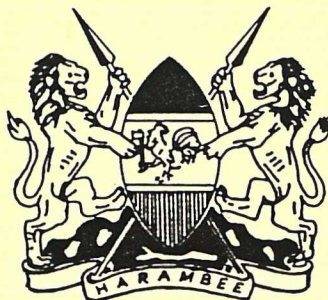


REPUBLIC OF KENYA



15 83-03

MINISTRY OF WATER DEVELOPMENT

WATER RESOURCES ASSESSMENT STUDY FOR THE NDEIYA & KARAI LOCATIONS

MAIN REPORT

ANNEX 6.1

INTEGRATED WATER SUPPLY AND DISTRIBUTION SYSTEM

DHV CONSULTING ENGINEERS
AMERSFOORT, THE NETHERLANDS

OCTOBER 1982

Government of Kenya
Ministry of Water Development

Government of the Netherlands
Ministry of Foreign Affairs
Directorate General for
International Cooperation

Water Resources Assessment Project

Phase 1: Ndeiya-Karai

Integrated Water Supply and Distribution System for
the Ndeiya Karai Area

file 3-2025-44-01

October 1982

DHV Consulting Engineers

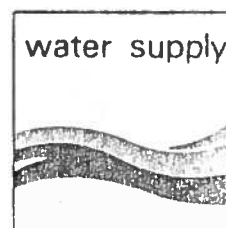


TABLE OF CONTENTS	PAGE
1. PRESENT SITUATION	7
1.1. General	7
1.2. Hydrology	7
1.3. Population and landuse	8
1.4. Rural water supplies	8
1.4.1. Production wells	8
1.4.2. Bathi River Water Scheme	8
1.4.2.1. History	11
1.4.2.2. Scheme description	11
1.4.2.3. Operation and maintenance	13
1.4.2.4. Shortcomings in the present Bathi River Water Scheme	13
1.4.3. Evaluation of present water supplies	14
2. WATER DEMAND	15
2.1. General	15
2.2. Average daily demand	15
2.2.1. Average daily demand in the initial phase	15
2.2.2. Average daily demand in the year 1995	16
2.3. Fluctuations in the demand	16
2.3.1. Maximum daily demand	16
2.3.2. Maximum hourly demand	16
2.3.2.1. Maximum hourly flow without storage at CWP's	16
2.3.2.2. Maximum hourly flow with storage at CWP's	17
2.4. Increase of the water demand	18
2.5. Total water demand and supply area	18
3. AVAILABLE WATER RESOURCES	22
3.1. Surface water	22
3.1.1. Bathi River Water Supply	22
3.1.1.1. Safe yield	22
3.1.1.2. Available water for project area	24
3.1.2. Alternative surface water sources	24
3.2. Groundwater	26
3.2.1. Existing production wells	26
3.2.2. Groundwater development	26
3.3. Conclusions	28

TABLE OF CONTENTS (continued)	PAGE
4. PROPOSED WATER SUPPLY SYSTEM	29
4.1. General	29
4.2. Design water supply system	29
4.2.1. Connection of production wells	29
4.2.1.1. Criteria for well design	29
4.2.1.2. Selection of wells	30
4.2.1.3. Connection to the existing distribution system	31
4.2.2. Adaptations and extensions of Bathi Water Scheme	31
4.2.2.1. Transport lines	34
4.2.2.2. Communal water points	34
4.2.2.3. Storage	34
4.3. Operation and maintenance	38
4.4. Engineering and construction activities	40
4.5. Phasing of activities	40
4.6. Project investment costs	41
4.6.1. General	41
4.6.2. Unit costs	41
4.6.3. Project costs	41
4.6.4. Evaluation	42

Annex 1 Project investment costs

List of tables

1. Population census data
2. Well data
3. Increase water demand
4. Population density
5. Population water demand in the supply areas
6. Water consumption upstream project area
7. Expected groundwater quality
8. Required additional supply
9. Well production and additional demand
10. Design flow
11. Proposed storage

List of figures

1. General map
2. Project area
3. Storage reservoir in Bathi River
4. Required supply per reservoir
5. Design flow proposed system
6. Capacity of existing and modified system

List of maps

1. Existing water supply system
2. Future water supply system
3. Proposed water supply system

Abbreviations

c	capita
BH	Borehole
CWP	Communal water point
d	day
DG	Dutch Guilder
EAPL	East Africa Power and Lighting
GL	Ground Level
h	hour
IC	Individual connection
K.C.C.	Kiambu County Council
Ksh	Kenyan shilling
l	litre
m ³	cubic metre
min	minute
M.o.W.D.	Ministry of Water Development
s	second
TWL	top water level (reservoir)
W/S	Water Scheme

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Phase 1: Ndeiya-Karai
October 1981

INTRODUCTION AND SUMMARY

The Water Resources Assessment Project, carried out under the responsibility of the Ministry of Water Development has invited DHV Consulting Engineers to formulate a proposal and costing for an adequate water supply in the Ndeiya-Karai area.

This study has been carried out during the period July-September 1982 and is presented herewith.

It is proposed to supply the area with groundwater from a faultzone east of the actual project area.

Twelve new wells should be drilled and some existing wells should be connected to the supply system. Already existing water supply schemes will be integrated in the proposed system.

The project costs will amount to Ksh 36 million (DG 9 million) at current price level and the scheme should be fully operational in 1995.

1. PRESENT SITUATION

1.1. General

The Ndeiya and Karai locations are situated in the south western corner of Kiambu district, at a distance of 25 km from Nairobi (see figure 1).

The project area for which the water supply proposals are made does not only cover the above named locations, but also includes part of Kamirithu and Muguga Jet Settlement sublocations.

The elevation of the project area is between 1500 and 2300 m above sea level. The project covers an area of 87,5 km².

The area can be divided into the eastern (upper) part and the western (lower) part. The western (lower) part is bordered by the escarpment that descends to the Rift floor. The Rift floor extends in westward direction.

There are no all weather roads in the project area. During rains the roads are slippery and the steep hills make going hard.

Outside the project area lies the main road from Nairobi to Naivasha which is asphalted. A power line runs alongside the road upto Rironi, after which it diverts to the north.

The area, together with the administrative boundaries and roads can be seen in figure 2.

1.2. Hydrology

Like most parts of Kenya the area has two rainy periods.

The first occurs in the months March, April and May and shows the highest maxima (25% of the annual rainfall in the month of April).

The second rainy period is during the months November and December (13% of the annual rainfall in the month of November).

The more elevated eastern area receives more rainfall than the western lower part. The long term average yearly rainfall is 960 mm for the higher and 600 mm for the lower project area.

Surface drainage is confined to the western zone where the landsurface slopes towards the Rift Valley bottom. The eastern and central parts of the project area are internally drained. This is an area with swamps in which the runoff of the surrounding hills accumulates during rains. There are no springs in the project area and during a dry period no surface water is present.

The project area is crossed by a few fault zones. These faults run in a north-south direction. The eastern fault zone is known as the Lari-Ondiri fault. The western faults are at the transition between the upper and the lower part of the project area, and between the lower part and the Rift Valley bottom.

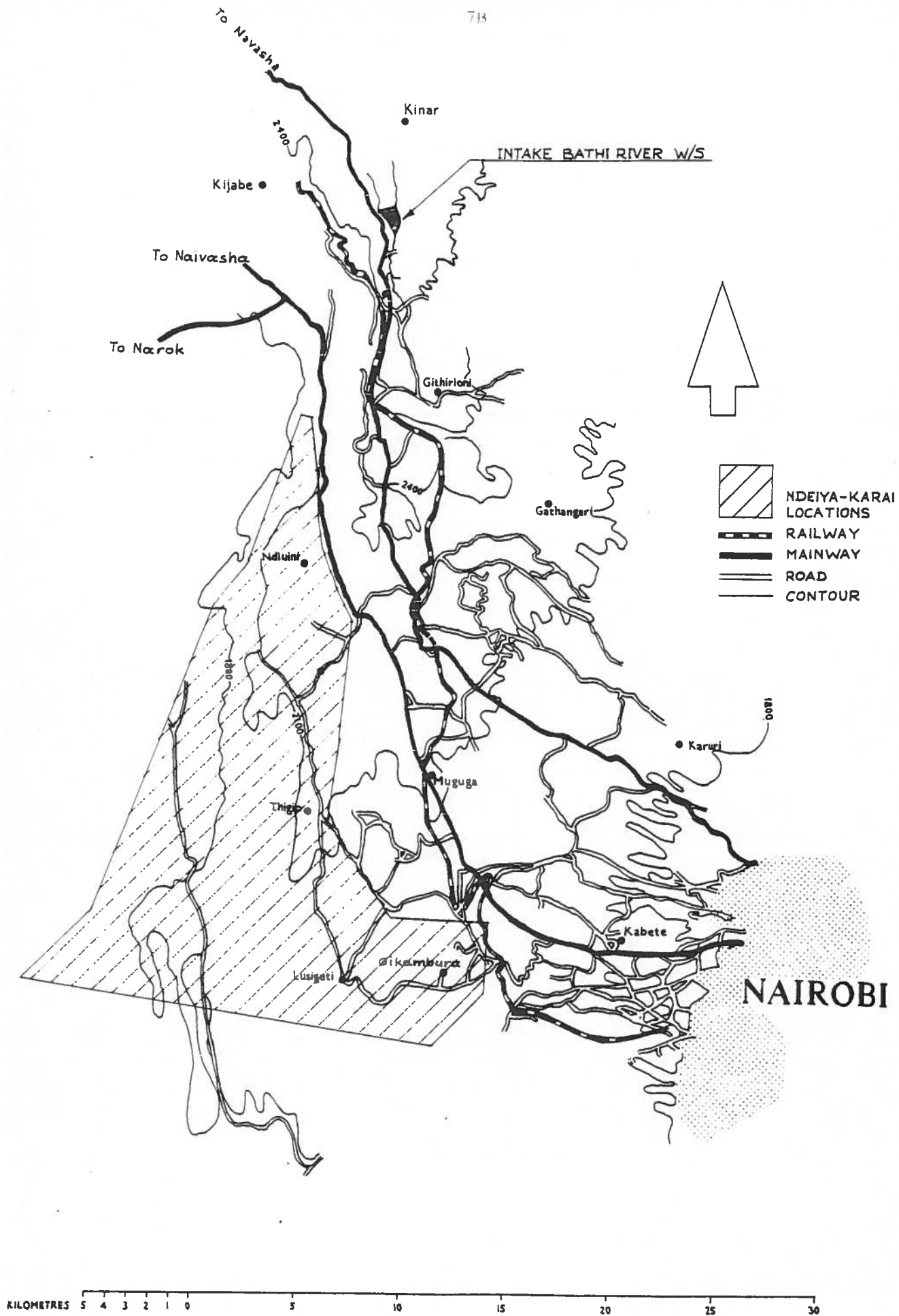


Figure 1: GENERAL MAP

1.3. Population and landuse

The population of the Ndeiya Karai locations lives mainly in the upper part of the project area. The western lower part and the swamps are used as grazing area.

In the eastern part where the rains are fairly abundant, the land is used for small scale subsistence farming. The main crops are maize and beans. The cash crop is pyrethrum.

Although the average farm size is about 2 ha, 50% of the families owns plots of much smaller size and 15% is landless.

Cash income is derived from the sale of agricultural products and by employment in urban centres.

The 1979 population census data per sublocation are given in table 1. This table includes population figures for other sublocations which are relevant to the study.

At present 43,100 people are living in the project area for which a water supply system is studied.

The population growth rate is taken as 3.5%. This assessment is probably conservative because the growth rate is nearing 4% at the moment.

1.4 Rural water supplies

1.4.1 Production wells

There are several production wells in the project area. Some of these wells are owned by private persons or institutions.

However, most of the well supplies have the aim to serve the public.

They are operated by the following public agencies:

- Ministry of Water Development (M.o.W.D.)
- Kiambu County Council (K.C.C.)
- the public, organized in selfhelp groups

The locations of the wells can be seen on map 1.

More information about ownership and specific well data are gathered in table 2.

1.4.2 Bathi River Water Scheme

Recently a water supply scheme has been constructed that makes use of a surface water source located 20 km north of the project area.

This scheme is called the Bathi River Water Supply (W/S) and is supposed to supply water to an area that includes the project area.

With the exception of the intake the water is transported by gravity.

Table 1 - Population census data

location	sub-location	1979 population (census)
Lari	Kijabe	3,782
	Bathi	3,598
	Magina	2,657
	Mbauini	1,731
	Kambaa	3,191
	Kirenga	3,540
	Githioroni	2,562
Limuru	Gitithia	4,429
	Bibirioni	11,880
	Kamirithu.	9,567
Ndeiya	Ndiuni	1,902
	Tiekunu	2,093
	Nderu	5,310
	Thigio	5,581
Karai	Renguti	3,560
	Nachu	1,556
	Lusigetti (or Rusigetti)	5,346
	Gikambura	7,852
	Karai-Muslim	479
Ngecha	Rironi	4,400
Kikuyu	Muguga Jet Settlement	9,192

Source: Population census 1979

Table 2 - Well data, source M.o.W.D.

borehole number	owner	head			tested yield (m ³ /h)	well equipped	present yield (m ³ /h)	remarks
		static	dynamic					
P52	K.C.C.	157	-		-	yes	3.8	
C440	K.C.C.	149	-		9.5	yes	3.8	
C2717	K.C.C.	323	-		4.0	yes	3.6	
C2378	K.C.C.	178	-		9.1	yes	8.0	
C2338	K.C.C.	229	-		6.8	yes	6.0	
C2758	K.C.C.	168	-		13.6	yes	8.8	
C416	K.C.C.	81	-		15.7	yes	13.6	
C93	M.o.W.D.	39	-		40.9	yes	30.2	supplies Rironi town
C4893	M.o.W.D.	-	-		<<	no	-	R, NT
C4974	M.o.W.D.	-	-		<<	no	-	R, NT
C4886	M.o.W.D.	156	-		-	no	-	R, NT, AY = 7.5
C2358	M.o.W.D.	290	-		1.4	no	-	R
C4909	M.o.W.D.	280	-		-	no	-	R, NT, AY = 5
C4850	M.o.W.D.	40	40.1		22.3	no	-	
C4861	M.o.W.D.	82	84		11.0	no	-	
C4245	public	106	-		13.6	no	-	
C3087	public	55	-		4.5	yes	4.5	
C4848	public (Kerwa W/S)	62	73		17	no	-	
C4865	public	81	85		13.5	-	-	

Remarks:

R = Recently drilled

NT = Not tested

AY = Assumed yield for design calculations (m³/h)

1.4.2.1. History

The final design of this scheme was presented by H.P. Gauff Consulting Engineers in 1975.

The scheme has been constructed in two phases. The first phase is called Bathi I and consists of:

- the construction of a dam in the Bathi river
- the construction of intake and treatment works
- the construction of reservoirs and the laying of transport and distribution lines in the northern part of the scheme (upstream of reservoir II)
- the construction of a reservoir and the laying of transport and distribution lines in the utmost southern part of the scheme (around the village Gikambura)
- the connection of a production well to the supply system in the southern part of the scheme (connected to reservoir X near Gikambura)

The second phase, called Bathi II, consists of:

- the extended transport main with its branch lines. The transport main is now connected to the southern part of the scheme constructed in phase Bathi I
- the construction of reservoirs and the laying of distribution lines

Part of the implementation of Bathi I has been supervised by H.P. Gauff. The consultant Chauhan Kiptoon and Partners took over and supervised the construction of the treatment plant (completed 1977) and the dam (completed in 1981).

Bathi I has been commissioned and is working satisfactory.

Bathi II has not yet been commissioned but the construction works are considered to be completed.

The MoWD has proposed to make more extensions besides the already existing ones. The aim is to supply the area around Kijabe with water from the Bathi river. This phase is called Bathi III and is included in the planning programme Rural Water Supplies IV.

1.4.2.2. Scheme description

The scheme consists of the intake works, the treatment plant, the transportation and distribution lines and the reservoirs along the pipelines. With the exception of reservoir IV, all these tanks function as break pressure tanks.

- Intake:

The water source for the gravity scheme is the Bathi River.

By building an earthdam a reservoir has been created. This enables a draw-off during dry periods when the discharge of the Bathi river decreases almost to zero. The earth dam has a rock toe for drainage.

The dam is equipped with a drop inlet spillway and a scour pipe to remove silt deposits.

The scour pipe valve is fitted with a bypass and is manually operated. The handwheel is at the bottom of the valve chamber.

According to the design calculations the valve has to be opened during heavy rains to increase the spillway discharge. This will prevent overflowing of the dam.

- Treatment:

The raw water is pumped through a 200 mm cast iron pipe from the storage reservoir to the pumphouse.

A 200 mm PVC pipe leads then to the 225 m³ raw water tank.

The lowest intake water level is 4.5 m below the center of the raw water pumps. The water has to be pumped 9 m to the top water level of the raw water tank. The pumps are driven by electric engines.

The treatment proces consists of: chlorination, coagulation and flocculation followed by sedimentation and rapid filtration.

The upward flow in the sedimentation tanks is 1.1 m/h. There are four sedimentation tanks each with a surface area of 34 m².

After the sedimentation the water flows with an average velocity of 3.5 m/h through two rapid gravity filters.

Each filter has a surface area of 14 m² and the total depth of the filter structure is 4.1 m.

Back washing is done by connecting the higher 225 m³ washwater tank to the filter drains.

The washwater tank is built on more elevated terrain (13 m above the filters) and filled during the day by pumping.

The clear water is collected in two 225 m³ balancing tanks. These tanks form the beginning of the gravity supply scheme.

The flow through the treatment plant is mainly regulated by the water level in the raw water tank. To ensure a constant flow the raw water tank is equipped with float switches and a constant flow device is fitted in the outlet.

The design capacity of the treatment plant is 42 l/s.

- Distribution system:

The main line from the treatment plant up to Gikambura (the last reservoir) has a length of 44 km. Different pressure classes are used and the diameter of the pipes varies between 100 and 300 mm. Quite a number of branch lines are connected to the main.

The diameter varies between 40 and 125 mm.

Ten reservoirs are part of the Bathi River W/S distribution system.

The reservoirs have a storage volume between 90 and 225 m³.

The total installed storage capacity is 1400 m³.

At present the scheme serves the public by means of communal water points. Only a few private connections are made.

The pipe alignments of the phases I and II can be seen on map 1.

1.4.2.3. Operation and maintenance

The part of the scheme that has been commissioned falls under the responsibility of the Kiambu District Water Office.

This is a section of the Operation and Maintenance branch of the M.o.W.D.

1.4.2.4. Shortcomings in the present Bathi River W/S

- Intake:
 - . the toe of the dam shows signs of serious erosion. This is probably due to a wrong grading of the filter layer
 - . the valve in the scourpipe cannot be opened due to the valve chamber being filled with water
- Treatment:

Most of the switch gear and mechanical components are out of order. Broken down are:

 - . level and pressure switches
 - . dosing pumps
 - . watermeters

When the water in the storage reservoir drops to minimum levels cavitation in the pumps will occur.

- Distribution system:
 - . Illegal extension have been made in the northern part of the scheme. This increases the water demand and it also results in high leakage losses because the extensions have not been made under the supervision of trained technicians.
 - . The pipelines of phase II (not yet commissioned) have been laid in the middle of the road. They form a serious traffic hazard and it hampers a reliable operation of air and section valves.
 - . Frequent pipe bursts are reported in most of the scheme area. Some of these bursts can be explained by the installation of wrong pipe classes. Other bursts are possibly caused by water hammer. Manipulations with the freely accessible ball valves in the reservoirs could generate water hammer. It is reported that thrustblocks are not installed properly causing slippage of joints.
 - . Communal water points.

Most of the water points are in a bad state. The taps are worn out or missing completely.

The high pressure on the system results in considerable leakage losses.

- Operation and maintenance:
The Kiambu District Water Office does not have facilities to operate and maintain a scheme of this size.
They are particularly lacking:
 - . transport and telephone facilities
 - . technicians and trained plumbers
 - . workshop facilities and spare parts (pipes)

1.4.3 Evaluation of the present water supplies

To evaluate the existing water supply system one has to take into consideration:

- the demand for reliable drinking water
- the amount of available water
- the distance between the consumers and the supply points

The existing water supply system produces little water at irregular times. The supplied amount does not meet the demand and many consumers have to walk a long distance.

In this report the possibilities of a future water supply system will be studied.

The objective is a technical proposal and cost estimate of the future system. The project horizon for the system is the year 1995.

2. WATER DEMAND

2.1. General

To assess the required water supply quantity for a given area the average daily consumption per capita should be calculated.

After the fluctuations in the demand are determined, the variations in the supply to the area will be known.

2.2. Average daily demand

In calculating the average daily demand a consumption per capita is assumed as described in the design manual for the M.o.W.D.

These demands are:

- 25 l/c/d for people served by communal water points (CWP's)
- 50 l/c/d for people having an individual connection (IC)
- 75 l/u/d for the water consumption by a live stock unit

Further assumptions in calculating the average daily demand are:

- in the initial phase of the project 100% of the population depends on CWP's. In the design year 1995, 50% of the population will have an individual connection IC
- a livestock population ratio of 0.036 is used (see: final design Bathi II). This means that on an average 36 live stock units are owned by 1000 inhabitants
- the institutional water demand amounts to 6% of the total water demand (according final design Bathi II)
- leakage losses amount to 20% of the total water demand (a generally accepted figure).

2.2.1. Average daily demand in the initial phase

In the calculations the number of inhabitants of a given area is represented by the letter P.

Average daily consumption by

people and livestock:	$= 25 \times P + 75 \times 0.036 P$	$= 27.7 \times P$ (l/d)
Institutional demand 6%		$= 1.7 \times P$ (l/d)
Leakage 20%		$= 5.9 \times P$ (l/d)

Daily demand		$= 35.3 \times P$ (l/d)
--------------	--	-------------------------

If the consumption by livestock is excluded the average daily demand for a population P amounts to $32.6 \times P$ (l/d).

2.2.2. Average daily demand in the year 1995

It is assumed that in the year 1995 50% of the population P will have an IC.

Average daily consumption
by people and
livestock

$$= 25 \times \frac{P}{2} + 50 \times \frac{P}{2} + 75 \times 0.036 \times P = 40.2 P \text{ (l/d)}$$

Institutional
demand 6%
Leakage 20%

$$= 2.4 \times P \text{ (l/d)}$$

$$= 8.5 \times P \text{ (l/d)}$$

The average daily demand

$$= 51.1 \times P \text{ (l/d)}$$

If the consumption by livestock is excluded the average daily demand for a population P amounts to $48.4 \times P \text{ (l/d)}$.

2.3. Fluctuations in the demand

The water demand will vary through the year and over the day.
This variation can be described by the ratio (peak factor) between the maximum and the average demand.

2.3.1. The maximum daily demand

As is generally accepted the maximum daily demand is taken as 120% of the average daily demand. Thus the peak factor is 1.2.

2.3.2. The maximum hourly demand

The maximum demand is a function of consumer habits. The maximum flow through the pipelines of the system is however not only a function of consumer habits but depends also on the location of storage.
CWP users have the habit of not closing the taps during a peak hour and thus the peak factor can be very high.
For the institutional demand and for people having an IC a peak factor of 1.8 is assumed.
Leakage losses and cattle watering are considered not to cause a peak flow.

From the calculations below can be concluded that if no storage is provided at CWP's the overall peak factor will be 2.4.
If storage is provided at CPW's the peak factor will be lowered to 1.5.

2.3.2.1. Maximum hourly flow without storage at CWP's

One CWP is designed to serve 120 consumers at 10 l/min (see final design Bathi II).

During a maximum hour taps are supposed to be running permanently. This causes a flow per consumer of:

$$\frac{60 \times 10}{120} = 5 \text{ (l/c/h)}$$

For consumers having an IC and for the institutional demand a peakfactor of 1.8 is assumed.

The maximum hourly flow is:

$$\text{People having an IC: } 1.8 \times \frac{50}{24} = 3.8 \text{ (l/c/h)}$$

$$\text{Institutional demand: } 1.8 \times \frac{2.4}{24} = 0.2 \text{ (l/c/h)}$$

For the consumption by livestock and the leakage losses no peak factor is considered.

The maximum hourly flow is:

$$\text{Consumption by livestock: } \frac{2.7}{24} = 0.1 \text{ (l/c/h)}$$

$$\text{Leakage losses: } \frac{8.5}{24} = 0.4 \text{ (l/c/h)}$$

When 50% of the population P makes use of CWP's the maximum hourly flow is:

$$5 \times \frac{P}{2} + 3.8 \times \frac{P}{2} + 0.1 \times P + 0.2 \times P + 0.4 \times P = 5.1 \times P \text{ (l/h)}$$

$$\text{Peakfactor} = \frac{\text{maximum hourly flow}}{\text{average daily flow/24 h}} = \frac{5.1 \times P}{2.1 \times P} = 2.4$$

2.3.2.2. Maximum hourly flow with storage at CWP's

By providing storage at CWP's sufficient to cover the initial higher demand the peakflow can be leveled of.

Now the maximum hourly flow equals the average hourly demand and amounts to:

$$\frac{25}{24} = 1 \text{ (l/c/d)}$$

When 50% of the population makes use of CWP's the maximum hourly flow is:

$$1 \times \frac{P}{2} + 3.8 \times \frac{P}{2} + 0.1 \times P + 0.2 \times P + 0.4 \times P = 3.1 \times P \text{ (l/h)}$$

$$\text{Peakfactor} = \frac{\text{maximum hourly flow}}{\text{average daily flow/24 h}} = \frac{3.1 \times P}{2.1 \times P} = 1.5$$

2.4. Increase of the water demand

Because of the increasing number of individual connections in time, the future water demand per capita is higher than the initial one. It is assumed that the individual connections will be made gradually and that the increase of the water demand will be linear.

Due to the population growth the number of consumers will increase also. The ultimate effect of these two influences has been calculated (table 3). If the water demand for a given area in the year 1995 is taken as 100%, table 3 learns that the water demand for that specific area in the years 1985 and 1990 will be 49% and 60% respectively.

2.5. Total water demand and supply area

The supply of the Ndeiya Karai locations with water distributed by the existing Bathi Water Scheme has been investigated.

To make effective use of the existing supply system, taking into account its potential, the water demand of a larger area has to be investigated. The supply area does not only cover the Ndeiya and Karai locations but also part of the sublocations Kamirithu and Muguga Jet Settlement. More specified: The area that is presently served by the reservoirs IV and V of the Bathi scheme.

The boundaries of the supply areas are the neighbouring public water systems or the public grazing areas.

The total service area of the scheme is subdivided into smaller supply areas, that are each assigned to a particular gravity supply line (map 2). The surface of the supply areas has been estimated. By using the population density data of table 4, the population per supply area is calculated. The results are shown in table 5. The average daily water demand is calculated. The results are shown in table 5.

Table 3 - Increase water demand

year	population (growth rate 3.5%)	specific water demand			total water demand	
		including livestock	excluding livestock		including livestock	excluding livestock
1995	P95	D95 = 51.1 (1/c/d)	0.95 x D95		W95 = P95 x D95 = 51.1 x P (1/d)	0.95 x W95
1990	P90 = 0.84 x P95	D90 = 0.85 x D95	0.79 x D95		W90 = 0.84 x 0.85 x W95 = 0.60 x W95	0.56 x W95
1985	P85 = 0.71 x P95	D85 = 0.69 x D95	0.64 x D95		W80 = 0.71 x 0.69 x W95 = 0.49 x W95	0.45 x W95

Table 4 - 1995 population density

sublocation	1979 population (census data)	1995 population (3.5% growth)	populated area (km ²)	1995 population density (capita/km ²)	remarks
Ndiuni	1,902	3,298	4	850	
Tiekunu	2,093	3,629	12.2	300	
Nderu	5,310	9,207	10	950	
Thigio	5,581	9,677	11.7	850	
Renguti	3,560	6,173	5.7	1,100	
Nachu	1,556	2,698	5.6	500	
Lusigetti	5,346	9,270	11.2	850	
Gikambura	7,852	13,615	9.0	1,500	
Karai M	479	830			rural town
Kamirithu	9,567	16,589	15.5	1,100	
Rironi	4,400	7,629	4.6	1,100	correction for Rironi town
Muguga Jet	9,192	15,938	24.0	700	

Table 5 - Population and water demand in the supply areas

area	surface km ²	population density c/km ²	population 1995	total	average daily demand l/c/d	daily demand m ³ /d	total demand m ³ /d
A1-1	4.6	850	3,910				
A1-2	1.9	300	570				
A1-3	7.7	300	2,310				
A1-4	1.1	950	1,045	7,835	51	400	
A2-5	3.1	800	2,480	2,480	51	126	526
				10,315			
B1-1	5.8	1,100	6,380				
B1-2	3.4	300	1,020	7,400	51	377	
B2-3	2.3	1,000	2,300				
B2-4	1.7	700	1,190	3,490	51	178	555
				10,890			
C1-1	6.3	950	5,985				
C1-2	3.2	850	2,720	8,705	48	417	
C2-3	5.0	750	3,750	3,750	51	191	
C3-4	7.6	850	6,640				
C3-5	2.2	1,100	2,420	8,880	48	426	
C4-6	3.5	1,100	3,850				
C4-7	5.6	500	2,800	6,650	48	319	1,353
				27,985			
D1-1	11,3	1,500	16,950				
D1-2	6,0	850	5,100	22,050	51	1,125	
D2-3	5,2	850	4,420	4,420	48	212	1,337
				26,470			
Total	87,5		75,660				3,771
					year		
					1985	1990	1995
Total demand in different years (m ³ /d)					1,850	2,260	3,770

3. AVAILABLE WATER RESOURCES

3.1. Surface water

Within the project area no surface water is available. Possible surface water sources are only found outside the project area.

Bathi River and other alternative surface water sources will be discussed.

3.1.1. Bathi River Water Supply

The Bathi Water Scheme draws its water from an artificial reservoir in the Bathi River.

The catchment area upstream of this reservoir is very small (6 km²). Unfortunately lacking of flow measurement data prohibits the assessment of the safe yield of this river. The current meter notes of the river gauging stations are mixed up and no conclusions can be drawn.

3.1.1.1. Safe yield

According to the computation made by H.P. Gauff Consulting Engineers storage should facilitate a draw off for a dry period of 70 days. In this dry period the inflow of the river is negligible.

The storage capacity and the water surface of the reservoir have been calculated from drawing 2080/I/D/2.1/1/1. The life storage is $280 \times 10^3 \text{ m}^3$ and the average water surface $40 \times 10^3 \text{ m}^2$ (fig. 3).

For the calculation of the evaporation losses data gained at the Ruiru dam will be used. This station is 14 km to the east of the reservoir in the Bathi river and has the same climatological conditions. The average evaporation during the dry period January-March is 4 mm/day.

The evaporation losses during a dry period of 70 days amounts to:

$$70 \times 4 \times 10^{-3} \times 40 \times 10^3 = 11 \times 10^3 \text{ m}^3.$$

A small catchment shows more fluctuations in the inflow and this requires a larger storage volume.

The effective storage of a small catchment area is taken as 80% of the life storage minus the evaporation losses.

With a draw off period of 70 days the average water production is:

$$\frac{0.8 \times (280 \times 10^3 - 11 \times 10^3)}{70} = 3100 \text{ m}^3/\text{day}$$

The treatment plant uses 6% of the raw water quantity for backwashing and internal use. This is the average measured in one production year. Thus the maximum average water production during a dry period is:
 $0.94 \times 3100 = 2890 \text{ m}^3/\text{day}.$

Minimum water level: 2441.6 m
 Maximum water level: 2450.1 m

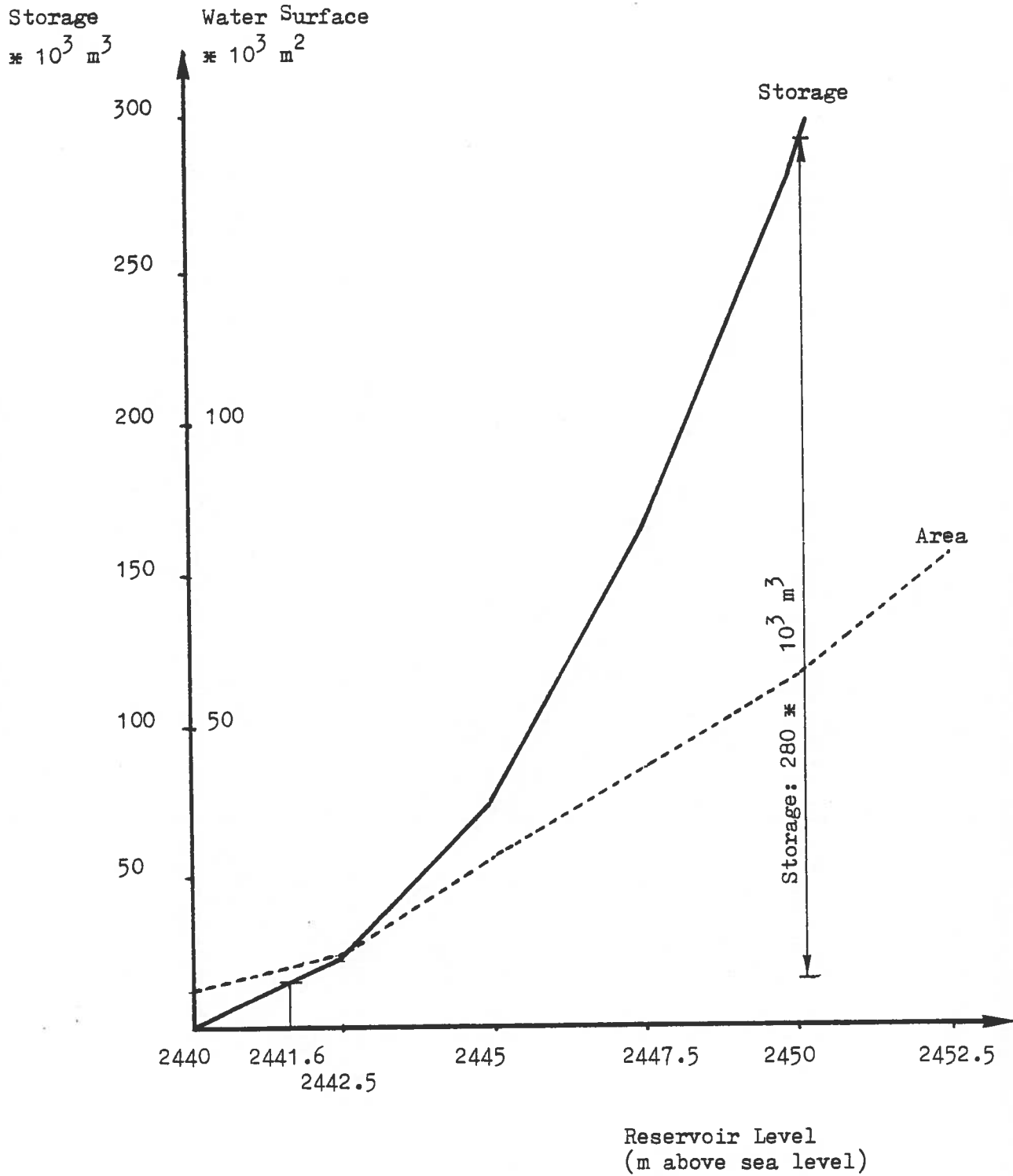


Figure 3: Storage Reservoir in Bathi River.

3.1.1.2. Available water for project area

The water demand in the area that is presently served by the Bathi River Scheme exceeds the average water production of the treatment plant in a dry period.

It has been assumed that the area between the treatment plant and the project area will get the highest priority.

Thus the available water for the project area is the water production from the treatment plant minus the water consumption between the treatment and the project area.

In the design reports of the Bathi W/S the boundaries of the supply area have been defined.

Together with the population census data the number of consumers upstream of the project area can be calculated.

The average daily demand is taken as 48 l/c/d (daily water demand without livestock as sufficient sources for watering cattle are available).

Taking into consideration the population growth (3.5%) and the increasing water demand as outlined in section 2, the upstream consumption is calculated for the year 1985, 1990 and 1995 and amounts to 2550 m³/d (table 6).

The remaining supply for the project area in the year 1995 is the treatment plant production (2890 m³/d) minus the upstream consumption (2550 m³/d) and amounts to 340 m³/d.

In the years 1985 and 1990 the water supply to the project area will be limited to 900 m³/d by the upstream pipe capacity.

Increase of the pipe diameter is not thought feasible because of the flow to the project area is decreasing rapidly after 1990.

3.1.2. Alternative surface water sources

For a new water supply system limited surface water sources outside the project area are available. Possible sources are:

- A connection to a new gravity supply scheme.
Suitable intake sites are relatively far away from the project area (more than 40 km). The costs of such a scheme will be higher than groundwater development.
- A decreased consumption of the Bathi River Water Supply in the upper scheme areas.
In this way surface water is saved and more water can be supplied to the project area.
Such a decrease can be realised by making alternatives sources available in the upper scheme areas. This possibility is not likely to be cheap or fitted for short term implementation and is beyond the scope of this study.

Table 6 - Water consumption upstream project area

location	sublocation	1979	1995	consumers		consumers		consump- tion 1995 48 l/c/d (m ³ /d)
		popula- tion (census data)	popula- tion (3.5% growth rate)	Bathi I & II %	number	Bathi III %	number	
Lari	Kijabe	3,782	6,600	-	-	60	4,000	
	Bathi	3,598	6,200	80	5,000	-	-	
	Magina	2,657	4,600	100	4,600	-	-	
	Mbauini	1,731	3,000	80	2,400	-	-	
	Kambaa	3,191	5,500	100	5,500	-	-	
	Kirenga	3,540	6,100	100	6,100	-	-	
	Githioroni	2,562	4,400	90	4,000	-	-	
Limuru	Gitithia	4,429	7,700	30	2,300	-	-	
	Bibirioni	11,880	20,600	20	4,100	-	-	
	Kamiritu	9,539	16,500	-	1,800	-	-	
Total					35,800		4,000	1,910
Emergency supply to Bibirioni								285
Supply to escarpment settlement scheme (planned)								355
Total								2,550 m ³ /d

Note:

- The planned extension to Rironi will use well water..
- The planned extension to Muguga Jet settlement scheme is included in the present project.
- The percentage of a sublocation served by the Bathi W/S is described in: Preliminary investigations Bathi W/S.

- Water from the Kikuyu springs.
Presently this water is used for the Nairobi water supply.
Several governmental authorities are involved in the development of this source.

It is not expected that the project area gets such a high priority that this source can be used before 1995.

3.2. Groundwater

3.2.1. Existing production wells

The present wells in the project area serving the public, deliver 1650 m³ a day. It is assumed that they run for 20 hours continuously on an average day.

As will be discussed in section 4.2.1.2 a number of these wells are selected for connection to the future system. The daily average production of these wells will be 1220 m³.

3.2.2. Groundwater development

Future wells are most promising if located in a fault zone or at a crossing of faults.

In the project area the main fault zone is between the lower grazing area and the more elevated land.

The fault zone with the highest potential water production is the Lari-Ondiri fault. This fault zone is located outside the project area.

With the exception of CO₂-contents and pH the quality of the water found in these fault zones is good (see table 7).

The only required treatment is:

- removal of the free CO₂ (agressive)
- pH adjustment
- safety chlorination

The western fault zone (located in the project area) is less suitable for the allocation of production wells compared to the Lari-Ondiri fault because of:

- The high investment costs.
The bore-holes have to be deep (200 to 300 m) and due to the low yields (2.5 tot 7.5 m³/h) many have to be drilled.
- The high production costs.
In the western fault zone the water level is deep (150 to 200 m).
The pumping lift to deliver the water at ground level is considerable.
From ground level the water has to be pumped against a substantial head (100 to 200 m) to reach the consumers.

Table 7 - Expected groundwater qualityExpected groundwater quality Lari-Ondiri fault. Source: M.o.W.D.

item	value
pH	5.5-8.5 mg/l
TDS	120-270 mg/l
CaCO ₃	10-80 mg/l
HCO ₃	50-180 mg/l
Fe	0.01-6 mg/l
Cl	10-65 mg/l
F	0.1-1.3 mg/l

Table 8 - Required additional supply

source	water supply (m ³ /d)		
	1985	1990	1995
Bathi river W/S	900	900	340
Existing boreholes, to be connected in the proposed system	1220	1220	1220
Total supply	2120	2120	1560
Water demand in the project area	1850	2260	3770
Required additional supply	-	140	2210

- Groundwater in the western zone is more sensitive to the phenomena of overpumping (see: water resources assessment project Ndeiya-Karai).

3.3. Conclusions

With the known available supply from surface and groundwater sources and the water demand for the project area (section 2) the required supply from additional sources can be estimated by subtracting the two. The results are shown in table 8. For the years 1990 and 1995 the additional sources have to deliver 140 and 2210 m³/d respectively .

4. PROPOSED WATER SUPPLY SYSTEM

4.1. General

From the foregoing it will be clear that a future supply system has to make use of groundwater in addition to supplies from the Bathi water scheme.

Existing public wells in the project area will be connected to the future system. New wells are preferably planned in the Lari-Ondiri fault zone.

The present distribution network should be integrated in the future supply system to minimize the costs.

4.2. Design of water supply system

The design of the future supply system consists of the selection of existing and future wells and their connection to the distribution system. Hereafter the adaptations of the existing system can be determined.

4.2.1. Connection of production wells

For the connection to the future public supply system, wells are taken into consideration that are presently owned by M.o.W.D. of K.C.C.

It is doubtful whether a well that has been initiated and operated by a selfhelp group or other private institutions can be connected to a public supply system. The owners are reluctant in selling their water to a governmental body unless they are certain of a reliable replacement.

4.2.1.1. Criteria for well design

The design of the future well supply system started from the following principles and assumptions:

- Bore-hole siting.
The locations should have the appropriate geological characteristics.
- Operation and maintenance.
Operation and maintenance of the scheme should be easy and at the lowest cost.
 - . The M.o.W.D. should operate the scheme.
 - . If more authorities co-operate in the initial phase of the scheme their tasks and responsibilities have to be outlined clearly.
 - . A cluster of wells should be assigned to a specific supply area.
 - . The wells should be in the vicinity of a power line.
This enables the use of electric power with easy operation and maintenance.

- . Wells should be clustered (as much as feasible) nearby an all weather road. This diminishes the logistical problems and enables an easy use of the standby equipment.
- Cost aspects.
The costs of the future water supply can be divided into initial and running costs.
 - . Initial costs.
A cluster of wells will be cheaper because of the lower mobilisation and preliminary costs.
A cluster asks for larger units (treatment, pumps, storage). These are cheaper per supplied m^3 of water.
 - . Running costs.
To minimize the pumping costs a low and constant pumping head is required. Furthermore a cluster enables an efficient use of staff and equipment and is therefore cheaper.
- Technical aspects.
 - . If new boreholes are planned they are assumed to be 200 m deep.
The static water level is taken as 100 m below the ground level.
The maximum yield will be about $10 \text{ m}^3/\text{h}$ and causes a drawdown of 20 m.
 - . Production wells are designed to run for 20 hours on an average and for 24 hours on a maximum day.
 - . The water treatment consists of CO_2 removal, pH adjustment and safety chlorination.
 - . A standby well or an emergency flow should prevent a supply shortage caused by a break down of engine, pump or well.
Extra storage will be installed to prevent a supply shortage during a power failure. A power failure is not likely to last for more than a few hours.

4.2.1.2. Selection of wells

Some of the existing wells are not connected because they do not satisfy the design criteria of section 4.2.1.1 (low yield and/or high pumping lift).

Many are located in and at the border of the grazing areas (C 440, C 2717, C 2758).

The wells are owned by the K.C.C. and their main function is and will be in the near future to supply water for livestock.

In calculating the water demand of the supply areas bordering these grazing areas the consumption by livestock has been excluded.

Some of the recently drilled wells will not be equipped (with submersible pump etc.) because of their poor characteristics (C 4893, C 4974, C 2358, C 4909).

The existing bore-holes that will be connected to the distribution system are: P 52, C 4245, C 4886, C 93 and C 2338.

Possible locations for the additional wells are given by the water resources assessment study.

The well locations are chosen to satisfy the design criteria in the best possible way.

The locations of the new wells can be seen on map 3.

4.2.1.3. Connection to the existing distribution system

The connection of the production wells with the existing scheme is made after the water has been treated.

The treatment consists of: removal of free CO_2 , pH adjustment and safety chlorination. For the treatment the standard designs used at the M.o.W.D. are proposed.

After the treatment the water is pumped into a break pressure tank of the Bathi Water Supply Scheme.

A new break pressure tank in the Bathi W/S is projected to enable an economical connection with future production wells.

This tank is located between the existing reservoir VI and VII.

The planned production wells and the pipeline alignment for connecting the wells to the Bathi scheme can be seen on map 3.

The production wells delivering water to reservoir X have the longest transport main. The water flows under gravity through the line after being pumped to a reservoir nearby the wells.

The total pipe length used for connecting wells to the Bathi W/S is 43 km. The material will be PVC and the diameters are 50, 80, 100 and 150 mm.

More information and specifications about the required capacity are given in annex 1.

4.2.2. Adaptions and extensions of the Bathi Water Scheme

The existing and planned wells that will be integrated in the future system are discussed in section 4.2.1.

In section 3.5 the water demand for the different supply areas has been calculated. Each of these areas is supplied (by gravity) from a particular reservoir.

With the water demand per supply area and the average day production of the existing wells the required additional supply per reservoir can be calculated.

This is done in table 9 and graphically presented in figure 4. Also the transport of water from a given reservoir to a supply area farther away can be taken from this table.

Table 9 - Well production and additional demand

average daily demand (m ³ /d)				production well delivering to area	
area	demand for consumption in own area	demand for transport to other areas	total demand	borehole code	20 hours production (m ³)
A1	400	50	450	new	450
A2	176	-	176	P52	76
B1	377	-	377	new	377
B2	178	-	178	C4245	272
C1	417	345 + 41	803	new	803
C2	191	-	191	C4886	150
C3	426	319	745	new	400
C4	319	-	319	-	-
D1	1125	92 - 604	613	new C93	613 604
D2	212	-	212	C2338	120

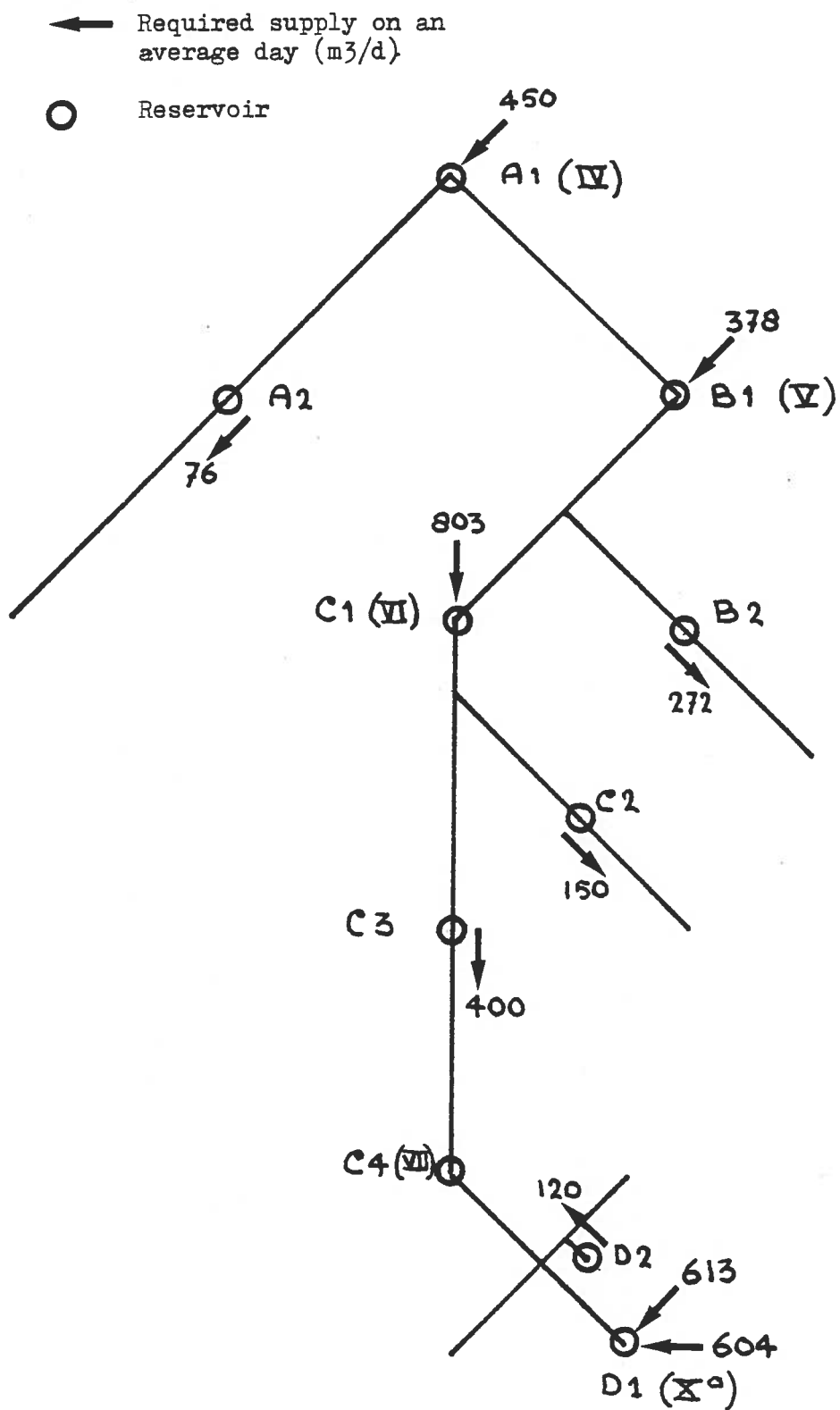


Figure 4: Required supply per reservoir.

4.2.2.1. Transport lines

The pipes must be able to carry the maximum expected flow: the design flow.

In most cases the design flow is the sum of the local peak flow increased with the flow to downstream areas.

The transport is designed to satisfy the maximum daily demand of the downstream area.

When a production well is out of order the required water will be supplied from an upstream reservoir.

This emergency flow can be higher than the flow caused by the daily transport under normal conditions.

For the design of the pipe the highest of the two is taken into account. The result of the calculation can be seen in table 10 and is graphically presented in figure 5.

With the exception of the line between reservoir VI and VII the present scheme can deliver the design flows (see fig. 6). Between these two reservoirs a new break pressure tank is planned.

Also 3 km pipeline with a present diameter of 50 mm has to be replaced by 150 mm. The capacity of the thus modified system can be seen in figure 6.

4.2.2.2. Communal water points

480 consumers are assigned to one CWP (final design Bathi II), with a total daily demand of 14.4 m³ on a maximum day.

To level off the peak flow, a storage of 6 m³ per CWP is considered to be sufficient.

It is assumed that in the initial phase all the consumers will have to make use of CWP's and 50% of the consumers will have an IC in the year 1995.

The scheme will serve 54,000 people in the year 1985 and 76,000 in the year 1995.

Thus the required number of CWP's is 110 in 1985 and 80 in 1995.

This means 80 CWP's have to be upgraded and 30 have to be constructed.

4.2.2.3. Storage

Storage is installed for the purpose of:

- leveling off the peakflow
- preventing an interruption in the supply during a power failure

At least 20% of the maximum day supply is required as storage to level off the peakflow at a maximum day. A permanent 24 hours inflow is assumed.

Table 10 - Design flow

area	average daily demand (m ³ /d)	peak- flow (l/s)	average daily transport (m ³)	transport flow on max. day (l/s)	emergency flow (m ³ /d)	emergency flow on max. day (l/s)	design flow (l/s)
A1	400	8.3	50	0.7	126	1.7	10.0
A2	126	2.6	-	-	-	-	2.6
B1	377	7.9	-	-	178	2.5	10.4
B2	178	3.7	-	-	-	-	3.7
C1	417	8.7	386	5.4	200	2.8	16.9
C1	417	8.7	345	4.8	200	2.8	16.3
C2	191	4.0	-	-	-	-	4.0
C3	426	8.9	319	4.4	-	-	13.3
C4	319	6.6	-	-	-	-	6.6
D1	1125	23.4	92	1.3	212	2.9	(several distribu- tion lines from D1)
D2	212	4.4	-	-	-	-	4.4

$$\text{Peak discharge} = \frac{1.5 \times 1.2 \times \text{average day demand (m}^3\text{)}}{86.400} \quad (\text{l/s})$$

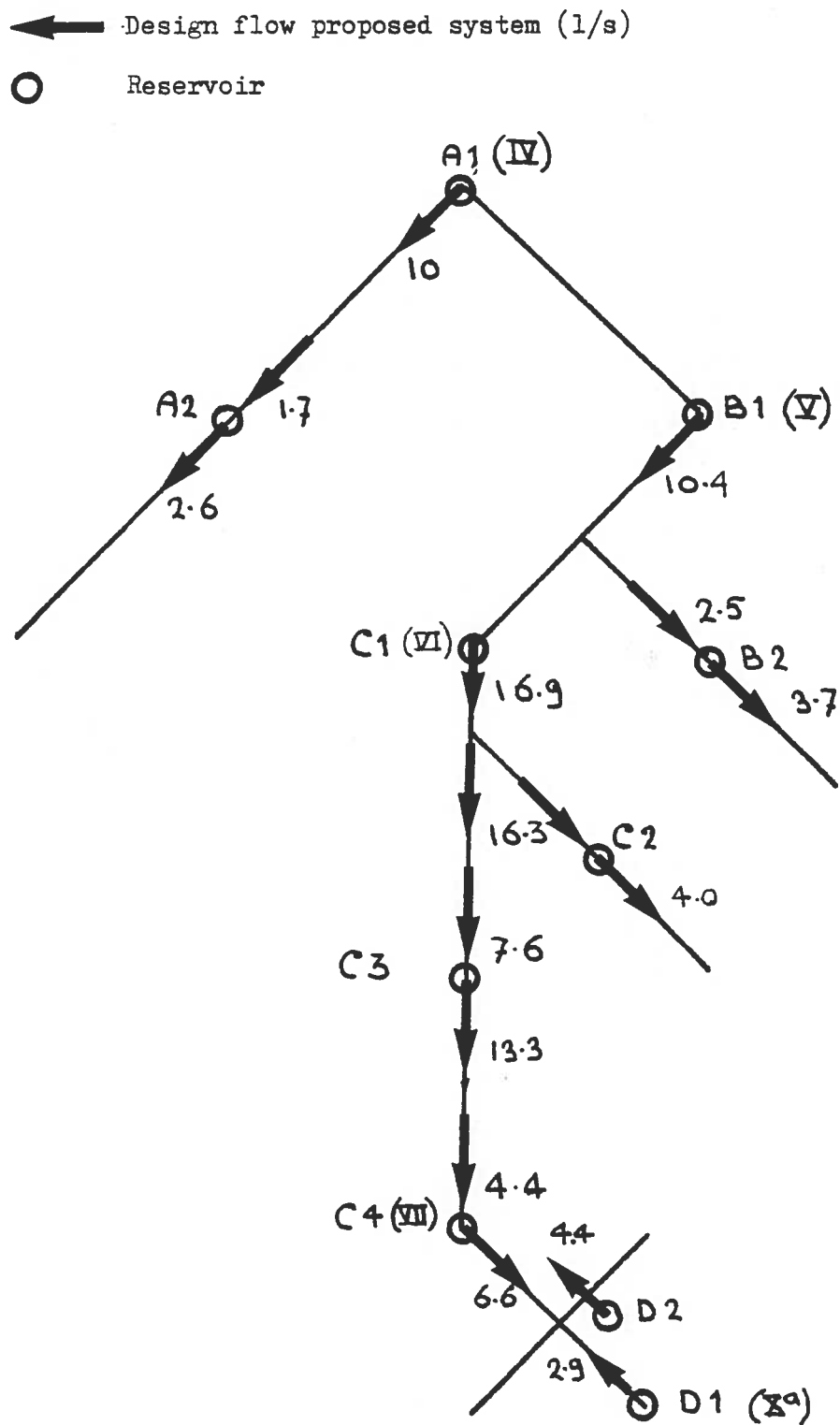


Figure 5: Design flow proposed system.

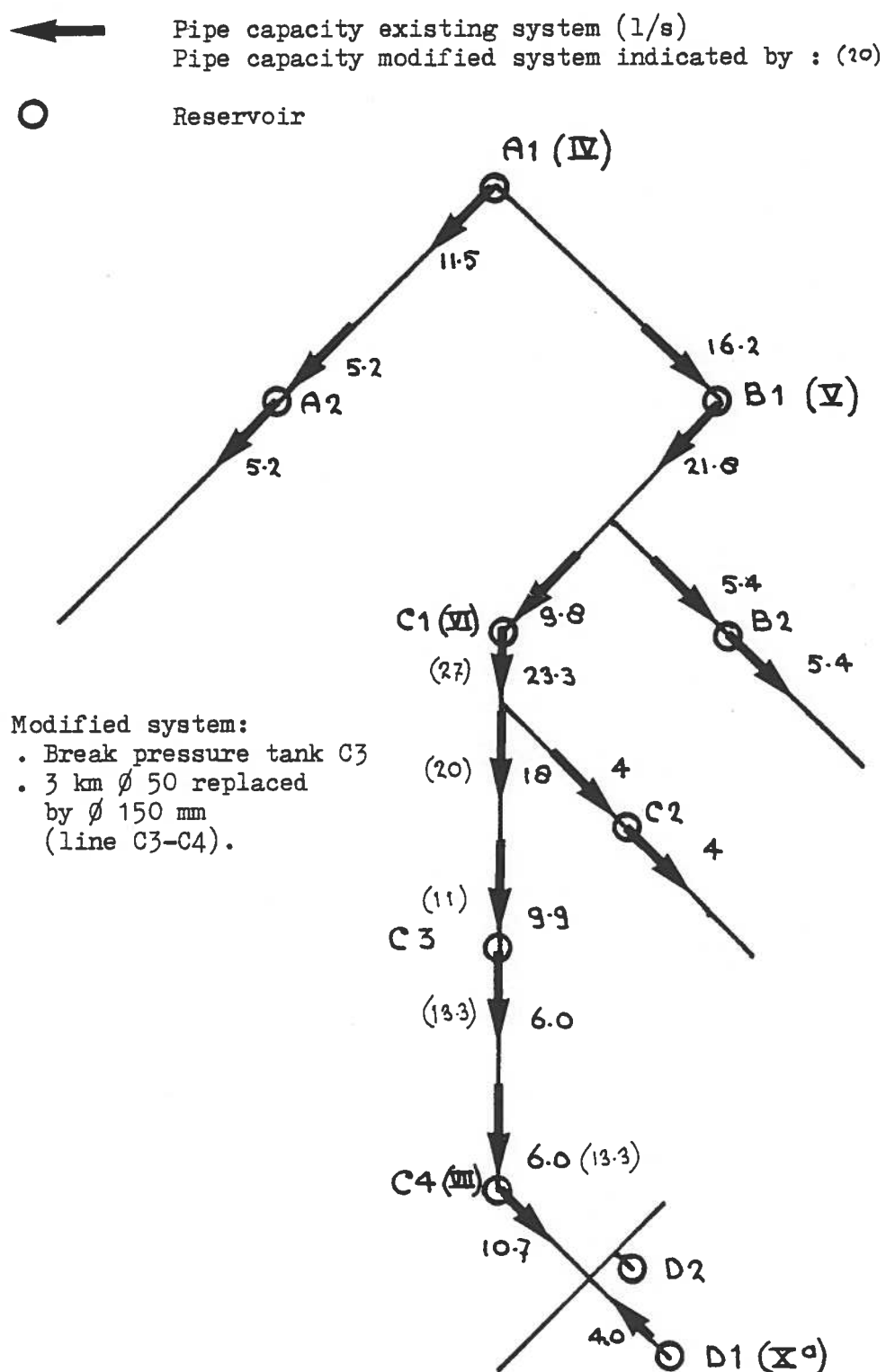


Figure 6: Capacity existing and modified system.

If the power for the pumps is supplied from the East Africa Power and Lighting (EAPL), an electricity failure is very unlikely. Installation of gensets as standby units will be expensive.

It is also doubtful if the gensets will work properly when needed.

Practice has learned that after some time the gensets are removed and are used for other wells where the generator has broken down.

As a safety measurement it is therefore proposed to increase the storage capacity up to 50% of the average daily demand, while no standby gensets are planned.

The total storage installed at the CWP's is $6 \times 80 = 480 \text{ m}^3$.

This is $\frac{480}{3770} \times 100 = 12.7\%$ of the average daily demand.

The storage to level off the peakflow is taken as 25% of the average daily demand. This is $25/1.2 = 20.8\%$ of the maximum daily demand.

The storage to provide a supply during a power failure is taken as 15% of the average daily demand.

The total installed storage will be: $12.7 + 25 + 15 = 52.7\%$ of the average daily demand.

The proposed storage can be seen in table 11.

4.3. Operation and maintenance

After the scheme has been commissioned it will be run by the Operation and Maintenance branch of the M.o.W.D.

This branch of the Ministry has a district headquarter in Kiambu town. From here the operation and maintenance activities are undertaken.

The following activities are required to keep the gravity scheme in a good operational condition:

- the regular inspection of the treatment plant
- patrolling the pipelines for leakages
- the maintenance of the electrical and mechanical equipment in the scheme
- the cause of malfunctioning supply must be monitored and corrected
- new connections have to be made. Worn out valves, water meters and taps will be replaced
- administrative activities concerning the collection of revenues, buying and stocking of chemicals and spare parts and the overall administrative work.

The responsible authority for running the scheme must have an administrative and technical section.

Each section should have the required means at its disposal: transport, office (telephone) and workshop facilities.

Table 11 - Proposed storage

reservoir	25% storage for peak- flow	15% storage for safety purpose	storage			
			required	existing	proposed	
A1 (IV)	100	68	168	135	-	gravity supply from treatment gives 50 m ³ extra storage
A2	32	11	43	90	-	
B1 (V)	94	57	151	135	100	storage also for future demand
B2	45	27	72	-	100	
C1 (VI)	104	120	224	225	-	
C2	48	23	71	-	100	
C3	107	60	167	-	200	
C4 (VII)	80	-	80	90	-	
D0	-	92	92	-	100	
D1 (X)	281	91	372	225	200	
D2	53	18	71	-	100	
				900	900	

Good operation and maintenance is a crucial factor in creating a reliable water supply and it is stressed that much attention is given to the organisational set up and the necessary means.

At present the District Water Office in Kiambu does not have these facilities.

4.4. Engineering and construction activities

To realize the future supply system the following activities are envisaged.

To get a full insight in the condition of the existing supply system it will be pressure tested.

This will form the basis of a detailed rehabilitation program.

The proposed supply lines will be surveyed and detailed designs made.

The designs concern:

- the rehabilitation work
- the pipelines
- the boreholes
- the civil constructions like: production, treatment, reservoirs, pump and staff houses
- the electrical and mechanical equipment

Tender documents of the rehabilitation work and the proposed system will be prepared.

After the tendering the construction work can be started.

4.5. Phasing of the activities

It will take several years to realize the proposed supply system, because of the testing and engineering activities and the drilling of the proposed 12 wells.

The planning horizon is only 13 years ahead and it is advised to start the testing and engineering activities as soon as possible.

The already existing boreholes have to be equipped and connected to the gravity supply system in the year 1985.

In 1990 the first newly drilled wells should deliver water to the project area and in the year 1995 the proposed scheme should be operational.

The detailed phasing of the project will be based on the above described general criteria. During the detailed engineering activities the final phasing should be decided upon.

4.6. Project investment costs

4.6.1. General

To get a realistic costing of the proposed water supply system, unit prices (obtained from the M.o.W.D.) will be used.

The required quantities can be taken from map 3 and the drawings in annex 1.

With these data a costing of the project has been prepared.

It was not possible during the restricted time available to assess the engineering and implementation costs for testing and rehabilitation of the existing gravity supply scheme.

These costs have been taken "pro memorie".

4.6.2. Unit costs

Tender prices of different items have been gathered by the design section of the Ministry.

These prices include taxes, the cost of labour, materials, equipment and the miscellaneous work that is involved in realizing a project.

The drilling costs of bore-holes are calculated from the data provided by the drilling section of the Ministry.

The prices for mechanical equipment were obtained from a local supply agent.

The unit costs are described in Annex 1.

4.6.3. Project costs

A detailed breakdown of the project costs is given in Annex 1.

The project investment cost are summarized as follows:

	Ksh x 10 ⁶
Bore-hole drilling (12 bore-holes)	3.6
Installation and equipment costs (18 wells)	4.9
Mechanical equipment (17 submersible pumps, 10 low- and 2 highlift- pumps, 12 electrical engines, 2 gensets)	2.7
Electricity supply at the well site (16.3 km powerline, 16 transformers)	1.1
Pipelines (43 km, material: PVC)	6.5

Construction of civil buildings	3.0
Access road	0.3

Rehabilitations and extensions Bathi Water Scheme:

- Storage (5 reservoirs of 100 m ³ , 2 of 200 m ³)	2.0
- Communal water points (upgrading 80, 30 new ones)	1.8
- Extensions and replacements of pipelines (total 12 km)	1.5
	Ksh 27.4 x 10 ⁶
Engineering 5%	1.4 x 10 ⁶
Preliminaries 10%	2.7 x 10 ⁶
Contingencies 15%	4.1 x 10 ⁶
Total project costs	Ksh 35.6 x 10 ⁶

N.B. Cost of testing and rehabilitation of the existing gravity supply system have not been included.

4.6.4. Evaluation

The scheme is designed to supply approximately 3800 m³ water a day to 76,000 people in the year 1995.

This means the additional investment costs per capita are 430 Ksh/c.
The investment costs to supply one m³ water a day is 8700 Ksh/m³.

These figures compare reasonably with the costs of other water projects supplied by deepwells.

Annexes

ANNEX 1 - PROJECT INVESTMENT COSTS

TABLE OF CONTENTS

1. UNIT COSTS
2. PROJECT INVESTMENT COSTS
 - 2.1. Rehabilitation and extensions Bathi W/S
 - 2.2. Production fields and connection to Bathi W/S

List of figures

1. Breakdown borehole costs
2. Installation costs production wells
3. Water treatment costs
4. Pipeline costs
5. Storage costs
6. Production wells delivering to reservoir A1
7. Production wells delivering to reservoir A2
8. Production wells delivering to reservoir B1
9. Production wells delivering to reservoir B2
10. Production wells delivering to reservoir C1
11. Production wells delivering to reservoir C2
12. Production wells delivering to reservoir C3
13. Production wells delivering to reservoir D1
14. Production wells delivering to reservoir D2

1. UNIT COSTS

These costs are obtained from the M.o.W.D. They include taxes and represent the price level of July 1982.

	Unit	Costs Ksh x 1000
Boreholes, deep 200 m (see cost breakdown figure 1)	pcs	300
Installation costs production wells	pcs	see figure 2
Water treatment	treated m ³	see figure 3
Pumphouse (standard pumphouse to accomodate 2 to 4 small pumping units, with attached workshop)	pcs	75
Pipelines (material PVC)	class/diameter/km	see figure 4
Storage	stored m ³	see figure 5
Staff house, double grade IX house (accomodation for personnel)	pcs	180
Acces road (all weather road with loose surface)	km	100
Upgrading CWP's (installing 6 m ³ storage, pipelines fittings and drainage)	pcs	15
New CWP's (6 m ³ storage, pipelines, standpipe concrete work, fittings, drain)	pcs	20

Preliminaries:

This are the expenditures from the contractor before he can start with the actual work. Generally taken as 10% of the total costs.

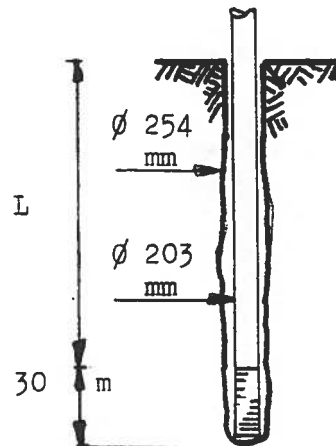
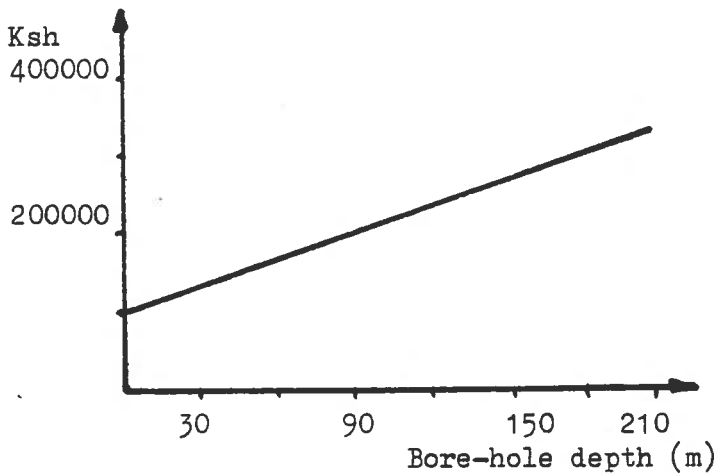
The following costs are obtained from the EAPL. The costs include taxes and represent the price level of July 1982.

Powerline (10 KV)	km	50
Transformer (50 KVA)	pcs	20

The prices of pumps and engines are obtained from a local supply agent. The prices include taxes and represent the July 1982 price level.

BORE-HOLE COSTS

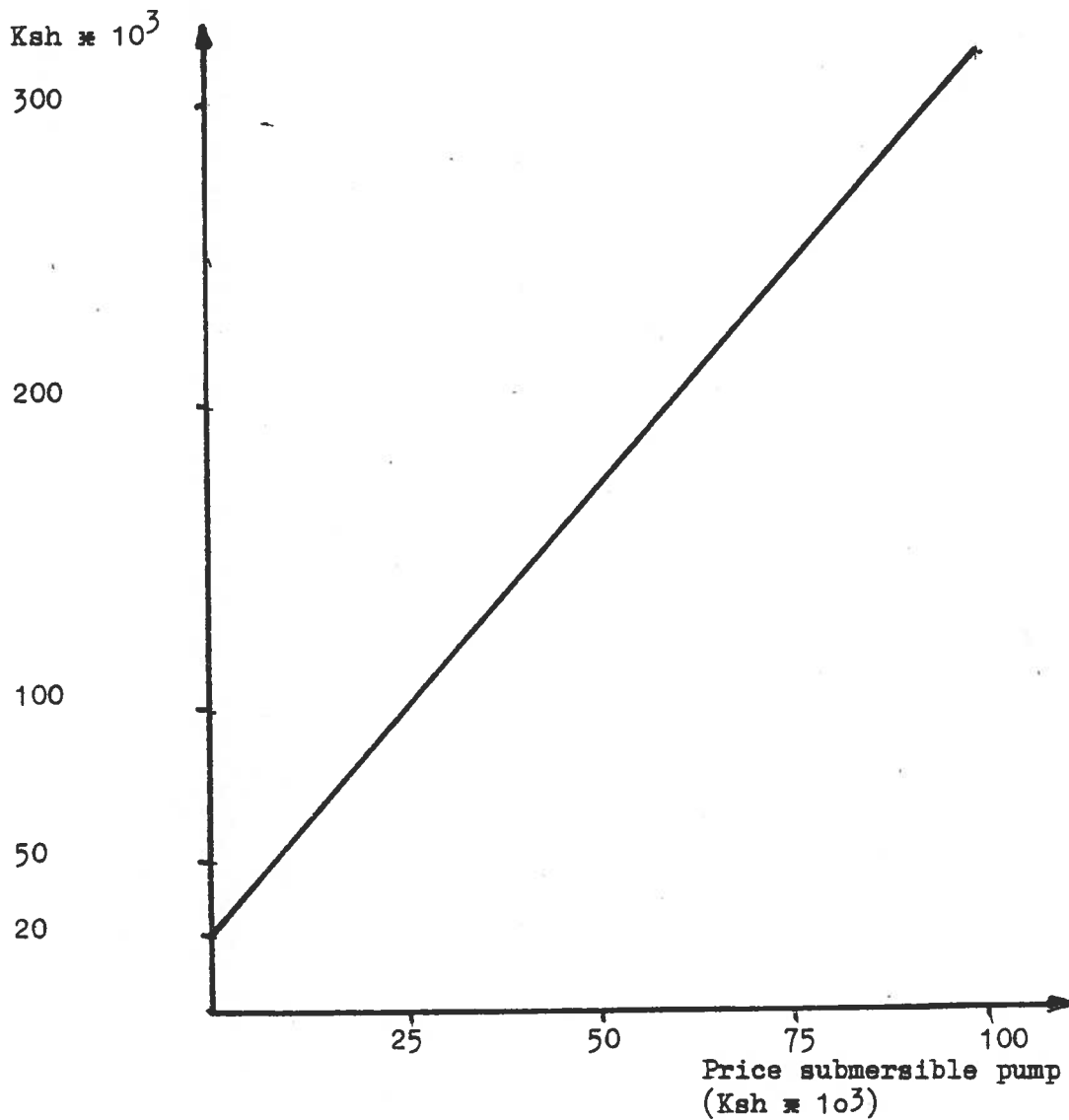
Source: M.b.W.D - July 1982



		borehole	costs
1.	Mobilization and transport of whole drilling unit 100 km à 23	2,300	
2.	Erecting and dismantling	8,700	
3.	Drilling ϕ 254 mm L + 30 m à 263 Ksh/m	7,890	263 x L
4.	Borehole logging L + 30 m à 30 Ksh/m	900	30 x L
5.	Insert plain steel casing L m à 225 Ksh/m		255 x L
6.	Supply cost plain steel casing (203 mm) L m à 439 Ksh/m		439 x L
7.	Bridge slot screen ϕ 203 mm 30 m à 1,800 Ksh/m	54,000	
8.	Gravel pack 10 m ³	10,000	
9.	Cementation	1,000	
10.	Development; installation and removal of development equipment - actual development	3,000	
11.	Installation of testpump equipment and removal actual testpumping	15,360	
12.	Preparation well heaf, cleaning	2,000	
		107,150	987 x L

SAY COSTS ARE 110,000 + 1,000 x L

Figure 1 - Breakdown bore-hole costs

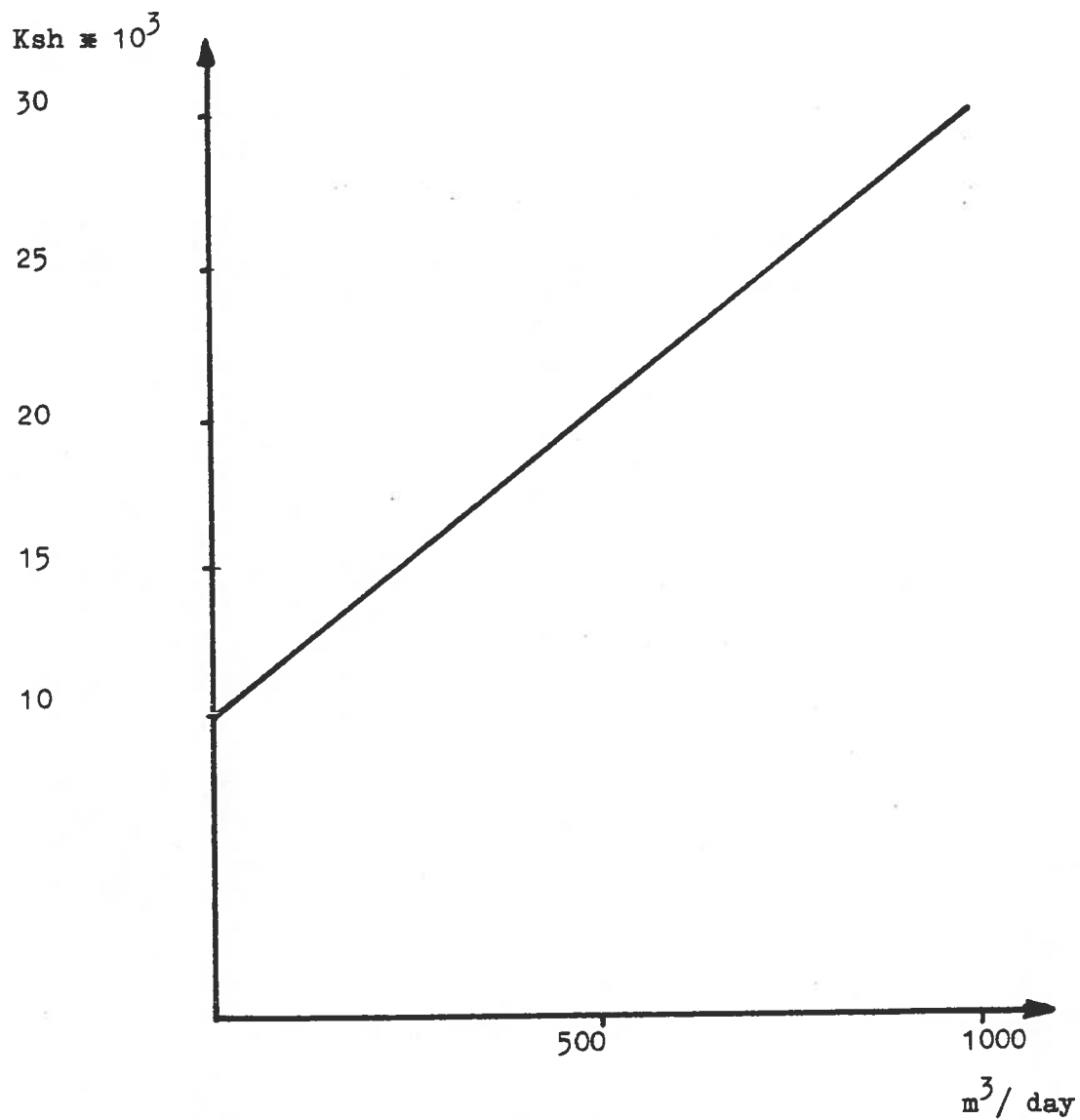


Well installation costs.

Including: Gantry, Rising main, Cable, Switch gear,
Wiring, Air valve, Fittings.

Source: M.o.W.D. July 1982

Figure 2: Installation costs production wells



Treatment costs for free CO₂ removal
and pH adjustment.
Including: Tanks, Buildings, Dosing equipment, Installation etc.

Source: M.o.W.D. - July 1982.

Figure 3: Water treatment costs

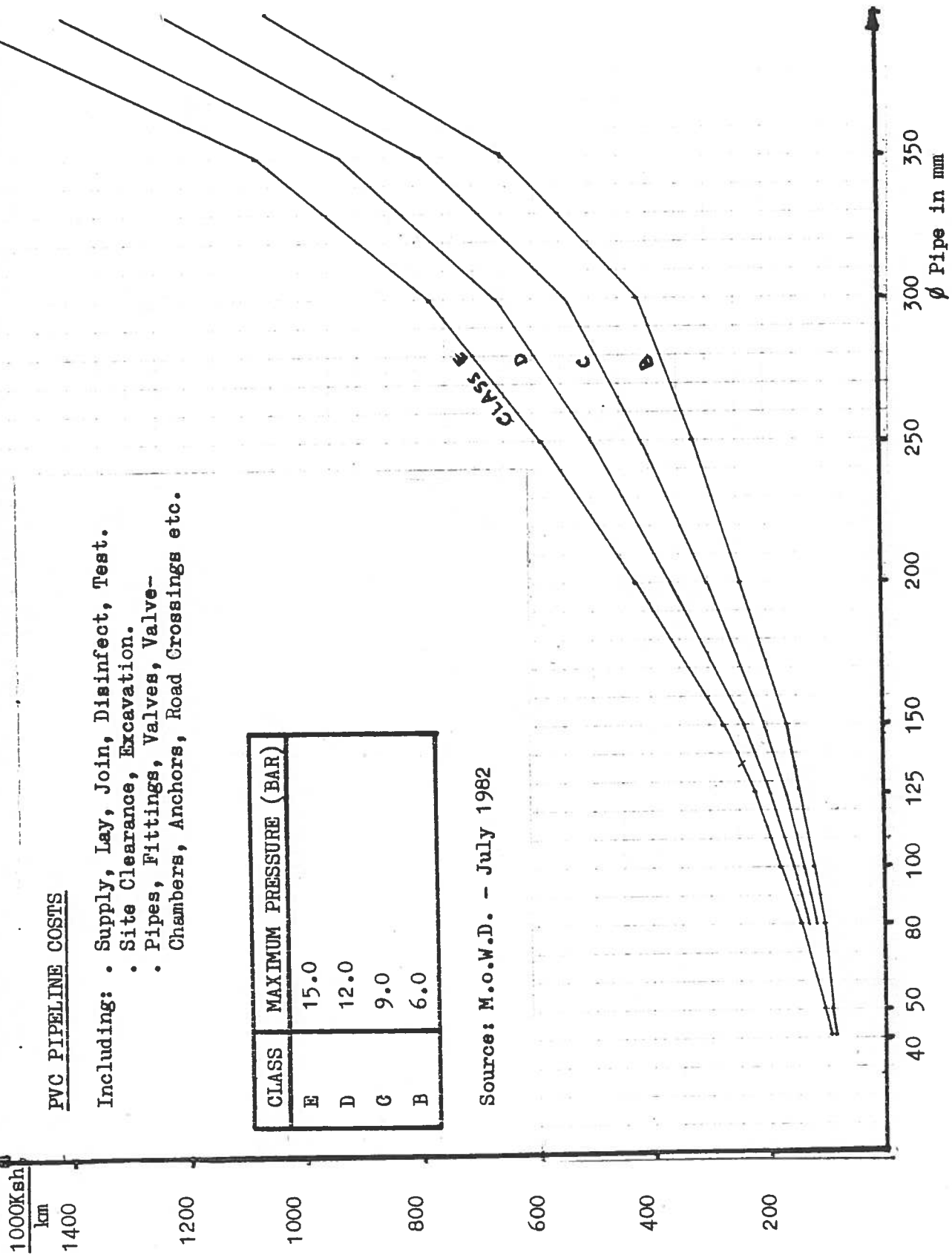
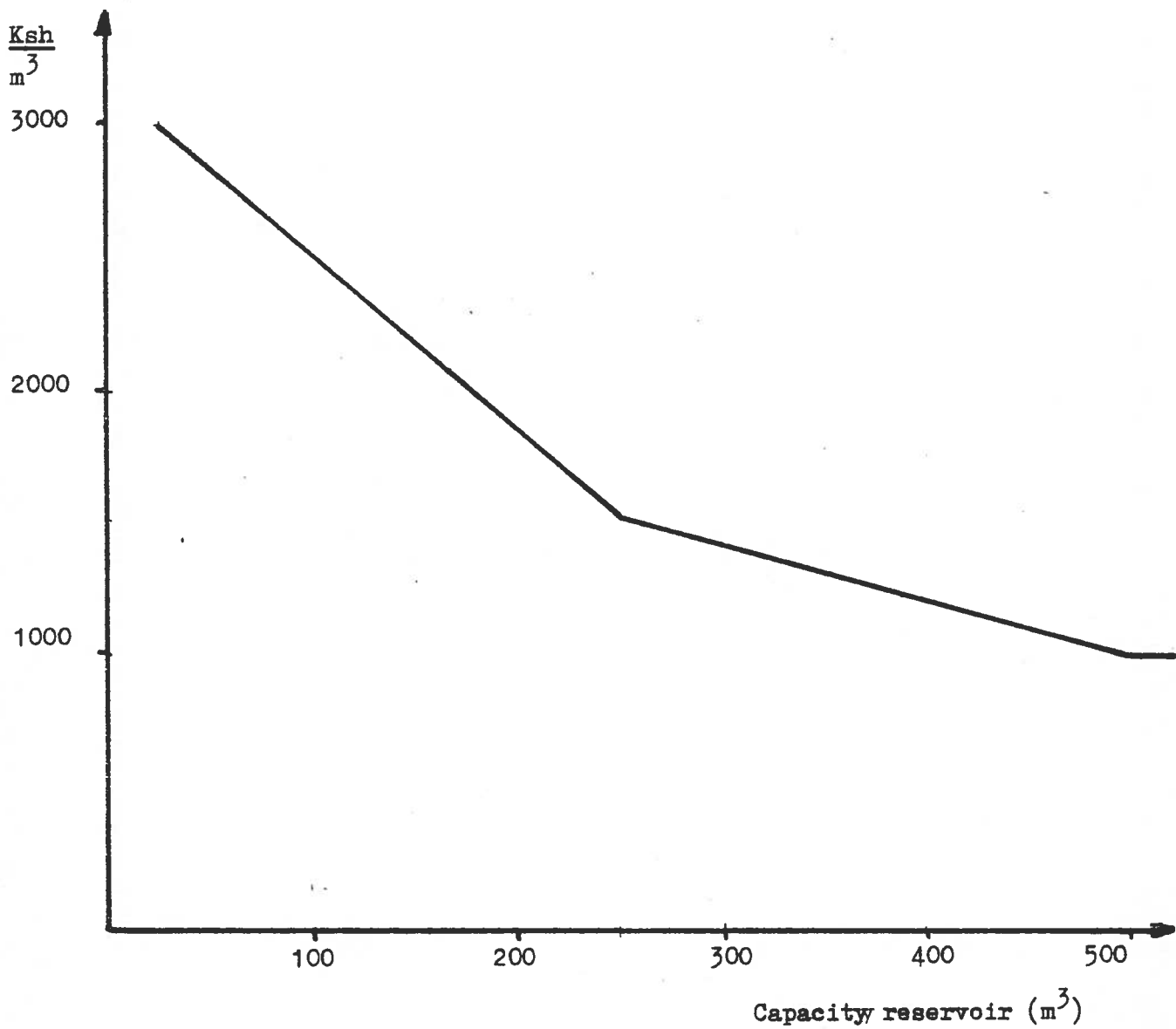


Figure 4: Pipeline costs.



Storage reservoirs according to standard designs M.o.W.D.

Source: M.o.W.D.

Figure 5: Storage costs.

2. PROJECT INVESTMENT COSTS

2.1. Rehabilitation and extensions Bathi W/S

	quantity	unit costs	costs Ksh
<u>Reservoirs</u>			
100 m ³	5	2,500 Ksh/m ³	1,250,000
200 m ³	2	1,800 Ksh/m ³	720,000
<u>CWP</u>			
New	30	20,000 Ksh	600,000
Upgrading	80	15,000 Ksh	1,200,000
<u>Extensions</u>			
Line D upto Nduma Ø 80 mm	3 km	130,000 Ksh/km	390,000
Connection between mainline and BH C2758 Ø 80 mm	3 km	130,000 Ksh/km	390,000
Change pipeline between C2 and C3 from Ø 50 to Ø 150 mm	3 km	250,000 Ksh/km	750,000
			<u>5,300,000</u>

2.2. Production fields and connection of Bathi W/S

Legend for the figures 6-14.

	Existing bore-hole
	Planned production well
	Water-treatment
	Pumps
	Existing pipeline
	Planned pipeline
	Reservoir

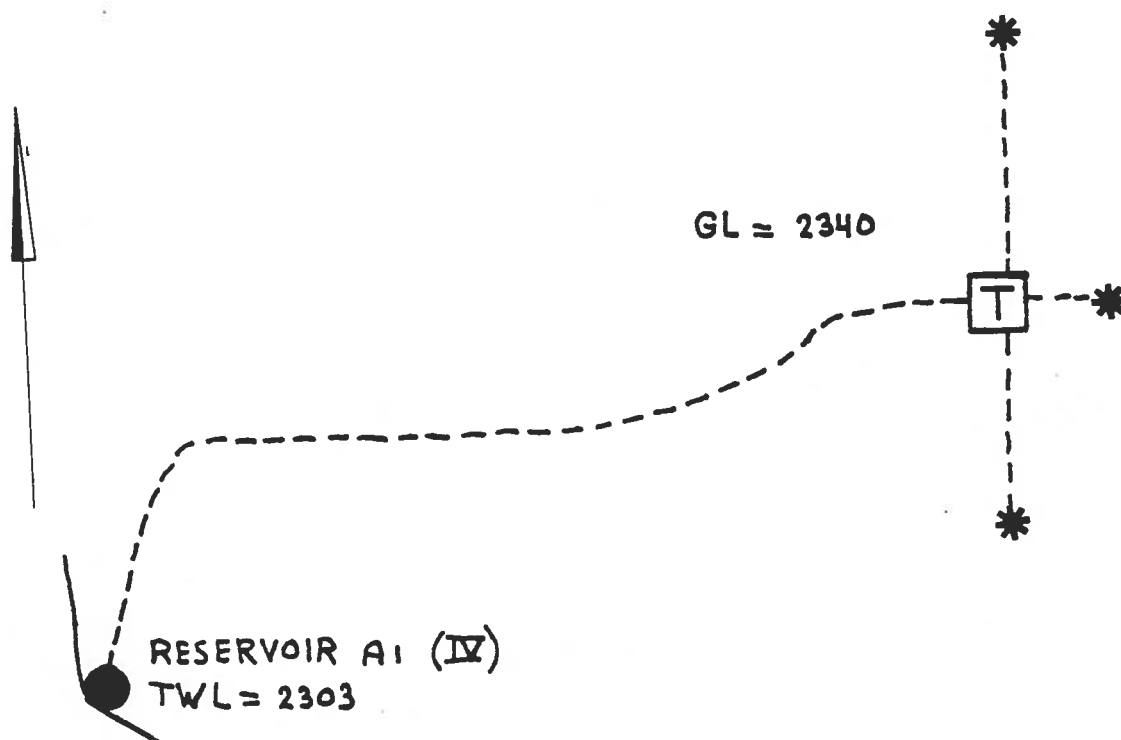


Figure 6: Production wells delivering to reservoir A1

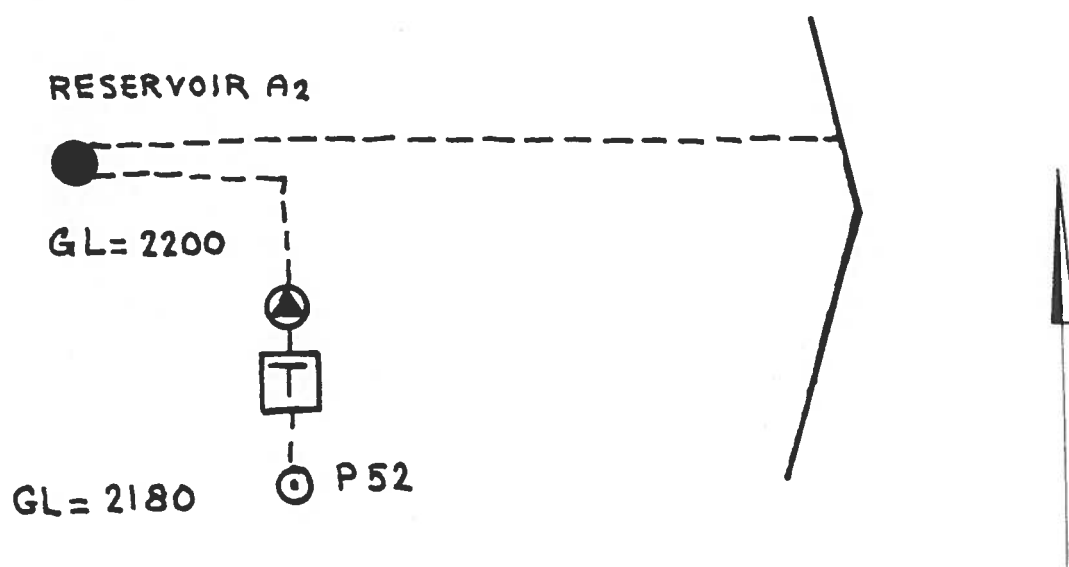


Figure 7: Production wells delivering to reservoir A2

PRODUCTION WELLS DELEVERING TO RESERVOIR: A1

MAXIMUM DAY PRODUCTION 540 m³/d (6.25 l/s)

		quantity	unit costs Ksh x 1000	costs Ksh x 1000
PRODUCTION WELLS				
existing boreholes		- pcs	-	-
new boreholes		3 pcs	300	900
installation costs (except pumps & power supply)		3 pcs	290	870
PUMPS, ENGINES AND GENSETS				
	power input kW	discharge m ³ /h	total head m	
submersible:				
- existing	-	-	-	- pcs
- new	6	10	145	3 pcs
liftpumps:				
- low	-	-	-	- pcs
- high	-	-	-	- pcs
engine (KW output):	-	-	-	- pcs
genset (KW output):	-	-	-	- pcs
POWER SUPPLY				
supply line		0.75 km	50	40
transformer & connections		3 pcs	20	60
PIPES & FITTINGS				
pipeline	Ø 100 mm	7 km	150	1050
	Ø - mm	- km	-	-
ROADS				
access road		0.75 km	100	75
CIVIL WORK				
pump house		- pcs	-	-
treatment		540 m ³ /d	-	20
staff house		1 pcs	180	180

PRODUCTION WELLS DELEVERING TO RESERVOIR: A2

MAXIMUM DAY PRODUCTION 91 m³/d (1 l/s)

	quantity	unit costs Ksh x 1000	costs Ksh x 1000
PRODUCTION WELLS			
existing boreholes: P52	1 pcs	-	-
new boreholes	- pcs	-	-
installation costs (except pumps & power supply)	1 pcs	100	100

PUMPS, ENGINES AND GENSETS

	power input kW	discharge m ³ /h	total head m			
submersible:						
- existing	3	3.8	200	1 pcs	-	-
- new	-	-	-	- pcs	-	-
liftpumps:						
- low	0.6	3.8	40	1 pcs	50	50
- high	-	-	-	- pcs	-	-
engine (KW output): 1	-	-	-	1 pcs	25	25
genset (KW output): 4	-	-	-	1 pcs	55	55

POWER SUPPLY

supply line	- km	-	-
transformer & connections	- pcs	-	-

PIPES & FITTINGS

pipeline	Ø 80 mm	1 km	130	130
	Ø - mm	- km	-	-

ROADS

access road	- km	-	-
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CIVIL WORK

pump house	1 pcs	75	75
treatment	91 m ³ /d	-	15
staff house	1 pcs	180	180

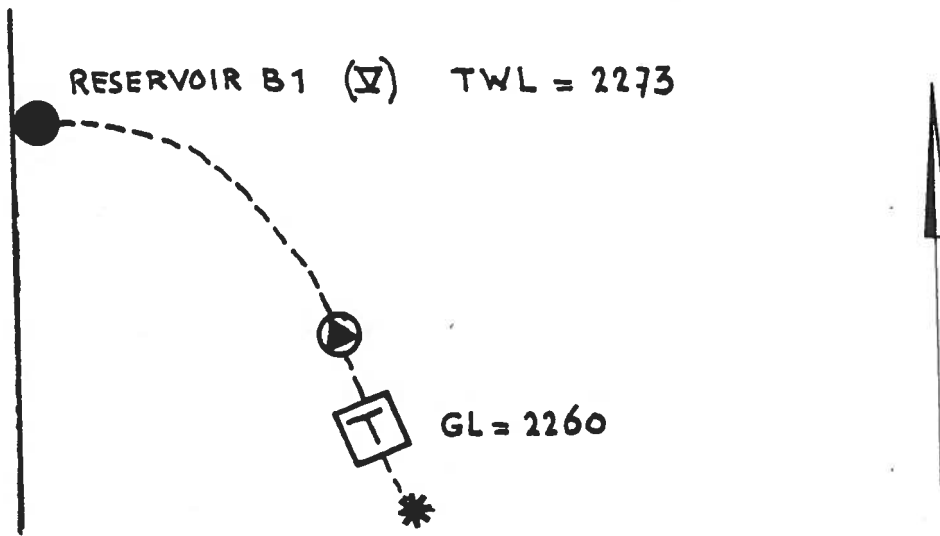


Figure 8: Production wells delivering to reservoir B1

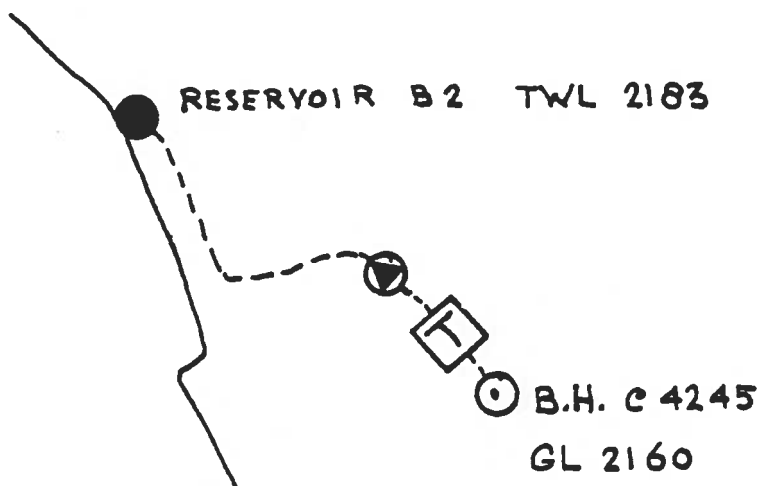


Figure 9: Production wells delivering to reservoir B2

PRODUCTION WELLS DELEVERING TO RESERVOIR: B1

MAXIMUM DAY PRODUCTION 200 m³/d (2.3 l/s)

	quantity	unit costs Ksh x 1000	costs Ksh x 1000
PRODUCTION WELLS			
existing boreholes:	- pcs	-	-
new boreholes	1 pcs	300	300
installation costs (except pumps & power supply)	1 pcs	275	275

PUMPS, ENGINES AND GENSETS

	power input kW	discharge m ³ /h	total head m			
submersible:						
- existing	-	-	-	- pcs	-	-
- new	5	10	120	1 pcs	85	85
liftpumps:						
- low	1.5	10	35-	1 pcs	50	50
- high	-	-	-	- pcs	-	-
engine (KW output):	1.5	-	-	1 pcs	25	25
genset (KW output):	-	-	-	- pcs	-	-

POWER SUPPLY

supply line	2.5 km	50	130
transformer & connections	1 pcs	20	20

PIPES & FITTINGS

pipeline	Ø 50 mm	1 km	100	100
	Ø - mm	- km	-	-

ROADS

access road	0,25 km	100	25
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CIVIL WORK

pump house	1 pcs	75	75
treatment	200 m ³ /d	-	15
staff house	1 pcs	180	180

PRODUCTION WELLS DELEVERING TO RESERVOIR: B2

MAXIMUM DAY PRODUCTION 330 m³/d (3.8 l/s)

		quantity	unit costs Ksh x 1000	costs Ksh x 1000
PRODUCTION WELLS				
existing boreholes: C 4245		1 pcs	-	-
new boreholes		- pcs	-	-
installation costs (except pumps & power supply)		1 pcs	290	290
PUMPS, ENGINES AND GENSETS				
	power input kW	discharge m ³ /h	total head m	
submersible:				
- existing	-	-	-	- pcs
- new	7	13.6	140	1 pcs
lift pumps:				
- low	2.5	13.6	40	1 pcs
- high	-	-	-	- pcs
engine (KW output):	2.5	-	-	1 pcs
genset (KW output):	-	-	-	- pcs
POWER SUPPLY				
supply line		0.0 km	-	-
transformer & connections		1 pcs	20	20
PIPES & FITTINGS				
pipeline	Ø 80 mm	2 km	130	260
	Ø - mm	- km	-	-
ROADS				
access road		- km	-	-
CIVIL WORK				
pump house		1 pcs	75	75
treatment		330 m ³ /d	-	20
staff house		1 pcs	180	180

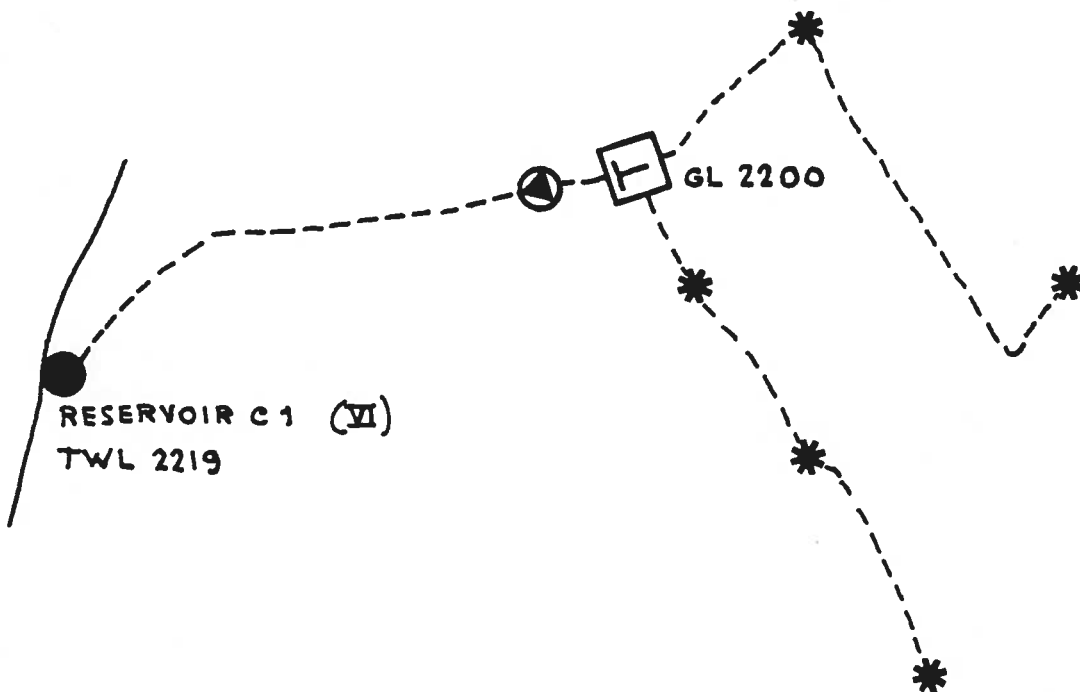


Figure 10: Production wells delivering to reservoir C1

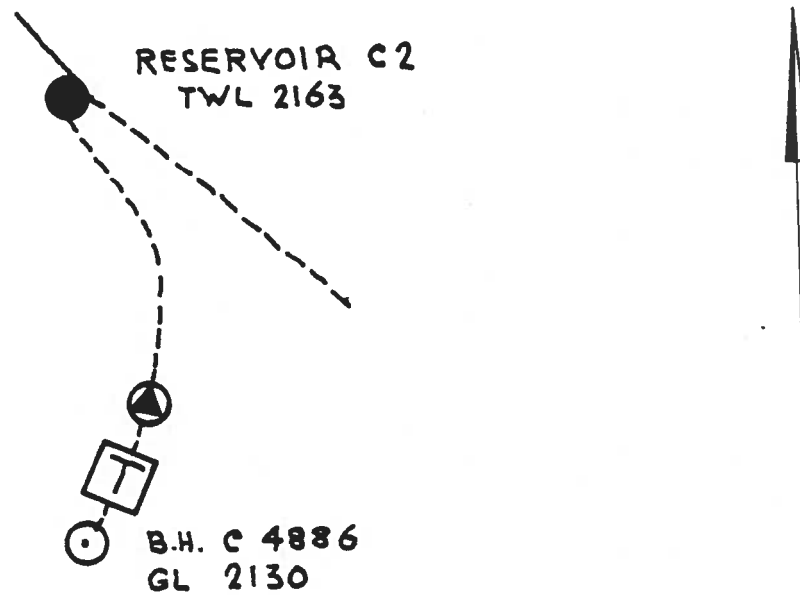


Figure 11: Production wells delivering to reservoir C2

PRODUCTION WELLS DELEVERING TO RESERVOIR: C1

MAXIMUM DAY PRODUCTION 970 m³/d (11.2 l/s)

	quantity	unit costs Ksh x 1000	costs Ksh x 1000
PRODUCTION WELLS			
existing boreholes: P52	- pcs	-	-
new boreholes	5 pcs	300	1500
installation costs (except pumps & power supply)	5 pcs	290	1450

PUMPS, ENGINES AND GENSETS

	power input kW	discharge m ³ /h	total head m			
submersible:						
- existing	-	-	-	- pcs	-	-
- new	6	10	150	5 pcs	90	450
liftpumps:						
- low	4.5	25	45	2 pcs	50	100
- high	-	-	-	- pcs	-	-
engine (KW output):	4.5	-	-	2 pcs	30	60
genset (KW output):	-	-	-	- pcs	-	-

POWER SUPPLY

supply line	3 km	50	150
transformer & connections	5 pcs	20	100

PIPES & FITTINGS

pipeline	Ø 150 mm	3 km	250	750
	Ø 100 mm	3 km	150	450

ROADS

access road	0.5 km	100	50
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CIVIL WORK

pump house	1 pcs	75	75
treatment	970 m ³ /d	-	30
staff house	2 pcs	180	360

PRODUCTION WELLS DELEVERING TO RESERVOIR: C2

MAXIMUM DAY PRODUCTION 180 m³/d (2.1 l/s)

	quantity	unit costs Ksh x 1000	costs Ksh x 1000
PRODUCTION WELLS			
existing boreholes: C 4886	1 pcs	-	-
new boreholes	- pcs	-	-
installation costs (except pumps & power supply)	1 pcs	290	290

PUMPS, ENGINES AND GENSETS

	power input kW	discharge m ³ /h	total head m			
submersible:						
- existing	-	-	-	- pcs	-	-
- new	4	7.5	140	1 pcs	90	90
liftpumps:						
- low	1.5	7.5	40	1 pcs	50	50
- high	-	-	-	- pcs	-	-
engine (KW output):	1.5	-	-	1 pcs	25	25
genset (KW output):	-	-	-	- pcs	-	-

POWER SUPPLY

supply line (from planned borehole C3)	2 km	50	100
transformer & connections	1 pcs	20	20

PIPES & FITTINGS

pipeline	Ø 80 mm	1 km	130	130
	Ø 100 mm	4 km	150	600

ROADS

access road	- km	-	-
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CIVIL WORK

pump house	1 pcs	75	75
treatment	180 m ³ /d	-	15
staff house	1 pcs	180	180

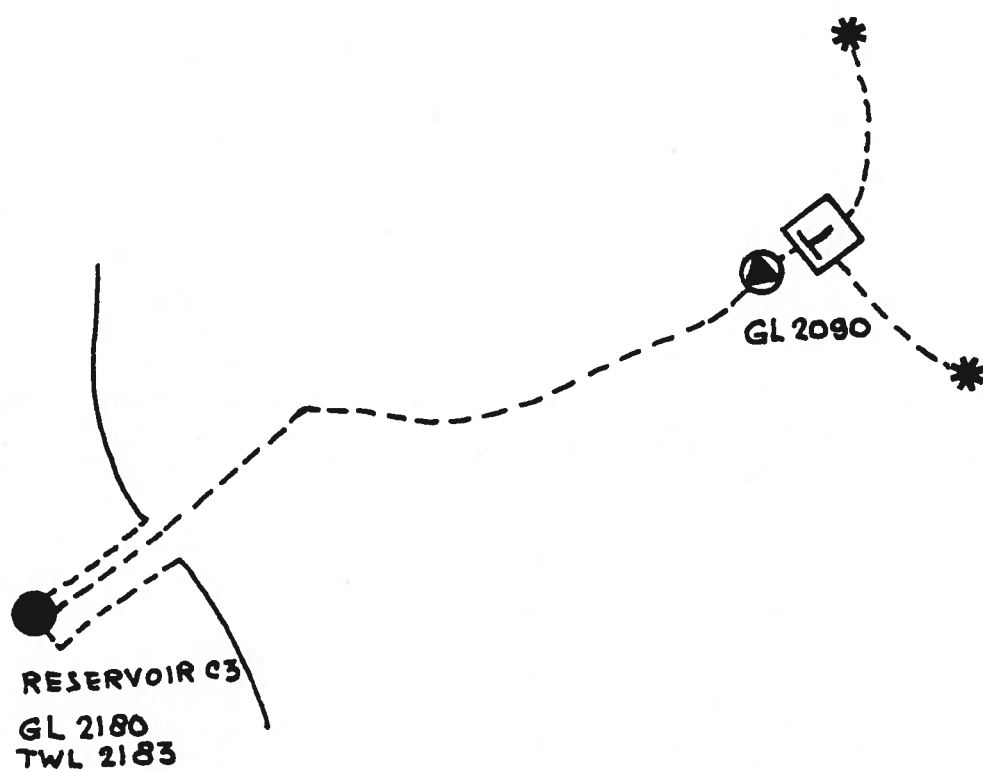


Figure 12: Production wells delivering to reservoir C3

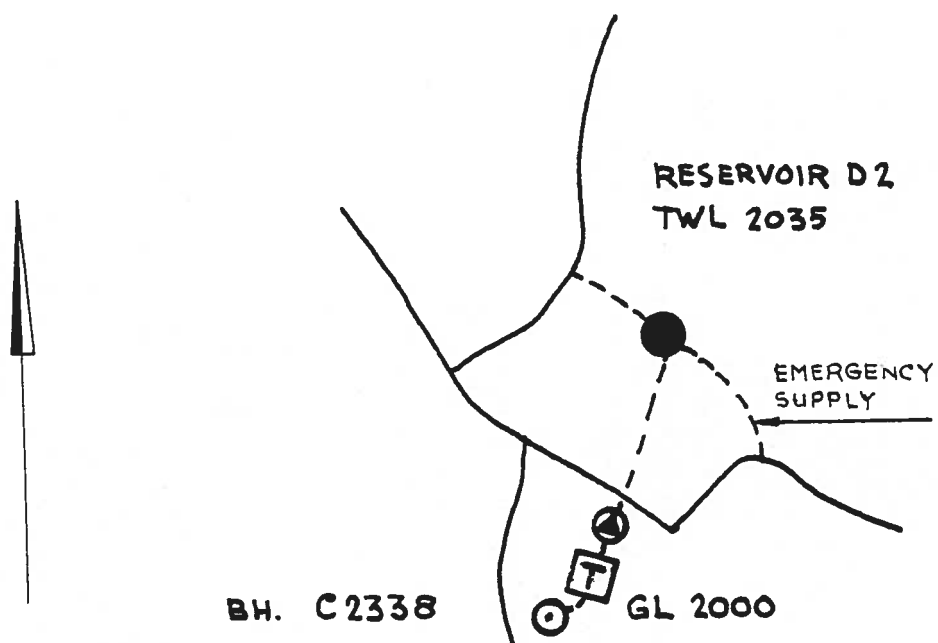


Figure 14: Production wells delivering to reservoir D2

PRODUCTION WELLS DELEVERING TO RESERVOIR: C3

MAXIMUM DAY PRODUCTION 480 m³/d (5.6 l/s)

	quantity	unit costs Ksh x 1000	costs Ksh x 1000
PRODUCTION WELLS			
existing boreholes:	- pcs	-	-
new boreholes	2 pcs	300	600
installation costs (except pumps & power supply)	2 pcs	290	580
PUMPS, ENGINES AND GENSETS			
	power input kW	discharge m ³ /h	total head m
submersible:			
- existing	-	-	-
- new	5	10	135
	- pcs	-	-
	2 pcs	90	180
liftpumps:			
- low	-	-	-
- high	6	10	150
	- pcs	-	-
	2 pcs	90	180
engine (KW output):	6	-	-
	2 pcs	90	180
genset (KW output):	-	-	-
	- pcs	-	-
POWER SUPPLY			
supply line	5 km	50	250
transformer & connections	2 pcs	20	40
PIPES & FITTINGS			
pipeline	Ø 100 mm	6 km	150
	Ø - mm	- km	-
ROADS			
access road	0.5 km	100	50
CIVIL WORK			
pump house	1 pcs	75	75
treatment	480 m ³ /d	-	20
staff house	2 pcs	180	360

PRODUCTION WELLS DELEVERING TO RESERVOIR: D1

MAXIMUM DAY PRODUCTION 740 m³/d (8.6 l/s)

			quantity	unit costs Ksh x 1000	costs Ksh x 1000
PRODUCTION WELLS					
existing boreholes: C 4861, C 4850			2 pcs	-	-
new boreholes			1 pcs	300	300
installation costs (except pumps & power supply)			3 pcs	290	870
PUMPS, ENGINES AND GENSETS					
	power input kW	discharge m ³ /h	total head m		
submersible: new	4	10	100	1 pcs	70
	5	11	100	1 pcs	90
	6	22	70	1 pcs	90
low liftpumps:	3.5	20	40	1 pcs	50
	1.6	10	40	2 pcs	50
engine (KW output):	3.5	-	-	1 pcs	25
	2	-	-	2 pcs	25
genset (KW output):	-	-	-	- pcs	-
POWER SUPPLY					
supply line			3 km	50	150
transformer & connections			3 pcs	20	60
PIPES & FITTINGS					
pipeline	Ø 100 mm		13 km	150	1950
	Ø - mm		- km	-	-
ROADS					
access road			0.75 km	100	75
CIVIL WORK					
pump house			1 pcs	75	75
treatment			740 m ³ /d	-	25
staff house			2 pcs	180	360

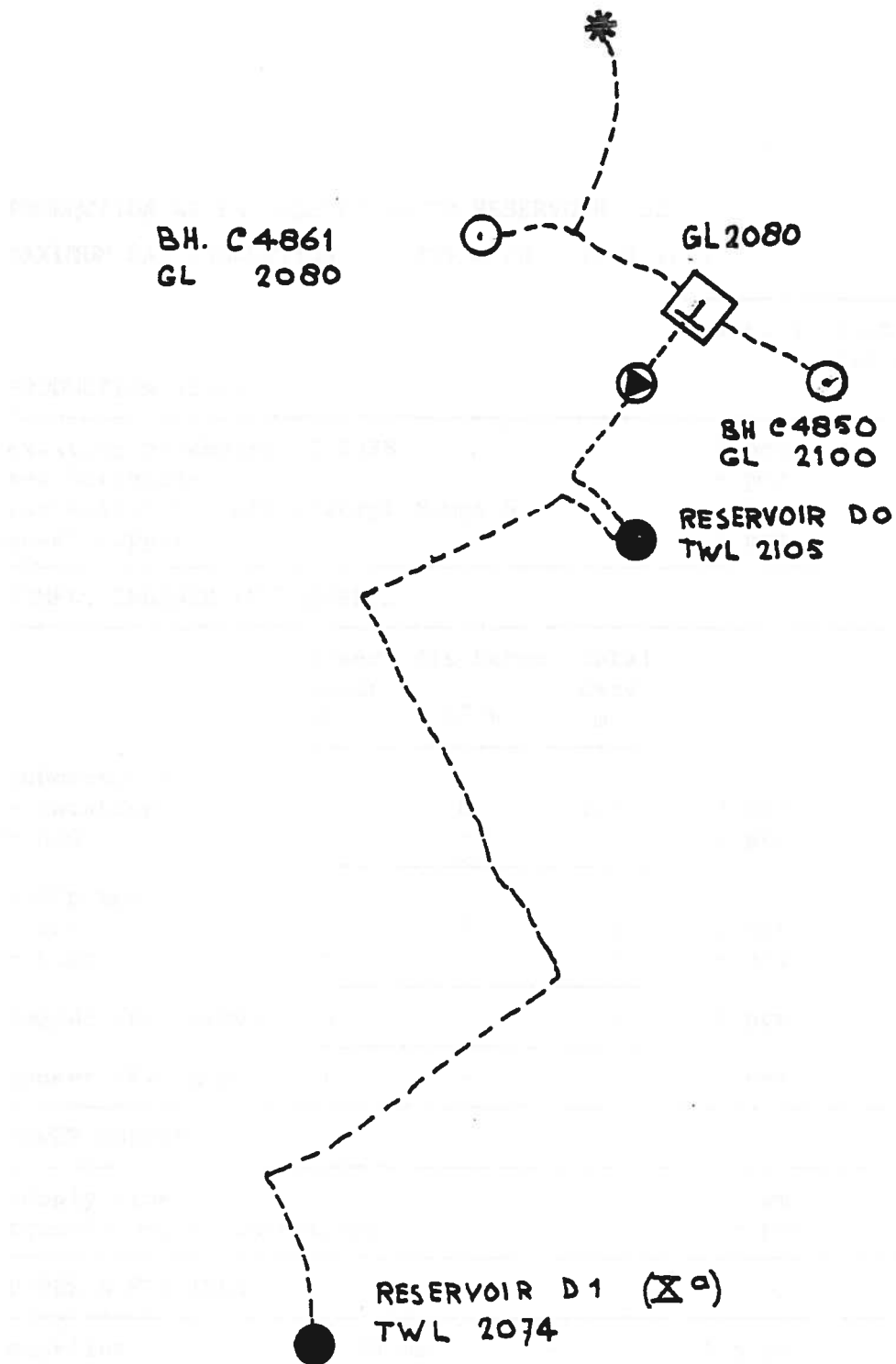


Figure 13: Production wells delivering to reservoir D1