27. New construction costs of major spring protection.

Item	Estimated costs KES
Capital costs (equipment and vehicles)	500
Service and repair of equipment and vehicles	100
Transportation	300
Labour	400
Construction materials	
- sand	500
- ballast	500
- cement	2 520
- blocks	320
- plastic membrane	35
- pipes	300
- round bars and wire mesh	300
- fencing	320
Total	6 095

9.2 Rehabilitation Costs

The rehabilitation costs for hand-dug wells and protected springs have been estimated from the local labour and material costs in the study area.

9.2.1 Hand-Dug Wells

Most of the hand-dug wells have strong walls and thus it was thought economical to line only the top 2 m to avoid surface runoff going into the wells. For hand-dug wells where the soil caves in, the rehabilitation costs include full depth lining. An average depth of 6,5 m is used in the cost estimate. Both brick and concrete ring lining have been used in the estimate (Tables 28, 29 and 30). Tables 31 and 32 show the cost estimated for converting a hand-dug well to a tube well.

Table 28. Rehabilitation costs of a hand-dug well (2 m brick lining depth).

Item	Estimated costs KES
Excavation of 2 m depth and 1 m width	100
Lining 2 m depth	200
Lining materials (bricks and cement mortar)	300
Filling the lining edges with puddled clay	100
Concrete apron and drain	900
Cover slab with anchor bolts	400
Hand pump (WECO) only	5 752
Total	7 752

Table 29. Rehabilitation costs of a hand-dug well lined with bricks (depth 6,5 m).

Item	Estimated costs KES
Capital costs (lorry and tools)	800
Service and repair of the lorry	200
Transportation	500
Labour	800
Construction materials	
- bricks	460
- cement	504
- sand	500
- ballast	500
- reinforcing steel	300
- cover slab with anchor bolts	400
- concrete apron and drain	900
- plastic membrane	120
- hand pump (WECO) only	5 752
Total	11 736

Table 30. Rehabilitation costs of a hand-dug well lined with concrete rings (depth 6,5 m).

Item	Estimated costs KES
Capital costs (lorry and tools)	2 000
Service and repair of the lorry	200
Transportation	1 500
Labour	500
Construction materials	
- concrete rings	2 000
- concrete blocks	192
- cement	336
- sand	500
- ballast	500
- reinforcing steel	300
- cover slab with anchor bolts	400
- concrete apron and drain	900
- hand pump (WECO) only	5 752
Total	15 080

Table 31. Rehabilitation costs of converting a hand-dug well to a tube well (depth 6,5 m).

Item	Estimated costs KES
Tube well casing (PVC)	800
Earth and gravel materials	300
Filling the lining edges with puddled clay	200
Concrete apron and drain	900
Cover slab with anchor bolts	400
Hand pump (WECO) only	5 752
Total	8 352

Table 32. Rehabilitation costs of converting a hand-dug well to a tube well (depth 15 m).

Item	Estimated costs KES
Tube well casing (PVC) 15 m 5 m slotted length	1 170 550
Filling the lining edges with puddled clay	400
Concrete apron and drain	900
Cover slab with anchor bolts	400
Hand pump (WECO) only	5 752
Total	9 172

9.2.2 Protected Springs

Rehabilitation costs for the protected springs have been considered separately for each spring according to the extent of damage, number of users and the topographical features of each spring. The costs for the four springs are shown in Tables 33, 34, 35 and 36.

Table 33. Rehabilitation costs for Nyakenyomisia Spring (SP 1).

Item	Estimated costs KES
Capital costs (equipment and vehicles)	400
Service and repair of equipment and vehicles	100
Transportation	200
Labour	200
Construction materials	
- sand	150
- ballast	150
- cement	672
- blocks	240
- plastic membrane	35
- pipes	226
- round bars and wire mesh	200
- fencing	100
Total	2 673

Table 34. Rehabilitation costs for Nyakemwate Spring (SP 2).

Item	Estimated costs KES
Capital costs (equipment and vehicles)	400
Service and repair of equipment and vehicles	100
Transportation	200
Labour	200
Construction materials	
- sand	300
- ballast	300
- cement	1 260
- blocks	280
- plastic membrane	35
- pipes	300
- round bars and wire mesh	200
- steel cover	200
- fencing	150

Table 35. Rehabilitation costs for Teya/Moturi Spring (SP 3).

Item	Estimated costs KES
Capital costs (equipment and vehicles)	300
Service and repair of equipment and vehicles	100
Transportation	200
Labour	200
Construction materials	
- sand	150
- ballast	150
- cement	420
- blocks	120
- plastic membrane	35
- fencing	150
Total	1 825

Table 36. Rehabilitation costs for James Buyeke Spring (SP 4).

Item	Estimated costs KES
Capital costs (equipment and vehicles)	300
Service and repair of equipment and vehicles	100
Transportation	100
Labour	100
Construction materials	
- sand	150
- ballast	150
- cement	504
- blocks	120
- plastic membrane	35
- pipes	410
- fencing	100
Total	2 069

9.3 Cost Comparisons for Rehabilitation

The general concept of rehabilitation is the comparative cost of improving the scheme immediately and the construction cost of a new scheme. Table 37 gives the cost comparison of spring protection and rehabilitating protected springs.

Table 37. Cost comparison of spring protection and rehabilitation of protected springs.

Item	Spring protection cost KES a	Rehabilitation cost of protected spring KES b		Per cent b/a
Minor spring protection	3 051			
		SP 1	2 673	87
		SP 3	1 825	60
		SP 4	2 069	68
Major spring protection	6 095			
		SP 2	3 925	64

The cost of rehabilitating hand-dug wells does not include costs for well siting and digging. However, the construction and equipment of a new hand-dug well have higher capital investment than rehabilitation of an existing hand-dug well.

9.4 Construction Cost per Capita

The construction cost per capita has been based on the current number of source users. For the construction of new spring protection for both minor and major protection, an average number of persons served per day was obtained from several springs under similar protection requirements. Tables 38, 39 and 40 show the per capita costs for spring protection, hand-dug well rehabilitation and spring rehabilitation respectively.

Table 38. Spring protection cost per capita.

Type of spring	Average number of persons served per day	Construction cost KES	Per capita cost KES/person
Minor spring protection	110	3 051	27
Major spring protection	350	6 095	17

Table 39. Hand-dug well rehabilitation cost per capita.

Type of well protection	*Average number of persons served daily per well	Rehabilitation cost KES	Per capita cost KES (36 persons/ well)	Per capita cost KES (250 persons/ well)
2 m brick lining	36	7 752	215	31
6,5 m brick lining	36	11 736	326	47
6,5 m concrete rings lining	36	15 080	419	60
Conversion well to tube well				
6,5 m depth	36	8 352	232	33
15 m depth	36	9 172	255	36

* The average number of persons served by one well per day is obtained from the average number of three families using one well with 12 persons per family.

Table 40. Spring rehabilitation cost per capita.

Spring source	Number of persons served per day	Rehabilitation cost KES	Per capita cost KES/person
Nyakenyomisia	60	2 673	44
Nyakemwate	300	3 925	13
Teya/Moturi	250	1 825	7
James Buyeke	150	2 069	14

9.5 Discussion

Cost estimates for minor and major spring protection are evaluated in order to compare with the rehabilitation cost of protected springs. It is evident from Table 37 that the springs recommended for rehabilitation are viable in cost.

The cost per capita for hand-dug wells is high when compared with the cost per capita for protected springs. This is mainly from the high cost of rehabilitating hand-dug wells and few families using hand-dug wells when compared with the protected springs. Definitely, the cost per capita of rehabilitating protected springs is very encouraging for any investment. Although on average the rehabilitation cost for hand-dug wells is ten times the cost per capita of the rehabilitation of protected springs, the value is within the capability of the average earning families. If these hand-dug wells can be rehabilitated to serve a maximum of 250 persons per day, the cost per capita can smoothly be compared with the cost per capita for protected springs (Table 39). All families having hand-dug wells have coffee farms earning an annual average of 5 000 KES. Assuming other crops earnings can be used for household miscellaneous expenses and sharing of well with five families encouraged, the cost of well rehabilitation can be accommodated comfortably upto a tune of 2 000 KES per family.

10 CONCLUSIONS AND RECOMMENDATIONS

The bacteriological water quality results of the investigated hand-dug wells, protected and unprotected springs revealed that 97 % of these sources are unacceptable according to the current WHO (1984) guidelines. A field survey for the investigation of the conditions and sources of pollution left no doubt in the water analyses. With these results, rehabilitation of the sources is inevitable for the sake of providing safe and reliable water.

Appropriate rehabilitation alternatives are proposed based on the site conditions for protection against water pollution and improvements to increase the yield to a reliable level all the seasons. Hand-dug wells are to be rehabilitated to provide safe water by partial or full well lining plus installation of a hand pump. For the unreliable wells in dry season, conversion to a tube well is the option. Rehabilitation of protected springs involves mainly the cleaning of the backfill, refilling with boulders, repair of headwall, provision of drainage and covering the backfill with polythene sheet to avoid surface runoff from infiltrating into the water. A spring serving more than 200 families per day is to have a spring box.

The average rehabilitation cost per capita for hand-dug wells is 289 KES and for protected springs 20 KES. These costs are within the financial affordability of most people. Unfortunately, the knowledge of hand pump for hand-dug wells is a new idea in the area.

Considering the broad spectrum of public water supplies in the rural areas which are sufficiently small or simple to be managed by the local users without a need to involve the Ministry of Water on a continuing basis, it is recommended that:

1) The Ministry of Water Development to review all traditional sources and identify those which are economically, technically and socially suitable for rehabilitation.

2) The Ministry of Water Development to help indirectly in the rehabilitation and subsequent operation and maintenance of protected springs and communal hand-dug wells by providing technical assistance to the responsible group of beneficiaries. The users must demonstrate a willingness to pay for the continuing operation of the water supply in some manner.

3) A health education programme by the Ministry of Health under Rural Health Care Programme to be launched concerning water quality, use of water for personal and domestic hygiene and water related diseases. The women groups currently registered in the Ministry of Culture and Social Services should have frequent workshops organized jointly by the current ministry where they are registered, the Ministry of Water Development and the Ministry of Health concerning the relationship between water quality and related water diseases.

4) The Ministry of Water Development in conjunction with the Ministry of Health to study the WHO guidelines for drinking water quality. Carefully consider the standards within the context of national, local or other factors when improving national programmes for the quality control of drinking water. Currently the WHO guideline values are rigid standards.

5) The Ministry of Water Development to provide and install a hand pump in a communally acceptable hand-dug well at Magwagwa market as a demonstration to the people. The well will give the people the idea of sanitary method of hand-dug well water withdrawal.

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