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MINISTRY OF WATER DEVELOPMENT

THE STUDY ON THE NATIONAL WATER MASTER PLAN

SECTORAL REPORT (M)

INTEGRATED WATER RESOURCES DEVELOPMENT PLANNING

JULY 1992

JAPAN INTERNATIONAL COOPERATION AGENCY

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2.	Vol.2	Master Action Plan towards 2000 Part 1 : National Water Master Action Plan
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PREFACE

Interpretation of Report

The original objective of this NWMP Study is to propose a nationwide framework for orderly planning and development of water resources in the country. The Study also deals with the formulation of individual development schemes. However, it should be noted that the plans formulated in this Study remain at a national level and do not provide complete details at local level. Further details should be examined in subsequent studies on each river basin, district, and project basis which are separately recommended in this Study.

Administrative Division of Districts

In this Study, the original 41 districts were considered and various statistical data, particularly socio-economic information, were collected for these districts. During the progress of the Study, six districts were detached from the original ones and established as new districts. In the report, the data on these new districts are grouped together with the corresponding original districts as shown below.

	Original Districts	New Districts	Data included in:
1.	Machakos	Makueni	Machakos/Makueni
2.	Kisii	Nyamira	Kisii/Nyamira
3.	Kakamega	Vihiga	Kakamega/Vihiga
4.	Meru	Tharaka-Nithi	Meru/Tharaka-Nithi
5.	Kericho	Bomet	Kericho/Bomet
6.	South Nyanza	Migori	South Nyanza/Migori

(Note: The last three Districts were established very recently.
The report refers only to the names of the original 41 districts.)

The administrative boundary map used in this Study is the latest complete map set covering the whole country (41 Districts, 233 Divisions and 976 Locations), prepared in 1986 by the Survey of Kenya, Ministry of Land, Housing and Physical Planning.

Data and Information

The data and information contained in the report represent those collected in the 1990-1991 period from various documents and reports made available mostly from central government offices in Nairobi and/or those analyzed in this Study based on the collected data. Some of them may be different from those kept in files at some agencies and regional offices. Such discrepancies if any should be collated and adjusted as required in further detailed studies of the relevant development projects.

Development Cost

The cost and benefit estimate was based on the 1991 price level, and expressed in US$ equivalent according to the exchange rate of US$1 = KShs25.2 prevailing at that time. The same exchange rate was used in calculating the development cost in K£/KShs currency.

THE STUDY ON THE NATIONAL WATER MASTER PLAN

SECTORAL REPORT (M)
INTEGRATED WATER RESOURCES DEVELOPMENT PLANNING

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M1. INTRODUCTION

Water resource is an important constituent in practically every phase of social and economic life. Successful and well balanced planning for water resource development takes an important role in view of limited availability and geographical maldistribution of water sources. Experience has proved that the supply of clean water to an individual is the foundation on which rests the health and economic progress of the community.

The rate of water use is affected by climate and ecological factors. There are relatively abundant water sources in high potential land areas than in medium and low potential areas, and this is reflected in the distribution of population and the level of economic development. In most areas of low potential, the population density is very low and the cost per capita of water supply schemes in these areas is considerably higher than elsewhere, assuming the same degree of services.

Urban centres have been more advantaged in the supply of piped water than rural areas. The advantage lies in the fact that local authorities have methods of raising revenues which make them competent to borrow from international banks at low rates of interests.

The development of rural community centres was a government strategy for developing rural areas. The government then provided amenities at these community centres, one of which was public health and a communal water supply point for domestic and livestock water supplies.

Water supply for irrigation development is also important to achieve food self-sufficiency in major food production. To develop irrigation potential areas, the schemes with high priority can be drawn up considering government policy and present socioeconomic condition of Kenya; they are, (i) small scale irrigation, (ii) irrigation area adjoining densely populated District or Location and (iii) the area where only irrigation is the watering method for agriculture.

The hydropower development is in and around geographical region of the Kenya Highlands which provide the two important sources for hydropower generation; they are, (i) perennial river flow providing water source and (ii) water head as the difference in elevation. At present, hydroelectric power generation plays a key role in supply of electric power in the country. As of June 1989, the share of hydropower stations is 70% in terms of the installed capacity and 87% in energy supply including energy import from Uganda.

On the other hand, Kenya is blessed with abundant wildlife, one of the most valuable natural resources in the country. Wildlife viewing is a major component of the tourism industry which is an important source of foreign exchange for the national economy. To supply the watering points for wildlife is therefore inevitable under the formulation of development plan.

Water resource development by the above major water use sectors has carried out independent of one another because the combined demand in the past did not exceed the readily available water sources. However, the shortage of water has already identified in many places of the country at the year 1990 level of demand in spite of the available water resources exceeding the combined demand as a whole.

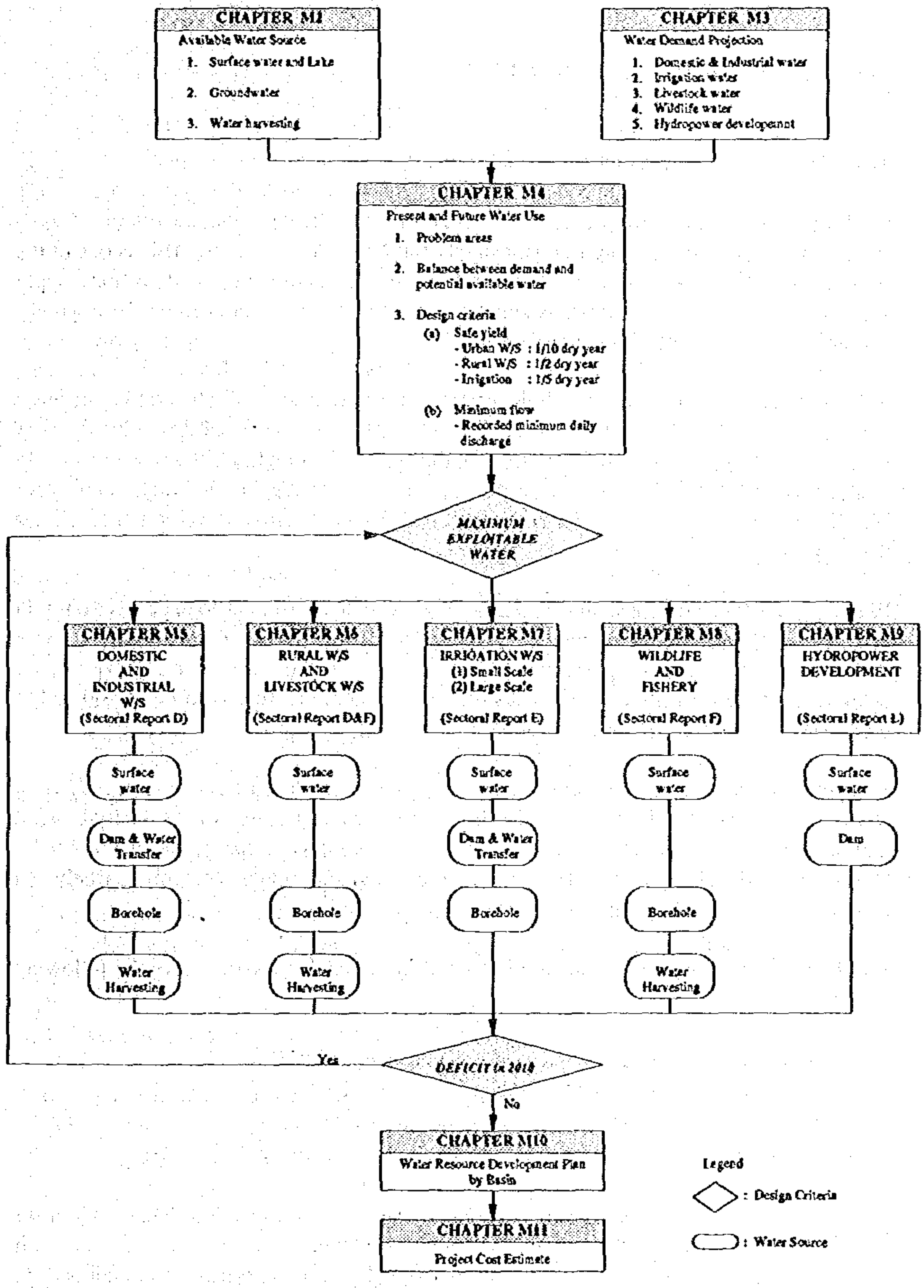
As the readily available water sources of major water demand appears to have already been committed, an integrated approach to the development of water sources will be necessary to meet the requirement of all the sectors of major water demand to avoid competition and conflict in water use and to optimize the use of limited water resources.

The available water sources and their water costs in the 1990 price level are described in Chapter M2. Chapter M3 shows present water demand of major sectors and the projection of combined water demand in the year 2010. Chapter M4 describes the present condition of water balance in Kenya and the design criteria for the integrated water resource development towards the year 2010.

Development policies for major water use sectors are depicted in Chapters M5 to M9; they are, domestic and industrial water supply (Sectoral Report D), rural and livestock water supply (Sectoral Reports D and F), irrigation water supply (Sectoral Report E), wildlife and fishery (Sectoral Report F) and hydropower development (Sectoral Report L).

Chapter M10 describes the integrated water resource development plan towards the year 2010 by basin. The plan is established with the high priority of domestic and industrial water supply. The development cost for the plan is summarized in Chapter M11.

The schematic diagram for integrated water resource development is shown below.



Schematic Diagram for Integrated Water Resource Development

M2. AVAILABLE WATER SOURCES

2.1 Source Development

In Kenya, many water supply systems depend on unreliable water sources, and such systems have been affected by frequent supply failure for long periods. This is one of the reasons why the consumers in the service area are reluctant to support the water supply systems. It is a fact that some systems having received less support have been poorly maintained to the extent of being broken down.

The water holding capacity of the drainage areas in Kenya is generally low and river flows reach their minimum flow almost every two years or so. As a result of this, a low level of supply reliability, for example 80 % dependability, causes supply failure in almost every two years or so. It becomes necessary to select a rather high supply reliability, not only for benefits of water users but also for sustainability of water resources development facilities themselves.

Water source development shall proceed from less expensive sources to expensive ones, in principle. Development of clean and perennial flow (river or spring) by gravity transmission offers the cheapest alternative. However, most of such sources have already been utilized. In this Study, every possible development measure is to be considered in order to balance water demand and supply.

Source development, such as interbasin water transfer to closed river basins, may raise environmental issues. If environmental issues are to be considered on a priority basis, it may cause other social and economic issues which are beyond the scope of this Study. Hence source development for balancing water demand and supply is examined firstly and related issues are examined in Sectoral Report N.

Available water sources development in Kenya were mainly classified into the following methods;

(a) Water supply from perennial main river channel and lakes,
(b) Water transfer from the other subbasins,
(c) Groundwater, and
(d) Water harvesting

2.2 Surface Water

2.2.1 Perennial rivers

Surface water has been predominantly utilized among water resources in Kenya. Present water balance shows that the readily available water has been consumed in the sub basins with major water demand.

In such sub basins, it is necessary not only to develop a water supply system to provide consumptive water but also to augment available surface water by constructing storage dams for flow regulation. If no potential damsite is in the sub basin and no additional storage is available, it is further necessary to transfer water firstly from another sub basin in the same river basin (intra-basin water transfer) and secondly from another river basin (inter-basin water transfer).

The present water abstraction of surface water can be estimated based on the water permit data in the database of MOWD. The data is classified into two categories: that is, (i) under normal flow condition and (ii) under flood flow condition. According to MOWD's information, in case that the river water level at water abstraction point is lower than 80% of annual mean water level, the water permit on flood flow condition is not effective - namely, the water permit on normal flow condition has been issued mainly for the purpose of domestic water supply, while those on flood flow condition have been issued for irrigation water supply. The water permit data on normal flow condition are enumerated below.

Surface water abstraction rates by drainage area
(normal flow condition)

(Unit: MCM/year)

Drainage Area	1	2	3	4	5	Total
Water Permit	254.3	46.8	133.1	595.4	42.1	1,071.7

Source : Water permit database, MOWD

2.2.2 Lakes

The fresh water lakes holds about 315 MCM of water that is currently underutilized. It is expected that domestic water supply and small-scale irrigation projects in the riparian areas will be initiated to utilize the lake water. Besides, irrigation, fish farming and recreational use of lakes will be added forms of economic activities that might boost development around the lakes.

2.3 Groundwater

The major use of boreholes is for domestic, industrial, irrigation and livestock water supplies. Of the registered 9,462 boreholes in the database of MOWD, 2,147 boreholes are utilized for public water supply although about half of boreholes have no information.

From the results of the well survey carried out under this study, the ratio of production to the sum of initial yield was estimated at 22.6%. Using this ratio, the present groundwater abstraction rate in Kenya is estimated at 57.2 million m^3/year as enumerated below.

Estimated groundwater abstraction rates by drainage area

(Unit: MCM/year)

Drainage Area	1	2	3	4	5	Total
Abstraction Rates	9.34	11.67	27.76	4.79	3.65	57.21

Source: Sectoral Report C

2.4 Water Harvesting

Water harvesting, which has been practiced for many years in the arid and semi-arid regions, is the process in which rainfall from house roofs and runoff from small catchment area is redirected and collected in tanks and reservoirs for the consumption mainly during the dry months. It is particularly suited for the supply of water for small domestic and livestock demands.

The potential for water harvesting providing a viable water supply at specified locations is mainly determined by the following conditions.

- The amount of rainfall and its seasonal variation,
- Availability of existing catchment surface such as rocks and corrugated iron roofs,
- Cost of water harvesting,
- Availability of alternative source, and
- Cultural acceptability

In the Study, a method with relatively high reliability among water harvesting methods was adopted to the allocation study for source development.

2.4.1 Small dam

Small-scale earth dams or pans are designed to provide either seasonal water lasting only during the rains and for a short time in seasonal rivers or alternatively as permanent and reliable water sources in perennial rivers. However, its retention of water depends on low permeability of the soils. An experimental result at Baringo District (Ref.M.1) shows that the working range of seepage for the observed pans was 2 mm/day in depth for 3 m deep-pan on an average.

The location and number of existing small dams and pans which were extracted from the topographic map of 1:50,000 scale are shown in Table M2.1 and Figure M2.1, respectively. However, it should be noted that the small dams that have not been inserted in the topographic maps have not been included. From the figure it can be seen that the existing small dams and pans are mostly distributed in semi-humid and semi-arid areas and within the range of more than 400 mm of annual rainfall. It is conceivable that for scattered and small water demand, small dam and pan are unquestionably reliable water sources in view of their relatively low construction cost and unreliable rainfall compared with a large dam.

The typical layout of small dam is shown in Figures M2.2 and M2.3. The average storage capacity for water supply was assumed to be 50,000 m^3 and about 77,600 m^3 of gross storage is estimated including sediment and evaporation loss in reservoir. The small dam often requires rehabilitation by desiltation to maintain its life-span. A storage balance calculation with 90% dependability was carried out for various catchment area for each subbasin as given in Appendix M.1. The water cost was estimated at 0.18 US$/$m^3$ on an average.

2.4.2 Roof catchment

Rainwater from sheet metal or corrugated roofs of households, schools and public buildings is collected through gutters and stored in tanks for use. Water is usually of high quality and is mainly for drinking. As the population and income increases in both urban and rural areas, corrugated iron roofs are becoming popular for household. This method is suited to rural areas which are remote from more conventional water resources. Typical tanks for roof catchment are shown on Figure M2.4 (Ref.M.2).

A storage balance calculation with 90% dependability was carried out for various roof catchment areas and demands by sub basin. The following criteria were adopted to the calculation;

Initial loss	:	0.6 mm/storm in total, where direct evaporation of 0.1 mm and retention loss of 0.5 mm.
Effectiveness	:	0.8 (for removal of dirty water)

The results are given in Appendix M.2. The water cost was estimated at US$2.92/$m^3$ on an average assuming that the average roof area was estimated at 53 m^2 for a semi-permanent house in Kenya and the construction cost of water tank with a capacity of 3 m^3 was at KShs 7,700.

2.4.3 Rock catchment

The rainfall on the exposed rock surface is collected, drained towards the lowest point and stored in a tank or reservoir. The tank or reservoir may be filled twice a year during wet seasons. Water is extracted from the tank or reservoir by gravity flow through a pipe with separate outlets for domestic and livestock consumptions. Problems associated with rock catchments include (Ref.M.3);

(1) low water quality due to the open nature of the reservoir,
(2) keeping the catchment area clean and clear of vegetation or silt,
(3) unsound wall foundation conditions,
(4) waterproofing and sealing the reservoir, and
(5) evaporation from the reservoir surface

Typical small scale structures of rock catchment are shown in Figure M2.5. However, suitable locations where rocks are exposed is quite limited in Kenya. Table M2.2 and

Figure M2.6 show the possible site for rock catchment where there is exposed rock extracted from the topographic map on a scale of 1:50,000.

An average total storage capacity of wall structure was assumed at about 600 m^3 including evaporation loss of 250 m^3. The average unit cost per 1 m^3 of water was estimated at US$0.39 on an average.

2.4.4 Subsurface/sand dams

Building subsurface or sand dam can be a good alternative to build surface dams when solving a water storage problem. This is due to the high construction cost of surface dams, evaporation losses, sedimentation and their occupation of valuable land.

(1) Subsurface dam

Subsurface vertical wall are constructed across the river bottom in the alluvium and down to the bedrock to intercept subsurface water flowing within the alluvium. The wall is usually constructed of stone masonry with a cement plaster for waterproofing the upstream face. The storage is limited due to the space taken up by the alluvium particles within the reservoir. Water quality is usually better than water from open surface reservoirs as it is less accessible to animals and human.

(2) Sand dam

Low dams with a few metres high are built across the luggas retaining only the low velocity flows which carry sand. After a few flood seasons the space behind the dam is filled with sand. Water flowing in the wadi fills the sand reservoir in the pore space.

In view of suitability of storage water in riverbed, the suitable area for the construction of subsurface flow dams was selected by the following area criteria; that is, (i) for sand dam, mainly geology excluding volcanic and quaternary in geology map and (ii) for subsurface dam, soil textures of heavy (fine textured) and medium (moderately fine texture, medium textured and moderately coarse textured) in soil map. The estimated suitable area for subsurface dam and sand dam are shown in Figures M2.7 and M2.8 respectively.

The average storage capacity of subsurface and sand dams was estimated at 3,500 m^3 for supplying water of domestic and livestock as shown on Figures M2.9 and M2.10. The unit cost per 1 m^3 of water was 0.53 US$ for subsurface flow dam and 0.39 US$ for sand dams.

M3. WATER DEMAND

3.1 Domestic and Industrial Water

(1) Water use in general

In Kenya, population has concentrated on high lands, often on ridges far from perennial water source.

In the past when population density was low, peoples living on high lands took water from small streams or springs nearby. Small water supply systems were developed relying on such water sources. Nowadays, population has grown and water demands exceed by far the supply capacity of such sources.

Perennial water sources with large quantity (perennial rivers) are often located far from the demand centers of water or in the lower elevation. Such relationship between water sources and demand centres makes water supply development in Kenya difficult and expensive.

(2) Water undertakers

The Water Act stipulates as follows:

124. (1) For the purpose of the distribution of water supplies in any area, the Minister, after consultation with the Water Resources Authority(*1), may appoint water undertakers who shall be responsible for the provision of an adequate supply of water for the area within their limits of supply, and who shall comply with the provision of this Act.

124. (3) The area of the limits of supply of a water undertaker shall be determined by the Minister, after consultation with the Water Resources Authority(*1), and water shall not be supplied by the water undertaker to any person outside such limits of supply without the prior consent of the Minister.

Water undertakers are

- Ministry of Water Development
- National Water Conservation and Pipeline Corporation
- Municipal Councils
- County Councils
- Institutions such as schools and prisons
- Kenya Railway Corporation
- Religious Organizations

(*1) The Water Resources Authority was defunct. The MOWD has been performing its function.

Water supply associations (self-help)
Private

The exact number of water undertakers is not known, although the Water Act stipulates as mentioned above. The number of the gazetted water supplies is around 500, far smaller than the existing water supply systems.

(3) Water supply systems

It is believed that there are more than 1,000 water supply systems, but the exact number is yet unknown. According to the Socioeconomic Survey carried out under this study in 1991, out of 1,783 centres, 1,570 centres reported to have water supply systems as shown below: (See Sectoral Report A)

MOWD systems	:	579	
NWCPC systems	:	188	
Community systems	:	339	
Self-help systems	:	243	
Local authority systems	:	164	
NGO systems	:	53	
Donor systems	:	4	Total : 1,570
No information	:	213	Total : 1,783

The total amount of domestic and industrial water actually supplied and consumed in all of Kenya is not known, since almost all the private systems have no measuring devices and some public water supply system also have no or broken measuring devices. The water abstraction permits give a very rough figures of 2.9 MCM/day or 130 litres per capita per day.

(4) Domestic water demand projection

For the purpose of water demand projection, the Design Manual for Water Supply in Kenya (Ref.M.4) stipulates standards and criteria. For this Study, the following planning horizon has been adopted:

initial year	1990
future	2000
ultimate	2010

- Residential demand

population projection: as explained in Sectoral Report A

service type

potential in rural area: high, medium and low potential areas

	measured by overlapping administration map on agro-climatic map by GIS
urban housing class:	The following figures were adopted. high class 5 % medium class 70 % low class 25 %
individual connection rate:	Table M3.1

- Livestock demand

livestock population	Livestock population in locations is assumed to distribute in proportion to population distribution. In urban areas, per capita livestock holding is assumed to be one forth of that in rural areas.

- Institutional demand

	Rural	Urban
boarding schools (pupil/pop.)	2 %	2 %
day schools (pupil/pop.)	28 %	28 %
Inpatient hospital (bed/1,000pop.)	0	29.9
outpatient (pop./1,000pop.)	2.5	2.5
administrative. officer (pop./1,000pop.)	0	83.6

- Commercial demand

hotels High (bed/1,000pop.)	0	4
Medium	0	8.7
Low	5	4.5
shops (no./1,000 pop.)	0	23.6

- Industrial water demand

Separately estimated as explained in next Subsection.

Unit water consumption rates as shown in Table M3.2

Domestic water demand projection was made on the Location basis. Results were presented in Sectoral Report D.

(5) Industrial water demand projection

Industrial water requirement was estimated as a product of three components : 1) the number of manufacturing establishments by industrial type; 2) value added (VA) of respective industrial types; and 3) unit water consumption rates (cubic meter per value added (KShs.billion)) by industrial type.

The former two components were already combined and estimated as "District" distribution of VA aggregated for all industrial types into a manufacturing sector. The distribution is broken down to the "Location" level up to the target year 2010.

Since information on unit water consumption rates by industrial type in Kenya are not made public, consumption rates which were surveyed in Japan in 1986 as indicative of industrialized conditions, are applied for estimation of water requirement with the following modification:

a) Monetary values such as production and value added are transferred by following foreign exchange rates: KShs16.2/US$ and J¥160/US$ (year 1986).

b) Water recirculation system was not taken into consideration in estimation of the industrial water consumption in 1988. It was assumed that water recovery would reach the level of a half of the recovery rate achieved by industrialized countries. For instance, the food, beverages and tobacco industry consumes 8,330 m^3/day/KShs. billion of value added in 1988, but it would reduce net water consumption to 6,610 m^3/day/KShs. billion in 2010, as shown in Table M3.3.

c) Industrial water requirement by "Location" was estimated by distributing the value added to each location.

Table M3.4 shows the water requirement of manufacturing industry by District to the year 2010. In 2010, water demand in Nairobi was estimated as 282 thousand m^3/day, accounting for 57% of the national total requirement. Secondly, Mombasa accounts for 14% or 67,000 m^3/day. Manufacturing establishments in Nakuru, Machakos, Kiambu, Kilifi, Uashin Gishu and Kisumu Districts would also consume plenty of water.

(6) Total potential water demand

The table below tabulates the estimated total water demand for Kenya.

Total Water Demand in Kenya

unit : Thousand m^3/day

		1990	2000	2010
Rural	Residential	376.2	560.2	932.6
	Non-residential	155.9	189.1	229.1
	Sub-total	532.1	749.3	1,161.7
Urban	Residential	491.2	1,004.5	1,642.9
	Non-residential	82.2	164.4	263.2
	Sub-total	573.4	1,168.9	1,906.1
Livestock		326.7	426.5	621.4
Industry		218.7	377.5	494.0
Total		1,650.9	2,722.2	4,183.2
Overall per capita (l/c/d)		73	89	104

(See details in Tables M3.5 to M3.7)

As shown in the above table, the potential demand for residential water in the urban areas and industrial water is projected to grow rapidly due to rapid urbanization and industrialization. Per capita levels of water consumption including livestock consumption seem moderate when taking into account the large livestock population in the country.

3.2 Irrigation Water

(1) Present condition

In Kenya three major types of irrigation are practiced, i.e. private large scale irrigation, smallholder irrigation and Government managed irrigation. Total area of irrigation covered by these three types is about 75,500 ha as tabulated below.

Irrigation Type	Area (ha)
Private Large Scale	25,800
Smallholder	27,200
Government managed	12,000
Total	65,000

The size of these schemes varied from less than 1 ha to 20,000 ha. 100 large schemes are occupying about 38,000 ha or 73% of the total area. More than 60% of the total number of schemes have area of less than 100 ha.

Monthly water use by existing irrigation scheme was estimated as shown below. While basin by basin water demand of the existing irrigation schemes are described in Sectoral Report E.

Water Use by Existing Irrigation Schemes

Unit m^3/sec

JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	Average
23.7	26.9	45.2	53.1	57.2	48.2	39.7	40.4	50.4	54.1	57.3	54.5	45.9

Note: In volume: 1,448 MCM/year or 4.0 MCM/day (annual average)

(2) Demand projection

About 160 irrigation schemes with a total area of about 118,000 ha have been proposed by various agencies as given in Table M3.8. Water demand calculation was made only for those schemes which have enough information for estimating, such as area and location.

The calculation method described in Sectoral Report E was applied except in water permit forecasting. For estimating future water permits, past trend curve was prepared for each Basin. However, it was not possible to establish a trend for all Basins. Then the annual mean water permits was applied for estimating additional water permits in future.

The estimated monthly irrigation water demand in 2010 is given in Table M3.9 as summarized below.

Irrigation Water Demand in 2010

Unit m^3/sec

JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	Average
93.4	100.4	126.1	133.9	143.9	130.4	110.2	128.6	158.6	184.3	162.5	146.4	134.9

3.3 Livestock Water

(1) Present condition

The number of livestock per subbasin was estimated by redistribution of district based livestock data in order to estimate basin by basin livestock water demand. Water demand for each subbasin in 1990 is summarized below.

Livestock Water Demand in 1990

Drainage Area	1	2	3	4	5	Total
Demand (m^3/s)	1.257	0.770	0.412	0.616	0.708	3.763
(MCM/day)	0.109	0.067	0.036	0.053	0.061	0.326

(2) Demand projection

Future carrying capacity in each District as given in Table M3.10 was estimated based on the following assumptions.

- Priority order for using land is;
  first for crop land
  second for managed pasture for grade cattle
  third for grassland for other livestock.
- Livestock may move over within crop and grass land

In this Study, projected LU in each District was used to estimate livestock water demand in each District and Location disregarding the livestock distribution stated above.

A unit water requirement of 50 litre/day /LU was used to estimate the water demand for livestock. To convert livestock population into livestock unit , average live-weight of each livestock as given in Table M3.11 and unit weight of 1LU of 450 kg were used. Average live-weight is estimated from MOLD information of herd composition and standard weight. Table M3.12 presents the calculations and the results.

3.4 Wildlife and Fishery

3.4.1 Wildlife

There are many varieties of animal species in the country. The distribution and abundances of some of these animal species are monitored and assessed by DRSRS. DRSRS has conducted a detailed survey of livestock/wildlife population over rangelands of 15 districts. The total surveyed area assessed in 1987 - 1988 is about 439,700 km^2 which is approximately 75% of total area of Kenya. The estimated numbers and distributions of the major species are mentioned in Table F2.1 of Sectoral Report F.

The major species were grouped into (i) Group-A with daily water consumption of 5.0 litre/100 kg-weight and (ii) Group-B of 2.5 litre/100 kg-weight.

On the basis of the above estimated water consumption rates and the estimated wildlife numbers, water demands for the major 20 species were calculated in 15 districts. Total daily water demand for 20 major species was estimated at about 7,700 m^3 in the 15 districts. Taking the coverage of surveyed area (75% of total area of Kenya) and many other species of wildlife into consideration, total daily water demand for wildlife would be more than 21,000 m^3 of fresh water.

3.4.2 Fishery

There is no information available at all about water consumption amount or rate for fish farming. Hence, the following assumptions were made to estimate present water use:

- water will be changed once a year
- average water depth is 1 m
- water will be supplied with compensation amounts of 5 mm for evaporation and 1 mm for percolation.

Based on these assumption, total amount of water use is estimated at about 16 million tons in whole Kenya.

Fish Farming Water Use in Kenya

Unit : million tons

	Basin 1	Basin 2	Basin 3	Basin 4	Basin 5	Total
Amount	3.4	0.3	0.8	8.1	3.6	16.2

Future fish production demand was estimated at 222,000 tons(*1) in the year 2010, however it was not possible to allocate this demand projection to the three fishery activities, i.e. marine fishery, lake fishery and fish farming. The future fish farming activity was therefore based on the trend of fish farming production. The production of fish farming was estimated at about 2,240 tons(*2) in 2010.

Assuming it is possible to achieve a national production of 2.5 t/ha in future, 896 ha of ponds would be required to produce 2,240 tons of fish. Taking into account the above assumption, the total fish farming water use in the year 2010 was estimated at about 28.6 MCM or 0.906 m^3/sec. Required 896 ha ponds will be absorbed by newly constructed reservoir which will be implemented under the dam development plan towards 2010. This dam development plan will bear about 23,000 ha of reservoir.

3.5 Hydropower

(1) Power Supply System

KPLC is operating a national power grid. The system is organized into six regions since 1989/90:-

(i) Nairobi region,
(ii) Coast region,
(iii) Central Rift Valley region,
(iv) Western region,
(v) Mt.Kenya region, and
(vi) North Rift Valley region

(*1) 40,305,000 person x 5.5 kg/person = 222,000 tons
(*2) Trend projection of fish farming activities from past 10 years. See Figure F3.7 of Sectoral Report F.

(2) Power Generation

Power generating facilities in Kenya are classified into hydroelectric, conventional thermal and geothermal power plants. The total installed capacity of these facilities as at January 1991 in the interconnected power system was 705 MW. Composition of generating facilities is summarized as follows:

Plant	Installed Capacity (MW)	Installed Capacity (%)	Effective Output (MW)	Effective Output (%)
Hydropower*	495.3	70.3	477.8	74.5
Conventional thermal	145.9	20.7	112.8	17.6
Geothermal	45.0	6.4	43.0	6.7
Diesel	18.3	2.6	8.0	1.2
Total	704.5	100.0	641.6	100.0

* excluding Turkwel (106 MW) and Owen Fall supply

Historical records of generation by plant type are outlined as below:

	1979 (GWh)	1984 (GWh)	1988/89 (GWh)	Share (%)	Growth* (%)
Supply (GWh)					
Hydro	1,288	1,471	2,449	83.5	7.00
Geothermal	-	233	322	11.0	-
Oil Thermal	205	174	25	0.9	-
Diesel & G.T.	2	1	23	0.8	-
Import	160	215	112	3.8	-
Total Supply	1,655	2,094	2,931	100.0	6.20
Station Use	22	28	27		
Net Supply	1,633	2,066	2,904		6.25
System Losses	220	276	466		8.22

Note: * Growth rate during 9.5 years from 1979 to 1988/89.

As seen in the above tables, hydroelectric generation plays a major role in the supply of power and energy in the country; 75% in effective power output and 84% in energy generation (excluding hydropower from Uganda).

(3) Power Demand Projection by KPLC

Electric power and energy demand in Kenya were forecasted up to the year 2005 in the "National Power Development Plan (NPDP), 1987". The forecast was amended in "Feasibility Study for A Geothermal Power Station at North East Olkaria (1989)."

National Power Development Plan (1987)

The forecast was based on a combination of detailed disaggregated forecasts in short term (1986 - 1990), and on economic models of total power sales in the longer term after 1990.

Three load forecast was prepared, namely an expected median forecast, a high forecast and a low forecast as given in Table M3.13. The median forecast anticipated an improvement in the performance of the Kenyan economy due to greater efficiency of new capital investment, and higher growth in the agricultural and industrial sectors than experienced. The low forecast after 1990 is largely a continuation of the historic growth rates in Kenya since 1979. The high forecast is based on the Government of Kenya's official target growth rates. The median forecast indicates an average annual growth rate of 6.0% in energy generation from 1985 to 1990, and then 5.3% from 1990 to 2000.

Feasibility Study for North East Olkaria Geothermal Plant (1989)

The power and energy demand forecasts made in the National Power Development Plan were updated by EPL in their feasibility study for the North East Olkaria geothermal plant, based on the methodology adopted by NPDP.

The principle method of revising the load forecast was to use the actual sales for 1987 as a base, and to assume growth rates for 1968 to 2006 consistent with those of NPDP's medium or high forecast.

The results of the revised demand forecasts were converted from calendar year to fiscal year as given in Table M3.14, because of changes in KPLC accounting and record-keeping procedure.

Updated National Power Development Plan

The National Power Development Plan (1987) had listed 11 hydropower schemes worthy of further consideration, but recently its updated plan (1991) was re-examined for 8 hydropower schemes. In the updated NPDP, the load forecast in NPDP was also updated as shown in Table M3.15.

M4. PRESENT AND FUTURE CONDITION OF WATER USE

4.1 Problem Areas

In Kenya, readily available surface water has already been consumed in the subbasins with major water demand centres. Although the development of groundwater use has been developed in the whole country, the estimated groundwater abstraction rates show that a rather small volume of 57.2 MCM/year is utilized comparing it with that of surface water of 1,071.7 MCM/year during low flow. Water harvesting, which has been practiced for many years in ASAL regions, is particularly suited for the supply of water for small domestic and livestock demand.

The provision of piped water to the community has grown considerably. For example, less than 7 % of the population had access to clean water in 1963 and 15 % of the population had access to piped water in 1978 (Ref. M.5). The situation continues to improve with the current government policy.

There are relatively more abundant water sources in high potential land areas than in medium and low potential land areas, and this is reflected in the distribution of population and the level of economic development. In pace with rapid socioeconomic development in high potential area, subbasins with water deficit are expanding gradually. The relatively large deficits will occur in the year 2010 at urbanized areas such as Nairobi, Machakos, Kitui, Mombasa, Eldoret, Nakuru and Nyahururu.

In subbasins with a seasonal river, no surface water is utilized during 10-year drought. The combination of groundwater development and water harvesting is necessary for permanent and reliable water sources in these areas. For the development of groundwater, it is cheaper to supply water from shallow well than from boreholes.

4.2 Balance between Demand and Available Surface Water

4.2.1 Safe yield

The concept of safe yield is defined in the "Design Manual for Water Supply in Kenya (MOWD)" as follows;

(1) for principal towns and urban centers

The 96% - probable daily low flow shall be regarded as the safe yield of a river. The flow - frequency analysis shall be made by using the lowest recorded daily flow of each calendar year for which records are available for the dry season.

(2) for rural areas and local centers

The 96% - probable monthly low flow shall be regarded as the safe yield of a river. The flow-frequency analysis shall be made by using the recorded lowest average flow during one calendar month for each year for which records are available for the dry season.

Since rivers having daily discharge records with durations long enough for probability analysis are limited in number, and long-term river discharges over the country had to be generated on the monthly basis due to limitation of data, it was necessary to check the relationships between the probability of daily discharges and the monthly discharge.

To do this, discharge records at 15 water level gauging stations having daily discharge records for more than 15 years with few missing data were selected. The data, however, was not for 15 consecutive years.

At first, the flow - frequency analysis was made by using the lowest recorded daily flow of each calendar year and the probable low daily discharges were estimated for the recurrence intervals of 2, 5, and 10 years. Secondly, the flow duration curves by station were developed by sorting all the monthly data in descending order.

Table M3.1 shows that the relationship between the probable daily low flow discharges and flow duration curve on a monthly basis. The probability of low flow discharge is equivalent to the following duration on average.

Recurrence interval (years)	Duration on monthly basis (%)
2	95.6
5	99.2
10	99.8

Therefore, the recorded minimum monthly discharge is equivalent to the daily discharge with the probability of once in 10 years. In case that an intake structure is designed on the basis of recorded minimum monthly discharge, the supply failure would occur for 21 days on an average in 10 years. While, in the case where the design discharge having 96 % - probable monthly low flow discharge is adopted at rural areas as mentioned in the "Design Manual for Water Supply in Kenya", its probability of daily low flow discharge is equivalent to the recurrence interval of once in about 2 years on average.

4.2.2 Maintenance of minimum flow

The concept of minimum flow of perennial river is not mentioned in the "Design Manual for Water Supply in Kenya". The minimum flow of perennial river is required to maintain water depth, conservation of groundwater and people's amenity. The minimum flow of perennial river is also the indicator of the allowable limit of water withdrawal from the river. The concept of minimum flow is schematically illustrated in Figure M4.1.

In the water balance calculation of the Study, the recorded lowest daily discharge was assumed, tentatively, as minimum flow which needs clarification by rivers. The ratio of recorded minimum daily discharge to annual average discharge was roughly estimated at 6.2 % on the basis of the discharge record at the aforementioned 15 stations.

4.2.3 Available surface water

(1) Perennial River Model

Perennial river model for surface water balance calculation was established according to the following procedures;

(a) Catchment

Subbasins with a perennial main river were further divided into sub-basins taking the location of potential damsite and the confluence of tributaries into consideration.

(b) Point of water balance calculation

Water balance was calculated at the following points;

(i) downstream end of catchment,
(ii) confluence, and
(iii) immediate downstream of potential damsite

(c) Naturalized discharge

Naturalized discharge without present water abstraction was estimated for subbasins with a perennial main river. In the Study, the objectives of the estimation of naturalized discharge were to (i) clarify the water deficit by subbasin during low flow discharge with a 10-year probability and (ii) to specify subbasins where a water deficit will occur in 2010.

The generation of naturalized discharge was carried out on a monthly basis for 30 years by the one of following 3 methods - namely: (i) preliminary water balance model for Drainage Area 1, (ii) discharge correlation for major rivers and (iii) runoff ratio in semi-arid areas on the basis of that of the Tsavo River. (See Appendix B6 of Sectoral Report B).

Table M3.2 shows the run-off ratio of perennial rivers in Kenya. The annual runoff in the Table is the naturalized discharge at the downstream end of river basin. Table shows that about 9.5 % of annual rainfall depth flows down through main river channel. The isohyetal map of annual average runoff depth is shown in Figure M4.2 and that of minimum monthly runoff depth is also shown in Figure M4.3.

(d) Demand

Water balances in the years 1990, 2000, and 2010 were calculated by subtracting the future demand from the naturalized monthly discharge for 30 years. The future demand was first organized into domestic, industrial, and livestock demands (First Trial), while, the irrigation demand was not counted on the premise that the irrigation water would not be abstracted at such a critical drought period as occurring once in 10 years.

Second, after ensuring the water source for domestic, industrial and livestock demands, the irrigation demand on monthly basis in 2010 was examined in surface water balance calculation (Second Trial). The monthly irrigation demand was then subtracted in case that the simulated monthly discharge ensures the 80% reliability.

(e) Flow regulation by existing dam

Flow regulation of existing dams was considered in the generation of naturalized discharge in the upper reach of the Tana River. Therefore, the naturalized discharge in Tana river basin was already been controlled by the existing dams.

For the remaining subbasins, the naturalized discharge was estimated under "without-dam" condition.

(2) Water Balance between Demand and Available Surface Water

Perennial river model and its results of water balance calculation of First Trial are given in Appendix M.3. The water balance calculation for the years 1990, 2000, and 2010 was carried out taking the increase of domestic and industrial demands into considerations. In some subbasins, surface water deficit has already been identified in 1990, especially in urban areas. The deficit in these areas will expand gradually in proportion to the increase of domestic and industrial demands toward the year 2010 as shown in Figure M4.4.

4.3 Maximum Exploitable Groundwater

The data of existing recovery tests and recovery tests obtained in the field surveys of NWMP were analyzed and drawdown analyses carried out for 927 boreholes. The results of drawdown analysis show that available boreholes, which are pumped up at the rate of their initial yield after 20 years of pumping, have a maximum drawdown within 10 meters. A ratio of available boreholes to all the boreholes referred to as "availability factor" means a ratio of production boreholes which can continue to produce their initial yield after 20 years of pumping and the maximum drawdown will be within 10 meters. The availability factors are calculated by location and an average value of the availability factor in the country is estimated to be 0.0766.

The detailed safe abstraction rates of boreholes are estimated by location. Total safe abstraction rate in Kenya is estimated at 193 million cubic meters per year.

The water balance expressed as maximum exploitable groundwater volume vs. required water demand was examined by subbasin as shown on Figure M4.5.

4.4 Balance between Demand and Potential Available Water

To clarify the potential available surface water and maximum exploitable groundwater is one of indexes defining the subbasin which requires the construction of storage dams or water transfer scheme. Table M4.3 shows the subbasin having deficit in the year 1990, 2000 and 2010 and their major demand centers. Many urban centers in Kenya, however, are located astride a few subbasin so that the same urban area is mentioned as the major demand center in a few subbasin. No major demand center is mentioned in rural areas.

Figure M4.6 shows the result of water balance calculation by subbasin.

M5. WATER SOURCES FOR URBAN WATER SUPPLY

5.1 Domestic Water Supply Policy

The latest statement on the water supply policy is shown in the current Five-Year National Development Plan for the period from 1989 to 1993 as "During 1974, Government promulgated the National Water Plan with the expressed aim of ensuring the availability of potable water to within 4 kilometers of every household by the year 2000". The earlier documents made statements ensuring of piped water by the year 2000.

Targets during the current five-year development plan period are to increase the proportion of the population in the rural areas having access to water from 26% (4.91 million people in 1987) to 50% (11 million people) by 1993 and in the urban areas from 75% to 95% by 1993.

Taking into account the Government policy on the water supply sector, this Study assumes provision of safe and reliable water to all the population in the year 2010.

5.2 Water Supply Sources and Supply Measures

5.2.1 Water availability

In Kenya, meteorological and hydrological conditions vary largely with Location, and there are few or no reliable surface water sources in ASAL areas.

The groundwater sources, if its quality is suitable for drinking use, require least cost for treatment. However, uncertainty of successfully exploiting the planned quantity of groundwater, the often shortening of lifetime of boreholes owing to screen trouble, etc. and the high exploitation, operation and maintenance costs of boreholes give a rather low priority to groundwater development. Hence, groundwater development for the domestic water supply might be limited to the following Locations:

Locations having no reliable surface water source

Locations with low demand density which will result in a high cost of surface water supply

In these two types of Locations, methods of water harvesting will be taken into account.

Major springs, in general, provide good quality water at a low cost. However, most of the spring sources are already utilized, except for several springs like Mzima. Future spring source utilization is therefore considered as a continuation of present use with improvement (spring protection).

5.2.2 Supply measures

Long Term Guideline of Infrastructure Facilities in Various Level of Centres (source: PPD's Chart for Urban and Rural Organization) in the Design Manual stipulates the following guideline for the water supply:

Centre	Population Served	Population Resident	Water Supply
Principal	>1,000,000	>100,000	Piped Grid Water Supply
Urban	>100,000	>5,000	Piped Grid Water Supply
Rural	>50,000	>2,000	Piped Grid Water Supply
Market	>15,000	Negligible	Communal Point Water Supply
Local	>5,000	Negligible	Communal Point Water Supply

In this Study, the Principal Towns and Urban Centres are considered for bulk water supply, and other Centres are considered to be covered by area/rural water supply. In principle, rural water supply in the high potential areas and part of the medium potential areas where permanent surface water is available, will be covered by piped water supply from surface water sources. The remainder of the medium potential areas and low potential areas will be covered by spot supply from groundwater, water harvesting or others.

5.3 Concept of Urban Water Supply Development

5.3.1 On-going schemes

According to the Project Status Report prepared by MOWD in February 1991, there are many water supply projects under construction as reported in Sectoral Report D. Most of them are expected to be completed by 1993. However, completion of some of them will have to be postponed owing to financial constraints.

5.3.2 Studied and planned urban water supply schemes

There are many proposed water supply schemes which have been studied and planned in the past, but not yet implemented. Among those schemes, there are some having an ultimate supply year in the period between 1995 and 2010 which corresponds to the period of this Study. Their implementation is generally behind schedule, and completion of their ultimate phases, therefore, might not be realized until late 2010's or so.

5.3.3 Priority order of urban supply schemes

The water supply sector is one of the most difficult sectors in which to give a clear priority to schemes within the sector. There is no appropriate yard stick by which to measure seriousness of water shortage applicable throughout the country. Hence, attention should be paid to this issue.

The Kenyan economy has always been affected by the ceiling of the foreign exchange reserve. Hence, an increase of foreign exchange earning is a must. To do this, it is necessary to improve tourism, but this demands the reliable supply of high quality potable water in large quantity. In this context, argumentation of reliable safe water to Nairobi, the coastal strip, north and south of Mombasa/Malindi and elsewhere should be urgent matters given high priority.

Rapid urbanization is on-going. However, concentration into Nairobi and Mombasa is causing serious urbanization problems. Hence, development of secondary urban cities, say towns with population of more than 10,000 in 1990, should be looked into with priority to curb further growth of Nairobi and Mombasa. The shifting of urbanization to the secondary towns may relieve water supply system from high water demand.

5.3.4 Assumed improvement of water supply sector

In planning the urban water supply development, several improvements in the water supply sector were assumed.

(a) Reduction of Leakage and Unaccounted For Losses

The present high rates of leakage loss and unaccounted for losses will be reduced gradually but steadily to a total loss of around 20% of the water produced and supplied will be reached by the year 2010.

(b) Cost Recovery

It is the Government policy to recover the full cost of urban water supply schemes and the O & M cost of rural water supply through collection of users' water tariff. It is assumed that this Government policy will be realized by the year 2000. Then, the urban water supply schemes will become self-sustaining after the year 2000 with arrangement of appropriate financing measures such as long-term credit or bond.

In order to facilitate collection of users' water tariff, it will be necessary to install water meters in water supply systems.

(c) Water Saving Policy

It is assumed that the Government will take policies to minimize wasteful use of treated water such as ascending tariff structure and phasing out of flat rate system.

(d) Emergency Preparedness

Kenya has suffered from severe drought in the past, which caused critical conditions in the medium and low potential areas. Preferably boreholes and shallow wells may be sought as standby supplies or emergent supplies for augmentation during severe droughts. On this account, a higher supply reliability for raw water sources is sought for : supply failure for less than 20 days in 10 years.

M6. WATER SOURCES FOR RURAL AND LIVESTOCK WATER SUPPLY

6.1 Approach to the Study

In view of the vastness of the study area and varying type of water sources envisaged, it was found almost impracticable to formulate definite water supply plans specific to each rural area. The study therefore attempted to evaluate potential water sources available in each area and to estimate the conceptual costs of the development.

The study adopted the following approaches for this purpose:

- Step - 1: Listing of potential water sources and their combinations envisaged in each sub-basin/Location (Ref. Section 6.3)
- Step - 2: Setting-up of source potential evaluation criteria (Ref. Section 6.4)
- Step - 3: Setting-up of source allocation criteria (Ref. Sections 6.5 and 6.6)
- Step - 4: Computer processing for assessing water sources development in each sub-basin/Location (Ref. Section 6.7)

6.2 Water Sources and Development Menu

6.2.1 Potential water sources

The following water sources were examined in this study:

Source	Description	Purpose
Surface water	This includes springs, streams and rivers available as natural runoff.	Domestic (D) and Livestock (L)
Groundwater	Either by borehole or shallow well.	D and L
Roof catchment	Rainwater collected by roofs, mainly for domestic drinking purpose. Water quantity exploitable is varying by sub-basin dependent on rainfall.	D only
Small dam	Small surface water storage built on streams. Water quantity exploitable is varying by hydrological region (sub-basin) and size of reservoir/catchment.	D and L

Subsurface dam	This includes both sand dam and subsurface dam. A typical design is assumed for each.	D and L
Rock catchment	This source development is quite location specific, and therefore applicable only to area where the potential is identified.	D and L
Pipeline	Pipeline built for urban water supply. This could serve for some rural areas on the pipeline route.	D and L

The main objective of this source evaluation study is to examine the potential development of perennial water sources. Other type of seasonal water sources are dealt with separately and only as supplementary measures which would be effective in shortening the access distance to water in the rainy season.

6.2.2 Concept of development sequence

This study assumed that the development of water sources in rural areas will be undertaken in the following two (2) stages:

Stage 1: Provision of water sources within walking distance, i.e. within 1 km in high potential area and within 4 km in semi-arid/arid areas, but the water available is not always of "potable water" quality.

Stage 2: Provision of piped water supply systems with water treatment, to ensure its potability.

For each of the water sources, the development sequence would be;

	Stage 1	Stage 2
Surface water	Water as available on the site (abstraction of water by people themselves)	Piped water supply, with treatment (except for spring water)
Groundwater	Spot supply at the borehole/well sites	Piped water supply, with treatment where necessary from water quality aspect

Roof catchment	Rainwater as stored	As Stage 1. No water treatment is deemed necessary.
Small dam	Water as impounded, with protection from contamination sources (e.g. livestock)	Piped water supply, with treatment
Subsurface dam	Water as stored and supplied at pipe outlet (sand dam) or well (subsurface dam)	Piped water supply, with treatment
Rock catchment	Water as stored, with protection of catchment	As Stage 1. No water treatment is deemed necessary.
Pipeline (built for urban supply and passing in rural areas)	Supply of water at water stands provided on the pipeline route. Water is treated.	Extension of branch pipeline system. Water is treated.

The descriptions in this Chapter deal chiefly with the availability of water sources in each region/area with a concept of "Stage 1" development above. Cost requirement for upgrading to "Stage 2" is discussed separately in Chapter M10.

It is noted that neither piped water supply nor water treatment is required for livestock watering, i.e. livestock water supply is planned at "Stage 1" level.

6.3 Potential Water Sources and Their Combinations

In the preliminary evaluation of the availability of water sources in all sub-basins, various combinations of water source development were delineated as summarized in Table M6.1. Bearing these source development menus in mind, succeeding Sections 6.4 to 6.6 examined various evaluation criteria.

6.4 Source Potential Evaluation Criteria

For each sub-basin and Location (administrative unit), the potentiality of water sources development was then evaluated. The evaluation was based on relative comparison indices. The parameters and criteria set out in the evaluation are described hereunder.

(1) Pipeline (PL):

This was applied to specific Locations where a treated water pipeline (built for an urban water supply) is passing. The pipeline coverage area was assumed as follows:

PL1: Coverage of 1 km width on both sides of the pipeline in high potential area
PL2: Coverage of 4 km width on both sides of the pipeline in semi-arid/arid area
PL3: No pipeline scheme proposed

The coverage ratio in % was assessed for each of the relevant Location and given as input data.

(2) Perennial rivers/streams coverage (PR):

Coverage of perennial rivers/streams were evaluated for each Location (1 km on both sides in high potential area and 4 km in semi-arid/arid area).

PR1: Coverage 75% over
PR2: Coverage 50 - 75%
PR3: Coverage 25 - 50%
PR4: Coverage 25% under
PR5: No perennial river/stream

(3) Groundwater resources:

Four parameters were evaluated:

(a) Groundwater development activity (GA):

GA1: Present development activity is high.
GA2: Present development activity is moderate.
GA3: Present development activity is low.
GA4: Present development activity is nil.

(b) Groundwater quality (GQ):

GQ1: Groundwater quality is good (meeting WHO guidelines).
GQ2: Groundwater quality is acceptable (below WHO guidelines, but within a usable limit).
GQ3 Groundwater quality is not so favourable for meeting the domestic use.

(c) Share between borehole/shallow well developments (GS):

Type of groundwater development was assessed for each Location in consideration of hydrogeological characteristics and classified into the following five groups:

	Borehole	Shallow Well
GS1	20%	80%
GS2	40%	60%
GS3	60%	40%
GS4	80%	20%
GS5	100%	Nil

(d) Groundwater exploitation cost (GC):

Cost of groundwater exploitation was assessed for each location by type of development. The estimated cost indexes are shown in Table C5.3 of Sectoral Report C. The index was used for prioritisation of development between groundwater development and other water harvesting measures (see Section 6.5.5).

(4) Roof catchment (RC):

Cost of water exploitable by roof catchment was evaluated for each hydrological region (sub-basin). This index was used mainly for comparison with groundwater cost.

(5) Small dam

Three parameters were evaluated for each sub-basin/Location.

(a) Small dam-hydrological potential (SH):

SH1: Small dam can have perennial water storage
SH2: No perennial water storage is expected due to less rainfall and high evaporation

In this hydrological evaluation, the catchment area of small dam was assumed to be 10 km^2 as a typical case.

(b) Small dam - topographical potential (ST):

This index was evaluated only for areas where SH index above is classified as SH1.

	Existing development	Topographical potential
ST1	Active	High
ST2	Moderate	Medium
ST3	Scarce	Low
ST4	Nil	Nil

(c) Small dam water development cost (SC):

Water exploitation cost was assessed for each hydrological region, assuming a typical design of small dam. This cost index was used for comparison of relative merit with groundwater exploitation. The above evaluation assumed a typical small dam having a catchment area of 10 km^2 and an active storage volume of 50,000m^3.

(6) Subsurface dam

This includes two types of developments; i.e. (i) sand dam and (ii) subsurface dam, for both of which a typical development plan was prepared as well as an estimation of the construction cost and water exploitation cost (per m^3).

For evaluation of subsurface dam potential in each area, two parameters were examined:

(a) Subsurface dam - topographical potential (TP)

This evaluates subsurface dam development potential from viewpoints of topography and river morphology in the areas.

TP1: Development potential appears to be high
TP2: Development potential appears to be low, but still exist
TP3: No notable potential or no need of development, particularly in surface water abundant area

Figures M2.7 and M2.8 show the potential of subsurface dam development evaluated by GIS from the viewpoint of soils and geology. This information was taken into account in the above evaluation.

(b) Subsurface dam - type of development (TD)

The study attempted to select one of the two types of developments; either (i) sand dam or (ii) subsurface dam, through examining topographical and river morphological aspects of each area. However, there were exceptional cases where both types of development would still be envisaged.

Hence, the following assessment criteria were set forth:

	Development Potential in the Area	
	Sand Dam	Subsurface Dam
TD-1	100%	Nil
TD-2	75%	25%
TD-3	50%	50%
TD-4	25%	75%
TD-5	Nil	100%

The above assessment was made only for the areas where the need and potential of subsurface dam development was delineated in the TP index evaluation above.

(7) Rock catchment

This type of development is very locational specific as was noted before. It was impracticable for this master plan study to identify all the potential sites. Nevertheless, an identification attempt was made on 1:50,000 topographic map. The result is shown in Figure M2.6.

In this source development assessment, it was assumed that all the potential sites identified on the map will be developed as a substitute of either small dam, subsurface dam, or groundwater development.

In the calculation, the number of potential sites was given as input data for the assessment. A typical plan was assumed to estimate water yield and cost as shown in Figure M2.5.

(8) Other water harvesting measures

(a) Water pan

This is regarded as a reduced size development of small dams. A portion of water development allocated to "small dam" could be substituted by "water pan", especially in relatively humid areas where the water pan could sustain a perennial water storage. The cost is regarded to be covered by that assessed for small dam.

(b) Small ground catchment

This include smaller water storages in excavated water pits and/or pools (such as road catchment) mainly for livestock watering. These facilities could be built anywhere in the country, provided that the area has a certain amount of rainfall. In most cases, these facilities can not be a perennial water sources, and are hence regarded as a supplementary measure provided by people on ad-hoc basis to shorten access distance to water points during the rainy season.

(c) Water hole

This is also a seasonal water source available during and immediately after the rainy period. This facility can be built by people's own effort and expense and hence it facility was not included in the source evaluation study.

(d) Paved ground catchment

The concept of this water exploitation is similar to that of rock catchment. The facility could be built everywhere in the country, provided that a certain amount of rainfall is available.

In this source potential evaluation study, this facility was regarded as an alternative to roof catchment and/or groundwater development, only to be applied to specific areas where water demand could not be met by roof catchment/groundwater resources.

(e) Large dam

Construction of large dams specifically for rural water supply was not considered in this study. Instead, a group of small dams were taken into account in the development menu. However, there may be cases where preference may be given to the construction of large dams rather than that of a group of small dams. This examination will be left to subsequent detailed studies to be undertaken for each region/location.

6.5 Source Allocation Criteria - Domestic Water Supply

Potential water sources available in each sub-basin/Location are evaluated in the preceding section (Section 6.4). The next step of evaluation is to determine the allocation of water sources to meet the demands in the respective areas.

In view of the varieties of water sources and demand area characteristics, there would be essentially an almost indefinite number of source allocation menus if all sub-basins/Locations are scanned. The study had to adopt a simplified approach to evaluating the source allocation plans just sufficient for the formulation of a future water development framework in each region.

The establishment of quantitative allocation criteria relied on rather rule-of-thumb estimates based on empirical judgement since no previously known criteria was available.

6.5.1 Urban water supply pipeline

A number of inter-regional pipeline schemes are proposed for urban water supply (see Chapter M5). Some of them pass through rural areas. The areas covered by these pipelines were assumed to receive supplies from the pipelines.

6.5.2 Basic concept of source allocation plans

The study adopted two basic concepts:

(a) Main water supply sources would be surface water and groundwater, and

(b) Other water harvesting measures be planned as subordinate measures to supplement and/or substitute the surface water/groundwater sources.

With regard to (b) above, the following groupings were proposed in view of development concepts given below:

(i) Subordinate measure to supplement/substitute surface water sources:

- *Small dam:* This is virtually augmentation of surface water resources. The facilities are provided at headwaters where the catchment is relatively small and/or at middle/lower reaches where perennial flow decreases.

(ii) Subordinate measure to supplement/substitute groundwater sources:

- *Roof catchment:* To be planned in semi-arid and arid areas where perennial rivers/streams are sparse. The need is significant in areas where groundwater quality is not favourable.

- Subsurface dam: To be developed particularly in areas where only groundwater sources are available and/or groundwater quality is not favourable.

- Rock catchment: To be developed in areas where the potential site exists, with the same concept as for subsurface dam. In view of a better quality of water exploitable, a preference is given to rock catchment over subsurface dam.

6.5.3 Allocation between main water sources (surface water and groundwater)

A primary assumption is that the development of surface water sources will preceded that of groundwater sources, in view of easy accessibility and in most cases cheaper abstraction cost. On this basis, a set of allocation scenarios were proposed as shown in Table M6.2.

6.5.4 Allocation ratio of subordinate measures

A set of source allocation scenarios was also established for each small dam, roof catchment and subsurface dam (sand dam and subsurface dam). They are shown in Tables M6.3 to M6.5, respectively.

In the scenarios, maximum exploitable water quantity was assumed as follows for each type of development from the viewpoint of practically achievable limits:

- Small dam: 15% of surface water development
- Roof catchment: 70% of rural housings at the maximum, assuming that corrugated iron sheet roof will be dominant in future
- Subsurface dam: 5% of groundwater development

As for rock catchment, it was assumed that all known potential sites would be exploited substituting small dam/subsurface dam primarily and groundwater development secondarily.

6.5.5 Comparison of water cost

After the initial allocation of water sources, unit water exploitation costs (per m^3) was compared and the following adjustments were made:

(a) If the water cost of a subordinate measure is cheaper than that of groundwater, the water allocation to the former is increased by 15%.

(b) If the case is contrary, water allocation is decreased by 15%.

The above is also applicable to the comparison between small dam and groundwater, in case both developments are feasible together in the area.

6.5.6 Cross check with available water source

(1) Check with available surface water

This intends to check whether surface water resources could meet the development requirement. The check was made by comparing the following two parameters for each sub-basin:

(a) Total water requirement allocated to "surface water" source in the sub-basin

(b) Available surface water resources, herein defined as the 10-year probable dry discharge available in each sub-basin

A specific criterion adopted here is that (a) should not exceed 50% of (b). This criterion was introduced in consideration of conservation of water sources for other water uses (e.g. minor irrigation) and also maldistribution of the sources within the sub-basin. In case this condition cannot be satisfied, use of surface water would be reduced to 50% of (b) and the balance be substituted by groundwater exploitation.

(2) Check with available groundwater source

There may be some cases that groundwater source cannot meet the water development requirement; for example, due to water quality reasons. In such a case, maximum affordable development of roof catchment and subsurface dam was planned, irrespective of the criteria set forth in Subsection 5.5.5. The rest of shortage will have to be supplemented by other measures such as water transfer from another area and/or provision of paved ground catchment. This will be examined separately for each specific case, once this sort of problem has been identified.

6.6 Source Allocation Criteria - Livestock Water Supply

The criteria set for allocation of livestock water sources are virtually similar to those applied to domestic water supply (Ref. Section 6.5). Several specific criteria separately applied to livestock water supply are described hereunder.

6.6.1 Urban water supply pipeline

Pipeline water (basically treated water) will be allocated to livestock use only in semi-arid and arid areas. Quantitative criteria are given in Table M6.6.

6.6.2 Allocation between surface water and groundwater sources

Livestock could have more dependence on surface waters than the case of domestic supplies.

(a) Livestock can move over a longer distance in search of water than humans.

(b) Livestock can have more watering points wherever stagnant water surface is available (e.g. water pans, water pools, etc.).

In this context, the study assumed that the utilization of surface water sources by livestock would be at least 25% more than the ratios estimated for domestic water supply (Ref. Table M6.2).

In this case, groundwater use is reduced by the corresponding quantity.

6.6.3 Subordinate measures

The following criteria were introduced:

Small dam:	Same allocation ratios as given in Table M6.2 to be applied. A larger allocation of surface water sources is already taken into account in Section 6.6.2.
Roof catchment:	Not considered for livestock
Subsurface dam:	More positive development particularly in dry areas, assumed to be 15% increase from the ratios given in Table M6.4.
Rock catchment:	Assumed that this facility is exploited primarily for domestic water supply

6.6.4 Comparison of water cost

Adjustment of source allocation is made by applying the same concept and method as given in Section 6.5.5.

6.7 Processing of Water Source Allocation Computation

6.7.1 Preparation of input data

Input data for assessment of source development for rural water supply (domestic and livestock) constitute the following:

	Data <u>assessed for</u>
(a) Water demand (Ref. Sectoral Report D):	
- Domestic and industrial water demand	Location
- Livestock water demand	"
(b) Demographic data (Ref. Sectoral Report A):	
- Population	Location
- Land area	"
- No. of persons per household	District
- Average housing area	"
(c) Source potential parameters evaluated for items shown in Section 6.4	Location

(d) Water yield and cost data:

	Location
- Groundwater	Sub-basin
- Small dam (for typical plan)	"
- Rock catchment (for typical plan)	"
- Roof catchment (for typical plan)	Common to all region
- Subsurface dam (for typical plan)	

Data and parameters assessed above are shown in Appendix M.4 of this report.

6.7.2 Computation of source allocation

Then, the data were processed using a computation programme specifically prepared for this purpose. The computation was based on criteria set out in Sections 6.5 and 6.6.

6.7.3 Computation outputs

The computation produced the following outputs:

	Per Sub-basin	Per District
(a) Source allocation plan (m^3/day)	Appendix M.5	Appendix M.8
(b) No. of proposed facilities (*)	Appendix M.6	Appendix M.9
(c) Water exploitation cost (*) - total exploitation cost - average water cost per m^3	Appendix M.7	Appendix M.10

Notes:

(i) The above represents source development plans at a level of "Stage 1 development" (Ref. Section 6.2.2)

(ii) (*) Excluding the facilities/costs for surface water exploitation wherein no artificial facilities are proposed at Stage 1 development level (to be included in Stage 2 development).

Nos. of facilities was not estimated in view of unpracticability of establishing a standard design (the size of facility is quite location specific). The Stage 2 development cost including water abstraction cost (intake cost) was estimated on the basis of water supply volume per km^2 (see Sectoral Report D).

(iii) (*) Excluding also the facilities/costs of water supply points on urban water supply pipelines, which is to be included in the urban water supply scheme.

M7. WATER SOURCES FOR IRRIGATION WATER SUPPLY

7.1 National Policy

According to the sixth Development Plan 1989-1993, the Government set up irrigation development targets during 1989-1993 period to be as follows.

Irrigation Development Target

Unit : ha

Targets	1989	1990	1991	1992	1993
Present	33,000	34,380	35,760	38,440	41,880
Increment	1,380	1,380	2,680	3,440	3,670
Total	34,380	35,760	38,440	41,880	45,550

This Development Plan emphasizes a low cost approach in the implementation, and the small scale irrigation projects and utilization of gravity flow are given preference.

7.2 Irrigation Potential

7.2.1 Surface water

Estimation of the irrigation potential for each subbasin was derived through matching mean flow/80% dependable monthly flow and irrigation demand and indicating the following assumptions:

1 Domestic & livestock water usage takes priority over irrigation,
2 Return flows are disregarded,
3 Surplus water is allocated to downstream requirements,
4 No storage facilities are considered, and
5 Sub-basin irrigable area is limited to be the area accorded to have irrigation land potential as assessed above.

In case that the basin mean monthly flows were applied to the calculation, about 470,000 ha of land is available for upland crop irrigation and 340,000 ha is available for paddy irrigation. A basin-wise break down of the irrigation potential is indicated below and Table M7.1 shows irrigation potential area of each subbasin.

Irrigation Potential Area by Surface Water

Unit : 1000 ha

Crop	Basin 1	Basin 2	Basin 3	Basin 4	Basin 5	Total
Upland Crops	214.2	84.3	22.4	132.7	16.0	469.6
	(178.5)	(52.0)	(21.0)	(89.2)	(9.3)	(350.0)
Paddy	136.6	47.9	21.9	117.3	14.6	338.3
	(114.7)	(33.1)	(20.3)	(85.0)	(8.5)	(261.6)

Note : Parenthesized figures shows the results for applying 80% dependable monthly flow.

7.2.2 Groundwater

Irrigation potential for groundwater is also assessed in the same manner as assessment of surface water potential.

(1) Groundwater availability

Ground water availability for each sub-basin was estimated as shown in Table M7.2 and summarized below (see Section 7.3).

Groundwater Availability

Unit : m^3/sec

	Basin 1	Basin 2	Basin 3	Basin 4	Basin 5	Total
water availability	1.408	3.668	2.604	4.985	7.939	20.604

(2) Groundwater quality

The quality of groundwater was evaluated for 1,169 boreholes where water quality data was available. Based on the FAO's evaluation guideline, the criteria for this evaluation was made as shown in Figure M7.1. Tables M7.3, M7.4 and M7.5 presents the FAO's evaluation guideline. Applying this criteria to available water quality data, about 500 boreholes have unsustainable water for irrigation use. The distribution of these boreholes is as shown in Figure M7.2.

(3) Potential area

Irrigation potential for each subbasin was derived through matching groundwater availability and irrigation demand and taking into account the following assumptions :

1 Available groundwater is calculated by multiplying land potential area with unit groundwater yield,

2 Return flows are disregarded, and

3 Surplus water can not be allocated to other subbasin

Calculation of the water balance between water demand and available groundwater, indicates that about 1,500 ha of land is available for upland crop irrigation and 1,000 ha is available for paddy irrigation. A basin-wise break down of the irrigation potential is indicated below.

Irrigation Potential Area by Groundwater

Unit : ha

Crop	Basin 1	Basin 2	Basin 3	Basin 4	Basin 5	Total
Upland Crops	598	544	372	0	0	1,514
Paddy	155	660	210	9	4	1,038

7.3 Irrigation Development

Kenya has considerable potential for irrigation. At present, only 17 % of potential area is irrigated. To develop these potential areas, the following strategy can be drawn up taking into account the government policy and social & economic conditions in Kenya.

- small scale irrigation scheme would be given the top priority
- irrigation area adjoining densely populated District or Location would be given high priority
- those area where only irrigation is the watering method for agriculture, would be given high priority

Under the above strategy, present proposed small scale irrigation schemes and some selected large scale irrigation schemes (see Section 9.3.2) are recommended to attain the agricultural/irrigation development target and to exploit the huge amount of irrigation potential in Kenya.

M8. WATER SOURCES FOR HYDROPOWER DEVELOPMENT

8.1 Hydropower Potential in Kenya

Hydroelectric potential in Kenya is in and around the geographical region of the Kenya Highlands which provide the two important sources for hydropower generation; they are, (i) perennial river flow providing the source of water and (ii) water head as the difference in elevation. The existing hydropower generation facilities are listed below.

Five small hydroelectric projects

- Mesco, Ndula, Sagana Falls, Selbey Falls, and Gogo (6.5 MW in total)

Seven cascade hydroelectric projects on the Tana River

- Wanjii 7.4 MW
- Low Tana 14.4 MW
- Masinga 40.0 MW
- Kamburu 94.2 MW
- Gitaru 145.0 MW
- Kindaruma 44.0 MW
- Kiambere 144.0 MW

Committed hydropower project

- Turkwel 106.0 MW

The remaining hydropower potential by drainage area is summarized as follows (Ref. M.6).

Hydropower Potential in 1991

Drainage Area	1	2	3	4	5	Total
Inst. Capacity (MW)	355	245	84	583	155	1,422
Annual Energy (GWh)	1,680	739	463	2,560	675	6,177

Source : Appendix Vol. 2, NPDP (1987)

8.2 Hydropower Potential by Basin

8.2.1 Drainage Area 1 (Lake Victoria Basin)

Hydropower potential exists on the rivers flowing from the western slopes of Highlands to Lake Victoria. Potential installed capacity in the basin was estimated at about 355 MW yielding 1,680 GWh/year of average energy and a firm output of 1,450 GWh/year. The potential hydropower resources are summarized in Table M8.1.

8.2.2 Drainage Area 2 (Rift Valley)

In the Turkwel River, Turkwel hydropower project of 106 MW was committed in 1986. The remaining potential hydropower resources are summarized in Table M8.2.

8.2.3 Drainage Area 3 (Athi River and Coast)

All of the potential hydropower development in the basin are aimed at combined irrigation and hydroelectric facilities. However, the highly seasonal variation of flow of the Athi River requires the flow regulation by large storage dam to make the agricultural projects possible. The potential hydropower resource in the basin are listed in Table M8.3.

8.2.4 Drainage Area 4 (Tana River)

The Tana river basin has both the largest existing generated hydropower and the greatest remaining hydropower potential which comprises of Karura, Mutonga, Grand Falls, Usueni, Adamson's Falls, and Kora. The total hydropower developments on the Tana River can provide an installed capacity of 470 MW and 2,070 GWh of average annual energy. The potential hydropower resources are listed in Table M8.4.

8.2.5 Drainage Area 5 (Ewaso N'giro and North)

A cascade hydropower development with three dams is possible in the middle reach of the Ewaso N'giro River. The potential installed capacity in the basin was estimated at 155 MW yielding 675 GWh of annual average energy output. The potential hydropower resources are listed in Table M8.5.

M9. WATER SOURCES FOR WILDLIFE AND FISHERY

9.1 Wildlife Watering

Wildlife is the most important tourism resource in Kenya. Wildlife inhabiting the National Park or Game Reserve area needs to be conserved for this purpose. According to the information from Kenya Wildlife Service (KWS), the present condition and issues in each National Park/Reserve in terms of water development are summarized in Table F2.4 of Sectoral Report F.

About half of the National Parks/Reserves have their own water development plans for supplying water to wildlife. These development plans are;

- rehabilitation of existing water source
- drilling of new boreholes
- construction of new small dams

The major water source for wildlife is river water. To keep the minimum maintenance flow in the dry season, water development plan in the upstream stretches should be required to consider the impact of the plan to the wildlife downstream. Those rivers which call for careful attention in order for them to cater for the wildlife water demand are:

Rivers which need wildlife conservation

Amboni	Kimakia	Mathioya	Ongorit
Bisanadi	Kindani	Mderit	Rojewaro
Bwatheroagi	Kinna	Mulika	Rombo
Chania	Kiolu	Murubara	Rupingazi
Dawa	Kipsonoi	Mwatate	Sandai
Ewaso Ngiro	Kirtiget	Mzima	Saoumua
Hembe	Kogou	Naishi	Seiya
Irati	Kurera	Narok	Syapei
Isiolo	Lamuriak	Ngare Karoh	Tsavo
Itake	Loolturesh	Ngare Mars	Tana
Kakungu	Magura	Ngeny	Thiba
Kanjoo	Makalia	Ngosorr	Turkwel
Kamar	Malewa	Njangiri	Tuthu
Katundu	Mara	Njoro	Wanjohi
Kerio	Maragwa	Nyamindi	Wei Wei
Kesup	Maringato	Olambwe	

Source: Kenya Wildlife Service

9.2 Fishery

Although the current national development plan such as Sessional Paper No.1 of 1986 or Development Plan (1989-1993), contain no specific goals for aquaculture development, it can be presumed to fall under the agriculture sector, foreign exchange earnings, and contribution to national economic growth. The agricultural sector strategy is to raise the quality and value of agricultural output through :

- increased intensity of application of current production techniques without a major increase in area cultivated;
- improved genetic potential of crops/livestock;
- diversification into high value activities.

Meat, which includes fish, is one of the major commodities to be improved. In the wake of the Government strategies to exploit the fisheries potential in both marine and inland fisheries, many projects have been carried out, by not only the Department of Fisheries but also LBDA, TARDA and KVDA.

As described in Section 2.4, the total amount of fish farming water use was estimated at about 28.6 MCM/year or 0.906 m^3/sec in 2010. However, the perennial river flow during wet season has been utilized for inland fishery. Present and future water uses for inland fishery may not cause mal-effect to downstream users in water balance in the dry period.

M10. WATER RESOURCES DEVELOPMENT AND USE PLAN BY BASIN

10.1 Urban Water Supply

Among the various water resources in Kenya, surface water has been predominantly utilized as the main source for urban water supply. The demand for surface water is constantly increasing due to expansion of urban centers. In selecting towns to which urban water supply systems will be provided, the following criteria were adopted;

- towns nominated as urban centres
- towns that will have population of more than 5,000 in the year 2000

In total, 158 urban areas were selected.

For each urban area, checking was made on (i) present supply capacity and (ii) present and future water sources referring to project reports, answers to questionnaires, information from MOWD, NWCPC and Provincial and District Water Engineers, etc.

Possible water sources were checked on the 1:50,000 topographic maps. However, water source study based on these maps is still at a macroscopic level, and water source for specific urban area is to be looked into on the project basis. Since the urban water demands are bulky, surface water sources were given priority. The water source of each urban area is presented in Table M10.1.

Due to insufficient river runoff with the required reliability, several urban areas will have to rely on water from storage reservoirs and/or interbasin water transfer.

In total, 28 damsites were selected for source development towards year 2010 as enumerated below;

Purpose	Damsite (nos.)
Single purpose	
- water supply	19
- irrigation	2
- hydropower	2
Multi-purpose	
- water supply and irrigation	2
- water supply, irrigation and hydropower	1
- irrigation and hydropower	2
Total	28

The locations of damsites are shown in Figure M10.1 and the list of dam for source development including hydropower generation and irrigation is given in Table M10.2. Of the total 28 dams, 22 dams are relevant to urban water supply schemes.

In case that none of the potential damsite is in the subbasin and no additional storage is available, it is further necessary to transfer water firstly from another subbasin in the same river basin (intra-basin water transfer) and secondly from another river basin (inter-basin water transfer). The list of intra-basin and inter-basin water transfer schemes are enumerated in Tables M10.3 and M10.4. Location map of water transfer scheme is shown in Figure M10.2.

The urban centers which has the possibility of augmentation of available surface water by construction of storage dam and water transfer pipeline are described hereinafter with their water sources.

(1) Drainage Area 1 (Lake Victoria Basin)

(a) Tributaries of Malaba River and Sio River Basin (1A)

Sio river basin (subbasins 1AH and 1AG) shows the deficit of present surface water balance. Although the volume of domestic water demand at **Busia** and **Nambale** is rather small compared with other urban centres, the surface water deficit will increase by the year 2010. Since no potential damsite is in the basin and the volume of groundwater is limited, the intra-basin water transfer scheme having a capacity of 48,400 cmd (0.56 cms) in total is required to augment the capacity of existing water supply pipeline from the Sio River .

(b) Nzoia River Basin (1B to 1E)

No water deficit in the upper reach of Nzoia river basin (1B) occurs by 2010. **Moiben dam** is, however, required to be constructed to supply 51,000 cmd (0.59 cms) of water to meet the domestic water demand at **Eldoret** (1CB). The Eldoret water supply scheme from the Nzoia River is proposed as an alternative.

Moiben dam also to supply 3,500 cmd (0.04 cms) of water to **Iten** in Kerio river basin (2CB) to meet the domestic water demand..

The surface water deficit of 49,300 cmd (0.57 cms) in total also will occur at **Kakamega** (subbasins 1EA and 1EB) in the year 2010. **Mukulusi Dam** is proposed to supply water to Kakamega to offset the deficit.

(c) Nyando River Basin (1G)

In the upper reach of the Nyando River, **Londiani dam** is proposed to supply 20,800 cmd (0.24 cms) of water to **Londiani** to meet the domestic water demand.

(d) Shore of Lake Victoria (1H)

Surface water deficit will occur at Kisumu (1HA) in the year 2000 and at Maseno (1HB) in the year 2010. The volume of deficit is estimated at 40,000 cmd (0.46 cms) at Kisumu and 30,200 cmd (0.35 cms) at Maseno. Kibos Dam is proposed for the Kisumu water supply. The construction of small dam, Edzawa Dam, will be required for Maseno water supply.

(e) Sondu River Basin (1J)

No surface water deficit will occur in the Sondu river basin. Upstream of Itare River, Itare dam is proposed to supply 127,000 cmd (1.47 cms) of water to drainage area 2 (2E and 2F) to meet to domestic water demand in Elburgon, Molo, Njoro and Nakuru.

(f) Kuja River Basin (1K)

Surface water deficit of 8,700 cmd (0.10 cms) will occur at Kisii, Manga and Keroka (1KA) in 2010. Bunyunyu dam is proposed to offset this deficit.

(2) Drainage Area 2

(a) Kerio River Basin (2C)

In 2010, surface water deficit of 1,700 cmd (0.02 cms) will occur at Kabarnet which is located astride the basin boundary between subbasin 2CB and 2EH. Kirandich Dam is proposed to offset this deficit.

(b) Lake Baringo basin (2E)

In the subbasin 2ED, Chemususu dam has been planned up to detailed design level. The dam is designed to supply 6,000 cmd (0.07 cms) of water to Eldama Ravine and Mogotio.

Surface water deficit in the basin will occur at Molo and Elburgon (subbasins 2EC and 2EG1) in the year 2010. The available groundwater is quite limited and none of potential damsite with a relatively large scale reservoir was identified in the basin so that the inter-basin water transfer scheme is therefore required. An inter-basin water transfer pipeline from Itare dam to supply 40,000 cmd (0.47 cms) of water to Molo and Elburgon areas is proposed.

(c) Lake Nakuru, Elementaita and Naivasha (2F and 2G)

Surface water deficit has already occurred in the urban centres in the basin, especially in the towns of Nakuru, Gilgil and Naivasha. In these basins, the volume of groundwater is also limited and only Malewa dam is the potential damsite of reservoir type. Although the water transfer scheme, the Greater Nakuru Water Supply Project, is under construction, the transferred water will not meet the demand in 2010.

After the construction of Malewa dam for the supply of 51,000 cmd (0.59 cms) to Gilgil and Nakuru, the inter-basin water supply scheme with Itare dam is proposed to cover surface water deficit at Nakuru and Njoro.

(d) Lake Magadi Basin (2H)

Surface water deficit of 10,400 cmd (0.12 cms) will occur at Magadi in the year 2010. To cover this deficit construction of another water pipeline along the existing one is proposed. Water pipeline from Ewaso N'giro River is proposed as an alternative scheme.

(e) Ewaso N'giro River Basin (2K)

Narok town suffers from a surface water deficit at the present and this deficit is estimated to reach 53,600 cmd (0.62 cms) of water in the year 2010. To cover this deficit, Upper Narok dam is proposed.

(3) Drainage Area 3 (Athi River and Coast)

(a) Athi River Basin (3A to 3H)

The largest surface water deficit in Kenya will occur in and around Nairobi in the year 2010. To cope with such a large deficit, Thika dam which is located in the upstream of Chania River is under construction. When completed it will supply 224,700 cmd (2.60 cms) of water to Nairobi. However, Thika dam will not meet the increasing demand of Nairobi towards the year 2010. Ruiru A dam and Chania B dam are therefore proposed to supply 26,000 cmd (0.30 cms) and 65,700 cmd (0.76 cms) of water to Nairobi. To cover the remaining surface water deficit at Nairobi, construction of Ndarugu dam is proposed. However, the volume of inflow into Ndarugu reservoir from subbasin (3CB) is not adequate to the demand in the year 2010. The additional inflow required, having a monthly fluctuation with the maximum of 8.0 cms is proposed to be transferred from Chania River intake; that is, Komu Transfer scheme.

Kiambaa Dam proceeds to construction stage for the water supply to Kiambu and Karuri towns.

Kiserian dam which proceeds to construction stage in the uppermost subbasin (3AA) of Athi River will supply 0.70 cms of water to Kajiado. Upper Athi dam is planned for the domestic water supply to Athi River town.

Another large deficit in the upper Athi river basin will occur in the upstream reaches of the Thwake River where Machakos town is located. Although a few potential damsites were identified in the basin, the development yields of dams do not meet the demand of Machakos in the year 2010. It is proposed to supply 80,400 cmd (0.93 cms) of water through pipeline from the main Athi River channel.

In the Tsavo river basin, the present water supply volume through Mzima pipeline of 0.43 cms will be increased to 0.83 cms in the year 2010 coping with the surface water deficit at Voi and Mombasa. Also, possible alternative plan for Mombasa water supply will be water transfer from Njoro Springs and/or Lake Jipe (subbasin 3J).

The extension of existing Sabaki water supply system in the lower reach of the Sabaki River is also proposed as an alternative to Mwachi and Pemba dams which supply domestic water to Mombasa and Malindi areas.

(b) Rare River Basins (3L)

Voi River is the uppermost river in the basin. The surface water of the river, however, dries up in the ASAL area which is located between Voi and the coastal area. The main channel of Voi River is not clearly identifiable in the ASAL area and appears again as Rare River in the mountainous region of the coastal area. The drainage system between Voi and Rare rivers is therefore discontinuous, especially in dry months.

The surface water deficit of Voi town of 8,700 cmd (0.10 cms) will be supplied by the second Mzima pipeline system. Rare dam will supply 32,900 cmd (0.38 cms) of water through a pipeline to Malindi areas.

(c) Mwachi River Basin (3M)

The largest surface water deficit in the coast area will occur in subbasin 3MD. The present water supply volume of 37,000 cmd (0.43 cms) through Mzima pipeline will be increased to 71,700 cmd (0.83 cms) coping with part of the water demand of 157,200 cmd (1.82 cms) at Mombasa in the year 2010. Mwachi dam is planned to supply the remaining part of the water demand.

(d) Pemba River Basin (3M)

Small surface water deficit of 2,400 cmd (0.03 cms) will occur in the coast area. **Pemba** dam is proposed to supply water to the coastal area at **Mombasa**.

(4) Drainage Area 4 (Tana River Basin)

In the upper reach of the Tana River, the amount of surface water is abundant comparing with the other drainage areas. **Thika** dam and **Chania B** dam are proposed to supply the domestic water to the urban centers in and around Nairobi (Drainage area 3). **Komu transfer** which is designed as run-of-river type development with open channel with a maximum capacity of 8.0 cms is proposed to augment inflow volume into Ndarugu dam or alternatively Munyu dam.

In the lower reach, both abundant surface water in upstream reach and the storage control by existing dams make an inter-basin water transfer schemes to the other drainage areas possible even in the dry months; that is, water supply scheme to **Lamu**. However, the first effort may be the maximum exploitation of groundwater resources in the Lamu Island.

(5) Drainage Area 5 (Ewaso Ngiro River and North)

In the dry months, surface water along the Ewaso N'giro River decreases to an extent that surface water flow at the lower reaches of the rivers is not available for a few months per year. Two potential damsites; namely, **Nyahururu** and **Rumuruti** damsites, were identified in the upstream reaches of the river. Both these damsites, however, have a relatively small catchment and the inflows into reservoirs are not sufficient to store and regulate their development yield throughout the year. However, there were no other potential damsites identified for the purpose of providing stable domestic water supply to **Nyahururu** and **Rumuruti**. These two storage dams are proposed for the seasonal supply of domestic water use for the above urban centres. The development of boreholes is proposed to supply about a half of domestic water demand in the towns.

About a half of water deficit of **Wajir** town of 6,235 cmd (0.07 cms) will be supplied by the inter-basin water transfer pipeline from **Ewaso N'giro River**. The remaining deficit will be supplied by the development of boreholes.

A primary assumption for the above allocation of water sources is that surface water will take precedence over groundwater sources in the development for urban water supply because of easy accessibility and cheaper abstraction cost in most cases. In the case that surface water can not meet water development requirement of urban water supply, groundwater will be utilized instead of surface water or a combination of the both.. There are some cases when surface water sources are not available and groundwater can not match the water development requirement due to water quality constraint. In these cases, maximum affordable development of roof catchment and subsurface dams may be considered instead of groundwater but this is particularly suited to peri-urban and rural areas.

According to the results of the domestic and industrial water supply study (Sectoral Report (D)), the following urban centres have to utilize groundwater as a major water source. Water balance expressed as available groundwater volume vs. required water demand was calculated for 22 urban centres as enumerated below, on the assumption that groundwater can be extracted within the location where the urban centres are situated or from the surrounding locations. Table M9.5 shows water balance calculation for 22 urban centers. Proposed numbers of boreholes and shallow wells were calculated as shown in the following table, on the assumption that 10 % of total water demand will be utilized from shallow wells for livestock and the remaining will be extracted from boreholes except for urban centres. Outer radii of borehole development were estimated in consideration of groundwater availability ratio. The ratio is equivalent to the ratio of safe abstraction to the potential abstraction.

Urban water supply mainly by groundwater for the year 2010

Urban center	Location	Water demand (m3/day)	Number of boreholes	Number of shallow wells	Outer radius of development (km)
Msambweni	Msambweni	2,671	50	54	32
Isiolo	Isiolo	9,343	167	187	58
Garbatula	Garbatula	1,417	22	28	22
North Horr	North Horr	1,218	29	23	24
Korr	Korr	3,366	76	68	39
Kargi	Kargi	3,241	90	61	42
Marsabit	Mountain	8,971	214	0	65
Sololo	Sololo	2,787	99	56	44
Moyale	Moyale	5,885	78	589	39
Mudo Gashe	Madogashe	1,121	27	22	23
Ijara	Ijara	584	13	11	16
Kotile	Kotile	534	26	11	23
Elwak	Elwak	4,170	100	84	45
Wajir	Wajir Town	6,148	188	224	61
Buna	Buna	3,047	162	61	57
Bute	Bute	989	24	20	22
Nyabikaye	Bugembe	1,370	32	28	25
Wamba	Wamba	2,604	124	51	50
Barogoi	Elbarta	2,252	205	45	64
Lodwar	Lodwar	7,792	179	155	60
Nyahururu	Nyahururu	4,282	172	10	60
Rumuruti	Rumuruti	780	32	16	23

A detailed groundwater study including physical prospecting would be indispensable for developing groundwater for the urban water supplies.

(1) Msambweni

The Ramisi river water is available for the urban water supply, but a great constraint is that the river water is said to be salty. The future water demand can be divided into two for groundwater and surface water. The following development plan can be proposed: (i) groundwater abstraction at the maximum practical extent and (ii) river water abstraction from the Ramisi river as a supplementary resource.

The groundwater resource in the location (code number of 324.1) was estimated to be 244 m^3/day or 89,165 m^3/year for boreholes and 15,096 m^3/day or 208,444 m^3/year for shallow wells.

The total water demand of the town for the year 2010 was estimated to be 2,671 m^3/day or 974,733 m^3/year. The average yield per borehole that is located within the location was calculated to be 48 m^3/day. Therefore, 50 boreholes and 54 shallow wells should be proposed in the town or around the town within an outer radius of 32 km.

Cost was tentatively estimated for the case of borehole and surface water developments. In addition to groundwater, water pans and roof catchments for public buildings may be used.

(2) Isiolo

Isiolo Town is served by Isiolo River. According to the WRAP study for Isiolo District, two major springs that are discharging 4,560 and 11,280 m^3/day are located 14 km south of Isiolo Town at an elevation of 1,585 m while Isiolo Town lies between 1,000 and 1,300 m. The spring water is of good quality and will gravitate to the town. The groundwater resource in the location (code number of 421.1) was estimated to be 9,730 m^3/day or 3,551,265 m^3/year for boreholes and 1,179 m^3/day or 430,188 m^3/year for shallow wells.

The total water demand of Isiolo Town for the year 2010 was estimated to be 18,685 m^3/day or 6,820,025 m^3/year. The surface water demand can be divided into two for groundwater and surface water. The average yield per borehole that is located within the location was calculated to be 50 m^3/day. Therefore, 167 boreholes and 187 shallow wells should be proposed in the town or around the town within an outer radius of 58 km. In the case that all the spring water can be utilized for Isiolo town, 51 boreholes and 57 shallow wells should be proposed in the town or around the town within an outer radius of 32 km.

Cost was estimated for the case of borehole and surface water developments. In addition to groundwater, water pans and roof catchments for public buildings may be used.

(3) Garba Tula

Garba Tula Town is served by a borehole and a number of shallow wells. The groundwater resource in the location (code number of 422.1) was estimated to be 5,122 m^3/day or 1,869,638 m^3/year and 5,651 m^3/day or 2,062,643 m^3/year. The borehole C3665 that is not in operation as of February of 1990 was tested by WRAP. According to the results of pumping tests, a specific capacity of 116 m^3/hr was obtained and a yield of 48 m^3/hr can be pumped at a drawdown of 10 m.

The total water demand of Garba Tula Town for the year 2010 was estimated to be 1,417 m^3/day or 517,205 m^3/year. The average yield per borehole that is located within the location was calculated to be 60 m^3/day. Therefore, 22 boreholes and 28 shallow wells should be proposed in the town or around the town within an outer radius of 22 km

Cost was estimated for the case of borehole development. In addition to groundwater, water pans and roof catchments for public buildings may be used.

(4) North Horr

North Horr Town is served by a shallow well. The water supply capacity is by far less than the present water demand of the town. The groundwater resource in the location (code number of 451.1) was estimated to be 4,422 m^3/day or 1,614,052 m^3/year for boreholes and 15,096 m^3/day or 5,510,018 m^3/year for shallow wells.

The total water demand of the town for the year 2010 was estimated to be 1218 m^3/day or 444,570 m^3/year. The average yield per borehole that is located within the location was calculated to be 38 m^3/day. Therefore, 29 boreholes and 23 shallow wells should be proposed in the town or around the town within an outer radius of 24 km

Cost was estimated for the case of borehole development. In addition to groundwater, water pans and roof catchments for public buildings may be used.

(5) Korr

The groundwater resource in the location (code number of 453.1) was estimated to be 2,982 m^3/day or 1,088,507 m^3/year for boreholes and 15,096 m^3/day or 5,510,018 m^3/year for shallow wells.

The total water demand of the town for the year 2010 was estimated to be 3,366 m^3/day or 1,228,590 m^3/year. The average yield per borehole that is located within the location was calculated to be 40 m^3/day. Therefore, 76 boreholes and 68 shallow wells should be proposed in the town or around the town within an outer radius of 39 km

Cost was estimated for the case of borehole development. In addition to groundwater, water pans and roof catchments for public buildings may be used.

(6) Kargi

Kargi Town is served by a borehole. The groundwater resource in the location (code number of 452.2) was estimated to be 5,145 m^3/day or 1,877,868 m^3/year for boreholes and 11,085 m^3/day or 3,680,897 m^3/year for shallow wells.

The total water demand of the town for the year 2010 was estimated to be 3,241 m^3/day or 1,182,965 m^3/year. The average yield per borehole that is located within the location was calculated to be 33 m^3/day. Therefore, 90 boreholes and 61 shallow wells should be proposed in the town or around the town within an outer radius of 42 km.

Cost was tentatively estimated for the case of borehole development. Maximum development of subsurface dams should be surveyed.

(7) Marsabit

Marsabit Town is served by the Karantina dam and Bakuli springs inside Marsabit Forest. This dam is seasonal and the average yield of the spring is 308 m^3/day, but the spring water level fluctuates during dry season. Thus, rationing is done throughout the year. In the case of the worst water shortage in July 1977, water was transferred by road tankers from a borehole in Logologo 50 km south of the town. The groundwater resource in the location (code number of 454.1) was estimated to be 399 m^3/day or 145,575 m^3/year for boreholes. Shallow wells showed no water supply prospects.

The total water demand of the town for the year 2010 was estimated to be 8,971 m^3/day or 3,274,415 m^3/year. The average yield per borehole that is located within the location was calculated to be 38 m^3/day. Therefore, 214 boreholes should be proposed in the town or around the town within an outer radius of 65 km, in the case that other dams or springs would not be available.

Cost was tentatively estimated for the case of borehole development. Maximum development of small dams within Marsabit hill area and subsurface dams at the hill area should be surveyed. The last alternative solution may be water transfer from Malgis subsurface dam or potential well field near Logologo and Laisamis.

(8) Sololo

Sololo Town is served by boreholes. The groundwater resource in the location (code number of 455.2) was estimated to be 2,982 m^3/day or 1,088,507 m^3/year for boreholes and 5,933 m^3/day or 2,165,716 m^3/year for shallow wells.

The total water demand of the town for the year 2010 was estimated to be 2,787 m^3/day or 1,017,255 m^3/year. The average yield per borehole that is located within the location was calculated to be 25 m^3/day. Therefore, 99 boreholes and 56 shallow wells should be proposed in the town or around the town within an outer radius of 44 km.

Cost was tentatively estimated for the case of borehole development. In addition to groundwater, construction of subsurface dams should be surveyed to exploit subsurface water from Mega Escarpment area in Ethiopia.

(9) Moyale

Moyale Town is served by a subsurface dam in Sya Lugga river and Lami Intake. There are also a number of hand dug wells. The groundwater resource in the location (code number of 456.1) was estimated to be 22 m^3/day or 7,865 m^3/year for boreholes and 128 m^3/day or 46,751 m^3/year for shallow wells.

The total water demand of the town for the year 2010 was estimated to be 5,885 m^3/day or 2,148,025 m^3/year. The average yield per borehole that is located within the location was calculated to be 38 m^3/day. Therefore, 78 boreholes and 589 shallow wells should be proposed in the town or around the town within an outer radius of 44 km, on the assumption that 50 % of total water demand will be utilized from shallow wells mainly for livestock and the remaining will be extracted from boreholes.

Cost was tentatively estimated for the case of borehole development. In addition to groundwater, maximum development of small dams and subsurface dams (to get groundwater from Mega Escarpment) should be pursued.

(10) Mudo Gashe

Mudo Gashe Town is served by shallow wells. The groundwater resource in the location (code number of 513.1) was estimated to be 574 m^3/day or 209,496 m^3/year for boreholes and 3,805 m^3/day or 1,388,865 m^3/year for shallow wells.

The total water demand of the town for the year 2010 was estimated to be 1,121 m^3/day or 409,165 m^3/year. The average yield per borehole that is located within the location was calculated to be 38 m^3/day. Therefore, 27 boreholes and 22 shallow wells should be proposed in the town or around the town within an outer radius of 23 km.

No boreholes should be drilled west of Mudo Gashe town due to saline water and low yield. Fresh water could be developed along the Ewaso N'giro from gravel-packed boreholes drilled within the floodplain.

Development of boreholes was tentatively assumed in cost estimate. However, the first approach should be to study the development potential of subsurface dams on the Galana Gof. Demand exceeding yields of subsurface dams will be matched by boreholes.

(11) Ijara

The groundwater resource in the location (code number of 515.2) was estimated to be 287 m^3/day or 104,677 m^3/year for boreholes and 1,821 m^3/day or 664,941 m^3/year for shallow wells.

The total water demand of the town for the year 2010 was estimated to be 534 m^3/day or 194,910 m^3/year. The average yield per borehole that is located within the location was calculated to be 38 m^3/day. Therefore, 13 boreholes and 11 shallow wells should be proposed in the town or around the town within an outer radius of 16 km.

Cost was tentatively estimated for the case of borehole development. In addition to groundwater, water pan may be used in the wet season and roof catchments for public buildings may be utilized for Ijara Town.

(12) Kotile

The groundwater resource in the location (code number of 515.3) was estimated to be 479 m^3/day or 174,903 m^3/year for boreholes and 2,250 m^3/day or 821,262 m^3/year for shallow wells.

The total water demand of the town for the year 2010 was estimated to be 534 m^3/day or 194,910 m^3/year. The average yield per borehole that is located within the location was calculated to be 18 m^3/day. Therefore, 26 boreholes and 11 shallow wells should be proposed in the town or around the town within an outer radius of 23 km.

Cost was estimated for the case of borehole development. In addition to groundwater, water pans and roof catchments for public buildings may be used.

(13) Elwak

The groundwater resource in the location (code number of 523.1) was estimated to be 1,801 m^3/day or 657,232 m^3/year for boreholes and 3,136 m^3/day or 1,144,583 m^3/year for shallow wells.

The total water demand of the town for the year 2010 was estimated to be 4,170 m^3/day or 1,522,050 m^3/year. The average yield per borehole that is located within the location was calculated to be 38 m^3/day. Therefore, 100 boreholes and 84 shallow wells should be proposed in the town or around the town within an outer radius of 45 km.

Maximum potential of groundwater development should be surveyed. Subsurface dams may also be studied as an alternative water source.

(14) Wajir

Wajir Town is served by a borehole and a number of shallow wells. The groundwater resource in the location (code number of 532.4) was estimated to be 54 m^3/day or 19,755 m^3/year for boreholes and 362 m^3/day or 131,972 m^3/year for shallow wells.

The total water demand of the town for the year 2010 was estimated to be 12,296 m^3/day or 4,488,040 m^3/year. The future water demand can be divided into two for groundwater and surface water. The average yield per borehole that is located within the location was calculated to be 15 m^3/day. Therefore, 188 boreholes and 224 shallow wells should be proposed in the town or around the town within an outer radius of 61 km.

The Mansa Gula Formation composing of a sequence of sandstones, silts, and other alluvial sediment forms the deeper aquifer below a thick clayey series. The water at greater depth, more than 200 m, may become saline.

Eastern and northern limits of the shallow aquifer could be assumed at 7 km north of Wajir Town. Also a lateral limit at some 20 km west of the town might exist because of absence of shallow wells west of Waghalla. The shallow aquifer in southern direction might extend over a larger distance.

The quality of the shallow groundwater is very poor, due to contamination of the wells and surroundings by bacteria, an excessive nitrate content and high content of dissolved solids.

Cost was estimated for the case of borehole and surface water developments. Water pans and roof catchments for public buildings may be used.

(15) Buna

The groundwater resource in the location (code number of 536.2) was estimated to be 1,849 m^3/day or 674,923 m^3/year for boreholes and 10,779 m^3/day or 3,934,488 m^3/year for shallow wells.

The total water demand of the town for the year 2010 was estimated to be 3,047 m^3/day or 1,112,155 m^3/year. The average yield per borehole that is located within the location was calculated to be 17 m^3/day. Therefore, 162 boreholes and 61 shallow wells should be proposed in the town or around the town within an outer radius of 57 km.

Cost was tentatively estimated for the case of borehole development. In addition to groundwater, water pans and roof catchments for public buildings may be used.

(16) Bute

The groundwater resource in the location (code number of 537.2) was estimated to be 412 m^3/day or 150,580 m^3/year for boreholes and 2,645 m^3/day or 965,509 m^3/year for shallow wells.

The total water demand of the town for the year 2010 was estimated to be 989 m^3/day or 360,985 m^3/year. The average yield per borehole that is located within the location was calculated to be 38 m^3/day. Therefore, 24 boreholes and 20 shallow wells should be proposed in the town or around the town within an outer radius of 22 km.

Cost was estimated for the case of borehole development. In addition to groundwater, the area may have the potential of small dam development during wet season. Water pans and roof catchments for public buildings may also be used.

(17) Nyabikaye

The groundwater resource in the location (code number of 646.8) was estimated to be 716 m^3/day or 261,359 m^3/year for boreholes and 4 m^3/day or 1,295 m^3/year for shallow wells.

The total water demand of the town for the year 2010 was estimated to be 1,370 m^3/day or 500,050 m^3/year. The average yield per borehole that is located within the location was calculated to be 39 m^3/day. Therefore, 32 boreholes and 28 shallow wells should be proposed in the town or around the town within an outer radius of 25 km.

Cost was estimated for the case of borehole development. In addition to groundwater, the area has the potential of springs and roof catchments for public buildings may also be used.

(18) Wamba

Wamba town is served by a borehole and a rock catchment. The groundwater resource in the location (code number of 842.4) was estimated to be 293 m^3/day or 106,867 m^3/year for boreholes and 2,103 m^3/day or 767,664 m^3/year for shallow wells.

The total water demand of the town for the year 2010 was estimated to be 2,604 m^3/day or 950,460 m^3/year. The average yield per borehole that is located within the location was calculated to be 19 m^3/day. Therefore, 124 boreholes and 51 shallow wells should be proposed in the town or around the town within an outer radius of 50 km, in the case that the abovementioned rock catchment would not be feasible.

Cost was estimated for the case of groundwater development. In addition to groundwater, water pans and roof catchments for public buildings may also be used.

(19) Barogoi

The water source of the town is a borehole whose yield is 0.9 m^3/hr. The water quality is good in colour and turbidity. The groundwater resource in the location (code number of 843.6) was estimated to be 453 m^3/day or 165,303 m^3/year for boreholes and 2,848 m^3/day or 1,039,373 m^3/year for shallow wells.

The total water demand of the town for the year 2010 was estimated to be 2,252 m^3/day or 821,980 m^3/year. The average yield per borehole that is located within the location was calculated to be 10 m^3/day. Therefore, 205 boreholes and 45 shallow wells should be proposed in the town or around the town within an outer radius of 64 km.

Cost estimate assumes tentatively that whole demand would be met by groundwater exploitation. An alternative water source may be subsurface dams on the Baragoi river, which should be surveyed. Water pans and roof catchments for public buildings may also be used.

(20) Lodwar

The water supply to Lodwar Town is from boreholes drilled on the banks of Turkwel River. Borehole C5888 is pumping approximately 40 m^3/day for 24 hours everyday. Water from the borehole is suitable for human consumption without any treatment. The groundwater resource in the location (code number of 853.5) was estimated to be 1,968 m^3/day or 718,467 m^3/year for boreholes and 4,010 m^3/day or 1,463,628 m^3/year for shallow wells.

The total water demand of the town for the year 2010 was estimated to be 7,792 m^3/day or 2,844,080 m^3/year. The average yield per borehole that is located within the location was calculated to be 39 m^3/day. Therefore, 179 boreholes and 155 shallow wells should be proposed in the town or around the town within an outer radius of 60 km.

When any more boreholes are available on the banks of Turkwel River and subsurface dams on the river, the above-mentioned number of boreholes and shallow wells can sharply decrease. Since potential water yield from a subsurface dam is not known, Initial approach would be to study the development potential of subsurface dams and assess how much water could be exploited by subsurface dams.

Cost was estimated for the case of groundwater development. In addition to groundwater including subsurface dams, roof catchments for public buildings may also be used.

(21) Nyahururu

The surface water of Nyahururu and Equator Streams is available for the urban water supply. The future water demand can be divided into two for groundwater and surface water. The following development plan can be proposed: (i) groundwater abstraction at a maximum practical extent and (ii) river water abstraction as a supplementary resource.

The groundwater resource in the location (code number of 733.9) was estimated to be 30 m3/day or 10,709 m3/year for boreholes.

The total water demand of the town for the year 2010 was estimated to be 8,565 m3/day or 3,126,043 m3/year. An average yield per borehole that is located within the location was calculated to be 43 m3/day. Therefore, 172 boreholes and 10 shallow wells should be proposed in the town or around the town within outer radius of 60 km.

Cost was tentatively estimated for the case of borehole and surface water developments. In addition to groundwater, water pans and roof catchments for public buildings may be used.

(22) Rumuruti

The Ewaso Narok River water is available for the urban water supply. The future water demand can be divided into two for groundwater and surface water. The following development plan can be proposed: (i) groundwater abstraction at a minimum practical extent and (ii) river water abstraction from the Ewaso Narok River as a supplementary resource.

The groundwater resource in the location (code number of 733.4) was estimated to be 62 m3/day or 22,451 m3/year for boreholes and 35 m3/day or 12,874 m3/year for shallow wells.

The total water demand of the town for the year 2010 was estimated to be 1,561 m3/day or 569,729 m3/year. An average yield per borehole that is located within the location was calculated to be 38 m3/day. Therefore, 32 boreholes and 16 shallow wells should be proposed in the town or around the town within outer radius of 23 km.

Cost was tentatively estimated for the case of borehole development. In addition to groundwater, water pans and roof catchments for public buildings may be used.

10.2 Rural and Livestock Water Supply

In view of the vastness of the study area and varying type of water sources envisaged, it was thought almost impracticable to formulate definite water supply plans specific to each rural area. The study therefore attempted to evaluate potential water sources available in each area and to estimate the conceptual costs of the development. The Study adopted the following approaches for this purpose (as described in Chapter M6):

Step-1 : Listing of potential water sources and their combinations by Subbasin/ Location

Several water sources were examined for evaluating the potential development of perennial water sources - they are, surface water, groundwater, roof catchment, small dam, subsurface dam, rock catchment and pipeline built for urban water supply. Other type of seasonal water sources are dealt with separately only as supplementary measures which would be effective to shorten the access distance in the rainy season.

Step-2 : Setting-up of source potential evaluation criteria

The study assumed that the development of water sources in rural areas will be undertaken in two stages - namely, (i) Stage-1 : provision of water sources within walking distance, wherein the water available is not always a grade of "potable water" quality and (ii) Stage-2 : Provision of piped water supply systems with water treatment, wherein the water would be "potable". The evaluation was based on relative comparison indices.

Step-3 : Setting-up of source allocation criteria

The study had to adopt a simplified approach to evaluating the source allocation plans just sufficient for formulation of a framework of future water development for both domestic and livestock water supplies because of the varieties of water sources and demand area characteristics. The basic concepts are (i) main water supply sources would be surface water and groundwater and (ii) other water harvesting measures are planned as subordinate measures to supplement and/or substitute the surface water/groundwater sources.

Step-4 : Assessing water sources development by Subbasin/Location

Data in 2010 for assessment of source development for rural water supply (domestic and livestock uses) is organdies into (i) water demand, (ii) demographic data, (iii) source potential parameters evaluated in Step-3, and water yield and cost data.

The rural water demand in 2010 was estimated at 1.705 MCM/day which is comprised of 1.155 MCM/day for domestic water demand and 0.550 MCM/day for livestock water demand as given in Table M10.6. Source allocation plan for rural water supply over Kenya is summarized in Figure M10.3. Source allocation plan by drainage area is summarized in Figures M10.4 and M10.5.

In addition, the Study recommends watering points (boreholes or shallow wells with windmill pump) in nomadic pasturage areas in arid lands. The objective is to promote nomadic production activities in such areas where pastures grow in the wet season but no watering points are available. Assuming that the watering point is provided at every 25 km, 559 watering points in 21 Districts within the arid lands (see Table M10.7) are required although a further study is needed to specify their location.

10.3 Irrigation Water

10.3.1 Small scale irrigation project

About 140 schemes are proposed and their total area is about 7,000 ha. In line with government policy for irrigation development, these small irrigation projects have top priority in implementation. These small scale schemes would be implemented by farmers themselves with assistance from MOA or other government agencies concerned.

10.3.2 Large scale irrigation project

The following 18 schemes are considered (See Figure M9.6).

Name	Area (ha)	Name	Area (ha)
Arror	1,340	Lower Rupingazi	1,800
Kano Plain	25,640	Mwea Extension	2,900
Kanzalu	4,055	Sabaki Extension	3,000
Kibwezi Extension	13,200	Tana Delta	12,000
Kimira	2,000	Taveta	3,780
Kunati	1,050	Thanantu	2,520
Lower E.Ngiro	10,000	Turkwel	600
Lower Kuja	1,900	Upper Nzoia	7,550
Lower Nzoia/Bunyala	10,480	Yala Swamp	7,540

1. Arror

This project is located at Kerio valley along the left bank of the Kerio River. The irrigable lands have been grouped into four Blocks with a net area of 1,340 ha and requires a peak flow of 2.0 m^3/sec. Two pipelines will convey the irrigation water from the Arror River, one is for Blocks 1 & 2 while the other one is for Blocks 3 & 4. Sprinkler systems are recommended for this area mainly due to the soil and topographic conditions.

2. Kano Plain

Project area extends southeast of Kisumu town and lies on the flat terrain - so called Kano Plain. At present (1991), a feasibility study is being undertaken by JICA to formulate optimal development plan on the Kano Plain Irrigation Project.

The total Project area of 73,000 ha consists of 13,000 ha of swamp, 50,000 ha of arable/natural vegetation, and 10,000 ha of other area. About 25,000 ha of paddy and upland field would be irrigated by transferring the Sondu river water after generating about 60MW of electricity at Sondu/Miriu Dam. Peak irrigation water requirement is about 29 m^3/sec occurring in October.

3. Kanzalu

The Kanzalu irrigable area is located between the Kanzalu Range and the Athi River about 60 km east from Nairobi. From a potential of 12,000 ha of irrigable area, about 5,000 ha was investigated which consists of three irrigable areas.:

Block A : covering a net irrigable area of 1,750 ha between Nditha and Athi Rivers;

Block B : covering a net irrigable area of 2,560 ha situated on the peneplain between the Kanzalu Range and the Nditha River; and

The valley bottoms located between irrigation blocks A and B.

The water source for the scheme is the regulated flow from Ndarugu Dam or Munyu Dam. Headworks would be constructed at downstream of Fourteen Falls in order to divert the required water of about 1.1 m^3/sec into a 21km main canal.

4. Kibwezi extension

The Kibwezi scheme is located on the right bank of Athi River, between the Yatta Gap and the Mtito Andei River with an area of around 30,000 ha. The area is divided into four Blocks:

Block A: 1,920 ha
Block B: 4,050 ha
Block C: 5,980 ha
Block D: 8,970 ha

The water sources for the scheme is the regulated flow from Yatta Dam in the Athi River.

Headworks would be constructed 8km downstream of Yatta Bridge on the Athi River. Diverted irrigation water will be conveyed to the proposed nightstorage reservoir by a 26 km long main canal. The location of the nightstorage reservoir will be within the Masongaleni River Valley. After the nightstorage reservoir, lined secondary and tertiary canals will convey the water to each irrigation block and fields.

In the scheme, the peak irrigation water of 17.0 m^3/sec is required in September. However, the maximum development of Yatta Dam would regulate 13.0 m^3/sec in September taking into consideration the water resource development and conservation in the downstream reach of the Sabaki River. The other water source should be further studied for full development of the scheme.

5. Kimira

The Kimira scheme is located west of Kendu Bay town in South Nyanza District. This area has very flat topography with an average elevation of 1,140m. Due to poor drainage condition and low topography level, part of the area is submerged during the rainy season. At present, the area is used as grazing land.

Irrigation water of about 2.2 m^3/sec will be diverted from the Awach Kibuon River and conveyed through about 3 km of unlined canal to the area.

6. Kunati

Kunati scheme is located east of Meru town in Meru District. Estimated peak irrigation water requirement is about 0.4 m^3/sec and annual mean requirement is 0.33 m^3/sec. The Thanantu River is the expected water source.

7. Lower Bwaso N'giro

The area is located to the west of Lake Magadi. It is suitable for large scale irrigation development due to favorable topography, soils and climate. The TARDA planned the following activities required for the implementation of this scheme;

- establishment of a pilot irrigation project
- aerial photography and topographical surveys of the project area
- semi detailed soil survey
- irrigation planning

Peak irrigation water requirement is about 13 m^3/sec occurring in November.

Headworks would be constructed at the tailrace of **Oldorko Dam** which is proposed for hydropower development.

8. Lower Kuja

Project area is located at about 110 km southwest of Kisumu town in South Nyanza District. Stage wise development plan, namely Phase I and Phase II will develop the 1,900 ha of total irrigation potential area. The irrigation water would be pumped from **Kuja River** by six engine pumps into a lined canal which will convey the water to the project area. Estimated peak discharge is 1.3 l/sec/ha.

9. Lower Nzoia/Bunyala Extension

These two irrigation schemes are located along both side of the Nzoia river near its Lake Victoria outlet in Busia and Siaya District. The area is about 125 km^2 with an average elevation of 1,180 m. This area includes the existing Bunyala irrigation scheme. Two main canals, one on each bank convey the irrigation water from the intake weir on the **Nzoia River**. An experimental farm is proposed to seek high value added crops under irrigated agriculture.

10. Lower Rupingazi

This scheme is located about 10 km south of Embu town. The area extends on both sides of Rupingazi River, having a net area of 1,800 ha. The land within the project area comprises slopes of less than 5% except along the existing streams. Sprinkler irrigation systems is recommended in this area due to the soil and social conditions. The peak water requirement is estimated at about 1.1 m^3/sec occurring in November. The **Rupingazi River** is the source of irrigation water.

11. Mwea extension

Mwea irrigation project is located near Sagana town about 80km northwest of Nairobi in Kirinyaga District with a total area of 16,000 ha. It extends over the flat land on the outskirts of Mt. Kenya with an elevation of 1,100 m. This irrigation project comprises the existing Mwea Irrigation Settlement Scheme of 12,000 ha and the Extension area of 4,000 ha. The following works are on going for existing Settlement Scheme:

Rehabilitation of headworks
Rehabilitation of main canal
Rehabilitation of link canal
Construction of a Pilot Farm

Extension area has 2,470 ha of paddy field and 430 ha of horticulture land. Thiba Dam with storage capacity of 18 MCM is proposed on the Thiba river for the whole Mwea irrigation project.

12. Sabaki Extension

The Sabaki irrigation area is located on the left bank of the Sabaki river on the flood plains of the Dagmra Area . For the purpose of costing , a 150 ha pilot scheme is proposed. Irrigation water for this pilot area will be extracted from the Sabaki River by means of boreholes along the river banks. During a two years pilot operation period, the following investigations or study are proposed:

- method of water conveyance
- method of water intake
- test drilling
- feasibility study for the full development of this project

Detail design and nine years construction works will follow this pilot scheme.

13. Tana Delta

The Tana Delta is a vast lowland located in the most downstream basin of the Tana River with an area of about 2,000 km^2. This project is situated in this Delta at about 9 km east of Garsen town with 12,000 ha, which is comprised of three empoldered areas - Polder-1 (4,500 ha), Polder-2 (3,850 ha) and Polder-3 (3,650 ha). Rice cultivation is proposed.

The Polder-1 area is now under construction. The TARDA is the execution agency for this project.

Irrigation water of about 24 m^3/sec at peak requirement in December will be diverted from the Tana River.

14. Taita Taveta

The area is situated near Taveta town in Taita Taveta District extending along the Lumi River. Existing small scale irrigation schemes, in total covering about 550 ha have some physical and organizational problems, namely:

- a part of the area is underlain by a caliche at a shallow depth
- lack of drainage systems
- saline groundwater
- regular flooding
- inadequate extension services and lack of a farmers organization

The water sources for those irrigation schemes are the **Lumi River** and **Njoro Springs**. A resources survey carried out by TARDA identified about 3,800 ha of irrigation potentials in this area. It is noted that about 70% of project area is in private land.The following detailed investigation are required for development of the whole area;

- detailed surface and groundwater resources assessment (including the present water abstraction rate for private land)
- aerial photograph and mapping of the project area
- semi detailed soil surveys
- irrigation planning

15. Thanantu

The scheme is located at about 20 km east of Meru town in Meru District. The Thanantu river forms the northern boundary while Kuuru river forms the southern boundary. A sprinkler system has been recommended due to the high permeability of the volcanic soils. Irrigation water will be diverted from **Thanantu River**.

16. Turkwel

The area is located at about 50 km downstream of **Turkwel Dam**. Total area of 600 ha, which comprise five small cluster of 120 ha each are scattered on both sides of Turkwel River. If ecological and institutional problems are disregarded, more than 7,000 ha can be irrigated around this area after the completion of Turkwel Dam.

17. Upper Nzoia

The area is located at about 20 km south of Kitale town in Bungoma District. This area covers a total area of 176 km^2 with altitudes of 1,700 m. The landform is hilly with occasional steep slopes. A Pilot scheme is proposed to obtain information on a series of agricultural, economic and social problems and to train an initial nucleus of technicians and farmers. This Pilot scheme will have an area of 300 ha and will need an investment of Kshs 36 million. Sprinkler irrigation is proposed to irrigate hilly area. The peak irrigation water of 4.4 m^3/sec is required in December. To irrigate the whole area of 9,400 ha in gross, **Hemsted Bridge Dam** having a capacity of 75 million m^3 is required after 2010.

18. Yala Swamp

The Yala Swamp is located in Siaya and Busia Districts of Nyanza and Western Provinces. The swamp itself was formed by the deposition of silt from the Yala at the point where the river flows into Lake Victoria. In addition to the Yala River, the Hwiro River (seasonal river) also flows into the Yala swamp.

The Swamp has been divided into three areas. The 2,300 ha Area I is the name given to the area which was reclaimed in 1970 and is now being cultivated. The 9,200 ha Area II forms the main body of the swamp and is the area which would be reclaimed by gravity drainage. The 6,000 ha Area III is the swamp which is generally below the level of Lake Victoria and is considered to be only reclaimable by the construction of polders and pumping out of the water.

The reclamation of the Yala swamp was first proposed in the Kenya Nile Basin Water Resources Study 1956. After this proposal various studies have been undertaken on the reclamation of the Yala Swamp.

As early as the 1960's a start was made with the reclamation of the Yala Swamp resulting in the drying out of Area I. Detailed designs and tender documents for Area II were prepared in 1982. Latest proposal is reclamation and development of Area II by extension and expansion of the existing **Yala river diversion canal,** diversion of the Hwiro river and reconstruction of existing dyke. A peak irrigation water of 12 m^3/sec is required in October.

10.4 Hydropower

In the 1987 NPDP, twelve of the most promising hydroelectric projects were compared in the prescreening analysis. The screening model calculated the expected life-cycle energy costs of the alternative plants. Costs were based on an assumption that each of the plants would come on-line in 1995 which is a realistic earliest possible completion date for each project. The summary of the preliminary screening results is shown in Table M10.8.

The National Power Development Plan (1987) had listed 11 hydropower schemes as being worthy of further consideration, but recently its updated plan (1991) reexamined 8 hydropower schemes. These hydropower schemes are listed in Table M10.9.

Comparing the 8 schemes, the updated plan recommended the implementation of five hydropower schemes towards year 2010 - Miriu, Low Grand Falls, Oldorko, Mutonga and additional installation of Gitaru No.3 unit. The updated plan also recommended a commissioning schedule of the above 5 schemes as given in Table M10.10.

Magwagwa was also evaluated favourably in Table M10.9, but it was left out in the updated plan by the reason that it will be developed in conjunction with a large irrigation development which will be late in the planning period. (Draft final report of Update of National Power Development Plan). Subsequently, the feasibility study of the Magwagwa project was completed in December 1991. The study revealed that the project would be technically and economically feasible for commissioning towards year 2003. This project is included in the implementation programme of this master plan.

The principal features of selected hydropower development schemes are described below.

(1) Sondu/Miriu

The annual mean discharge of the Sondu River was estimated at 41.0 m^3/s at the damsite. The layout of intake facilities consist of gated concrete weir type. The reservoir has a storage of 1.1 MCM with FSL at EL. 1,402.5 and the minimum operating level of EL. 1,400.0 m. The gross head is 196.6 m and installed capacity is 60 MW at FSL with a maximum plant discharge of 39.9 m^3/s.

The schemes has a plan of providing an additional powerplant (No.2 powerhouse). The proposed installed capacity is 20.6 MW.

(2) Magwagwa

The annual mean discharge of the Sondu River was estimated at 40.0 m^3/s at damsite. The layout of dam consists of concrete facing rockfill type embankment of 4.4 million m^3. The reservoir FSL is at EL. 1,665 m and the minimum operating level is at EL. 1,609 m with active storage capacity of 701 MCM which corresponds to 55.6% of annual inflow volume. The gross head is 180 m and installed capacity is 120 MW at FSL with a maximum plant discharge of 82 m^3/s.

(3) Oldorko

The annual mean discharge of the Ewaso N'giro (south) River was estimated at 8.0 m^3/s at the damsite. The layout of dam consists of a fill type embankment of 4.48 million m^3. The reservoir FSL is at EL. 1,300 m and the minimum operating level is at EL. 1,272 m with active storage of 885 MCM which corresponds to 351% of the mean annual inflow volume. The gross head is 480 m, installed capacity is 76 MW at FSL with a design discharge of 18.0 m^3/s.

(4) Mutonga

The annual mean discharge of the Tana River was estimated at 132.1 m^3/s at the damsite. The layout consists of a fill type embankment of 0.87 million m^3 across the Tana River. The reservoir FSL is at EL. 550 m and the minimum operating level is at EL. 542 m with active storage of 87.8 MCM which corresponds to 2.1% of annual inflow volume. The gross head is 37 m and installed capacity is 60 MW at FSL with a design discharge of 195.5 m^3/s.

(5) Low Grand Falls

The annual mean discharge of the Tana River was estimated at 146.2 m^3/s at the damsite. The reservoir FSL is at 512 m and the minimum operating level is at 500 m. The active storage is 857 MCM which is 18.6% of the annual inflow volume. The gross head is 68.2 m and installed capacity is 120 MW at FSL with a design discharge of 212 m^3/s. At this site, an alternative development plan is High

Grand Falls scheme. The merit of this multipurpose scheme should be assessed in a subsequent study.

10.5 Environmental Impact for Major Interbasin Water Transfer Schemes

10.5.1 Water Transfer to Nairobi

(1) Ndarugu Dam

Ndarugu Dam (36 m high) is proposed for the purpose of water supply to Nairobi, augmentation of river runoff of Athi River, and irrigation development in the middle reach of Athi River. The reservoir having an area of 18.8 km2 is located at the confluence of Ndarugu and the Komu rivers. The natural inflow volume of both rivers is insufficient to supply a relatively large amount of water to Nairobi so that river runoff of Chania River will be transferred to Komu River by an open channel with a maximum capacity of 8.0 m^3/s.

Although there are some discrepancies in the water quality data such as large variation of BOD and COD which need clarification, the data shows that the water appears to be suitable for domestic water supply purposes after appropriate treatment.

The development of reservoir will require the relocation and resettlement for the substantial number of people with associated compensation for property and crops.

(2) Other dams

Three other dams are proposed for Nairobi water supply; namely, Thika, Chania-B, and Ruiru-A. Among damsites, Thika Dam is at the construction stage. Chania-B Dam (101 m high) and Ruiru-A (69 m high) have a relatively small reservoir of 150 ha and 87 ha, respectively.

Both Chania and the Ruiru rivers have been used as sources of water supply. The water, therefore, is suitable for water supply purposes after appropriate treatment.

(3) Compensation flow of the Chania River

Water source for the above three dams is the water from Chania River. Sufficient water must remain in the river to maintain the ecology of the river ecosystem and to provide water for downstream users.

10.5.2 Water transfer to internal drainage area

(1) Malewa Dam

Malewa Dam is located on the upstream reach of the Malewa River. The purpose of the dam development is the augmentation of the capacity of Greater Nakuru Water Supply

Project. The detailed description of its environmental impacts is given in Chapter N8 of Sectoral Report N.

(2) Itare Dam

The site of this dam is located at upstream reach of the Itare River. The purpose of the dam development is to supply domestic water to Nakuru town via Molo, Elburgon and Njoro towns. The reservoir of 1.14 km2 lies almost entirely within the South Western Mau Forest Reserve which may have ecological impacts.

Although the river flow after abstraction is reduced immediately downstream of the damsite during dry months, the maintenance flow at damsite still remain in the river channel as several tributaries join and augment the river flow between the damsite and Chemosit River. Water transfer therefore may not cause a serious problem downstream of the dam.

(3) Sewerage system

Abstracted water is transferred to Lake Baringo and Lake Nakuru drainage basins. The sewerage treatment works discharge substandard final effluent. This situation for Lake Nakuru Drainage basin may change drastically when the transfer project becomes operational. In the Lake Baringo basin, the demand centres are located within the uppermost area and the rivers meanders about 60 km down to Lake Baringo. If the sewerage systems discharge standard effluent, it may be diluted by the perennial river flow of Perkerra River.

10.5.3 Water transfer to Kajiado

Water pipeline from the Kiserian River to Magadi via Kajiado is in operation. Nol-turesh water pipeline is also constructed from the foot of Mt.Kilimanjaro to Kajiado which bifurcates to Emali, Machakos and Athi River towns.

Kiserian Dam is at the construction stage for the augmentation of water supply volume to Kajiado. The route of the pipeline follows the existing water pipeline.

Kiserian River is one of the tributaries of Mbagathi River which flows down through Athi River town and joins the Athi River. Sufficient water must remain in the river to maintain the ecology of the river ecosystem and to provide water for downstream users.

10.5.4 Water transfer to Coast

(1) Second Mzima

Second Mzima pipeline is proposed for the augmentation of water supply volume to Mombasa town. At present, 0.43 m^3/s is abstracted from Mzima springs (4.0 m^3/s in total) and transferred without any treatment to Mombasa through Mzima pipeline system. The second pipeline system will require abstraction of 0.40 to 0.60 m^3/s when it becomes operational.

Spring flow after abstraction joins Tsavo River which is the only perennial river in the Tsavo East National Park. The river joins Athi River and forms the Galana (Sabaki) River. The river course which is an important habitat for wildlife needs to conserve perennial flow. In the Galana (Sabaki) River after the confluence of the Tsavo River, the river channel loss due to evaporation and seepage reduces its discharge. Excessive abstraction in the upstream reach would cause problems in the provision of water to downstream users. Maximum exploitable flow of the river should therefore be determined taking the following into considerations.

- Future water demand in Mombasa,
- Required maintenance flow of the Tsavo River for wildlife (river eco-system of the Tsavo River)
- Flow variation of the Galana (Sabaki) River

(2) Sabaki Extension

Sabaki extension pipeline is proposed as the alternative of Mwachi and Pemba Dams. The proposed route of the pipeline follows the existing pipeline which is in operation. Problems caused by this extension may include the impacts on forest clearance. Forest cover in the project area is unknown but it may include parts of the Arabuko-Sokoke Forest; this needs to be confirmed.

(3) Lamu water supply

Water abstraction from Tana River is estimated at 5,719 m^3/day (66 litre/sec) for Lamu water supply. The intake will be located at about 5 km upstream of Garsen. The abstracted water will be transferred through a pipeline of 120 km long to Lamu Island. The annual average discharge of the Tana River was estimated at 128 m^3/sec at Garsen. This water abstraction may not cause negative effects to the downstream users.

M11. PROJECT COST

11.1 Introduction

The construction costs of the proposed water-related schemes were estimated at the construction price of 1991. The construction costs are organized into direct construction cost, engineering and administration, land acquisition and physical contingencies. The direct construction costs were estimated based on the actual costs and estimates for similar projects in Kenya. Where cost curves were available, they were utilized in the estimate. The construction costs are expressed in US$ assuming an exchange rates of Kshs 25.20 for US$ 1.

11.2 Urban Water Supply and Sewerage

11.2.1 Urban water supply

Development cost of each system includes costs of intake, pipeline, raw water pumps, storage tanks having capacity equivalent to one-day demand, grid distribution system and allowance of 25%, but excludes costs of water source works of dams.Unit costs of several works in the above were referred to those presented in Design Manual after due up-dating. The estimated costs are as given in Table M11.1. Unit development cost (development cost / daily supply volume) was compared with those of already planned or designed water supply schemes and found to be within the range of those schemes (See Sectoral Report D). The total development cost was estimated at US$ 4,372 million excluding dam cost.

11.2.2 Urban sewerage

Urban sewerage is always necessary for protection of urban environment and human health when the potential water demands are met by water supply development.

In estimating required cost for urban sewerage development, it was assumed that the waste water from the manufacturing industries would be pre-treated by the industries before discharge into the sewerage system. Ratio of waste water to water supplied was preliminarily assumed at 1:1. Sewer system was assumed to cover 50% of the total area of the urban centres with a population more than 100,000 persons and 25% for the remaining urban centres. The total cost of urban sewerage development was estimated at US$ 705 million as given in Table M11.2.

It was considered that the urban sewerage system development would be made to keep pace with the urban water supply development.

11.3 Rural Water Supply

11.3.1 Water exploitation cost

As described in Chapter M6, the water source for rural water supply was allocated by Location for domestic and livestock uses. The water supply is organized into the following water sources.

(1) Surface water
The required amount of surface water for rural water supply was calculated by following the allocation criteria as described in Chapter M6. In case that the required amount of surface water for rural water supply was larger than the remaining safe yield of water balance calculation, the deficit of surface water was allocated to other water sources.

(2) Groundwater
Cost of groundwater exploitation was assessed for each location by type of development.

(3) Small dam
Cost of exploitation water was assessed for each hydrological region, assuming a typical design for small dam; that is, active storage volume of 50,000 m^3 with catchment area of 10 km^2.

(4) Roof catchment
Cost of water exploitable by roof catchment was evaluated for each hydrological region. The evaluation assumed a typical system with a roof catchment of 53 m^2 on average for semi-permanent house in Kenya and water tank with a capacity of 3 m^3.

(5) Subsurface/sand dam
Cost of water exploitable was evaluated by two parameters, namely; (i) potential of subsurface dam development and (ii) type of development of subsurface and/or sand dams. The evaluation assumed a typical storage volume of 3,500 m^3.

(6) Rock catchment
Cost of water exploitable by rock catchment was evaluated for hydrological region in which potential site for rock catchment was identified on 1:50,000 map. The evaluation assumed a typical storage capacity of wall structure of 600 m^3 including evaporation loss of 250 m^3 and the catchment area of rock surface of 10,000 m^2.

(7) Existing pipeline
The availability of a treated water pipeline which was built for an urban water supply was examined for each location.

Unit water exploitable cost for the above water sources were enumerated by subbasin as given in Table M11.3. The average unit cost of exploitable water was estimated as follows:

Unit Cost of Exploitable Water

(Unit:US$/m^3)

	Water Source	Cost
1.	Groundwater	
	- Borehole	0.53
	- Shallow well	0.12
2.	Small Dam	0.18
3.	Roof Catchment	2.92
4.	Subsurface Dam	0.53
5.	Sand Dam	0.39
6.	Rock Catchment	0.39

The water exploitation cost is summarized in Appendixes M.7 and M.10. Cost of water exploitable for surface water and existing pipeline was incorporated into the construction cost for urban water supply. The total water exploitation cost was estimated at US$ 1,414 million as given in Table M11.4.

11.3.2 Water supply cost

Water supply cost for rural water supply was estimated on the basis of the cost curves which includes the costs of intake facilities, 5-km raw water main, full treatment, storage with capacity equivalent to one-day demand and distribution (See Sectoral Report D). The cost was estimated by applying the cost curves with treatment for surface water source and that without treatment for groundwater source. The total cost for rural water supply was estimated at US$ 1,213 million as given in Table M11.5.

11.4 Livestock Water Supply

As described in Chapter M6, water source for livestock water supply is organized into the following sources:

- surface water
- groundwater
- small dam
- subsurface/sand dam
- existing pipeline

The water exploitation cost was summarized in Appendixes M.7 and M.10. Cost of water exploitable for surface water and existing pipeline was incorporated into the construction cost for urban water supply. The total water exploitation cost component was estimated at US$ 669.9 million as given in Table M11.6.The Study assumes that livestock will be supplied water basically at water source points on Stage 1 development so that the water supply/distribution cost was not included in the project cost.

In addition, the development cost of watering points in nomadic pasturage areas was estimated at US$ 73 million as given in Table M11.7.

11.5 Irrigation Water Supply

11.5.1 Small scale irrigation scheme

The cost for implementation was estimated at about US$ 11.4 million applying unit cost of US$ 1,630 /ha (Kshs 41,000 /ha).

11.5.2 Large scale irrigation scheme

Among about 160 irrigation schemes, 18 large schemes are selected for the formulation of water development plan. The construction cost was estimated as enumerated below.

Estimated Development Cost

Scheme	Area (ha)	Cost (million US$)
Amor	1,340	6.3
Kano Plain	25,640	232.5
Kanzalu	4,055	29.7
Kibwezi extension	13,200	81.9
Kimira	2,000	18.1
Kunati	1,050	3.5
Lower Ewaso Ngiro	10,000	57.0
Lower Kuja	1,900	5.6
Bunyala Extension	10,480	12.4
Lower Rupingazi	1,800	6.0
Mwea extension	2,900	63.7 *1
Sabaki extension	3,000	19.8
Tana Delta	12,000	141.4
Taita Taveta	3,780	11.9
Thanantu	2,520	17.3
Turkwel	600	1.8
Upper Nzoia	7,550	88.0
Yala Swamp	7,540	65.0
Total	111,355	861.9

Note : *1 includes the development cost of Thiba Dam.

11.6 Hydropower Development

In the Updated National Power Development Plan, hydroelectric cost estimates of 8 projects were reviewed. The recommended optimum development plan was selected through planning principal activities.

The recommended plan includes 4 new hydroelectric developments after Turkwel, with a total installed capacity of 312 MW plus an additional unit at the existing Gitaru power station. Geothermal power generation takes the most prominent role in the power generation expansion throughout the study horizon, with a total installed capacity of 394 MW of new developments. In addition, 400 MW of conventional thermal, 90 MW of medium speed diesel sets and 60 MW of peaking gas turbines will be developed.

Magwagwa hydropower development project was left out from the development plan because it will probably be developed following full implementation of the Miriu irrigation scheme which will be late in the planning period.

The construction cost for the above 5 hydropower development projects except the additional unit of Gitaru power station was summarized as follows.

Construction Cost for Hydropower Development

	Plan	Installed Capacity (MW)	Construction Cost (1000 US$)
1	Sondu/Miriu (No.1)	60.0	118,407
	" (No.2)	20.6	36,000
2	Low Grand Falls	120.0	290,821
3	Oldorko	76.0	70,806
4	Magwagwa	120.0	340,045
5	Mutonga	60.0	148,914
	Total	456.6	1,004,993

Source : 1990 Interim Update of National Power Development Plan 1990-2010, April 1991, Acres. (Excl. Sondu/Miriu No.2).

Note : Estimates in the latest studies (US$ million, excluding price escalation); Sondu/Miriu No.1 : 133 (Ref.M.7), Sondu/Miriu No.2 : 36 (Ref.M.8), and Magwagwa : 329 (Ref.M.9).

11.7 Allocation of Dam Cost

In total, 28 damsites were selected for source development towards year 2010. The construction cost was allocated tentatively in proportion to water use quantity by purpose; they are, (i) hydropower, (ii) irrigation water and (iii) water supply developments. The cost for water supply development was further allocated in proportion to domestic water use quantity by major demand center, while, the total cost was allocated for hydropower development. Table M10.7 shows the results of allocation of dam construction cost. The dam cost was allocated to US$ 656.7 million for hydropower development, US$ 175.6 million for irrigation water development and US$ 577.3 million for urban water supply. The total development cost was estimated at US$ 1,409.6 million.

11.8 Project Cost

The construction cost for water resource development was summarized as follows:

(Unit:million US$)

	Purpose	Development Cost
(1)	Urban Water Supply	
	– Water supply system	4,949*1
	– Sewerage system	705
(2)	Rural Water Supply	2,627
(3)	Livestock Water Supply	
	– Domestic water supply system	670
	– Watering points in nomadic pasturage activities	73
(4)	Irrigation Water Supply	
	– Small irrigation scheme	11
	– Large irrigation scheme	1,015*2
(5)	Hydropower Development	1,004*3
	TOTAL	11,055

Note *1 includes dam cost of US$ 577 million
*2 includes dam cost of US$ 176 million
*3 includes dam cost of US$ 657 million

The total construction cost for water resources development was estimated at US$ 11,055 million equivalent for implementation up to the year 2010. The major share was taken by water supply - related facilities

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M.6	KPLC, "National Power Development Plan, Appendix Vol. 2", 1987
M.7	KPC, Sondu/Miriu Hydropower Project - Design Report, October 1991, Nippon Koei
M.8	KPC, Sondu/Miriu Hydropower Project, Feasibility Study on Additional Power Station, April 1992, Nippon Koei
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